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Research on the application of collaborative learning in the practice teaching of garment 3D virtual fitting

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ABSTRACT – REZUMAT

Research on the application of collaborative learning in the practice teaching of garment 3D virtual fitting

With the integration of information science into the fashion field, both industry and university expect more informatics technology to be utilized in the fashion-related course and teaching of practical exercises. Among this informatics technology, virtual simulation, as an important experiment tool, has become very popular support for fashion students since it is possible to validate design ideas very efficiently and fast. However, because virtual simulation is quite technical, and it is very difficult to gain all the essential skills about the operation of the virtual simulation software within a short time, in the process of virtual simulation exercises, students largely rely on the guidance of teachers, which leads to the negative impact on students' learning motivation. To optimize the application of virtual simulation in the fashion-related course and teaching of practical exercises, this paper proposes a teaching method based on collaborative learning for fashion virtual simulation exercise teaching. 3D virtual fitting exercises realized by virtual simulation were adopted as the research object to verify its effectiveness. Two groups of students were involved in the experiments. One group was taught traditionally while another group was taught by the proposed collaborative learning. Through a set of learning and teaching process evaluation, experiment results demonstrated that collaborative learning will be beneficial to improving students' learning interest, efficiency, quality and facilitate the comprehensive capacity of autonomous learning, communication and cooperation, reduce the individual distinction and enhance self-confidence. This paper provides support for the future application of collaborative learning in other fashion related virtual simulation courses and exercises.

Keywords: *collaborative learning, virtual simulation, virtual fitting, exercise teaching, control experiment*

Cercetări privind aplicarea învățării colaborative în predarea practică a probării virtuale 3D a articolelor de îmbrăcăminte

Odată cu integrarea științei informației în domeniul modei, atât industria, cât și mediul universitar necesită ca tehnologia informatică să fie utilizată frecvent în cursurile de design și în predarea exercițiilor practice. În cadrul tehnologiei informației, simularea virtuală, ca instrument de experimentare important, a devenit un suport foarte popular pentru studenții de la facultățile de design, deoarece validează ideile estetice foarte eficient și rapid. Cu toate acestea simularea virtuală este destul de tehnică și este foarte dificil pentru studenți să dobândească toate abilitățile esențiale despre funcționarea software-ului într-un timp scurt, bazându-se în mare parte pe îndrumarea profesorilor, ceea ce duce la impactul negativ asupra motivației de învățare a studenților. Pentru a optimiza aplicarea simulării virtuale în cursul de design și predarea exercițiilor practice, această lucrare propune o metodă bazată pe învățarea colaborativă pentru predarea exercițiilor de simulare virtuală în domeniul modei. Pentru a verifica eficacitatea acesteia, au fost adoptate ca obiect de cercetare exerciții de probare virtuală 3D realizate prin simulare virtuală. Două grupuri de studenți au fost implicate în experimente. Un grup a fost supus predării în mod tradițional, în timp ce un alt grup a fost supus predării prin învățarea colaborativă propusă. Printr-un set de evaluare a procesului de învățare și predare, rezultatele experimentului au demonstrat că învățarea colaborativă va fi benefică pentru îmbunătățirea interesului acordat învățării, eficienței și calității și pentru a facilita capacitatea completă de învățare autonomă, comunicarea și cooperarea, reducerea distincției individuale și sporirea încrederii în sine. Această lucrare oferă suport pentru aplicarea viitoare a învățării colaborative în alte cursuri și exerciții de simulare virtuală legate de modă.

Cuvinte-cheie*: învăţare colaborativă, simulare virtuală, probare virtuală, predare cu exerciţii, experiment de control*

INTRODUCTION

In recent years, with the rapid development of information science, virtual simulation technology has been broadly applied to many disciplines with its intuitive and repeatable characteristics [1]. Virtual design systems realized by virtual simulation technology usually simulate the real systems; including human's realistic feeling in the visual, auditory, olfactory and tactile aspects in real life [2]. The virtual simulation was initially used in the design of aerospace, and now it is functionalized with a series of new technologies such as animation simulation, visual interactive simulation, virtual reality simulation, etc. Due to these advantages, it has been widely employed in the education field, such as the teaching of practice in biology, physics, geography, medicine and other disciplines. Virtual simulation exercise teaching is an important way for students to grasp related knowledge [4]. Compared with traditional teaching methods, it has the following advantages: reducing exercise costs and waste of experimental materials, having no specific requirements for the experiment environment, being convenient to control operational details and facilitating repeated operation, and rectifying experimental scheme [5].

In the field of textile and garment related teaching, virtual simulation is also widely employed, especially in practical exercise teaching. Existing garment virtual simulation exercises include virtual garment pattern generation, virtual anthropometry, virtual fitting, virtual brand operation and virtual garment production management [6]. For example, virtual garment fitting is realized by a set of technology in different disciplines, such as computer science, material science, fashion design and garment pattern design [7]. Hong et al. employed a virtual 3D-to-2D design method to simulate a garment block and then extend the garment block, obtaining personalized ready-to-wear garment products aimed at consumers with atypical morphology [8]. They also proposed a new collaborative design-based method for designing customized garments, aimed at the physically disabled people with scoliosis, which is relied on the abstraction of feature points from a complete digitalized 3D human model realized from the 3D human body scanning date [9]. A basic garment block wireframe aligned with body features is then established based on the defined feature points of the human body. Based on the deformed wireframe, a 3D expandable garment block is modelled [10].

However, virtual simulation also has some drawbacks in the exercise teaching process. A virtual simulation exercise is generally operated based on a set of virtual models provided by virtual simulation software (such as Lectra, Clo3D). But due to technical reasons, existing simulation software cannot simulate the objects in the real world without deviations. These deviations between the simulation effect and the real garment will lead to the misunderstanding of students in the learning procedure [11]. Moreover, students are beginners in the fashion field. They lack professional fashion knowledge (such as pattern making, fitting) and are not familiar with virtual simulation software operation. Subsequently, it is difficult for students to master fashion-related virtual simulation in a short time. Therefore, students are largely relying on teachers in their learning process. They tend to follow the instructions offered by the teachers for every single step which will lead to the fact that students passively accept knowledge.

To solve this problem, the concept of collaborative learning seems to be a good solution. The concept of collaborative learning was raised by Lanster and Bell in 1700, which mainly refers to the learning mode in which the learning group is the basic unit in the teaching process, and teachers guide them to realize the cooperation between teachers and students, students and students, teachers and teachers to complete the learning tasks together [12, 13].

Collaborative learning has proven to have the following advantages: improving individual learning motivation and enhancing students' sense of responsibility, changing the situation that students passively accept knowledge and thoroughly stimulating students' subjective initiative, exercising students' social skills and improving students' comprehensive ability [14]. At present, the research on the application of collaborative learning in virtual simulation exercise teaching is limited.

In this study, we propose to integrate the concept of collaborative learning into the teaching of fashion simulation practice in order to improve teaching efficiency. Virtual fitting is a typical case of the virtual simulation exercise. This paper takes virtual fitting as the research object to verify whether collaborative learning is suitable for virtual simulation exercise teaching. By comparing the teaching effects of traditional teaching mode and applying collaborative learning mode in virtual fitting experiment teaching, this paper analyses the advantages and disadvantages of the two teaching modes and puts forward guidance for subsequent teaching practice.

METHODOLOGY

Research framework

This research is carried out in order to explore whether or not the collaborative learning methods will be suitable for virtual fitting exercise teaching and make up for the defects of traditional teaching methods. The research framework of this study is shown in figure 1. A total amount of 120 students majoring in Fashion Design and Engineering from the College of Textile and Apparel Engineering, Soochow University in 2017 (60 students) and 2018 (60 students) were selected as the experimental samples. Grade 2017 was taken as the control group and Grade 2018 was taken as the experimental group respectively. The first experiment (*Experiment I*) was carried out from September 26th to September 30th, 2018. In *Experiment I*, the traditional teaching methods was employed to teach the 2017 Grade. These students were aged (20.5 ± 1.8 years) and 6 of them are males the rest 54 students are females.

The second experiment (*Experiment II*) was carried out from September 26th to September 30th, 2019. In *Experiment II*, collaborative learning methods were employed to teach the students of the 2018 Grade. These students were aged (20.3 ± 2.1) and 9 of them are males and the rest 51 students are females. The instructors, teaching contents and teaching materials of the students in the two groups were the same, and there was no significant difference in statistics when comparing the scores of college entrance examination between the two groups ($P > 0.05$).

Therefore, the two experiments take teaching methods as the independent variable, remaining other factors identical, to compare the differences of learning effect between traditional teaching methods and collaborative learning methods employed in virtual fitting

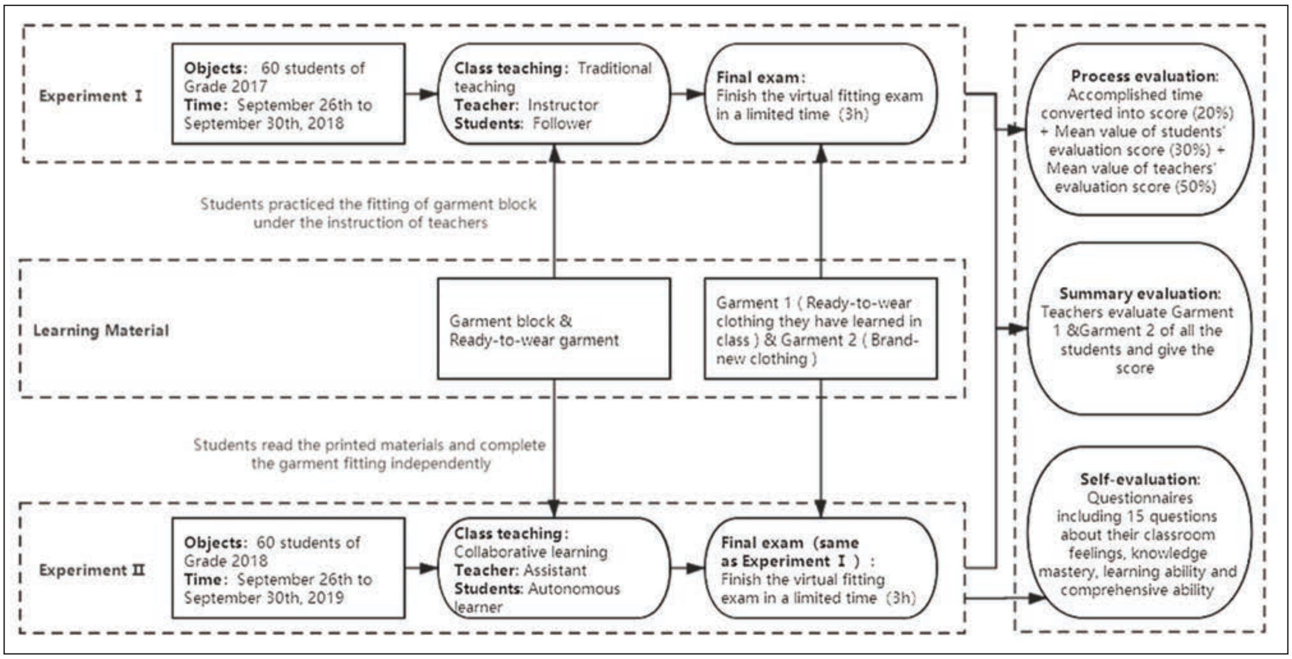

Fig. 1. Framework of research

exercise teaching. There are three evaluation procedures involved in the two experiments, which consists of two common evaluations (process evaluation and summary evaluation) and a particular self-evaluation for students in *Experiment II*. The first evaluation is performed during the learning process and the second evaluation is performed 1 month after the first evaluation. The first evaluation is designed in order to assess the learning effect including completion speed and quality of their works in the class. The second evaluation is designed to assess the maintenance of the learning effect after a period of time. The relationship between the two evaluations is the former evaluating short-term learning effects and the latter evaluating long-term learning effects respectively. The third evaluation is to investigate students' perceptions in relation to their study experience during collaborative learning.

Learning materials

The experiment subject of the two experiments (*Experiment I* and *Experiment II*) is 3D virtual garment fitting. 3D virtual garment fitting allows the simulation of all actual production sections of the fashion industry, such as stitching, fitting and visualization of textile materials on the garment [15]. The purposes of the experiment are to enable students to master the 3D virtual fitting software and skills of translating 2D pattern into 3D garment. The study of 3D virtual fitting includes not only the knowledge of garment pattern and garment sewing but also the understanding of the function of virtual fitting software and the evaluation method of the virtual fitting effect. Teaching contents include import of file → inspection and correction of 2D patterns → adjustment of mechanical properties of simulated sample fabric → setting of the size of virtual model → adjustment of the spatial position of patterns and sewing → simulation of try-on → evaluation of simulation effect of 3D clothing try-on.

Evaluation methods

As is explained in the previous section, there are 3 evaluation procedures involved in this research, namely Process evaluation, Summary evaluation, and Self-evaluation. In this section, the general procedure and data analysis methods of the involved evaluation will be explained.

Process evaluation

Scores were given to students of two experiments (*Experiment I* and *Experiment II*), which was used as the index of procedural evaluation. Teachers recorded the time for each student in each group to complete the fitting task of the same ready-to-wear garment, and the evaluation scores of the performance of the students were given according to different completion times, as is shown in table 1. After all the students finished their virtual fitting, their works were numbered and named as 60 anonymous files, and the students corresponding to each file were only known by teachers. 60 anonymous documents were randomly distributed to 60 students five times to ensure that each student's clothing received evaluations five times. At the same time, five teachers from the fashion department of Soochow University were asked to evaluate 60 sets of clothing respectively. The students' procedural evaluation score is the score corresponding to the speed of fitting (20%), plus the score evaluated by classmates (30%) and the score evaluated by teachers (50%), totalling 100 points.

We provided a scoring scale for teachers and students, which include three parts: overall effect, completion degree and details. The completion degree is

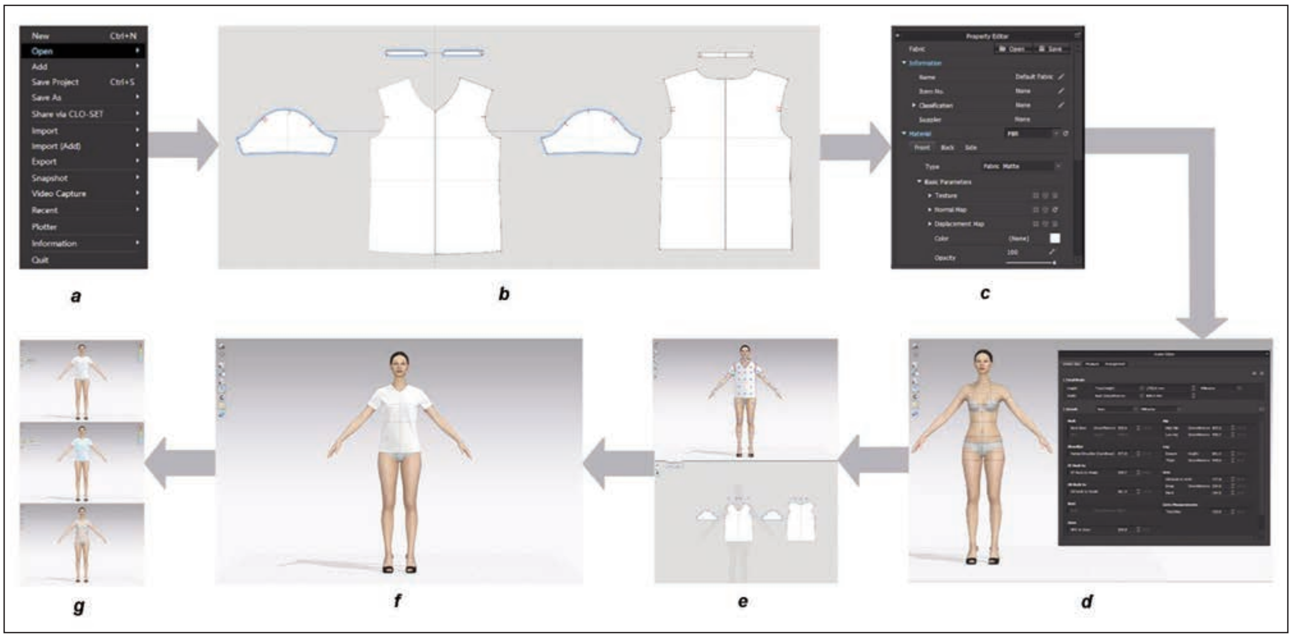

Fig. 2. A case study for the virtual fitting process: *a* – import of file; *b* – adjustment of 2D patterns; *c* – adjustment of fabric properties; *d* – setting of size of virtual model; *e* – adjustment of spatial position of patterns and sewing; *f* – simulation of try-on; *g* – evaluation

Table 1

COMPLETION TIME OF VIRTUAL FITTING AND ITS CORRESPONDING SCORE

Time (h)	≤2	2~3	3~4	4~5	>5
Score	100	90~100	80~90	70~80	60~70

divided into the completion degree of different garment parts (whether the sewing of the collar, sleeve, placket and other parts is completed, fabric attributes are set, etc.). The detailed score is given according to the quality of the finished part (whether the sewing lines of each part are accurate, the fabric attributes are set reasonably and the folding angle is set correctly as well as the aesthetic aspects about wrinkles, stitches, prints, etc.).

Summary evaluation

One month after the end of the experiment above, another set of experiments was performed to access the skills regarding the virtual fitting of the group of the involved students in *Experiment I* and *Experiment II,* including Garment 1 (the ready-to-wear clothing they have learned in class) and Garment 2 (a brand-new complex style clothing), which was assessed in a limited time (3h). The final clothing evaluation was completed by 10 teachers from the fashion department of Soochow University with a total score of 100 points (using the same scoring scale as process evaluation).

Self-evaluation

This study should not only pay attention to the objective learning effect under collaborative learning mode but also pay attention to students' subjective views on collaborative learning mode. Questionnaires were distributed to the students in *Experiment II* group, which included 15 questions in four aspects: classroom feelings, knowledge mastery, learning ability and comprehensive ability.

Statistical methods

Adopting SPSS statistical software, the measurement data is expressed as ($\bar{x} \pm s$), where $\bar{x}$ is the mean and s is the standard deviation. T test was used for independent samples between groups, and the counting data was expressed in (%).

T test calculation equation is the following:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{(n_1-1)S_1^2 + (n_2-1)S_2^2}{n_1 + n_2 - 2}\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}} \qquad (1)$$

$\bar{X}_1$, $\bar{X}_2$ are the mean of two samples, S_1^2, S_2^2 are the variance of two samples, and n_1, n_2 are the capacity of two samples.

EXPERIMENTS AND RESULTS

Experiments

Experiment I teaching methods and final examine

Experiment I adopted the traditional teaching methods. In the learning process, students will follow the instructions of the teachers for every single step of the software operation. Teachers demonstrated the fitting process of a set of garment block and a set of ready-to-wear garments respectively. Students practiced the fitting of garment block under the instruction of teachers and then completed the virtual fitting of a ready-to-wear garment according to their memory or notes by themselves. Teachers played a leading role in the whole teaching process, students received knowledge passively, and there was no interaction among students in the class. Students could ask teachers for advice when they encountered problems. One month after the end of the experiment above, students in *Experiment I* would finish the virtual fitting exam in a limited time, which includes Garment 1 (Ready-to-wear clothing they have learned in class) and Garment 2 (Brand-new clothing).

Experiment II teaching methods and final examine

Experiment II adopted the teaching method of collaborative learning. There are seven basic concepts of collaborative learning: competition, debate, cooperation, problem-solving, partnership, design and role-playing [16]. The 3D virtual fitting experiment can be taught using the concept of competition, cooperation and problem-solving. All the students were divided into 12 groups and there were 5 students in each group. The competition between groups was employed before the class. Printed instructions were distributed to each student in each group, and the garment sample to be used in the experiments was the same as that of the control group which is a garment block. First, each group of students were given 1 h to read and discuss the printed instructions, and then completed the fitting tasks of a set of clothes with the same ready-to-wear garment as the control group. During the fitting procedure, students were allowed to communicate and discuss with each other, and teachers could give additional instruction when the students encountered problems. One month after the end of the experiment above, students in *Experiment II* would finish the virtual fitting exam in a limited time, which included Garment 1 (Ready-to-wear clothing they have learned in class) and Garment 2 (Brand-new clothing).

Results

There are three different results involved in this study: i) procedural evaluation results; ii) summary evaluation results; iii) questionnaire survey results. Tables 2, 3 and 4 present these results respectively

The summary evaluation scores of the control group and the experimental group are shown in table 3.

A total of 60 questionnaires were distributed and 60 questionnaires were recovered, with a recovery rate of 100%. Descriptive statistical results of students' views on group collaborative learning model are shown in table 4 ($n = 60\%$).

DISCUSSION

Table 2 discusses the process evaluation of the involved experiments. It can be seen from table 2 that regarding the speed score, the result of *Experiment II* is higher than that of *Experiment I* in the process evaluation, indicating that the students in *Experiment II* can complete the complex style virtual fitting faster than students in *Experiment I*, and that the collaboration within the group and the competition between the groups can motivate the students to complete the task quickly. In addition, the evaluation score given by students and teachers in *Experiment II* is higher than that in *Experiment I*, which manifests that the collaborative learning mode can improve their learning efficiency and virtual fitting exercise skills. The standard deviation of *Experiment II* is smaller than that of *Experiment I*, which indicates that the individual difference between the students in *Experiment II* is smaller. It can be deduced that the collaborative learning model is more beneficial to improve the class average level. As $P \leq 0.05$ in the T-test, there is a significant difference between the two experiments relating to the completion speed score, score given by teachers and total score. The T-test result of students' evaluation scoring is $P > 0.05$ indicates that there is no significant difference between the two experiments, which may be due to the lack of evaluation experience of students.

Table 3 discusses the summary evaluation results. It can be seen from table 3 that the P values of Garment 1, Garment 2 and the total score of the two experiments are all less than 0.05, indicating that there are significant differences in learning effects

Table 2

PROCEDURAL EVALUATION RESULTS

Type size	Number	Speed score	Student evaluation	Teacher evaluation	Total score
Experiment I	60	75.63 ± 2.54	89.82 ± 3.74	85.51 ± 2.32	84.83 ± 2.79
Experiment II	60	76.77 ± 1.35	90.75 ± 3.67	87.15 ± 2.33	86.15 ± 2.54
T value	-	3.04	1.36	3.83	2.69
P value	-	0.003	0.179	0.000	0.009

Table 3

SUMMARY EVALUATION RESULTS

Group	Number	Garment 1	Garment 2	Total score
Experiment I	60	93.46 ± 3.10	80.68 ± 4.65	87.07 ± 3.88
Experiment II	60	95.38 ± 2.21	86.34 ± 3.35	90.86 ± 2.78
T value	-	3.87	7.58	6.10
P value	-	0.000	0.000	0.000

Table 4

QUESTIONNAIRE SURVEY RESULTS

Question	Totally agree	Agree	Uncertain	Disagree	Totally disagree
Recognition of collaborative learning model	35.0	36.7	10.0	10.0	8.3
Improve the enthusiasm of learning	43.3	38.3	8.3	6.7	3.3
Classroom atmosphere active	53.3	28.3	13.3	5.0	0
Conducive to analysing and solving problems	20.0	48.3	10.0	11.7	10.0
Conducive to understanding and mastering knowledge	51.7	31.7	5.0	8.3	3.3
Improve the experimental skills	38.3	36.7	10.0	10.0	5.0
Improve software skills	40.0	33.3	15.0	8.3	3.3
Improve professional knowledge	50.0	31.7	5.0	10.0	3.3
Improve the ability of autonomous learning	46.7	43.3	1.7	3.3	5.0
Improve the ability to cooperate	56.7	36.7	3.3	3.3	0
Improve the communication ability	51.7	33.3	5.0	5.0	5.0
Improve the sense of responsibility to the team	31.7	41.7	8.3	11.7	6.7
Improve the fun of classroom learning	28.3	33.3	11.7	8.3	1.7
Improve self-confidence	33.3	31.7	16.7	10.0	8.3
I also want to learn other courses in the mode of collaborative learning	40.0	33.3	16.7	8.3	1.7

between the two experiments. The scores of Garment 1 and Garment 2 in *Experiment II* are higher than those in *Experiment I*, and the standard deviation is lower than *Experiment I*, which indicates that the collaborative learning mode is more conducive to maintaining the learning effect and eliminating the individual differences among students in the group. The scores of Garment 1 in both experiments are obviously higher than those of Garment 2, because Garment 1 is the same as the clothing practiced in class, which verified that the practice in class enhances the students' memory of the virtual fitting process of Garment 1, while Garment 2 is a new style that students are not familiar with, which makes Garment 2 scores much lower than Garment 1. However, the score of Garment 2 in *Experiment II* was significantly higher than that in *Experiment I*, which indicates that the collaborative learning mode is more helpful for students to improve their capacity of analysing problems and drawing inferences from others.

Table 4 shows the descriptive statistical results of students' views on the group collaborative learning model. It can be seen from table 4 that, in general, 71.7% of students basically approve of collaborative learning mode, and 73.3% of students want to learn more courses in collaborative learning mode. Academically, 68.3% of the students think that collaborative learning is beneficial to analysing and solving problems, more than 70% of them think that collaborative learning has improved their exercise skills and software knowledge, more than 80% think that collaborative learning has improved their professional knowledge, ability to acquire knowledge and communication skills, and more than 90% think that collaborative learning has improved their autonomous learning ability and cooperation ability.

Psychologically and socially, more than 80% of the students think that collaborative learning has aroused their learning enthusiasm, 73.4% of the students think that collaborative learning has improved their personal sense of responsibility to the group, and more than 60% of the students think that collaborative learning has improved their classroom learning pleasure and self-confidence. It is inferred that students generally hold a positive attitude towards the group collaborative learning mode, which verifies the advantages of collaborative learning compared with traditional teaching methods. It is obvious that the collaborative learning mode is conducive to cultivating students' comprehensive abilities in autonomous learning, cooperation with others, communication and so on, and stimulating students' interest in learning and sense of honour and responsibility.

Williamson et al. report a study evaluating the implementation of collaborative learning in practice models at a university school of nursing and midwifery with practice partners across the South West of England. They found that collaborative learning is more helpful for nurses to contact and adapt to nursing practice than traditional instruction method in exercise courses [17]. In the research of Vijayalakshid et al., the second-year students of fashion design and marketing adopted collaborative learning method in a fashion design course. They evaluated the effectiveness of the collaborative learning method, finding that the method is efficient and they received positive response from students through questionnaire [18]. Different from the realistic practical operation and theoretical design, virtual simulation experiment is a practical operation in the virtual environment.

However, this study proves that the collaborative learning mode is also applicable in virtual simulation practice teaching.

It cannot be ignored that some students don't recognize the collaborative learning model, which also shows that the collaborative learning model has some drawbacks and can't be applied to all students. For example, some students are introverted and not good at communication, but their abilities are limited by the influence of others in collaborative study groups. In addition, some students have accustomed to the thinking mode of passively accepting knowledge because of long-term traditional teaching, but they can't accept the novel collaborative learning mode for a while. Teachers' position in collaborative learning is still important, and they should actively guide and supervise classroom discipline, so as to prevent students from being too active to discuss the content irrelevant to the classroom and some students from relying on their peers in the group to be lax and lazy.

CONCLUSION

In this paper, we investigated the application of collaborative learning in fashion related virtual simulation exercise. Our research consists of a group of control experiments (traditional teaching method and collaborative learning method) and three evaluations (process evaluation, summary evaluation and questionnaire survey). The results show that collaborative learning is more conducive to improving students' learning efficiency, maintaining students' memory of knowledge and skills, improving students' comprehensive ability and activating classroom atmosphere, and through questionnaires, most students generally adopt a supportive attitude towards collaborative learning. Therefore, it can be considered that the collaborative learning mode is more suitable for virtual fitting exercising teaching than the traditional teaching method. The collaborative learning method is anticipated to be used in other virtual simulation exercise teaching such as virtual garment pattern generation, virtual anthropometry. However, the questionnaire survey results show that a few students do not accept the collaborative learning mode. It indicates that our future researches will focus on optimizing collaborative learning in virtual simulation exercising teaching and making it applicable to all students.

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Prediction of the sewing standard time based on process difficulty coefficient

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ABSTRACT – REZUMAT

Prediction of the sewing standard time based on process difficulty coefficient

In garment production, the standard time is a unit widely used for production planning and calculating cost. It is very difficult to prepare manufacturing plans, short term and long-term forecasts, pricing, and other technical and managerial activities in a garment company without true standard time data. Therefore, standard time prediction as the core of standard time quota management is directly related to economic accounting, production schedule control, resource optimization, production cycles shortening, cost control and product quotation. The sewing process can be regarded as the most critical step for the entire garment production, substantially completing the shape of the garment. To achieve fast and accurate sewing process standard time prediction, this paper established the evaluation indicators for sewing process difficulty, obtained the weight of each expert to indicators analysed with analytic hierarchy process, and made group utility function to calculate the difficulty coefficient. The relationship between the sewing processes standard time and the difficulty coefficient was determined to predict the unknown standard time by curve fitting. The effectiveness and usability of this method were verified by examples. The results demonstrated that the proposed method could be a good alternative to existing prediction methods.

Keywords: *analytic hierarchy process, group utility function, garment sewing process, process difficulty coefficient, standard time*

Predicția timpului standard de coasere pe baza coeficientului de dificultate a procesului

În producția de îmbrăcăminte, timpul standard este o unitate utilizată pe scară largă pentru planificarea producției și calcularea costurilor. Este foarte dificil să se pregătească planuri de producție, previziuni pe termen scurt și lung, calcularea prețurilor și alte activități tehnice și manageriale într-o companie de îmbrăcăminte fără date reale de timp standard. Prin urmare, predicția timpului standard ca nucleu al gestionării normelor de timp standard este direct legată de contabilitatea economică, controlul programului de producție, optimizarea resurselor, scurtarea ciclurilor de producție, controlul costurilor și cotația produselor. Procesul de coasere poate fi considerat cel mai critic pas pentru întreaga producție de îmbrăcăminte, completând substanțial forma îmbrăcămintei. Pentru a realiza o predicție rapidă și precisă a timpului standard al procesului de coasere, această lucrare a stabilit indicatorii de evaluare a dificultății procesului de coasere, a obținut ponderea fiecărui expert la indicatorii analizați cu procesul de ierarhie analitică și a realizat funcția de utilitate de grup pentru a calcula coeficientul de dificultate. Relația dintre timpul standard al proceselor de coasere și coeficientul de dificultate a fost determinată pentru a preconiza timpul standard necunoscut prin ajustarea curbei. Eficacitatea și utilitatea acestei metode au fost verificate prin exemple. Rezultatele au demonstrat că metoda propusă ar putea fi o alternativă eficientă la metodele de predicție existente.

Cuvinte-cheie*: proces de ierarhie analitică, funcție de utilitate de grup, proces de coasere a articolelor de îmbrăcăminte, coeficient de dificultate a procesului, timp standard*

INTRODUCTION

In recent years, due to greater competition in the market, the patterns of product have become more diversified and their life cycle shorter. Adapting to the enterprise environment changes, improving the enterprise's agility and responding quickly to the customer's requirements is becoming more and more important. In such a context, the importance of efficient determination of standard time needs to be stressed even further. It is very difficult to prepare manufacturing plans, short term and long term forecasts, pricing, and other technical and managerial activities in a company without true standard time [1]. Standard time not only directly affects the working time, the utilization rate of the equipment, but also is the basic unit for calculating cost, and is widely used for cost management in manufacturing enterprises. Therefore, standard time prediction is directly related to economic accounting, production schedule control, resource optimization, production cycles shortening, cost control and product quotation. Besides, it ultimately promotes the improvement of labour productivity of enterprises and enhances their market competitiveness [2]. The term "standard time" is used to refer to the time required by an average skilled operator, working at a normal pace, to perform a specified task using a prescribed method [3]. It includes appropriate allowances to allow the person to recover from fatigue and, where necessary, an additional allowance to cover contingent elements which may occur but have not been observed.

The joining together of garment components, known as the sewing process, is the most labour intensive part of garment manufacturing [4]. The sewing process needs to be carried out strictly by the production plan, which includes not only the distribution of the production site, equipment and resources but also the arrangement of standard time. Standard time is a key indicator to measure the production efficiency of the sewing department [5]. Standard time is a common language between fashion brands and manufacturers for discussions on cost, time and floor capacity. A manager should know the time consumption of a new product processing exactly before acceptance. Industrial engineers take responsibility for measuring standard time for the given garment samples. The standard time of the same operation will be different if the working condition is changed, like the operator using a different machine, the operator sewing a bigger component, an operator using attachment and work-aids when sewing a garment. With the constant development and application of computer technology, more and more advanced manufacturing technology, scientific and digital management have been generally accepted in the clothing industry. The advantages of the standard time estimation method can effectively help clothing enterprises to reduce costs and improve production efficiency. In this study, we propose a sewing process standard time prediction method based on regression analysis, which involves difficulty coefficient variables that can be utilized for sewing standard time prediction at actual garment production. The process difficulty coefficient can be defined as the difficulty value of a certain process reaching a certain standard. The proposed approach offers the manager the possibility to easily formulate the sewing process standard time. In addition, the new method demonstrates an aided tool for decision in the field of standard time.

RELATED WORKS

Since Taylor defined standard time as the most fundamental way to represent productivity under the basic concept of "A Fair Day's Work", many methods on the determination of standard time have been performed such as time study, activity sampling, synthetic timing, analytical estimating, predetermined motion time systems(PTS) [6]. Chen et al proposed a synthetic timing method to solve the problem of making standard time of customized parts in a mass customization environment [7]. Pan et al. established standard time in the die manufacturing process using the activity sampling method [8]. Wang et al suggested the estimation procedure of standard time for companies manufacturing multi-pattern and extremely small quantity items [9]. Li et al. use the time study method to establish the man-hour quota calculation model, data structure and work improvement circulation model for an enterprise specialized in producing nuclear power pipes [10]. Hee et al. use the predetermined motion time systems method to establish a standard time for agricultural work in Korea [11].

There were also many studies to apply the above-mentioned approach to predict the standard time of the process in making clothes. Ye et al established standard time in the garment manufacturing process using the synthetic timing method [12]. Wu et al. propose an analytical estimating method for standard time based on the similarity of sewing processes [13]. Du et al. make use of the predetermined motion time systems method to calculate the standard time of the template sewing process [14]. Liu et al. performed a traditional time study method by using a stopwatch for garment producing companies [15]. However, these methods have their limitations. For instance, the results of the analytical estimating method depend on human knowledge and experience, so different people obtain different results of standard time estimation. The synthetic timing method needs a lot of work to build up books of times, it is not easy to update those books. Predetermined motion time systems are labour consumption methods, so it is not often used in pre-production especially in small-lot production. In this sense, the reliable, easy to update and reasonable way of sewing process standard time determination method is essential for efficient production planning and control under such a varying production environment.

METHODS

The procedure of garment sewing process standard time prediction based on difficulty coefficient

In this study, our goal is to build a sewing process standard time prediction model by using data from garment manufacturing companies as well as variables we considered. The main steps are as follows.

1. The evaluation model of garment sewing difficulty coefficient is constructed by using the analytic hierarchy process (AHP) and group decision theory.
2. Matlab software is used to curve fitting the process difficulty coefficient and standard time.
3. Estimating of sewing standard time by the regression equation.

Index system of sewing process difficulty

The difficulty coefficient of each sewing process is predicted in advance by comprehensively taking into account the characteristics of the sewing process, the environment, and past experiences. Therefore, even for identical sewing processes, different standard time can be predicted depending on several different factors. In general, many objective or subjective factors are involved in the complicated garment manufacturing process. Firstly, the complexity of a garment sewing process is determined primarily by clothing style, such as type of fabric, type of seams, and the size and shape of cutting patterns. Yukari et al study on the relationship between the seam ability and mechanical properties of wool fabrics showed that the mechanical properties of fabrics affect the quality and difficulty of garment productions [16]. Secondly, stable garment manufacturing processes requires advanced production equipment and good production condition. Thirdly, workers' level of effort and skill proficiency directly impact the production efficiency and actual standard time in garment manufacturing. It is well demonstrated in the garment industry that providing training for new workers or offering a pre-production process is effective to improve workers' ability to operate the equipment. Finally, professional management team and management practices also affect standard time. Higher wages or rewards motivate workers to maintain high levels of effort, encourage them to keep work interests and develop relationships with managers or colleagues. To summarize, the index system of sewing process difficulty consists of 5 primary factors including component character, production configuration, staff, management, environment, and 15 secondary indexes (table 1).

Table 1

INFLUENCE FACTORS OF SEWING PROCESS DIFFICULTY

First-level indicators	Second-level indicators
Component character	Fabric and accessory
	Cuttings shape
Production configuration	Equipment
	Delivery tool, template, et
	Technologic content
Staff	Staff training
	Proficiency
	Employee effort
	Multi-skilled worker
	Salary system
Management	Professional management team
	Good collaboration in the department
Environment	Stability of production conditions
	Flexibility of production line
	Production environment

Questionnaire investigation and weights of expert to indicators

A questionnaire-based survey methodology has been adopted. In the questionnaire, every indicator was classified and assigned score of 0 to 5, with 5 being the highest effect on standard time and 0 meaning no effect. In order to make the pairwise comparison, every expert is asked to select one of two elements according to a nine-point scale that indicates the degree to which one element is more important, preferred, or dominant. We make sure that each expert should provide pairwise comparisons preference information on the entire set of objects. The analytical hierarchy process (AHP) was used in this study to determine the weight coefficients of each expert to indicators. The analytic hierarchy process is the most popular multi criteria decision-making method that quantitatively measures the expert's opinion in the form of weights. The AHP initially involves a pair-wise comparison matrix wherein the relative dominance of each factor (or sub-factor) is compared with respect to the common variable. The consistency of derived weights (eigenvectors) is checked by calculating the consistency ratio (CR). A preference vector (w_{i1}, w_{i2}, …, w_{i15}) will be generated for each expert (W_1, W_2, …, W_m).

Weight of each expert

We can identify any group members "i" and "j" who share agreement by using the cosine method: finding the cosine of the angle between their corresponding weight vector W_i and W_j. We define this agreement indicator as:

$$\cos a_{ij} = \frac{W_i W_j}{||W_i|| \times ||W_j||} \quad (1)$$

where $W_i W_j$ is the dot product of the two vectors, and $||W_i||$, $||W_j||$ are the 2-norms of W_i, W_j, respectively. If W_i and W_j are fairly similar, then $\cos a_{ij}$ will be fairly close to 1. If the two vectors are very dissimilar (i.e., almost orthogonal), then $\cos a_{ij}$ will be close to 0. If we specify threshold values a (for strong agreement) and b (for strong disagreement), then group members "i" and "j" will be said to have strong agreement if $\cos a_{ij} > a$, and strong disagreement if $\cos a_{ij} < b$. A possible value for a is 0.67, and a possible value for b is 0.33. Hence, the group strong agreement quotient (GSAQ) value may thus be computed as follows:

$$GSAQ = \frac{\sum_{i \in T} \sum_{i<j} 2\eta(i,j)}{m(m-1)} \quad (2)$$

where $\eta(i,j) = 1$ if $\cos a_{ij} > a$, and $\eta(i,j) = 0$ if $\cos a_{ij} < a$, "T" is the index set for the group members, and "m" is the number of members in the group. Similarly, the group strong disagreement quotient (GSDQ) is computed as follows:

$$GSDQ = \frac{\sum_{i \in T} \sum_{i<j} 2\gamma(i,j)}{m(m-1)} \quad (3)$$

where $\gamma(i,j) = 1$ if $\cos a_{ij} < b$, and $\gamma(i,j) = 0$ if $\cos a_{ij} > b$. The individual consensus indicators may be calculated as follows:

$$ISAQ_i = \frac{\sum_{(i \in T, i \neq j)} \eta(i,j)}{m-1} \quad (4)$$

$$ISDQ_i = \frac{\sum_{(i \in T, i \neq j)} \gamma(i,j)}{m-1} \quad (5)$$

To sum up, the weight coefficients of each expert is obtained:

$$\lambda_i^* = \frac{ISAQ_i(1 - ISDQ_i)}{GSAQ(1 - GSDQ)} \quad (6)$$

Normalize the weight of experts, and the normalization formula is:

$$\lambda_i = \frac{\lambda_i^*}{\sqrt{\sum_{i=1}^{m} \lambda_i^{*2}}} \quad (7)$$

Calculation of difficulty coefficient

In group decision-making, how to attribute the preferences of each group member to the preferences of the group, and then construct the utility function of the group, is the key problem of group decision-making method based on the utility function. The group utility function is introduced to calculate the difficulty coefficient. The general form of the group utility function is:

$$U(x) = \sum_{i=1}^{m} \lambda_i U_i(x) \quad (8)$$

$U_i(x)$ (i = 1,2,…,m) represents the individual utility function of the ith evaluator in the group, λ_i is the weight of $U_i(x)$. Based on group utility function addition model, the difficulty coefficient is:

$$\text{difficulty coefficient} = \sum_{i=1}^{m} [\lambda_i \sum_{j=1}^{n} (w_{ij} x_{ij})] \quad (9)$$

"n" is the number of evaluation indicators, x_{ij} represents the ith (i = 1,2,…,m) expert's score to the jth (j = 1,2,…,n) secondary indexes.

Curve fitting of the difficulty coefficient and standard time

Curve fitting is the process of constructing a curve or mathematical function that has the best fit to a series of data points, possibly subject to constraints. Curve fitting can involve either interpolation, where an exact fit to the data is required, or smoothing, in which a "smooth" function is constructed that approximately fits the data. Fitted curves can be used as an aid for data visualization, to infer values of a function where no data are available, and to summarize the relationships among two or more variables. MATLAB (matrix laboratory) is a multi-paradigm numerical computing environment and fourth-generation programming language. In this paper, MATLAB curve fitting toolbox is used to establish the regression function between sewing process difficulty coefficient (independent variables or predictors) $U = [A_1,A_2,A_3,…,A_m]$ and standard time (dependent variable) $T = [B_1,B_2,B_3,…, B_m]$. The regression function between the two variables can be determined by the following steps:

1. Input data in MATLAB:

>> $U = [A_1,A_2,A_3,…,A_m]$

>> $T = [B_1,B_2,B_3,…,B_m]$

2. Enters the fitting window to fit the curve and select the best fitting curve.
3. Determines the regression function between sewing process difficulty coefficient and standard time.

Case study

ZS is a privately held family-owned clothing company based in China. The company was founded in 1989 and has 4 brands. The company has accumulated a lot of sewing process standard time data in many years of production. Take the linen dress produced by ZS company as an example, the assembly line has 25 people in total, and the order quantity is 820 pieces. We selected 13 sewing processes in the production of linen dress. The sewing process information and standard time are shown in table 2.

Table 2

PROCESS INFORMATION OF LINEN DRESS

Sewing process	Standard time (second)
Sewing darts	79
Joining shoulder seam	101
Top-stitching under collar	42
Joining under the collar and top collar	75
Sewing collar on and down	48
Joining sleeve seam	67
Setting in sleeve	64
Joining centre back seam	59
Stitching waistband and lining	66
Joining side seam	54
Attaching sleeve tab	Unknown
Attaching pocket to the garment	22
Attaching zipper	120

Based on the Influence factors of sewing standard time shown in table 1, five experts who have been a wide experience of 10 to 25 years in sewing processing are selected to fill in the questionnaire. According to equations 2 and 3, the group strong agreement quotient (GSAQ) and the group strong disagreement quotient (GSDQ) are calculated, and GSAQ = 0.751 > 0.67, which demonstrate that the group opinions of the experts are consistent, and the survey data can be used. Firstly, the survey data were standardized to get the evaluation value of each indicator, shown in table 3, the standardized value calculation formula is:

$$x_i' = (x_i - x_{min}) / (x_{max} - x_{min}) \quad (10)$$

where, x_i is the ith item in the sequence of scores; x_{min} is the minimum value of the sequence; and x_{max} is the maximum value of the sequence. Then using the AHP method to construct pairwise comparison matrices for each response among all the components in the extent of the hierarchy system, and obtain 5 groups of sorting vectors through single-level sorting, general level sorting and consistency detection, shown in table 4.

According to equations 4–7, calculate the individual strong agreement quotient, the individual strong disagreement quotient, weight of experts λ_i^* and standard weight of experts λ_i, as shown in table 5.

Table 3

STANDARDIZED SCORES OF SUB-FACTORS FOR EACH EXPERT					
i = 1,2,3,4,5	$X_{i=1}$	$X_{i=2}$	$X_{i=3}$	$X_{i=4}$	$X_{i=5}$
x_{i1}	0.67	1.00	0.67	0.67	1.00
x_{i2}	1.00	1.00	1.00	0.67	1.00
x_{i3}	0.67	1.00	0.67	0.67	0.67
x_{i4}	0.33	0.67	0.33	0.67	1.00
x_{i5}	1.00	0.67	0.33	0.67	0.33
x_{i6}	0.33	0.67	0.67	1.00	0.33
x_{i7}	0.67	1.00	0.67	0.33	0.33
x_{i8}	0.00	0.33	0.67	0.33	0.33
x_{i9}	0.33	0.67	0.33	0.67	0.67
x_{i10}	0.33	0.33	0.67	0.67	1.00
x_{i11}	0.67	1.00	0.67	0.67	1.00
x_{i12}	0.33	0.67	0.67	0.33	0.67
x_{i13}	0.33	0.33	0.67	0.33	0.33
x_{i14}	0.33	0.33	1.00	0.67	0.67
x_{i15}	0.33	0.67	0.00	0.67	0.67

Table 4

WEIGHTS OF SUB-FACTORS FOR EACH EXPERT					
i = 1,2,3,4,5	$W_{i=1}$	$W_{i=2}$	$W_{i=3}$	$W_{i=4}$	$W_{i=5}$
w_{i1}	0.076	0.082	0.078	0.078	0.090
w_{i2}	0.084	0.095	0.110	0.071	0.088
w_{i3}	0.053	0.073	0.076	0.069	0.064
w_{i4}	0.081	0.066	0.055	0.059	0.079
w_{i5}	0.101	0.077	0.052	0.066	0.050
w_{i6}	0.063	0.059	0.069	0.119	0.049
w_{i7}	0.047	0.090	0.071	0.047	0.047
w_{i8}	0.063	0.035	0.062	0.054	0.054
w_{i9}	0.078	0.059	0.049	0.079	0.067
w_{i10}	0.055	0.033	0.067	0.072	0.078
w_{i11}	0.087	0.080	0.068	0.066	0.084
w_{i12}	0.084	0.068	0.069	0.048	0.069
w_{i13}	0.043	0.057	0.056	0.043	0.056
w_{i14}	0.045	0.059	0.087	0.066	0.062
w_{i15}	0.047	0.076	0.038	0.073	0.068
CR	0.031	0.076	0.018	0.035	0.036

According to equation 9 calculate the difficulty coefficient, as shown in table 6. Based on MATLAB curve fitting toolbox and table 6 data, curve fitting is carried out with Exponential function (number of terms: 2), Gaussian function (number of terms: 1) and Polynomial function (degree: 2), the R-square are 0.9487, 0.9474 and 0.9464 respectively. It can be seen that the fitting effect of the Exponential function is the best for the standard time and difficulty coefficient of the sewing processes, shown in figure 1. The regression model for sewing process standard time and difficulty coefficient (x) as follows:

$$f(x) = -29120\, exp(0.4516x) + 29080\, exp(0.4593x) \quad (11)$$

Table 5

WEIGHT OF EXPERT					
Index	**Expert**				
	1	**2**	**3**	**4**	**5**
$ISAQ_i$	0.565	0.637	0.603	0.897	0.732
$ISDQ_i$	0.108	0.093	0.111	0.057	0.078
GSAQ	0.751				
GSDQ	0.095				
λ_i^*	0.742	0.850	0.789	1.245	0.993
λ_i	0.167	0.192	0.178	0.281	0.224

Table 6

DIFFICULTY COEFFICIENT OF THE SEWING PROCESS		
Sewing process	**Standard time4 (seconds)**	**Difficulty coefficient**
Sewing darts	79	0.46
Joining shoulder seam	101	0.53
Top-stitching under collar	42	0.38
Joining under the collar and top collar	75	0.45
Sewing collar on and down	48	0.4
Joining sleeve seam	67	0.42
Setting in sleeve	64	0.41
Joining centre back seam	59	0.37
Stitching waistband and lining	66	0.42
Joining side seam	54	0.36
Attaching sleeve tab	unknown	0.37
Attaching pocket to the garment	22	0.27
Attaching zipper	120	0.59

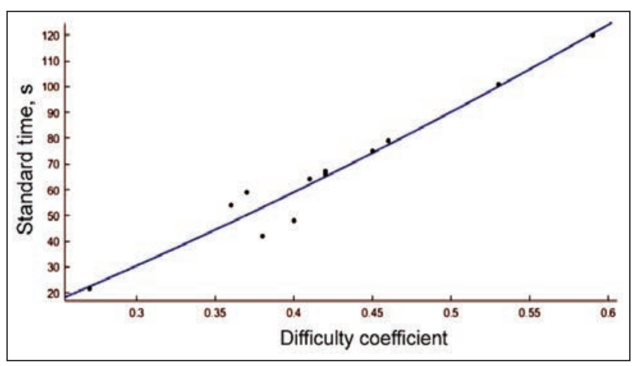

Fig. 1. The fitting curve of Exponential function

The difficult coefficient of attaching the sleeve tab is 0.27. According to formula (11), the standard time of attaching the sleeve tab is 50.8 seconds. It can be seen from table 7 that the predicted standard time based on the process difficulty coefficient method is close to the actual standard time. Therefore, after establishing the functional relationship between standard time and sewing process difficulty coefficient, we only need to determine the unknown sewing process difficulty coefficient, and then we can predict the standard time conveniently and accurately.

Table 7

COMPARATIVE ANALYSIS OF FORECAST STANDARD TIME AND ACTUAL STANDARD TIME

Method	Seconds
Actual standard time	51.6
PTS method	49.9
A method based on process difficulty coefficient	50.8

CONCLUSIONS

The sewin process is crucial for garment production. To arrange the resources and make a production plan reasonably. It requires effective prediction of standard time at the beginning of the production; therefore, a model is proposed to predict the standard time of the garment sewing process in this study, which provides a valuable guideline and provides a useful reference for engineers and managers in the production process. Firstly, 15 influencing factors related to the standard time of sewing are identified by using the literature review. Then, analysed with analytic hierarchy process (AHP), obtained the weight of each index, and made group utility function to calculate the difficulty coefficient. Finally, the MATLAB curve fitting toolbox is used to establish the regression function between the sewing process difficulty coefficient and standard time. An example is used to demonstrate the efficiency of the proposed approach.

The predictive model can effectively forecast the standard time of different sewing processes according to their difficulty coefficient. The proposed regression model with a very limited calculation time is very easy to use in the estimation of standard time for any garment production department of a company. The companies that do not know the exact sewing standard time of their products due to measurement difficulties can easily obtain these time values with the benefits of lower cost, shorter time, and higher accuracy for use in production planning.

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Effect of regenerated cellulosic fibre content in polyester/regenerated and cotton/regenerated blend yarns on comfort properties of woven fabrics

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ABSTRACT – REZUMAT

Effect of regenerated cellulosic fibre content in polyester/regenerated and cotton/regenerated blend yarns on comfort properties of woven fabrics

This study investigates some comfort properties of cotton and polyester fabrics blended with varying ratios (%) of regenerated cellulosic fibres including Viloft®, ProModal®, and bamboo fibre. 23 types of woven samples made of Viloft®, ProModal®, and bamboo regenerated cellulosic fibres blended with polyester and cotton at different proportions (100%, 67/33%, 50/50%, 33/67%) besides with 100% cotton and 100% polyester fabrics were produced. Woven samples were subjected to some comfort tests including air permeability (mm/sec), wicking rate (mm/sec), water absorption ratio (%), and water vapour permeability index was also obtained. Statistical test results regarding fibre type, fibre blend components, and blend ratio (%) on fabric comfort properties were evaluated by using the SPSS program. In the content of this experimental work, it was revealed that fibre type, fibre blend components, and blend ratio have a significant effect on some comfort properties such as air permeability, wicking rate, and absorption ratio. However, those parameters did not have any significant effect on the water vapour permeability index at a 95% significance level.

Keywords: *regenerated cellulose fibre, Viloft®, ProModal®, bamboo, wicking rate, water vapour permeability index*

Influența conținutului de fibre celulozice regenerate din fire în amestec de poliester și bumbac regenerat asupra proprietăților de confort ale țesăturilor

Acest studiu investighează unele proprietăți de confort ale țesăturilor din bumbac și poliester în amestec cu proporții diferite (%) de fibre celulozice regenerate, inclusiv Viloft®, ProModal® și fibre de bambus. Au fost produse 23 de tipuri de mostre țesute din fibre celulozice regenerate Viloft®, ProModal® și bambus amestecate cu poliester și bumbac în diferite proporții (100%, 67/33%, 50/50%, 33/67%) pe lângă țesături din 100% bumbac și 100% poliester. Probele țesute au fost supuse unor teste de confort, inclusiv permeabilitatea la aer (mm/sec), viteza de absorbție (mm/sec), raportul de absorbție a apei (%) și indicele de permeabilitate la vapori de apă a fost, de asemenea, determinat. Rezultatele testelor statistice privind tipul de fibre, componentele amestecului de fibre și raportul de amestec (%) asupra proprietăților de confort ale țesăturii au fost evaluate folosind programul SPSS. În conținutul acestei lucrări experimentale, a fost evidențiat faptul că tipul de fibre, componentele amestecului de fibre și raportul de amestec au o influență semnificativă asupra unor proprietăți de confort, cum ar fi permeabilitatea la aer, viteza de absorbție și raportul de absorbție. Cu toate acestea, acești parametri nu au avut nicio influenţă semnificativă asupra indicelui de permeabilitate la vapori de apă la un nivel de semnificație de 95%.

Cuvinte-cheie: *fibre celulozice regenerate, Viloft®, ProModal®, bambus, rata de absorbție, indice de permeabilitate la vapori de apă*

INTRODUCTION

The blending of fibres is a way of improving fibre features for emphasizing the good qualities and minimizing the poor qualities. Different fibre blending allows fabric production with high comfort and durability at the same time. Regenerated cellulosic fibres have been generally utilized in fibre blends for new yarn types [1] Those yarn types also may be presented as new raw material alternatives for new functional products. Today some regenerated fibres such as viscose, bamboo, Promodal®, Tencel®, Viloft® are frequently used in fibre blends at different ratios (%). Viloft® fibre which is known for its softness may be blended with cotton and polyester blends. This special fibre containing 70% air gap with a crenellated surface may be utilized in comfortable fabrics [2]. It was observed that Viloft® rich blends generally improved the thermal properties of the fabrics. According to the comparison of mechanical properties of Viloft® blend fabrics with that of polyester, Viloft® reach fabrics were found to be having lower bursting strength and pilling properties [3, 4].

Sportswear knitted fabrics produced from Viloft® and its blends with natural, synthetic, and functional fibres were evaluated in terms of mechanical and thermal comfort properties in another study. The authors concluded that Viloft®/wool blends of fabrics indicated higher thermal resistance and water vapour resistance while Viloft®/Coolmax fabrics revealed high liquid moisture comfort among Viloft® blended fabrics which showed they might be preferable for sportswear [5]. Tencel® known for its nanofibril structure absorbing a high amount of liquid and quickly releasing it again also provides a soft feeling. Promodal is a blend of Tencel and Modal which has a smooth structure and cotton-like section therefore combining the advantages of both Tencel and Modal fabrics rich in Promodal® are used for activewear, casual wear, intimate apparel, and home textiles [6]. Moisture management properties of bamboo, viscose and Tencel® single jersey knitted fabrics were investigated where the overall moisture management capacity decreased as the Tencel® content increased [7]. In another study, sportswear fabrics were developed from polypropylene and Tencel® fibres in a special knitted structure of "Ponte de roma".

Fabric properties were investigated in terms of structural, mechanical and comfort properties and the researchers concluded that Tencel®/polypropylene fabric is most suitable for active sportswear [8]. Bamboo fibre is also a kind of modal cellulosic fibre made from bamboo pulp. Bamboo can be utilized alone or may be blended with other fibres such as rayon, cotton, wool, silk, modal, etc. according to the required quality of the products. Bamboo fibre contributes the tenacity, thermal conductivity, resistivity to bacteria and high water and perspiration adsorption of textile products [9]. Majumdar et al. investigated the thermal properties of different knitted fabric structures produced from cotton, regenerated bamboo, and cotton/bamboo blended yarns. Three blends of fibres (100% cotton, 50/50% cotton/bamboo and 100% bamboo) were used as the raw material at three yarn counts (30, 24 and 20 tex). It was concluded by the authors that the thermal conductivity of knitted fabrics decreased as the proportion of bamboo fibre increased [10]. In the research conducted by Chidambaram and Govindan, cotton, bamboo fibre and blends of the two fibres (100% cotton, 100% bamboo, 50/50% cotton/bamboo, 67/33% cotton/bamboo, 33/67% cotton/bamboo) were spun into identical linear density (20 tex). Each of the yarns was converted to single jersey knitted fabrics with loose, medium and tight structures. It was analysed that the thermal conductivity of the fabrics decreased with an increase in the proportion of bamboo fibre. An increase in water vapour permeability and air permeability of the fabrics were also observed with the increase in bamboo fibre content [11].

Tausif et al. studied bamboo as an eco-friendly alternative to cotton fibre in polyester/cellulosic blends. Single jersey weft knitted fabrics made of polyester/bamboo and polyester/cotton blended yarns were produced. The yarn tensile strength, fabric bursting strength, bending length, thermal resistance and moisture management properties were evaluated. Authors concluded that polyester/bamboo blended fabrics had better mechanical properties and lower thermal properties in comparison to polyester/cotton blended fabrics [12].

To the best of our knowledge, most of the studies are evaluated in terms of some mechanical and comfort properties of knitted fabrics made of yarn blends with common regenerated fibres including viscose, bamboo, Modal etc. The objective of this study was to conduct an in-depth study for the evaluation of some comfort properties including air permeability (mm/sec), wicking height (cm), wicking rate (mm/sec), absorption rate (%) and water vapour permeability of polyester and cotton fabric samples blended with varying ratios of regenerated cellulose fibres including Viloft®, ProModal® and bamboo fibres which are yet to be investigated thoroughly.

MATERIALS AND METHODS

Materials

As raw material cotton with 4.5 micronaire fineness and 30 mm staple length was selected for the study. The physical properties of the rest of the raw materials used for this study (polyester, Viloft®, ProModal® and bamboo fibres) are given in table 1. Viloft®, ProModal® and bamboo regenerated cellulosic fibres were selected to be blended with cotton and also with polyester at different blending ratios (67/33%, 50/50% and 33/67%). The ring-spun yarn samples with 19.7 tex linear density were produced at the same production parameters (10.000 rpm spindle speed, ae=3.7). Additionally, 100% polyester, 100% cotton, 100% Viloft®, 100% ProModal® and 100% bamboo yarns were also prepared for a proper comparison [13]. Table 2 indicates yarn properties. Then, by using these yarn samples as weft yarn, a totally of 23 types of fabrics with different yarn blends were woven on a Picanol Optimax model weaving machine. As a warp, 100% cotton ring-spun yarn at 29.5 tex linear density was used for this study. Finally, woven fabric samples were processed with further singeing, de-sizing and finishing processes and thermal fixation at the same parameters for all woven fabric types.

Table 1

PROPERTIES OF RAW MATERIAL		
Raw material	**Linear density (dtex)**	**Staple length (mm)**
Polyester	1.3	32
Viloft®	1.9	38
ProModal®	1.3	38
Bamboo	1.5	38

Methods

Before all tests, all fabrics were conditioned for 24 hours in standard atmospheric conditions (at the temperature of 20 ± 2°C and relative humidity of 65 ± 4%). Since woven fabrics produced within the study are expected to be used for apparel garments, some comfort properties were considered to be evaluated. Comfort properties including air permeability

Table 2

YARN PROPERTIES								
Fibre type	**Fibre blend type**	**Blend ratio (%)**	**Tenacity (cN/tex)**	**Elongation (%)**	**Unevenness (%CVm)**	**IPI**	**Hairiness (H)**	**Diameter (2DØmm)**
CO Blend	Viloft®	100/0	13.88	5.16	13.51	59.00	6.24	0.241
	Viloft®	67/33	12.00	5.09	13.79	60.50	6.74	0.233
	Viloft®	50/50	10.79	5.30	14.34	82.50	7.07	0.235
	Viloft®	33/67	9.56	6.68	14.32	60.50	7.52	0.235
	Viloft®	0/100	10.30	9.73	17.05	332.50	9.48	0.239
	ProModal®	67/33	14.71	5.37	13.11	105.50	5.59	0.226
	ProModal®	50/50	15.18	5.67	12.32	69.50	5.63	0.222
	ProModal®	33/67	15.33	6.78	12.19	46.00	5.82	0.224
	ProModal®	0/100	20.36	8.24	12.78	51.50	5.86	0.217
	Bamboo	67/33	13.30	5.01	12.58	58.50	5.56	0.229
	Bamboo	50/50	12.62	5.33	12.49	38.50	5.25	0.221
	Bamboo	33/67	11.75	5.56	12.72	47.50	5.08	0.219
	Bamboo	0/100	13.98	12.72	14.11	56.50	5.20	0.214
PES Blend	Viloft®	100/0	27.43	10.80	15.49	40.00	5.66	0.212
	Viloft®	67/33	19.39	10.56	15.30	111.00	7.99	0.232
	Viloft®	50/50	16.77	10.28	16.06	198.00	7.44	0.229
	Viloft®	33/67	13.89	10.46	16.77	284.00	8.76	0.236
	ProModal®	67/33	24.19	9.52	12.34	53.50	5.74	0.219
	ProModal®	50/50	24.50	9.97	11.85	33.50	6.01	0.218
	ProModal®	33/67	22.55	9.62	13.15	30.63	5.96	0.218
	Bamboo	67/33	25.35	11.60	11.39	19.50	5.30	0.214
	Bamboo	50/50	22.83	11.21	11.40	22.50	5.13	0.213
	Bamboo	33/67	20.88	12.44	11.71	23.00	5.38	0.215

(mm/sec), wicking rate (mm/sec), water absorption (%) and water vapour permeability index were measured. Air permeability of the fabrics was measured based on EN ISO 9237 standard using a SDL Atlas Digital Air Permeability Tester Model M 021A at 20 ± 2°C and 65 ± 4% humidity. Measurements were performed by application under 200 Pa air pressure drop per 20 cm^2 fabric area. Averages of measurements from 10 different areas of fabrics were calculated. Wicking is described as the flow of the liquid in a porous substance concerning capillarity. There are many ways introduced for conducting wicking measurements in early research [14]. In this study, the wicking properties of the fabrics were evaluated in terms of wicking height (cm) and wicking rate (mm/s). Vertical wicking properties of the woven samples in the weft direction were evaluated with the help of the 20×2.5 cm strip test specimens which were suspended vertically with their 3 cm of lower end immersed in a reservoir of distilled red coloured water [15–19]. Wicking height (cm) of liquid was measured and recorded after 5, 10, 20 and 30 minutes. Wicking heights after 30 minutes were used for determined the wicking rates (mm/s) [14–16]. All the tests were completed over five samples for each fabric type. Water absorption area (%) is also an indicator for wettability. When the fabric is wetted, the interaction between the forces of cohesion and the forces of adhesion determines whether wetting takes place or not. To determine the absorption areas of the fabrics after dropping off 0.2 ml water, the image processing method was conducted by analysing the acquired image frame after 2 minutes. The image processing method was applied where the liquid existence after absorption will lead to different light transmission level in comparison to dry parts. The image frames were acquired just after solution drop fall and after 2 minutes. The water absorption area (%) was calculated as a percentage of absorbed area to the whole sample area. First, the acquired image frame was converted to a grey image. And then to increase image enhancement, some filters were applied. After improving the image quality, a suitable threshold value was applied so the image frame was transformed into binary form. The black pixels in the binary image referred to the liquid absorbed area and the white pixels referred to a dry area. The developed image acquisition system is indicated in figure 1. The results of image processing applied to the absorbed area is investigated in figure 2. Water vapour permeability should also be considered since the body requires to perspirate when the body temperature increases [20]. Water vapour permeability is the ability of a fabric to allow perspiration in water vapour

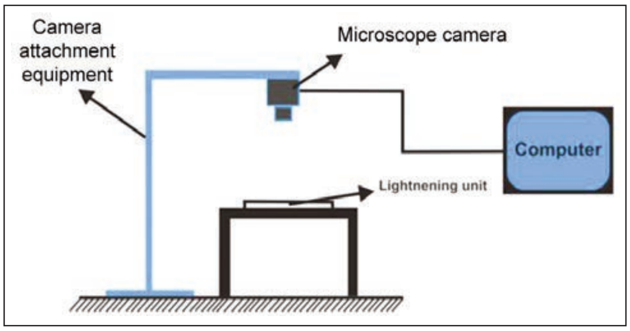

Fig. 1. Image acquisition system

form. A fabric of low moisture vapour permeability is unable to allow sufficient perspiration and this may lead to sweat accumulation in the clothing and hence discomfort. Within the study, water evaporation tests were measured by using SDL Atlas water evaporation tester according to the standard of BS 7209-1990.

Statistical analysis

For the evaluation of the statistical significance of fibre type, fibre blend type and blend ratio (%) on woven samples' comfort properties including air permeability, wicking rate, absorption ratio, water vapour permeability index, randomized three-direction ANOVA was performed. Besides ANOVA results, Student-Newman-Keuls (SNK) multi comparison tests (to evaluate the significance different of subgroups regarding fibre blend type were conducted for the comparison of means of the above-mentioned properties. The treatment levels in SNK tests were marked by the mean values and levels marked by a different letter (sorted by a, b, c) indicating the significant differences. The significance level (α) selected for all statistical tests in the study is 0.05.

RESULTS AND DISCUSSION

Fabric construction parameters (table 3) such as warp and weft density, fabric weight, fabric thickness is so closer to each other; yarn fibre type, fibre blend type and the blend ratio were considered as the main variables regardless of other fabric parameters.

Comfort performance properties

Air permeability of cotton and polyester blended woven samples are indicated in figure 3.

Within cotton blended and polyester woven samples, ProModal® and bamboo blended fabrics generally indicated higher air permeability values compared to Viloft® blended fabrics. 100% cotton samples generally have higher air permeability values compared to those Viloft®, ProModal® and bamboo blended fabrics. There was a prominent decrease in the air permeability of the cotton/Viloft® blended samples as the Viloft® fibre ratio increased. This result may be attributed to the fibre cross-section of Viloft fibre which effects intra-yarn gaps and which further affects the fabric porosity. The grooved structure of Viloft® fibre may decrease the porosity of the material by decreasing intra-yarn gaps which in turn leads to lower air permeability [21].

A fluctuating trend for air permeability was observed among Promodal® blended fabrics with varying ratios of fibre blends. Additionally, the increment of bamboo blend ratio did not seem to influence air permeability results of cotton/bamboo blended fabrics.

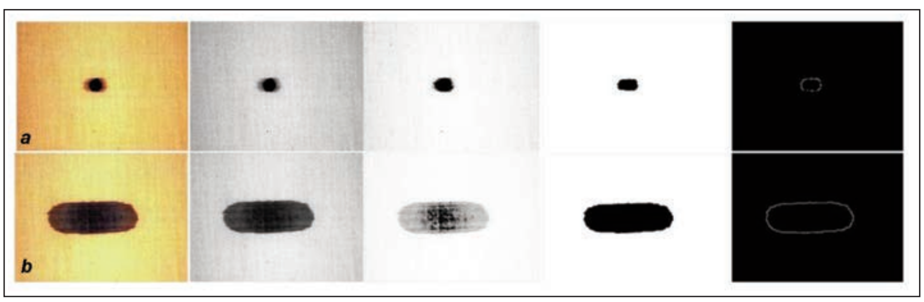

Fig. 2. Results of image processing applied on:
a – the absorbed area; *b* – solution drop fall after 2 minutes

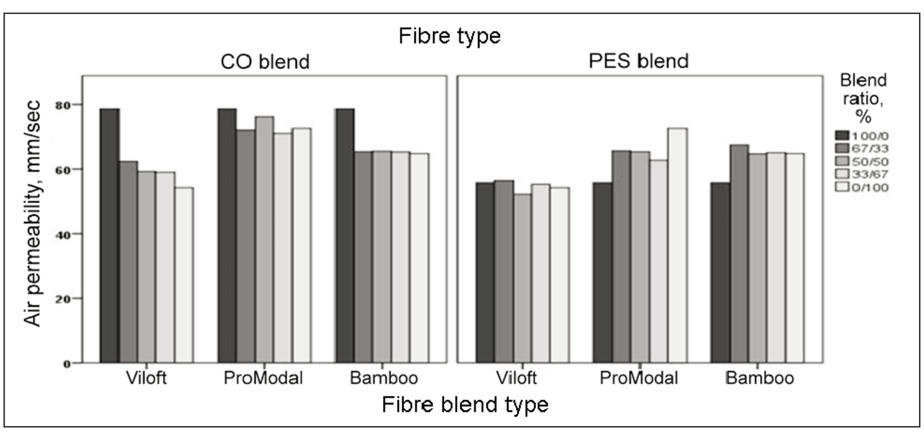

Fig. 3. Air permeability (mm/sec)

Considering polyester blended fabrics; it is prominently observed that 100% polyester fibres indicated lower air permeability than that of regenerated fibre blended samples. The air permeability values of blended samples generally seemed to be increased as the polyester content decreased. Our result is also supported by Tyagi et al.'s study where the air permeability decreased significantly with the increase in polyester content due to increased yarn diameter [22]. In another study related to the effects of regenerated cellulose fibres on thermal comfort properties

Table 3

FABRIC CONSTRUCTION PARAMETERS							
Fibre type	Fibre blend type	Blend ratio (%)	Yarn characteristic	Warp sett (ends/cm)	Weft sett (picks/cm)	Weight (g/m^2)	Thickness (mm)
CO Blend	Viloft®	100/0	100% Cotton	46	28	159.33	0.33
	Viloft®	67/33	67/33% Cotton/Viloft®	49	28	158.33	0.32
	Viloft®	50/50	50/50% Cotton/Viloft®	50	28	157.33	0.33
	Viloft®	33/67	33/67% Cotton/Viloft®	50	27	159.67	0.33
	Viloft®	0/100	100% Viloft®	49	28	160.67	0.33
	ProModal®	67/33	67/33% Cotton/ProModal®	49	28	155.67	0.33
	ProModal®	50/50	50/50% Cotton/ProModal®	49	28	154.33	0.32
	ProModal®	33/67	33/67% Cotton/ProModal®	49	28	156.00	0.32
	ProModal®	0/100	100% ProModal®	49	28	160.00	0.31
	Bamboo	67/33	67/33% Cotton/Bamboo	50	28	160.67	0.33
	Bamboo	50/50	50/50% Cotton/Bamboo	49	27	157.00	0.34
	Bamboo	33/67	33/67% Cotton/Bamboo	49	27	161.33	0.32
	Bamboo	0/100	100% Bamboo	52	28	165.00	0.31
PES Blend	Viloft®	100/0	100% Polyester	49	28	168.67	0.33
	Viloft®	67/33	67/33% Polyester/Viloft®	50	27	164.33	0.32
	Viloft®	50/50	50/50% Polyester/Viloft®	50	27	161.67	0.33
	Viloft®	33/67	33/67% Polyester/Viloft®	52	28	162.67	0.32
	ProModal®	67/33	67/33% Polyester/ProModal®	52	27	160.33	0.31
	ProModal®	50/50	50/50% Polyester/ProModal®	50	28	161.33	0.32
	ProModal®	33/67	33/67% Polyester/ProModal®	51	28	160.00	0.31
	Bamboo	67/33	67/33% Polyester/Bamboo	52	28	164.33	0.32
	Bamboo	50/50	50/50% Polyester/Bamboo	52	27	163.00	0.32
	Bamboo	33/67	33/67% Polyester/Bamboo	52	28	163.33	0.32

of compression stockings, knitted samples made of regenerated samples revealed higher air permeability compared to those made of 100% synthetic fibres [23]. To investigate the effect of fibre type, fibre blend type and blend ratio on air permeability properties of the samples; ANOVA was conducted (table 4). It was obtained that fibre type, fibre blend type and blend ratio have a significant effect on the air permeability of the samples at a significance level of 0.05. All interactions of independent parameters were also found as significant on-air permeability of the fabric samples at a significance level of 0.05. SNK results (table 5) also revealed that fabrics produced from different fibre blend type possessed different air permeability values at a significant level of 0.05. ProModal® blended fabrics indicated the highest air permeability while Viloft® blended fabrics revealed the lowest air permeability.

Wicking properties of synthetic fibres are generally known as better than natural fibres. Fabric wicking height results within 30 minutes period are indicated in figure 4. According to figure 4, the wickability properties

Table 4

ANOVA results of comfort properties				
Main source	Air permeability (mm/sec)	Wicking rate (mm/sec)	Absorption ratio (%)	Water vapour permeability index
Fibre type	0.00*	0.00*	0.00	0.56
Fibre blend type	0.00*	0.00*	0.01	0.23
Blend ratio	0.00*	0.00*	0.00	0.08
Fibre type * Fibre blend type	0.00*	0.00*	0.24	0.22
Fibre type * Blend ratio	0.00*	0.00*	0.00	0.08
Fibre Blend type * Blend ratio	0.00*	0.00*	0.66	0.46
Fibre type * Fibre blend type * Blend ratio	0.00*	0.00*	0.77	0.29

Note: * statistically significant (P < 0.05).

Table 5

SNK results for comfort properties				
Parameter: Fibre blend type	**Air permeability (mm/sec)**	**Wicking rate (mm/sec)**	**Absorption rate (%)**	**Water vapour permeability index**
Viloft®	58.75 a	0.046 b	10.84 ab	0.45 a
Bamboo	65.75 b	0.043 a	10.53 a	0.47 a
ProModal®	69.27 c	0.047 c	11.64 b	0.47 a

Note: The different letters next to the counts indicate that they are significantly different from each other at a significance level of 0.05.

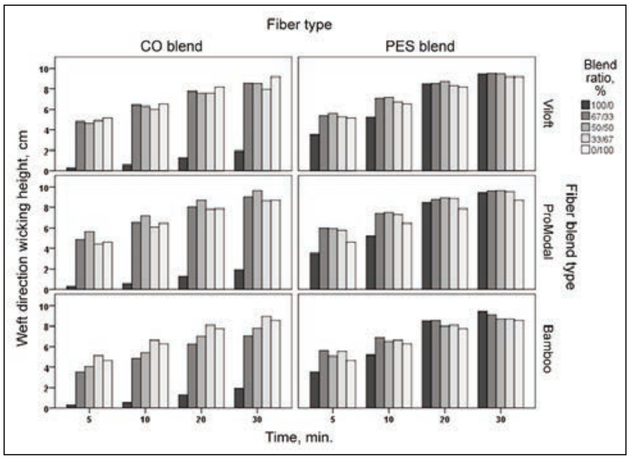

Fig. 4. Wicking height (cm) in the weft direction

of the fabrics improved as the Viloft® ratio in the blend increased. Wickability of 100% cotton fabrics were by far lower than the wickability of cotton/Viloft® blended fabrics. A gradual increment of wicking height was observed among the 100% polyester and also among the polyester/Viloft® blended fabric samples during the wicking period of 5, 10, 20 and 30 minutes. At the end of the 30 minutes, polyester/Viloft® blended samples indicated similar wicking height results with each other. When it comes to cotton blends with ProModal® fibre, it was observed that 100% cotton fabrics revealed the lowest wicking height compared to its blends with ProModal®. The groups of 67/33% cotton/ProModal® and 50/50% cotton/ProModal®, 33/67% cotton/ProModal® and 100% ProModal® blend ratios revealed an increasing trend for wickability during the wicking period of 5, 10, 20 and 30 minutes.

Considering the evaluation of polyester/ProModal® blends; 100% polyester fabrics first indicated low wickability then reached up to the similar wickability level with their counterparts of polyester/ProModal® blends after the 20th minutes. Considering the cotton/bamboo blends; cotton has indicated far lower wickability compared to samples of cotton/bamboo blends. It is clear that wickability increases with the increase in the bamboo blend ratio (%). When considering the polyester/bamboo blends; in the first 10 minutes, 100% polyester revealed lower wickability compared to polyester/bamboo blended fabrics. However, after 20 minutes, 100% pure polyester fabrics revealed slightly higher wickability compared to its blends with bamboo fibre.

The wicking rate after 30 minutes in the weft directions is indicated in figure 5. The wicking rate of the 100% cotton fabrics revealed lower values compared to cotton blends of Viloft®, ProModal® and bamboo fabrics. 100% Viloft® fabrics show the highest wicking rate within cotton/Viloft® blended fabrics. Blended fabric samples of 50/50% cotton/ProModal® have the highest wicking rate within cotton/ProModal® blended fabrics. Finally, 33/67% cotton/bamboo blended fabrics provided the highest wicking rate within the cotton/bamboo blends. Increment of cellulosic regenerated fibres blend ratio in the blend generally improved the wicking rates within cotton blended fabrics. However, increment of Viloft®, ProModal® and bamboo blend ratio within the blend resulted in a lower wicking rate after 30 minutes within the polyester blended fabrics. ANOVA analysis results were given in table 4. It was observed that fibre type, fibre blend type and blend ratio had a significant effect on the wicking rate of the fabrics after 30 minutes. The interactions between fibre type and fibre blend type, fibre type and blend ratio, fibre blend type and blend ratio also the interaction between fibre type, fibre blend type and blend ratio were influential factors on the wicking rate of the fabrics after 30 minutes at a significance level of 0.05. SNK results also indicated that fabrics produced from different fibre blend type possessed different wicking rate after 30 minutes. According to SNK results (table 5), the highest wicking rate was obtained from ProModal® blended fabrics while the lowest wicking rate was obtained from bamboo blended fabrics.

Water absorption rate after 2 minutes of the samples are given in figure 6. 100% Cotton fabrics prominently have a lower water absorption rate compared to its blends with Viloft®, ProModal® and bamboo fibres.

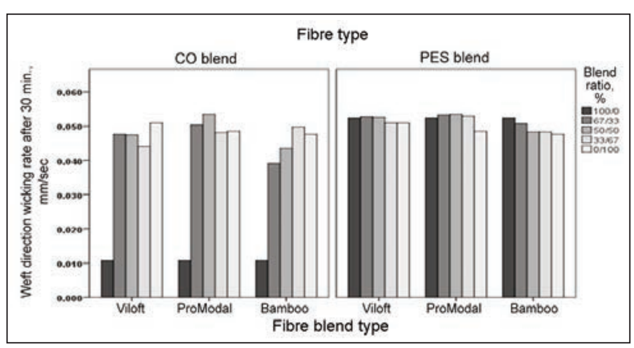

Fig. 5. Wicking rate after 30 minutes in weft direction (mm/sec)

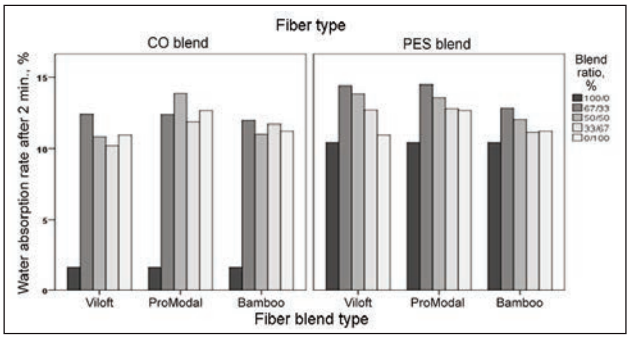

Fig. 6. Water absorption rate after 2 minutes (%)

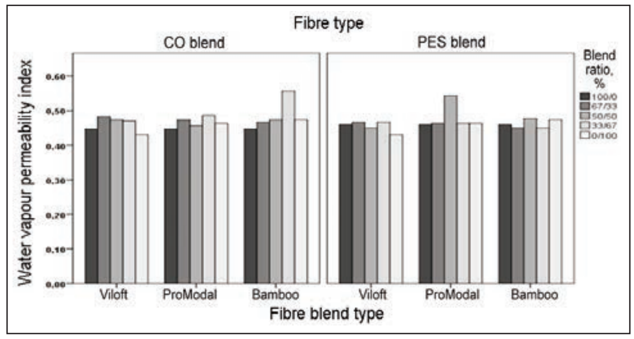

Fig. 7. Water vapour permeability index

Within the cotton/Viloft® blends; the highest water absorption was obtained from 67/33% cotton/Viloft® blended fabric samples. 50/50% cotton/ProModal® blended fabric samples indicated the highest water absorption rate among the cotton/ProModal® blends. Regarding bamboo blends. 67/33% cotton/bamboo blended fabrics indicated the highest water absorption rate among the cotton/bamboo blended fabrics. Increment of regenerated fibre blend ratio within the blends generally contributed positively to the water absorption for cotton blended fabrics. Considering the polyester blended fabrics; it can be said that cellulose fibre content has a significant contribution to the water absorption rates of the fabric samples. However, when the effect of blend ratio was analysed, it can be concluded that higher cellulosic fibre content (more than 33% within the blend) may lead to lower absorption rates. Fabric samples made of pure 100% Viloft®, Promodal® and bamboo fibre revealed higher water absorption rates compared to 100% polyester samples.

The further analyse related to ANOVA results (table 4) revealed that fibre type, fibre blend type, blend ratio factors have a significant effect on water absorption ratios, separately at a significant level of 0.05. Interaction of fibre type and blend ratio was found as a significant factor while the interaction of fibre type and fibre blend type, the interaction of fibre blend type and blend ratio and finally the interaction of fibre type, fibre blend type and blend ratio was found as non-significant factors on water absorption ratio of woven samples at 0.05 significance level. SNK results (table 5) also indicated that bamboo blended fabrics indicated the lowest absorption ratio whereas ProModal® blended woven samples revealed the highest absorption ratio regarding fibre blend type parameter.

The water vapour permeability may vary depending on the macro-porous structure of the constituent fibres [11]. Water vapour permeability index of the Viloft®, ProModal® and bamboo blends of cotton and polyester woven samples are revealed in figure 7. Viloft® and ProModal® cotton blended fabrics indicated similar water vapour permeability index values between each other. 100% pure Viloft® fabric samples provided a lower vapour permeability index compared to cotton/Viloft® blended fabrics. 33/67% cotton/bamboo blended fabrics revealed the highest water vapour permeability index among the cotton blends of regenerated cellulose fibres. When considering Polyester blended fabrics, 50/50% polyester/ProModal® blended fabrics revealed the highest water vapour permeability among the others.

There was not a prominent change in the fabrics' water vapour permeability index regarding regenerated fibre blend ratio among the polyester blended fabrics. Additionally, ANOVA results (table 4) indicated that; fibre type, fibre blend type and blend ratio were not found as influential factors on water vapour permeability index at a significance level of 0.05. None of the interactions between fibre types, fibre blend type and blend ratio parameters was found as significant factors on the water vapour permeability index at a significance level of 0.05.

CONCLUSIONS

This study has been conducted to make a detailed comparison between the cotton blended and polyester blended fabrics with varying blend ratios of regenerated cellulose fibres including Viloft®, ProModal® and bamboo fibres in terms of some comfort properties.

- Considering the ANOVA test results for comfort properties; fibre type, fibre blend type and blend ratio parameters have a statistically significant effect on air permeability, wicking rate, absorption ratio rate properties. However, those parameters did not significantly influence the water vapour permeability index at a significance level of 0.05. ProModal® and bamboo blended cotton fabrics indicated higher air permeability values compared to Viloft® blended cotton fabrics. 100% cotton samples generally revealed higher air permeability compared to its blends with Viloft®, ProModal® and bamboo fibre. Air permeability values generally improved with the increment of regenerated cellulosic fibre blend ratio in the blend within the polyester blends.
- Wickability of 100% polyester fabrics generally indicated better values compared to regenerate cellulose fibre blends of polyester also compared to regenerated cellulose fibre blends of cotton fabrics. 100% cotton fabrics prominently revealed a lower water absorption rate compared to its blends with

Viloft®, ProModal® and bamboo fibre. An increment in the ratio of the cellulosic fibre blends first improved the water absorption rate values. However further increment led to lower water absorption rates for the polyester blended fabrics. It can be concluded that fibre type, fibre blend type and also fibre blend ratio parameters have statistical significance on both the wicking rate and water absorption rate of woven fabric samples.

- Water vapour permeability index of cotton blends with regenerated fibres did not vary prominently regarding fibre type nor blend ratio. Bamboo blended cotton fabrics with a ratio of 33/67% indicated the highest water vapour permeability. Among the polyester blended fabrics, 50/50% polyester/ProModal® blended fabrics revealed the highest water vapour permeability index value.
- As a general conclusion, the comfort properties of polyester woven fabrics with regenerated cellulosic blends seem to be giving more satisfying results compared to fabrics made of cotton/regenerated cellulosic blended yarns. Polyester fabrics with regenerated cellulosic blends enhance high water absorption rates as well as high wickability property with considerable durability.

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Comparison of the physical properties of woven and warp knitted bathrobe towel fabrics produced with similar properties

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ABSTRACT – REZUMAT

Comparison of the physical properties of woven and warp knitted bathrobe towel fabrics produced with similar properties

In recent years, the use of towel fabrics produced by warp knitting machines in the production of bathrobe fabrics has gradually increased. These fabrics, which can be produced more massively at a lower cost, also show a more flexible character than woven towel fabrics. When working with two pile yarn groups whose raw materials or properties are different from each other, the creation of fabric structures with a completely different face and back is seen among the reasons for choosing these fabrics. In this study, after determining the basic performance characteristics such as weight, tensile strength, tear strength, bursting resistance, shrinkage, and water absorbency of the bathrobe towel fabrics produced with the weaving and warp knitting technique, which has undergone the same finishing processes, their performance and strength properties were compared with each other and the results were evaluated using statistical analysis methods. It has been determined that while woven towel fabrics give higher strength values, warp-knitted towel fabrics show higher stretch. The degree of hydrophilicity degree is increased significantly after sequential finishing processes in both towel fabrics. As a result of the finishing processes, there was a general decrease in the tear strength of the woven bathrobe terry fabric, while there was no systematic decrease in the other strength parameters and the strength properties of the warp-knitted towel fabric. In consequence of the finishing processes in both towel fabric structures, a significant reduction in size was observed in the warp direction.

Keywords: *bathrobe towel fabric, weaving, warp knitting, finishing processes*

Comparația dintre proprietățile fizice ale țesăturilor și tricoturilor din urzeală pentru halatele de baie, produse cu proprietăți similare

În ultimii ani, utilizarea tricoturilor produse de mașinile de tricotat din urzeală în producția de materiale pentru halate de baie a crescut treptat. Aceste materiale, care pot fi produse masiv la un cost mai mic, prezintă, de asemenea, un caracter mai flexibil decât țesăturile. Atunci când se lucrează cu două grupuri de fire de pluș ale căror materii prime sau proprietăți sunt diferite una de cealaltă, crearea unor structuri cu față și spate complet diferite este văzută printre motivele alegerii acestor materiale. În acest studiu, după determinarea caracteristicilor de bază ale performanței, cum ar fi masa, rezistența la tracțiune, rezistența la rupere, rezistența la plesnire, contracția și absorbția apei materialelor tip prosop pentru halate de baie produse prin tehnica de țesere și tricotare din urzeală, care au trecut prin aceleași procese de finisare, proprietățile lor de performanță și rezistență au fost comparate între ele, iar rezultatele au fost evaluate folosind metode de analiză statistică. S-a stabilit că, în timp ce țesăturile pentru prosoape oferă valori mai mari de rezistență, tricoturile din urzeală pentru prosoape prezintă o întindere mai mare. Gradul de hidrofobie este crescut semnificativ după procesele secvenţiale de finisare în cazul ambelor materiale pentru prosoape. Ca urmare a proceselor de finisare, a existat o scădere generală a rezistenței la rupere a țesăturii pentru halate de baie, în timp ce nu a existat o scădere sistematică a celorlalți parametri de rezistență și a proprietăților de rezistență ale tricoturilor din urzeală pentru prosoape. Ca urmare a proceselor de finisare în ambele structuri pentru prosoape, s-a observat o reducere semnificativă a dimensiunii în direcția urzelii.

Cuvinte-cheie*: material pentru halat de baie, țesere, tricotare din urzeală, procese de finisare*

INTRODUCTION

According to ASTM D 123-03 standard terminology for textiles, towel fabric is defined as “a textile product which is made with loop pile on one or both sides generally covering the entire surface or forming stripe, checks, or other patterns” [1].

Towels and bathrobes in the home textile group, which have an important place in the textile and apparel industry, are among the indispensable items of daily life. Especially today, where health problems are more common, the need for such textile products that provide hygiene is increasing.

Towel fabrics are produced with three yarn systems: ground warp, ground weft and pile warp. Here, while ground warp provides mechanical strength, pile warp gives water absorption properties due to its increased surface area [2–4].

Towel fabrics have been produced since ancient times using the weaving technique, and recently they have been produced with the warp knitting technique as well as weaving. Towel fabric formation with warp

knitting technique is more economical than weaving technique due to the higher production rate.
In order to add strength and stability to the fabric, filament polyester or polyamide ground yarn is also used in addition to cotton ground yarn in the towel fabrics produced by warp-knitting machines. In contrast to their cost effectiveness, very limited academic studies have been conducted on warp knitted towel fabrics [5, 6].
Bathrobe woven fabrics are produced with 2, 3, 4, 5 or more wefts per loop. Towels with the most common production are of the type with 3 wefts [7]. The sectional view of the bathrobe fabric along the warp direction can be given as in figure 1.

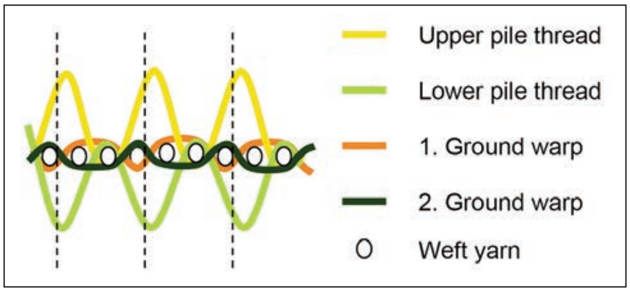

Fig. 1. Sectional view of the bathrobe fabric along the warp direction [8]

In the basic towel structure, the upper and lower loop warp groups and the first and second ground warps form a 2/1 ribs weave between themselves. Here, the ribs weave of the loop warps is one weft phase ahead of the ribs weave of the ground warps. This improves towel fabric strength by increasing the bonds along the warp [7].
In the warp knitting machine with two investment rails, if one rail has normal knitting needles and the other rail has plush/ pile loop platins, towel fabric is produced. In these towel structures formed on a single side, a basic (ground) pattern is formed on the rear comber rail. In the front comber rail, the warp threads are wrapped on the plush platins and form the towel loops. The pile length is adjusted by increasing or decreasing the distance between the needle rails [5, 6].
Warp knitting towel fabrics are pile fabrics with projecting loops on one or on each fabric face. The principle of loop formation consists in creating drop stitches, resulting in so-called terry loops. Such a terry loop is formed as follows: a loop, that has been placed around a needle, is cast off, but the loop head is not bound into the fabric ground. This situation appears if there is a loop on the needle shaft, but no new yarn is inserted into the needle head so that the loop is knocked over during the next stitch forming cycle, the loop head, however, is not tied in. İn other words: the head of the loop will stand out of the fabric ground in form of a terry loop [8]. The notation of warp-knitted terry bows is shown in figure 2.
While studies on towel fabrics mostly focus on woven towel fabrics, warp-knitted towel fabrics have been the subject of limited research studies. In addition, the water absorption phenomenon of towel fabrics has been extensively investigated and therefore other performance properties have been studied relatively poorly [2].
One of the earliest studies on knitted towel fabrics is a study comparing woven and warp knitted towel fabrics in terms of various performance properties including tensile strength, tear strength and dimensional stability. In this study, it was concluded that the mechanical performances of woven towel fabrics were better than knitted towel fabrics [6]. In another study, the loss of strength caused by washing warp knitted towel fabrics knitted with polyester and nylon ground warps and drying them in drum dryers was investigated and it was determined that warp knitted towel fabrics knitted with polyester ground warps were more durable [5].
The warp and weft densities applied in bathrobe towel fabrics vary between 20 and 30 and 15 to 25 threads/cm, respectively. The loop length per unit length (1 cm) can vary between 20–10 cm. It can be called pile/ground ratio. This length has a great effect on the weight of the bathrobe fabric [9]. Weft and warp densities are determinant in shrinkage that will occur immediately after the machine exit and after washing of the fabric [4].
The tensile strength and elongation values at rupture of fabrics with three different wales densities (wales per cm) produced in a warp knitting machine with two comber rails were reviewed and how they affect the fatigue values were investigated [10].

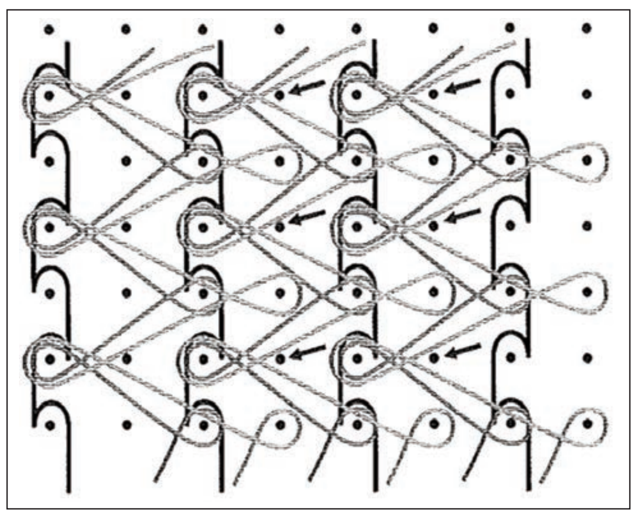

Fig. 2. Warp knitted bathrobe fabric structure [8]

MATERIAL AND METHODS

Material

In this research study, woven and warp knitted towel fabric structures were used.
Woven fabrics were produced on the Vamatex towel weaving machine with the following properties:
- Comb number 10 dents/cm;
- Pile warp open-end Ne 16/1 cotton;
- Ground warp open-end Ne 20/2 cotton;
- Weft yarn open-end Ne 16/1 cotton.

Warp knitted fabrics were produced on Karl Mayer KS4 FBZ warp knitting machine with four guide bars with the following properties:

- Machine fineness 24 fine;
- Machine width 136 inches;
- Backside pile warp open-end Ne 16/1 cotton;
- Front side pile warp open-end Ne 16/1 cotton;
- Ground warp 100 denier polyester (36 filaments);
- Weft yarn 100 denier polyester (36 filaments).

Methods

Pre-treatment and dyeing processes were carried out in a dyeing machine that can operate at high temperatures. Samples were exposed to finishing procedures representative of those currently used in industrial practice. Raw woven terry fabric was desized in a high-temperature machine prior to bleaching. Bleaching was carried out in presence of NaOH and H_2O_2 at 110°C for 20 min in the same machine. Following bleaching, the fabric was neutralized at 90°C for 10 min. The terry fabric was treated with enzymatic biopolishing agent Cellusoft Combi® at 50°C for 60 min. Then, the fabric was dyed with reactive dyestuff in presence of salt and soda at 90°C. After dyeing, the fabric was neutralized, washed, and then treated with a softening agent at 40°C for 20 min. In the last step, the fabric was treated with the mechanical whisking effect in the turbang (finishing machine) used in the mechanical finishing of the towel fabrics, and finally, a more voluminous and softer touch was achieved.

Test methods and standards applied to towel fabrics

Towel samples were conditioned at 22°C and 65% relative humidity for at least 24 hours before physical test processes. Tests were carried out using a set of 5 pieces from each sample prepared to determine fabric properties.

The fabric mass per unit area was determined according to the TS 251 method. The mass of the sample fabrics per unit area was measured by weighing the samples each consisting of 100 cm^2 area with a precision of 0.001 g.

The tear strength of the fabrics was measured according to the method of TS EN ISO 13937-2 using samples of 50 mm × 200 mm. Measurements were carried out in both warp and weft directions using the Tinius Olsen H10KT (R) tester equipped with QMat for Textiles (R) software. The crosshead speed was kept at 100 mm/min and the gauge length was set at 100 mm.

Tensile strength and elongation at break were measured according to the TS EN ISO 13934-1 method using 50 mm × 300 mm samples and then tested in both warp and weft directions. Measurements were carried out using the Tinius Olsen H10KT (R) Tester equipped with QMat for Textiles (R) software. The crosshead speed was kept at 100 mm/min, the gauge length was set to 200 mm, and a 5 N preload was applied during the measurements.

Bursting strength was measured according to the method of TS EN ISO 13938-2 using samples of 140 mm × 140 mm for measurement.

Dimensional change tests during washing and drying were carried out according to TS 5720 EN ISO 6330 method, using samples of 500 mm × 500 mm.

500 mm. Washing was carried out using detergent ECE without optical brightener in a washing machine at 40 + 3°C for 47 minutes. The loading weight was kept at 2000 + 100 g. The fabrics were laid flat on the floor and dried.

The water absorption of towel fabrics was determined using 500 mm × 500 mm sized samples according to the TS 866 method. According to the testing procedure, the fabric sample was placed horizontally on a cup of distilled water, and the time it took for the sample to sink (i.e., fully wet the fabric with water) was recorded using a stopwatch.

For statistical analysis, observed data were subjected to one-factor and two-factor repeated variance analysis at α: 0.05 significance level.

RESULTS AND DISCUSSION

Results of weight measurements

The weight of woven and warp knitted fabric for the bathrobe was measured and the measurement results of the samples are given in table 1.

In woven towel fabrics, a continuous increase in fabric weight was observed with the compression effect of the turbang machine after the pre-treatment, dyeing processes and then the mechanical finishing process, respectively. It has been determined that warp knitted towel fabrics also increase in fabric weight in each process step. The reason for this can be explained as the polyester yarn used in the ground knitting structure of the knitted fabric shows the effect

Table 1

WEIGHT MEASUREMENT RESULTS OF BATHROBE FABRICS

Treatment operations	Woven towel fabric			Warp knitted towel fabric		
	Measurement avg. (gr/m²)	Std. Deviation (g/m²)	Change between stages* (%)	Measurement avg. (g/m²)	Std. Deviation (g/m²)	Change between stages* (%)
Raw fabric	370	5.41	-	367	3.51	-
Dyed fabric	438	10.46	18.3	390	4.16	6.2
Finished fabric	440	6.84	0.4	396	4.96	1.5

of gathering-shrinkage due to the temperature effect and collects in the fabric.

Results of tear strength measurements

The rupture strength measurements of woven and warp knitted bathrobe fabrics were made and the tear strength results in the warp direction are given in table 2.

In woven towel fabrics, the tear strength in the warp direction was higher due to the effect of impurities such as fats, waxes, oils and pectins on the raw fabric, while the tear strength values in the warp direction gradually decreased after the dyeing process and the subsequent turbang process. After finishing and subsequent mechanical finishing, the tear strength of warp knitted fabrics in the warp direction (wales direction) tended to increase.

The tear strength results of woven and warp knitted bathrobe towel fabrics in the weft direction are given in table 3.

The tear strength in the weft direction was initially high due to the impurities such as fats, waxes, oils and pectins on the raw fabric in woven towel fabrics. After the pre-treatment and dyeing process, these non-cellulose chemicals and sizing agents were removed, resulting in a serious decrease in the tear strength of the fabric in the weft direction. It was determined that the tear strength values decreased further after the mechanical end (turbang) process. Although the tear strength of warp-knitted towel fabrics in the weft direction increased after finishing, a decrease was observed after the mechanical finishing process.

Compared to their raw form, warp-knitted towel fabrics did not lose their tear strength in both warp and weft directions compared to woven towel fabrics, while a decrease in tear strength was observed in woven towel fabrics. As a result, it was determined that the tear strength of the finished towel fabrics was higher than warp knitted towel fabrics.

Results of tensile strength measurements

The tensile strength measurements of woven and warp knitted bathrobe fabrics were made and the results of the warp tensile strength are given in table 4. In woven towel fabrics, the tensile strength in the warp direction was higher due to the effect of impurities such as fats, waxes, oils and pectins on the raw

Table 2

MEASUREMENT RESULTS OF RUPTURE STRENGTH OF BATHROBE FABRICS IN WARP DIRECTION

Treatment operations	Woven towel fabric			Warp knitted towel fabric		
	Measurement avg. (N)	Std. Deviation (N)	Change between stages* (%)	Measurement avg. (N)	Std. Deviation (N)	Change between stages* (%)
Raw fabric	62	6.23	-	25	1.98	-
Dyed fabric	56	1.32	–9.7	26	1.42	4.0
Finished fabric	47	2.13	–16.1	26	1.52	0.0

Table 3

MEASUREMENT RESULTS OF RUPTURE STRENGTH OF BATHROBE FABRICS IN WEFT DIRECTION

Treatment operations	Woven towel fabric			Warp knitted towel fabric		
	Measurement avg. (N)	Std. Deviation (N)	Change between stages* (%)	Measurement avg. (N)	Std. Deviation (N)	Change between stages* (%)
Raw fabric	53	2.96	-	28	1.79	-
Dyed fabric	41	2.04	–22.6	32	1.48	14.3
Finished fabric	34	6.05	–17.0	29	2.85	–9.3

Table 4

MEASUREMENT RESULTS OF TENSILE STRENGTH OF BATHROBE FABRICS IN WARP DIRECTION

Treatment operations	Woven towel fabric			Warp knitted towel fabric		
	Measurement avg. (N)	Std. Deviation (N)	Change between stages* (%)	Measurement avg. (N)	Std. Deviation (N)	Change between stages* (%)
Raw fabric	390	148.71	-	222	26.67	-
Dyed fabric	369	137.71	–5.3	210	21.81	–5.4
Finished fabric	366	138.88	–0.8	236	25.57	12.4

fabric, while the tensile strength values in the warp direction gradually decreased after the dyeing process and the subsequent turbang process. Although the tensile strength of warp knitted fabrics in the warp direction (wales direction) decreased after finishing processes compared to their raw state, the tensile strength increased again after mechanical finishing.
Table 5 shows the tensile strength results of woven and warp knitted bathrobe towel fabrics in the weft direction.
In woven towel fabrics, the tensile strength of the fabric in the weft direction has increased after the pretreatment and dyeing processes. However, after the mechanical finishing (turbang) process, the tensile strength in the weft direction decreased again. The tensile strength of warp-knitted towel fabrics in the weft direction continued to increase both after finishing and after mechanical finishing.
As a result, it was determined that the tensile strength in the warp direction was higher in the warp-knitted towel fabrics, while the tensile strength in the weft direction was lower than the warp-knitted towel fabrics.

Results of burst strength measurements

Burst strength measurements of woven and warp knitted bathrobe towel fabrics were made and the results are given in table 6.
While the bursting resistance of the raw fabric was higher in woven towel fabrics, although there was a decrease in the bursting strength of the fabric applied with pretreatment and dyeing processes, an increase was determined again at the bursting strength after tightening-gathering of the fabric upon the mechanical finishing process. The bursting resistance of the warp-knitted towel fabrics continued to increase along with the finishing process. As a result, it has been determined that the bursting strength of woven towel fabrics is higher.

Results of hydrophilicity determination measurements

Hydrophilicity measurements of woven and warp knitted bathrobe towel fabrics were made and the measurement results are given in table 7.
It was determined that the hydrophilicity of both woven towel fabrics and warp knitted towel fabrics after pretreatment, dyeing and mechanical finishing

Table 5

MEASUREMENT RESULTS OF TENSILE STRENGTH OF BATHROBE FABRICS IN WEFT DIRECTION

Treatment operations	Woven towel fabric			Warp knitted towel fabric		
	Measurement avg. (N)	Std. Deviation (N)	Change between stages* (%)	Measurement avg. (N)	Std. Deviation (N)	Change between stages* (%)
Raw fabric	288	53.77	-	284	30.81	-
Dyed fabric	348	80.89	20.8	309	23.46	8.8
Finished fabric	301	68.62	–13.5	335	33.94	8.4

Table 6

BURST STRENGTH MEASUREMENT RESULTS OF BATHROBE FABRICS

Treatment operations	Woven towel fabric			Warp knitted towel fabric		
	Measurement avg. (kPa)	Std. Deviation (kPa)	Change between stages* (%)	Measurement avg. (kPa)	Std. Deviation (kPa)	Change between stages* (%)
Raw fabric	878	34.31	-	600	11.49	-
Dyed fabric	761	63.88	–13.3	626	36.42	4.3
Finished fabric	852	58.28	11.9	671	28.16	7.2

Table 7

HYDROPHILICITY MEASUREMENT RESULTS OF BATHROBE FABRICS

Treatment operations	Woven towel fabric			Warp knitted towel fabric		
	Measurement avg. (s)	Std. Deviation (s)	Change between stages* (%)	Measurement avg. (s)	Std. Deviation (s)	Change between stages* (%)
Raw fabric	178	0.54	-	1022	159.16	-
Dyed fabric	4	0.46	–97.7	5	0.54	–99.5
Finished fabric	3	0.53	–25	5	0.27	0.0

Table 8

MEASUREMENT RESULTS OF DIMENSIONAL CHANGE DETERMINATION OF BATHROBE FABRICS IN WARP DIRECTION						
Treatment operations	**Woven towel fabric**			**Warp knitted towel fabric**		
	Measurement avg. (mm)	**Std. Deviation (mm)**	**Change between stages* (%)**	**Measurement avg. (mm)**	**Std. Deviation (mm)**	**Change between stages* (%)**
Raw fabric	32	0.63	-	33	0.67	-
Dyed fabric	34	0.55	–6.2	35	0.50	–6.0
Finished fabric	34	0.36	0.0	35	0.49	0.0

Table 9

MEASUREMENT RESULTS OF DIMENSIONAL CHANGE DETERMINATION OF BATHROBE FABRICS IN WEFT DIRECTION						
Treatment operations	**Woven towel fabric**			**Warp knitted towel fabric**		
	Measurement avg. (mm)	**Std. Deviation (mm)**	**Change between stages* (%)**	**Measurement avg. (mm)**	**Std. Deviation (mm)**	**Change between stages* (%)**
Raw fabric	32	1.06	-	34	0.54	-
Dyed fabric	35	0.59	–8.5	35	0.46	–2.8
Finished fabric	35	0.57	0.0	35	0.53	0.0

processes continuously improved, reached the desired hydrophilicity in both fabric types, and the hydrophilicity value of woven towel fabrics was slightly better than warp knitted towel fabrics.

Results of dimensional variation determination measurements

Dimensional changes of woven and warp knitted bathrobe fabrics were measured and the dimensional change results in warp and weft directions are given in tables 8 and 9.

Compared to their raw state, a shrinkage rate of 6.2% in the warp direction, 8.5% in the weft direction were observed in the finished woven towel fabrics, while a shrinkage rate of 6.0% in the rod direction and 2.8% in the row direction was observed in warp-knitted towel fabrics. Accordingly, dimensional change in warp-knitted towel fabrics is less seen than in woven towel fabrics.

Statistical evaluation of the effects of the dyeing process

While the dyeing process caused an average increase of 18.3% on the weight of woven bathrobe towel fabric, it had an increasing effect of 6.2% on the weight of warp-knitted bathrobe towel fabric. (p values, respectively, $3{,}94 \times 10^{-4}$ and $1{,}26 \times 10^{-5}$). A small amount of shortening was observed in the weft and warp direction after washing and drying the towel fabrics with softening chemicals added after dyeing. Table 10 shows the effects of the dyeing process on the woven bathrobe fabric.

While there was no difference in tensile strength between the dyed and washed textile fabric and the fabric with softening chemical added ($p = 0.82$), a slight increase in the elasticity in the warp direction was recorded ($p = 0.0004$).

While there was a decrease in the tensile strength ($p = 0.0003$) between the dyed and washed bathrobe warp knitted fabric and the fabric added with softening chemicals, there was no statistical difference on the basis of elasticity ($p = 0.17$).

It was observed that the dyeing process caused an increase in the tear strength of the bathrobe towel woven fabric, especially in the warp direction ($p = 0.005$). This process did not cause a significant change in the rupture strength of the warp knitted fabric ($p = 0.17$).

While the dyeing process increased the burst pressure of the woven bathrobe fabric from an average of 761 kPa to 852 kPa, the warp-knitted bathrobe fabric burst pressure increased from an average of 626 kPa to 671 kPa (p values respectively 0.01 and 0.006).

Table 10

EFFECTS OF DYEING PROCESS ON WOVEN BATHROBE FABRIC		
Feature	**Effect of dyeing**	
	Statistical meaning	**p value**
Weight	There is a significant increase	3.94×10^{-4}
Tear	There is a significant increase (warp)	0.005
Tensile	No meaningful change	0.82
Burst	There is a significant increase	0.01
Hydrophilicity	No meaningful change	0.3

As a result of the softener addition process, there was no significant change in woven and warp knitted fabric hydrophilicity (p values 0.30 and 0.85, respectively).
Table 11 shows the effects of the dyeing process on warp knitted bathrobe fabric.

Table 11

EFFECTS OF DYEING PROCESS ON WARP KNITTED BATHROBE FABRIC

Feature	Effect of dyeing	
	Statistical meaning	**p value**
Weight	There is a significant increase	1.26×10^{-5}
Tear	No meaningful change	0.17
Tensile	There is a significant decrease	0.0003
Burst	There is a significant increase	0.006
Hydrophilicity	No meaningful change	0.85

Statistical evaluation of the effects of mechanical (turbang) finishing processes

It was determined that the mechanical finishing process tended to have an increase of 0.4% on the weight of dyed bathrobe woven towel fabric, while it was also determined that it increased 1.5% on the weight of warp-knitted fabric (p values 0.006 and 7.67×10^{-6}, respectively).
Table 12 shows the effects of the finishing processes on the woven bathrobe towel fabric.

Table 12

EFFECTS OF FINISHING PROCESSES ON WOVEN BATHROBE TOWEL FABRIC

Feature	Effect of dyeing	
	Statistical meaning	**p value**
Weight	There is a significant increase	0.006
Tear	There is a significant decrease	3.89×10^{-6}
Tensile	There is a significant decrease	0.055
Burst	No meaningful change	0.81
Hydrophilicity	There is a significant increase	0.02

There was no dimensional change in the woven and warp knitted towel fabric samples after the mechanical finishing process according to the situation after the dyeing process.
Mechanical finishing negatively affected the tensile strength of the bathrobe towel woven fabric in the weft direction and the elasticity in both directions (p values 0.055 and 2.18×10^{-7}, respectively). The reason for this decrease may be the decrease in elasticity values with the force applied to the weft length during the mechanical finishing process.
Mechanical finishing positively affected the tensile strength of the bathrobe warp knitted towel fabric ($p = 5.07\times10^{-6}$) and increased the elasticity ($p = 0.0006$). The increase in elasticity may be the reason for this increase. Table 13 shows the effects of the finishing processes on the warp-knitted bathrobe towel fabric.

Table 13

THE EFFECTS OF FINISHING PROCESSES ON WARP KNITTED BATHROBE TOWEL FABRIC

Feature	Effect of dyeing	
	Statistical meaning	**p value**
Weight	There is a significant decrease	7.67×10^{-6}
Tear	There is a significant decrease	0.02
Tensile	There is a significant increase	5.07×10^{-6}
Burst	No meaningful change	0.16
Hydrophilicity	No meaningful change	0.4

Mechanical finishing caused a decrease in the rupture strength of the bathrobe weaving and warp knitted towel fabric in the warp and weft direction (p values of 3.89×10^{-6} and 0.02, respectively). The drop was felt more in the woven fabric. The decrease in elasticity and adjustment of shrinkage may have caused this.
The mechanical finishing process did not significantly affect the burst pressure values of woven and warp knitted bathrobe fabrics (p values 0.81 and 0.16, respectively).
As a result of washing after the dyeing process, the immersion time of the woven fabric in water decreased from 3.7 seconds to 2.6 seconds, while the hydrophilicity of the warp knitted fabric did not change significantly (p values 0.02 and 0.40, respectively).

CONCLUSION

In this study, the effects of pre-treatment, dyeing and mechanical finishing steps applied to bathrobe towel fabrics on basic performance properties such as weight, tensile strength, tear strength, bursting strength, shrinkage, and water absorbency of woven and warp knitted towel fabrics with similar properties were investigated and the physical properties of these fabrics were compared with each other in terms of performance and strength.
Weight: In each of the towel fabrics per unit area, the increase in the finishing process continued. Although sizing and foreign materials are removed from the fibre and fabric structure in bleaching processes, weight loss is experienced, but an increase in unit area (g/m²) has been detected as a result of the changes in the width and length of the fabric.

Tear strength: Although it decreased 25–35% in bathrobe woven towel fabric, it increased in the warp-knitted towel fabric by 5%. Further studies can be done on the significant strength reduction in woven fabric.

Tear strength: Considering the weft-warp direction together, the increase and decrease in woven towel fabric neutralized each other, while there was a significant increase in warp-knitted towel fabric. After mechanical finishing processes, more intensive research can be done on the fact that both fabrics give approximately opposite results.

Hydrophilicity feature: It increased very markedly in both fabrics after hydrophilization. In order to prevent both hydrophilicity and strength losses, studies can be carried out on the ideal working conditions of the hydrophilization processes of towel fabrics.

Burst resistance decreased slightly in woven towel fabric and increased noticeably in warp-knitted towel fabric.

Dimensional shrinkage: Since finishing operations are carried out according to the shrinking method, although the fabric has been treated in the warp direction, it is higher in both fabrics.

Each finishing process had a positive or negative effect on the towel fabric performance properties. As a result of the finishing processes, there was a general decrease in the tear strength of the woven bathrobe towel fabric, while there was no systematic decrease in other strength parameters or in any strength properties of the warp-knitted towel fabric.

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Seam pucker detection through presser foot displacement monitoring

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ABSTRACT – REZUMAT

Seam pucker detection through presser foot displacement monitoring

The paper investigates the relation between seam pucker, woven fabric formability, and the presser foot displacement during stitch formation. Superimposed seams of class 1 were sewn in warp and weft direction using woven fabrics for tailored garments. The presser foot height was continuously monitored during stitch formation for different sewing machine speeds. The foot displacement during the sewing cycle was correlated with seam pucker. The obtained results showed various patterns of pressure foot displacement regarding the sewing machine speeds. It was found that at a lower machine speed there is no bouncing of the presser foot and the ratio of the height of the presser foot before and after rising and declining movement versus double thickness of the fabric (h/T_1), correlates significantly with the seam pucker percentage. The fabrics having a higher h/T_1 ratio showed a higher percentage of seam pucker. The obtained results suggest that online monitoring of this parameter can be a useful indication of on-seam pucker appearance, providing reliable means to obtain a quality seam.

Keywords: *seam pucker, presser foot displacement, online monitoring, formability, sewing dynamics*

Detectarea încrețirii cusăturilor prin monitorizarea deplasării piciorului de presare

Lucrarea investighează relația dintre încrețirea cusăturii, formabilitatea țesăturii și deplasarea piciorului de presare în timpul formării cusăturii. Cusăturile suprapuse de clasa 1 au fost realizate în direcția urzelii și a bătăturii folosind țesături pentru articole de îmbrăcăminte. Înălțimea piciorului de presare a fost monitorizată continuu în timpul formării cusăturii, pentru diferite viteze ale mașinii de cusut. Deplasarea piciorului în timpul ciclului de coasere a fost corelată cu încrețirea cusăturii. Rezultatele obținute au arătat diferite modele de deplasare a piciorului de presare, în funcție de viteza mașinii de cusut. S-a constatat că, la o viteză mai mică a mașinii nu sare piciorul de presare, iar raportul dintre înălțimea piciorului de presare înainte și după mișcarea de ridicare și scădere față de grosimea dublă a țesăturii (h/T_1), se corelează semnificativ cu un procent de încrețire a cusăturii. Țesăturile cu un raport h/T_1 mai mare au prezentat un procent mai mare de încrețire a cusăturilor. Rezultatele obținute sugerează că monitorizarea online a acestui parametru poate fi un indiciu util al aspectului încrețit al cusăturii, oferind mijloace fiabile pentru a obține o cusătură de calitate.

Cuvinte-cheie: *încrețirea cusăturii, deplasarea piciorului de presare, monitorizare online, formabilitate, dinamica coaserii*

INTRODUCTION

The apparel industry has been in constant demand for increasing the degree of sewing machines automation, directed towards improved control and higher quality of sewing operations. However, as a result of variation in structural fabric properties that influence sewability and garment appearance, there are still obstacles in achieving this goal. The appearance of seams on a finished garment is one of the most important properties of high-quality garments. As the interest in garment, quality has been increasing, seam quality problems have received more attention [1]. Seam pucker is defined [2] as "a ridge, wrinkle or corrugation of the material or several small wrinkles running across and into one another, which appear in sewing together two pieces of cloth". It has been regarded as one of the most serious faults in garment manufacturing, thus reducing the aesthetic value of garments [3]. It appears along the seam lines of garments when the material properties and sewing parameters are not properly chosen [4, 5]. For several decades, much research on-seam pucker was conducted to solve the problem in garment manufacturing. Researchers, including Dorkin and Chamberlain, have identified four primary causes of puckered seams [6]. Nowadays, technology offers online monitoring of the sewing operations parameters, which offers possibilities to reduce the percentage of faulty garments. Park and Ha developed a process for optimizing sewing conditions to minimize seam pucker using the Taguchi method [7]. The parameters selected for optimization were: sewing speed, stitch length, sewing thread tension, and presser foot pressure. Dobilaite and Petrauskas determined fabric deformation during the sewing process and assumed that the fabric shear and flexural rigidity are the main factors influencing the occurrence of pucker [8]. In addition, they found that surface density, extensibility, and formability of the fabric are also associated with this defect. Dobilaite and Juciene [9] investigated the effect of the rotational frequency of a sewing machine's main shaft and pressing force on-seam pucker. It was found, that in all cases the pucker height increases with the rotational frequency of the main shaft while decreasing with increasing pressing force. Mariolis and Dermatas have proposed a method of estimating the seam pucker with automatic control of the seam quality, focusing only on the evaluation of seam pucker [10]. Mak and Li have presented an objective method using image analysis and pattern recognition technologies for the evaluation of seam pucker [11]. Nassif has studied the influence of sewing machine parameters (sewing needle size, sewing thread tension, stitch density and sewing direction) on cotton woven fabrics seam pucker [12]. He has found that most sewing machine parameters have a significant influence on woven fabric seam pucker and also showed that there is a good correlation between the subjective and objective measuring methods of seam pucker, especially in the case of the effects of needle size and sewing thread tension. Kim et al. [13] have developed an automated sewing machine controller to find the optimum sewing conditions that minimize seam pucker. They developed a laser-based scanning system for the objective evaluation of seam pucker. The grade of seam pucker was evaluated by fractal dimension calculation based on the three-dimensional shape of the specimen. Chmielowiec and Lloyd [14] equipped a Pfaff lockstitch machine with sensors measuring presser-foot force and displacement, thread tension and needle penetration force. They investigated the effect of "presser-foot bouncing" and analysed correlations between presser foot compression force and seam pucker. It was found that seam pucker is influenced by a number of various factors, such as sewing thread and fabric properties, needle penetration and stitch formation, sewing thread tension, fabric feeding system and seam construction. Particular great attention was paid to fabric properties and sewing machine factors as well as to the compatibility of both in the process of sewing [15–19]. Mousazadegan and Latifi [20] have studied the formation of tension seam pucker in more detail in order to compute the thread compression load in terms of sewing thread tension. The results of this research helped to analyse the compression load on the fabric based on sewing thread tension. Muhammad *et al.* [21] have compared the numerical estimation of pucker derived from the model of a lockstitch seam (301), with fabric mechanics experiments and visual assessments of the phenomenon, showing that there is a good linear correlation between the two. The model was used to evaluate with precision, which of a selection of stiffeners, is required to reduce the pucker to an acceptable level, without over stiffening the seam.

Besides the increase in the degree of automation and monitoring of the sewing machine, there is still a need for getting information before production and especially during the sewing process, regarding fabric inclination to puckering in order to take action to minimize its incidence.

The aim of this paper is to investigate the occurrence of seam pucker of wool and wool blend woven fabrics for tailored garments using online monitoring of the sewing machine pressure foot displacement.

EXPERIMENTAL PART

Materials and methods

The object of the investigation is a series of wool and wool blend worsted woven fabrics for tailored garments, commonly used by this sector of the textile and apparel industry. The fibre composition of the fabrics varies from 100% wool and wool blend with elastane (*Lycra*) and polyester (PES). Fabrics are made in basic weaves of even repeat such as twill 2/1, twill 2/2 and plain weave. The mass per unit area of the fabrics ranges from 164–252 g/m^2 and fabric thickness ranges from 0.15 to 0.23 mm. In this fabric range, the highest mass per unit area and thickness fabric is 1.5 times greater than the fabric with the smallest mass per unit area and thickness. This variation in mass per unit area and thickness was expected to result in seam pucker variation on the finished seams. Some of the fabric features are shown in table 1.

In order to investigate fabrics formability, the samples were tested on a KES-FB system for fabric objective

Table 1

FABRIC PROPERTIES

Fabric	Composition	Warp density (cm^{-1})	Weft density (cm^{-1})	Mass per unit area (g/m^2)	Thickness (mm)	Weave
A	98% Wool 2% Lycra	32.0	24.8	204	0.18	2x1 twill
B	98% Wool 2% Lycra	32.0	26.2	212	0.21	2x1twill
C	100% Wool	31.2	27.6	164	0.15	2x1twill
D	100% Wool	31.2	28.0	186	0.17	2x1twill
E	100% Wool	30.8	25.6	194	0.20	2x2 twill
F	100% Wool	30.8	28.2	204	0.21	2x2 twill
G	44% Wool 54% PES 2% Lycra	29.0	20.0	204	0.20	plain
H	44% wool 54% PES 2% Lycra	35.4	24.4	252	0.23	2x2 twill

evaluation under small loads. The samples were sewn on a Pfaff 1183 industrial lockstitch sewing machine, stitch type 301, sewing needle size 100 Nm and sewing thread count of Tt = 25 tex. Two plies of fabrics were sewn with the class 1 superimposed seams type 1.01.01 and stitch density of 4 stitches per cm in warp and weft direction. The machine speed was varied between 1000, 3000 and 4000 rpm (revolutions per minute).

The sewing machine was equipped with a linear variable differential transformer (LVDT). This electromechanical device produces an electrical output proportional to the displacement of a separate movable core [22]. The core was linked to this presser bar and the cylindrical case attached to the machine frame, which together with a piezoelectric force transducer placed on the same bar, can provide information on feeding system dynamics during the sewing cycle. Thus, LVDT (with electronics to provide a dc output proportional to the displacement) was used for real-time monitoring of the movement of a presser foot bar [23]. That device is connected to a data acquisition board installed in a PC, with software that allows sensor calibration, online graphical display and signal processing functions (figure 1).

The results of the presser foot displacement represent the average of 20 stitches acquired in each experiment.

Fig. 1. The control device in the lockstitch sewing machine and connected PC

The degree of seam pucker for the sewn samples was calculated via percentage equation, where the percentage of pucker in the seam is calculated from the difference between the thicknesses of the seam and the double thickness of the tested fabrics for the Class 1 seam type, equation 1:

$$SP = \frac{T_2 - T_1}{T_1} \cdot 100 \quad (1)$$

where SP is seam pucker in %, T_1 – double thickness of fabric (two layers of fabric) in mm and T_2 – seam thickness in mm.

The thickness of the fabrics was determined according to ISO 5084:1996 standard using a fabric thickness meter [24]. The seam thickness is measured by a fabric thickness meter and the measurement is done along the length of the seam line.

The term formability has been established to describe the ability of two-dimensional fabrics to get converted into three-dimensional garments and for predicting fabric propensity to seam pucker occurrence, especially in sewing operations with overfeeding. For this investigation, the formability of the samples was calculated using Kawabata and Niwa equations 2 [25, 26]:

$$F = \frac{EM}{F_m \cdot LT} \cdot B \cdot \frac{G}{2HG5} \quad (2)$$

where F is formability in mm^2, EM – extensibility strain at 500 gf/cm of tensile load, B – fabric bending rigidity in gf·cm^2/cm, G – fabric shear stiffness in gf/cm·deg, F_m – maximum force of fabric extension of 500 gf/cm, LT – linearity of load/extension curve and 2$HG5$ – hysteresis of shear force at 5° shear angle in gf/cm.

RESULTS AND DISCUSSION

The results of seam thickness, fabric thickness and seam pucker percentage for seams in warp and weft directions are depicted in table 2. The warp, weft and average formability according to Kawabata and Niwa are shown in table 3.

The results of the seam pucker percentage (table 2) show that all samples in the warp direction obtain higher pucker than weft samples. On average, the pucker of the warp direction seams is 32.9% and in the warp direction seam is 26.6%, i.e., warp seams

Table 2

SEAM PUCKER PERCENTAGE IN WARP AND WEFT DIRECTION

Fabric	T_{21} * (mm)	T_{22} * (mm)	T_1 (mm)	SP_1 (%)	SP_2 (%)
A	0.95	0.92	0.36	31.9	27.8
B	1.00	0.95	0.41	22.0	15.9
C	0.90	0.85	0.29	55.2	46.6
D	0.95	0.90	0.34	39.7	32.4
E	1.05	1.00	0.39	34.6	28.2
F	1.07	1.02	0.41	30.5	24.4
G	0.95	0.90	0.39	21.5	15.4
H	1.15	1.10	0.45	27.8	22.2

Note: SP_1 and SP_2 – seam pucker in warp and weft direction in %; T_{21} and T_{22} – seam thickness for seams in warp and weft direction in mm; T_1 – double thickness of fabric (two layers of fabric) in mm.

Table 3

FORMABILITY OF THE FABRICS BY WARP – F_1, WEFT – F_2 AND AVERAGE – F

Fabric	F_1 (mm^2)	F_2 (mm^2)	F (mm^2)
A	0.0589	0.4250	0.1881
B	0.0576	0.3850	0.1783
C	0.0210	0.1214	0.0596
D	0.0310	0.0841	0.0537
E	0.0473	0.1735	0.0992
F	0.0503	0.1691	0.1005
G	0.0208	0.3993	0.1343
H	0.0281	0.6323	0.2044

show on average 6.3% higher pucker than weft seams.

Weft formability ranges from 0.0841 to 0.6323 mm^2 and is higher than warp formability which ranges from 0.0208 to 0.0589 mm^2. The difference is a result of the unbalanced fabric set which affects the mechanical properties in both directions. Average weft formability is 7.6 times higher than the warp one. This suggests that seams in weft directions are expected to show less puckering than the warp ones. The lowest average and weft formability is obtained for fabrics C and D which have the lowest fabric mass per unit area, while the highest formability is obtained for sample H (the largest fabric mass per unit area out of all samples). The highest coefficients of linear correlation obtained are –0.70, between the seam pucker in the warp direction and average formability and –0.65, between the seam pucker in weft and average formability.

Figure 2 represents graphs of presser foot displacement during the sewing cycle for fabric C (figure 2, *a*) and fabric D (figure 2, *b*) at sewing speeds of 3000 and 4000 rpm. The sewing cycle diagram starts from 0 degrees and represents the beginning of the descending movement of the feed dog below the throat plate; from 20–70 degrees the feed dogs are at the lowest position and began rising to throat plate level; where at 80 degrees they are exactly at throat plate level. So, in all these sequences from 0–100 degrees, the presser foot is at the throat plate level. Above 100 degrees, the feed dog has a rising movement along with presser foot, reaching its maximum height and declining afterwards till 260 degrees, when returning at the throat plate level. Finally, after 280 degrees, the feed dog drops to its lowest position at 360 degrees. Therefore, from 260 till 360 degrees, the presser foot is again at the throat plate level.

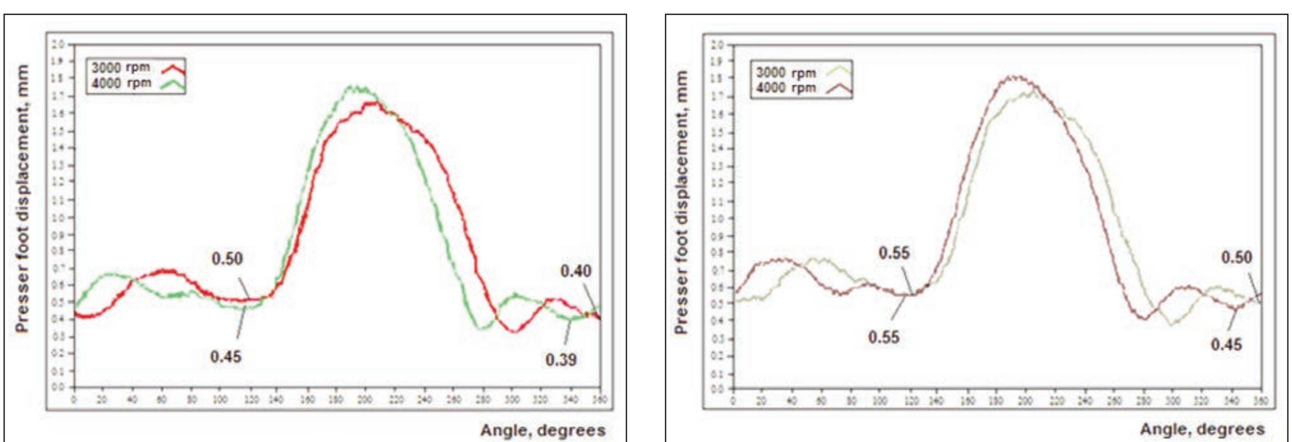
The highest position of the pressure foot at 4000 rpm is higher than at the speed of 3000 rpm for both investigated fabrics (figure 2, *a* and *b*), suggesting that increasing the machine speed increases the maximum height of the pressure foot displacement due to higher presser foot inertia at higher speeds. Although the results indicate some relation between the machine speed and maximum pressure foot height, there is no correlation between the maximum pressure foot height and the occurrence of seam pucker. Therefore, the maximum presser foot height does not provide relevant information regarding the occurrence of seam puckering during the online monitoring of the pressure foot displacement.

The height of the presser foot before and after the rising and declining movement varies for both machine speeds and obtains several values depending on the main shaft position. Generally, this happens from 0–100 degrees and from 260–360 degrees, (the pressure foot is at the throat plate level) and is the result of presser foot bouncing. This is the case for both fabrics (figure 3) and similar graphs were obtained for all other fabrics. This presser foot bounce phenomenon appears to result from high inertial forces being transferred into the presser foot by the feed dog at higher speeds [27].

Again, there is no good correlation between seam pucker and presser foot height, before and after the rising and declining movement for speeds of 3000 and 4000 rpm. Moreover, there are several levels of pressure foot heights in this phase (from 0.39 to 0.55 mm), as indicated in the graphs.

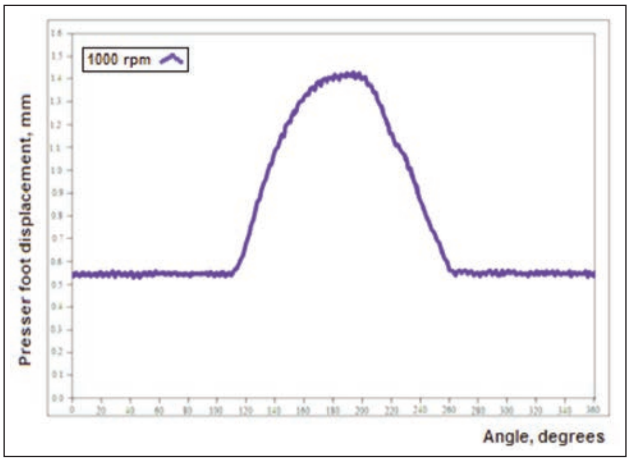
In further investigation, the machine speed was lowered to 1000 rpm and the results are shown in figure 3, *a* for sample C and figure 3, *b* for sample D, respectively. Graphs show that at 1000 rpm, the height of the presser foot does not vary before and after rising and declining movement and there are no indices of pressure foot bouncing. In this case, the height of displacement of the presser foot is the same before and after the peak (from 0–110 and to 260–360 degrees).

Various relationships between the height of the presser foot, fabric thickness, and seam pucker percentage, were investigated at the sewing speed of 1000 rpm. The best significant linear correlation was found between the seam pucker percentage and the

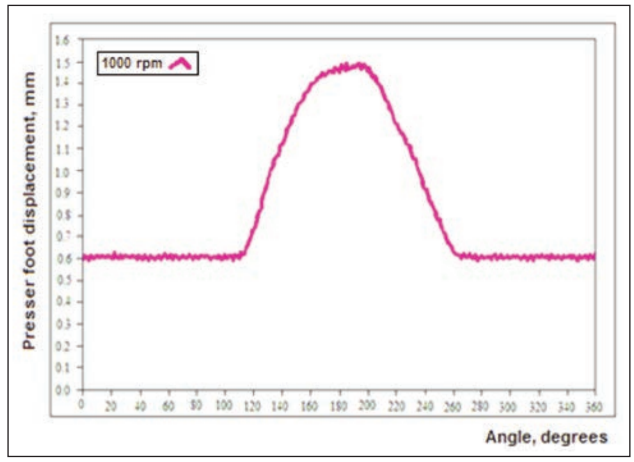


a *b*

Fig. 2. Presser foot displacement at sewing speeds 3000 and 4000 rpm, sewing in warp direction:
a – fabric C; *b* – fabric D



a



b

Fig. 3. Presser foot displacement at sewing speed 1000 rpm, sewing in warp direction: *a* – fabric C; *b* – fabric D

ratio of presser foot height versus the thickness of two layers of fabric (h/T_1). The value of pressure foot height before and after rising and declining movement (at the throat plate level), is actually the thickness of the seam at the moment of sewing. So, the higher ratio value of the h/T_1 when monitoring the pressure foot height during the sewing process can indicate that at that very moment, the seam of higher thickness is created, which in turn points out that seam pucker is created.

Table 4 shows the values of the ratio h/T_1 at sewing speed 1000 rpm for all tested fabrics. The values of the ratio h/T_1 confirm that this relationship may be a relevant indicator for the occurrence of seam pucker. The highest h/T_1 ratio of 0.95 is obtained for sample C, which has the highest seam pucker in both directions of 55.2% and 46.6% (table 3). Samples with a lesser h/T_1 ratio have a lower percentage of seam pucker. This is the case for fabric G which has h/T_1 values of 0.78 and 0.85, in the warp and weft direction, respectively, and seam pucker of 21.5% and 15.4%, in warp and weft directions.

The relationship of seam pucker (*SP*) and ratio h/T_1, in warp and weft directions, are presented in figures 4 and 5. The highest significant correlation was obtained between *SP* and h/T_1 ratio: 0.89 for warp seams and 0.82 for weft seams.

Table 4

DISPLACEMENT OF PRESSER FOOT AND RATIO h/T AT SEWING SPEED 1000 rpm

Fabric	h_1 (mm)	h_2 (mm)	h_1/T_1	h_2/T_1
A	0.64	0.64	0.89	0.89
B	0.66	0.65	0.80	0.79
C	0.55	0.55	0.95	0.95
D	0.60	0.60	0.88	0.88
E	0.67	0.71	0.86	0.91
F	0.70	0.71	0.85	0.87
G	0.61	0.66	0.78	0.85
H	0.79	0.81	0.88	0.90

Note: The indices 1 and 2 marked samples by warp and weft, respectively: *h* – the height of presser foot before and after the rising and declining movements in mm; T_1 – double thickness of fabric (two layers of fabric) in mm.

The graph in figure 4 shows that the seams in warp direction having the ratio h/T_1 of 0.85 and higher during the sewing process, obtained 30% and higher puckered seams. Therefore, monitoring pressure foot height at the throat plate level, at lower speeds, usually at the beginning of sewing and calculating the h/T_1 ratio, can provide relevant information, warning the user regarding the possibility of occurrence of puckered seams while sewing.

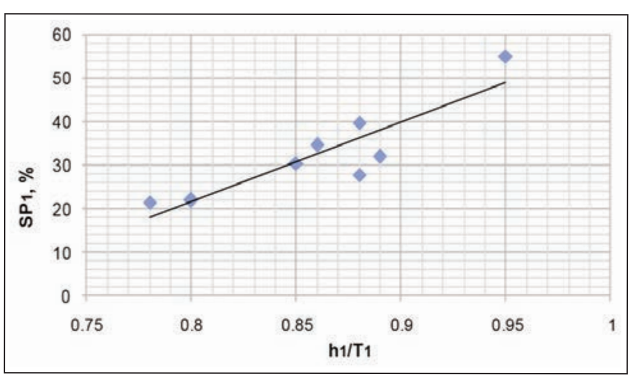


Fig. 4. Relationship of seam pucker and h_1/T_1 ratio, for seams in warp direction

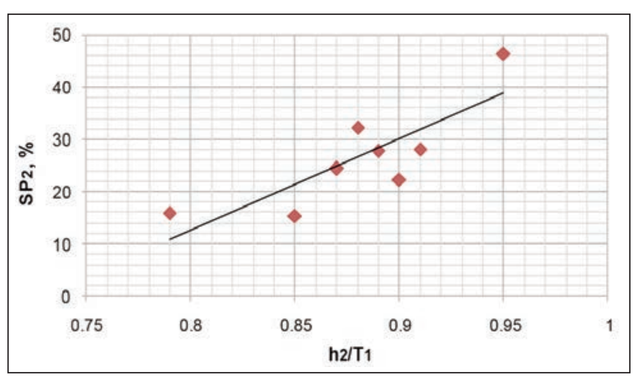


Fig. 5. Relationship of seam pucker and h_2/T_1 ratio, for the seams in weft direction

CONCLUSION

The relationship between seam pucker and presser foot displacement during the stitch formation cycle has been investigated for seams of class 1 made of woven fabrics for tailored garments.

The results show that warp seams show on average 6.3% higher pucker occurrence than weft seams. Fabric formability in seams developed in the weft direction is 7.6 times higher than in the warp direction. The highest linear correlation was found between the average formability and seam pucker in the warp direction.

Monitoring of the presser foot displacement during the stitch cycle formation showed that the maximum value of presser foot height varies as a result of the machine speed.

The value of presser foot height, before and after the raising and declining movements, at higher speeds obtained various values, due to presser foot bouncing, and does not correlate with seam pucker.

A significant correlation was found between seam pucker percentage and the ratio h/T_1 before and after the rising and declining movements of the pressure foot, at a machine speed of 1000 rpm. The higher value of the ratio h/T_1 can indicate the formation of seams with a high percentage of seam pucker occurrence. Therefore, monitoring h/T_1 values at lower sewing speeds can be used to detect the occurrence of seam pucker during the sewing process and it is expected that the concept can be applied to other types of textile materials.

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Competitiveness indicators assessment of the textile organizations from Serbia

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ABSTRACT – REZUMAT

Competitiveness indicators assessment of the textile organizations from Serbia

An assessment of the indicators contributing to the success of the textile organizations doing business in Serbia from the point of view of their specificities in relation to the other industrial sectors is the subject matter of the research study presented in this paper. The original premise says that there are numerous factors that determine the competitiveness of textile organizations, all those factors have a different influence on the results of those organizations' business activities. The study is aimed at singling out and assessing the factors significant for the adaptation of the existing concept of the business operations undertaken by Serbian textile organizations through continuous changes in the textile and clothes global market. Namely, once the Textile Agreement made between the member states of the World Trade Organization ceased to be in force, trading textile products between the member states became completely liberalized, which led to the competition within the world frameworks becoming much more severe. In order to respond to said changes, there is a need for textile organizations to engage qualified personnel with competencies, knowledge and skills (know-how), who is simultaneously able to respond to all the challenges they are faced within the conditions of accelerated changes in the numerous indicators that determine their competitiveness. The obtained results are indicative of the fact that the following are the key factors for their business success: design functions through the continuous improvement of employees' knowledge, investment in relationship marketing and the development of domestic brands, together with the procurement of modern technological solutions and equipment. In the subject-matter research study, the following methods were used, namely: hypothetical-deductive, analytical-deductive and comparative, historical and statistical-descriptive, as well as comparative statistics methods (chi^2-test, ANOVA).

Keywords: *knowledge, technological solution, brand, design function, marketing*

Evaluarea indicatorilor de competitivitate a organizațiilor textile din Serbia

O evaluare a indicatorilor care contribuie la succesul organizațiilor textile care desfășoară afaceri în Serbia din punctul de vedere al specificului acestora în raport cu celelalte sectoare industriale este subiectul studiului de cercetare prezentat în această lucrare. Premisa originală spune că există numeroși factori care determină competitivitatea organizațiilor textile, toți acești factori au o influență diferită asupra rezultatelor activităților de afaceri ale acestor organizații. Studiul urmărește să evidențieze și să evalueze factorii importanți pentru adaptarea conceptului existent al afacerilor întreprinse de organizațiile textile sârbe prin schimbări continue pe piața globală a textilelor și îmbrăcămintei. Și anume, odată cu încetarea Acordului privind textilele încheiat între statele membre ale Organizației Mondiale a Comerțului, comerțul cu produse textile între statele membre s-a liberalizat în totalitate, ceea ce a dus la o concurență și mai mare la nivel mondial. Pentru a răspunde acestor schimbări, este nevoie ca organizațiile textile să angajeze personal calificat, cu competențe, cunoștințe și abilități (know-how), care să poată răspunde simultan tuturor provocărilor cu care se confruntă, în condițiile schimbărilor accelerate în numeroşii indicatori care determină competitivitatea acestora. Rezultatele obţinute indică factorii cheie pentru succesul în afaceri: funcţiile de proiectare prin îmbunătăţirea continuă a cunoştinţelor angajaţilor, investiţiile în marketing relaţional şi dezvoltarea mărcilor autohtone, împreună cu procurarea de soluţii tehnologice și echipamente moderne. În studiul de cercetare tematică au fost utilizate următoarele metode și anume: ipotetico-deductivă, analitico-deductivă și comparativă, istorică și statistico-descriptivă, precum și metode statistice comparative (testul chi^2, ANOVA).

Cuvinte-cheie: *cunoștințe, soluție tehnologică, marcă, funcție de design, marketing*

INTRODUCTION

It is a fact that today, the growing competition has become a major challenge for the textile organizations doing business in Serbia [1], and the design and planning of manufacturing systems are an activity of great significance for their industrial competitiveness. The speed and diversity of the technological changes [2] being made in a business environment exert an influence on textile organizations in that they are required to pay more significant attention to studying it and defining the strategic variants that will enable them to create, maintain and develop competitive advantage [3] in international marketing.

In recent decades, the Serbian organizations doing business in the textile industry have trodden the path from having been engaged in the field of processing jobs to the business level in which they are more significantly focused on design and penetration into the international market. The success in foreign markets is a clear reflection of their systematic capability of not only producing competitive products but consistently improving their market position as well, simultaneously competing with rivals from other countries [4]. The question of the improvement of an organization's competitiveness is essentially the question of the improvement of employees' knowledge, i.e., the question of the application of modern management methods and techniques [5], where the quality management system concept [6] is central. That means that a more adequate use of knowledge is the most significant direction for the improvement of the competitiveness of domestic textile organizations.

Starting from the fact that the crucial specificity of textile organizations in relation to the other industrial sectors lies in the design function, the question of which concrete indicators determine their competitiveness is imposed as well, also taking into consideration the level and length of doing business in order for domestic exporters to become more competitive abroad. The study purposefully singled out and analysed the success factors that define the ambience in which the organization management process takes place: the improvement of employees' knowledge, investment in the development of domestic brands, the improvement of marketing relationships and the procurement of modern technological solutions and equipment.

How effective the design function will be, depends mostly on the organization's employees' knowledge [7]. Namely, each organization's competitiveness, the same working for textile organizations as well, is based on the main capabilities [8], as well as the employees who have those capabilities. The employed in a textile organization is a unique and irreplaceable resource, and they are the basis of its long-term success and a permanent source of its competitive advantage. All the more so, a textile designer is the most important figure providing a textile organization with the value, rarity and non-imitability of a textile product solution [9].

Permanent changes in market conditions, and all the more frequent changes in fashion trends, among other things, require employees' flexibility and creativeness, their readiness to learn [10] and improve, and their ability to quickly master new systems. A concrete Serbian textile organization can achieve the key advantage on the contemporary market through its creative segment – the design function. This is all the more so due to the fact that the textile product designing activity is an extremely "non-routine" activity, whereas it is extremely regulated and for the most part standardized in the technical implementation segment. In order for a goods mark of a domestic textile organization to become a brand, the consumer must be aware of its specific value, which distinguishes it from other products on the market. An organization's competitiveness, its recognizability in relation to the competition, the user's perception of the brand quality and brand satisfaction explicitly depend on the quality [11] of a domestic brand. What is extremely important to the domestic textile workers appearing on foreign markets is the fact that, first of all, they should direct marketing [12] efforts towards distributors in order to enable their product(s) to penetrate such foreign markets, while simultaneously finding it worth increasing marketing efforts towards end-users as well [13] in order for their product(s) to be accepted.

By improving its marketing relationships [14], the organization should build a marketing network with interested stakeholders, who will enable it to make changes in the competitiveness field. In order for an organization to build relationships with some of its partners' segments, it is necessary for it to understand their capabilities, resources, needs and goals.

Modern technological solutions and pieces of equipment are included in all the value-creating activities conducted by an organization. Thanks to the influence technology exert on literally every single activity, it also exerts an influence on a textile organization's competitiveness.

RESEARCH METHODOLOGY

The research was done as a cross-sectional study of an empirical character in the function of analysing the influence of the subject-matter indicators on the successfulness of the textile organizations doing business in Serbia. The bibliographical-speculative method was used before the base explicative method in the paper's theoretical framework setting procedure, and during the results, processing and interpretation, multiple comparisons and statistical test methods were used. A survey was conducted as the research technique in order to collect primary data and pieces of information.

The research study was carried out on a sample of 136 organizations, selected from the database of the Republic of Serbia's Business Registers Agency, of which 19% were micro-organizations, 28% were small organizations, 29% were medium-sized organizations, whereas large organizations accounted for 24%. When speaking about the inclusion of the organizations in relation to the business operation sector, the largest number of them were included from the textile industry sector (10.3%). The observed sample included the largest number of the organizations doing business on the international market (46%), only to be followed by those operating on the national market (25%), the organizations doing business on the regional market (17%), whereas those only doing business on the local market accounted for the smallest percent (12%). When making a selection of the enterprises to be included in the sample, the success of their business operations was the determining factor.

The purpose of the questionnaire was to collect pieces of information and analyse the indicators significant for the successfulness of the business operations of the organizations doing business in Serbia in the context of the elements needed for the development of their competitive capability. The questionnaire consisted of a few questions – the independent variables [15]: the size of the organization (a micro-organization up to 10 employees, a small organization from 11 to 50 employees, a medium-sized organization from 51 to 250 employees, and a big organization over 251 employees); the duration of the business of the organization; the activities of the organization; the sector of the business of the organization; the level (market) of the business of the organization (locally, nationally, regionally, internationally) and so on. The dependent variables in the questionnaire concerned: the grades for the key factors of the improvement of the business of the Serbian organizations (the business quality improvement, the improvement of the employees' knowledge and the technical-technological basis of business operations, the development of integrated management systems, the internationalization of business, etc.); the assessment of the elements for the development of the competitive capability of the Serbian organizations (the standardization of the quality of business operations, investments in marketing and in the development of domestic brands, the continuous improvement of all the employees' knowledge, the improvement of marketing relations, the procurement of modern technological solutions and equipment); and the assessment of the primary obstacles in the development of the competitiveness of Serbian textile enterprises (the inadequate use of contemporary management methods and techniques, the shortage of the resources, the outdated equipment and technologies, the inadequate application of the marketing concept, the business operations not based upon international standards, etc.). The envisaged options for the respondents to grade the analysed indicators were very significant, significant and not significant, and not significant. The respondents were given an option to grade some characteristics in the business operations (the level, the length) by assigning them the grades from 1 to 5, where 1 was the lowest grade, and 5 was the highest grade. The differences in the assessment of the effects in a sense of improving the successfulness of the business operations of those organizations by taking into consideration the answers received from the respondents were processed by doing the ANOVA test and the nonparametric $\chi 2$ test (the existence of a statistically significant difference for the values Sig≤0.05). The primary sources of information and knowledge were mainly used in the research segment presented in this paper.

RESULTS AND DISCUSSION

The analysis of the factors significant for the improvement of the competitiveness of business doing as a strategic goal of each organization, and a textile organization as well, began with the evaluation of the elements singled out in advance, the accent is placed on the assessment of the continuous improvement of the employees' knowledge through the improvement of the design function, investment in marketing relationships and the development of domestic brands, as well as the procurement of modern technological solutions and equipment in relation to the other elements. Comparative statistics were used to analyse the independent variables in comparison with the dependent ones so as to determine the connections/relations and compare the included indicators. Based on the obtained results, it is possible to draw a conclusion that continuous improvement of the employees' knowledge and the procurement of modern technological solutions and equipment were singled out as significant factors (the percentage ranging from 83.1% to 86.0%). The respondents were given the following options – the indicators are strongly needed, the indicators are needed and are not needed, and the indicators are not needed – to grade the indicators.

The grades in the absolute and relative indicators of a concrete indicator necessary for the development of the competitive capability of the analysed organizations from within the textile sector are presented in table 1. According to the table [15], it is possible to see that the continuous improvement of the employees' knowledge, the procurement of modern technological solutions and equipment, as well as investment in marketing and the development of domestic

Table 1

THE ASSESSMENT OF THE INDICATORS NECESSARY FOR THE DEVELOPMENT OF THE COMPETITIVE CAPABILITY OF THE SERBIAN TEXTILE ORGANIZATIONS

The elements for the development of the competitive capability	Strongly needed		Needed and not needed		Not needed	
	Af	Rf	Af	Rf	Af	Rf
The continuous improvement of the knowledge of all the employees'	113	83.1	17	12.5	6	4.4
Investment in the development of domestic brands	100	73.5	28	20.6	8	5.9
The improvement of marketing relationships	82	60.3	50	36.8	4	2.9
The procurement of modern technological solutions and equipment	117	86.0	17	12.5	2	1.5
The application of management modern methods and techniques	81	59.6	47	34.6	8	5.9
Business doing quality standardization	114	83.8	18	13.2	4	2.9

Note: Af – absolute frequencies; Rf – relative frequencies (percentages).

brands are graded as strongly needed indicators in the highest percentage.

Figure 1 shows the continuous improvement of the employees' knowledge as observed through the prism of the design function as an element significant for raising the level of the success of Serbian textile organizations on the contemporary market, as assessed by the managers of the same that do business at a different level (local, national, regional and international). The improvement of the employees' knowledge is the foundation of the competitiveness of textile organizations. How successful the design function will be, depends mostly on the knowledge the organization's employees have. All the more so for the reason of the fact that a textile designer is a key figure ensuring the value, rarity and non-imitability of a textile product solution for a textile organization.

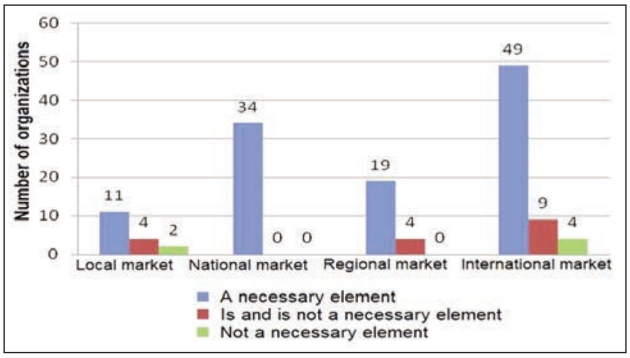

Fig. 1. The continuous improvement of the knowledge of all the employees as an indicator significant for the development of the competitiveness of Serbian textile indicators

Table 2 presents the existence of differences in the grades for the continuous improvement of the knowledge of all the employees by the managers of the organizations operating at a different level. The outcomes reveal that Sig.=0.033<0.05, so it is possible to conclude that the differences at the level of the business operations of an organization do importantly influence the grade for the importance of the continuous improvement of all the employees for the improvement of the competitiveness of Serbian textile organizations.

Table 2

THE SIGNIFICANCE OF THE CONTINUOUS IMPROVEMENT OF ALL THE EMPLOYEES FOR THE DEVELOPMENT OF THE COMPETITIVENESS OF SERBIAN TEXTILE ORGANIZATIONS

Indicator	Value	df	Sig.
Pearson chi square ($\chi 2$ Xi square)	13.714	6	0.033

Figure 2 shows the differences in the grades for investment in the development of domestic brands as an element needed for the development of the competitiveness of Serbian textile organizations. In a market game intensified by globalization, a brand helps a textile organization to survive thanks to the built loyalty and safety created by the brand.

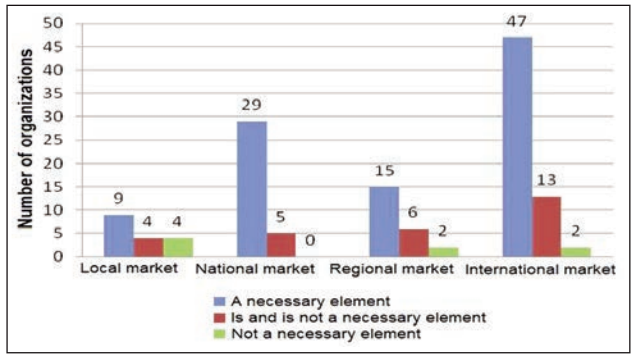

Fig. 2. Investment in the development of domestic brands as an element needed for the development of the competitiveness of textile organizations

Table 3 shows the significance of the difference in the grades of the textile organizations doing business at a different level with respect to the importance of investment in the development of domestic brands for the development of their competitiveness. It can be seen that Sig.=0.021<0.05, so it can be concluded that the level of the business operations of an organization has a significant role with respect to the grades.

Table 3

THE IMPORTANCE OF INVESTMENT IN THE DEVELOPMENT OF DOMESTIC BRANDS FOR THE DEVELOPMENT OF THE COMPETITIVENESS OF SERBIAN TEXTILE ORGANIZATIONS

Indicator	Value	df	Sig.
Pearson chi square ($\chi 2$ Xi square)	14.918	6	0.021

Figure 3 shows the significance of the improvement of marketing relationships and activities as an indicator significant for the improvement of the success of textile organizations as assessed by the managers of those organizations doing business at a different level. Table 4 accounts for the differences in the grades for the improvement of marketing relationships as an

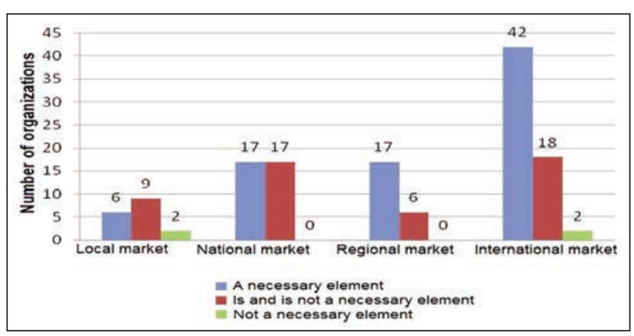

Fig. 3. The improvement of marketing relationships as an indicator significant for the improvement of the competitiveness of textile organizations

element significant for the development of the competitiveness of Serbian textile organizations. The results show that Sig.=0.026<0.05, which means that the level of the business operations of the textile organizations significantly influences the differences in the grades for the assessment of marketing relationships as a significant element for the improvement of the competitiveness of the same.

Table 4

THE IMPROVEMENT OF MARKETING RELATIONSHIPS AS AN INDICATOR SIGNIFICANT FOR THE IMPROVEMENT OF THE COMPETITIVENESS OF TEXTILE ORGANIZATIONS			
Indicator	**Value**	**df**	**Sig.**
Pearson chi square ($\chi 2$ Xi square)	14.383	6	0.026

Figure 4 shows the importance of the procurement of modern technological solutions and equipment as an indicator significant for the improvement of the competitiveness of Serbian textile organizations as assessed by the managers of those organizations doing business at a different level.

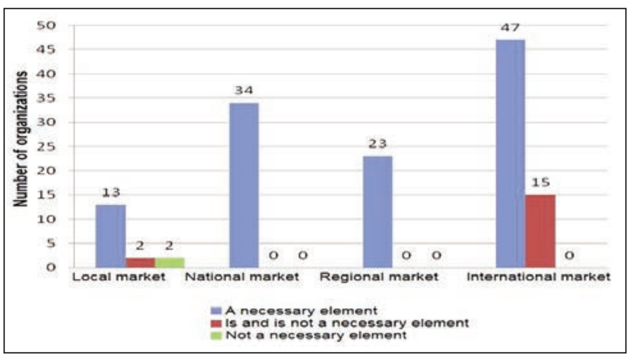

Fig. 4. The significance of the procurement of modern technological solutions and equipment as an element significant for the development of the competitiveness of the textile organizations in Serbia

Table 5 shows the difference in the grades for the significance of the procurement of modern technological solutions and equipment by the organizations doing business at a different level. The results show that Sig.=0.000<0.05, so it can be concluded that there is a significant difference in the grades for the significance of the procurement of modern technological solutions and equipment as an element important for the development of the competitiveness of Serbian textile organizations as assessed by the managers of the same, which do business at a different level. It is possible to note that the level of the business operations of those textile organizations significantly influences the grades.

Table 5

THE PROCUREMENT OF MODERN TECHNOLOGICAL SOLUTIONS AND EQUIPMENT AS AN ELEMENT SIGNIFICANT FOR THE IMPROVEMENT OF THE COMPETITIVENESS OF SERBIAN TEXTILE ORGANIZATIONS			
Indicator	**Value**	**df**	**Sig.**
Pearson chi square ($\chi 2$ Xi square)	30.142	6	0.000

Furthermore, a two-factor analysis was conducted to determine that the length of the business operations and the level of the business operations have an influence on the differences in the characteristics of the business operations of the textile organizations as a precondition for their competitiveness. The obtained mean values of the grades of the technological level of the textile organizations doing business for a different period of time and being at a different business operation level (doing business on different markets) enabled us to see that the best graded was the technological level with the organizations doing business at a regional level in a period from six to ten years and at a regional level in a period from 21 to 30 years (the mean 5.00, the std. deviation 0.000).

Figure 5 shows the mean values of the grades for the technological level of the organizations doing business for a different period of time and being at a different business operation level (doing business on different markets). Here, it is possible to see that the best graded was the technological level with the organizations doing business at a regional level in a period from six to ten years and at a regional level in a period from 21 to 30 years.

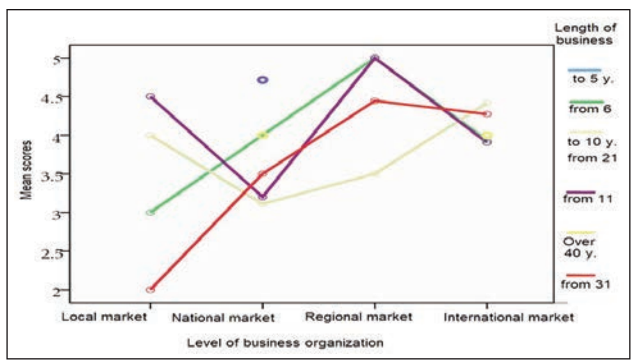

Fig. 5. The mean values of the grades for the technological level of the organizations of a different business operation level and a different length of doing business

The influence of the interaction between the length of the business operations of the organization and the business operation level is given in table 6. In the column "Business Operation Level/Length of Doing Business", Sig=0.000, which is less than 0.05, so it can be concluded that there are differences in the grades for the technological level of the organizations which are at a different business operation level and of a different length of doing business. The influence of the interaction between the business operation level and the length of doing business is statistically significant. After the analysis of the joint influence, an analysis of separate influences was carried out.

Namely, in the column "Sig.", the value for the business operation level is 0.001, which is less than 0.05, so it is concluded that the level of the business operations of an organization has a significant influence on the grades for the technological level of the organization. Also, the Sig. for the length of doing business is less than 0.05 (the same being 0.006), which also significantly influences the differences in the assessment of the level of the technological level of the organization. It is concluded that the business operation level and the length of doing business play an important role with respect to the differences in the technological level of the organizations.

Table 6

THE INFLUENCE OF THE INTERACTION BETWEEN THE VARIABLES "THE BUSINESS OPERATION LEVEL" AND "THE LENGTH OF DOING BUSINESS" ON THE GRADE FOR THE TECHNOLOGICAL LEVEL OF THE ORGANIZATIONS

Variables	Df	Mean Square	F	Sig.
Business operation level	3	4.229	6.265	0.001
The length of doing business	5	2.306	3.417	0.006
Business operation level/The length of doing business	10	2.531	3.749	0.000

CONCLUSION

In the conducted research study, the sample consisted of the textile organizations of different sizes, levels and lengths of doing business, while the inclusion of the organizations as per the size was simultaneously proportional. The focal point of the research study was on the concrete factors of the competitiveness of a textile organization which should primarily be influenced through adequate measures so that Serbian exporters can become more competitive abroad. Apart from the other indicators, the continuous improvement of employees' knowledge, investment in marketing relationships and the development of domestic brands, as well as the procurement of modern technological solutions and equipment, are singled out.

The improvement of employees' knowledge is the basis for the competitiveness of textile organizations. How successful the design function will be, depends mostly on their knowledge. The outcomes show that Sig.=0.033<0.05, so it can be concluded that the differences in the level of the business operations of an organization do importantly influence the grade for the importance of the continuous improvement of all employees for the purpose of improving the competitiveness of textile organizations.

In market competition, investment in the development of a domestic brand significantly helps a textile organization to survive thanks to the built loyalty and safety created by a brand. The results show that Sig.=0.021<0.05, so it is concluded that the business operation level of an organization has a significant role with respect to grades.

The improvement of marketing relationships and activities as an indicator significant for raising the level of the success of textile organizations by the managers of the organizations doing business at a different level was assessed as very important. The results show that Sig.=0.026<0.05, which means that the level of the business operations of textile organizations significantly influences the differences in the grades for the improvement of marketing relationships as a significant element for the improvement of the competitiveness of the same.

Furthermore, the results show that there is a significant difference in the grades for the importance of the procurement of modern technological solutions and equipment as an element important for the development of the competitiveness of Serbian textile organizations, where Sig.=0.000<0.05, which refers us to the conclusion that the level of the business operations of textile organizations significantly influences the obtained grades. At the same time, the individual influences of the business operation level and the length of doing business differ from one another. There is an especially significant difference in the technological level of the organizations doing business on the national and regional markets and the organizations doing business on the national and international markets.

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Heritage textiles – an integrated approach for assessment and future conservation

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ABSTRACT – REZUMAT

Heritage textiles – an integrated approach for assessment and future conservation

The digital revolution has been present in our lives more and more since the beginning of the third millennium and until now, has affected the way in which cultural heritage is valued, preserved and passed on. In this context, the present study aims to use digital technologies (digital radiography and Reflectance Transformation Imaging) to contribute to assessing the conservation status of a heritage textile fabric; a traditional women's shirt about 100 years old from Bihor County (ie). The investigations concerned both the fine details that are not visible to the naked eye, regarding the internal structure of the material and external (damaged areas, embroidery with traditional motifs, etc.). The results obtained show high suitability of the methods used for the analysis performed on historical textiles, having major importance in identifying the visual representation of the weave, the fibres and the surface of the fabric, the deterioration and also the current state of preservation and contributing to the identification of optimal restoration-conservation solutions.

Keywords: *digital radiography, Reflectance Transformation Imaging, digital techniques, cultural heritage textiles*

Patrimoniul textil – o abordare integrată pentru evaluare și conservare

Revoluția digitală a fost prezentă din ce în ce mai mult în viața noastră de la începutul mileniului al treilea și până în prezent, afectând modul în care patrimoniul cultural este valorificat, conservat și transmis. În acest context, studiul de față își propune să utilizeze tehnologiile digitale (radiografie digitală și tehnica RTI – Reflection Transformation Imaging) pentru a contribui la evaluarea stării de conservare a unui articol vestimentar de patrimoniu: o cămașă tradițională pentru femei, veche de aproximativ 100 de ani, din județul Bihor. Investigațiile au vizat atât detaliile fine care nu sunt vizibile cu ochiul liber, privind structura fibrelor, cât și externe (zone deteriorate, broderii cu motive tradiționale etc.). Rezultatele obținute arată o adaptare ridicată a metodelor utilizate pentru analizele efectuate pe textile istorice, având o importanță majoră în identificarea si reprezentarea vizuală a țesăturii, a fibrelor, a suprafeței materialului, deteriorarea, starea actuală de conservare și contribuie la identificarea soluțiilor optime de restaurare-conservare.

Cuvinte-cheie: *radiografie digitală, RTI (Reflection Transformation Imaging), tehnici digitale, patrimoniul cultural textil*

INTRODUCTION

The importance of the elements that make up the cultural heritage lies mainly in the significance they have for the community, representing a span between the past, present and future. Undoubtedly, through its diverse functionality, simplicity, beauty, sensitivity, the textile heritage is certified as one of the most valuable samples that make up the material cultural heritage of a nation [1–2]. Whether it is represented by textiles with aesthetic values (paintings on canvas, decorative elements, etc.) [3–5] or practical ones (traditional garments, etc.) [6–8], the textile heritage facilitates the connection of the traditional universe, especially the rural one [9], to the largely informational society that characterizes the present.

For Romanians, one of the most significant and defining objects of textile cultural heritage is undoubtedly the traditional shirt called "ie". This part of the traditional costume, both men's and women's, is an unofficial Romanian brand that embodies the very spirit of this nation, depicting continuity (through its origins in the characteristic garment of the Dacian tribes – ancestors of the Romanians) and unity (by sharing this garment in different varieties, throughout Romania) [10].

The passing on of this cultural heritage to future generations involves sustained efforts to evaluate-preserve the authentic elements, considering that by their formation, the production techniques and materials used, traditional shirts are movable objects. To achieve this goal, both traditional methods of analysis and new ones, updated to the requirements of a constantly changing cultural heritage, must be taken into account. The study indicates some possibilities of application in the practice of methods for assessing the conservation and capitalization and evolution stages of the heritage materials. Another considerable importance for practice is to point out the risk of damage to the health of museum and archive staff coming into contact with the preserved historical artefacts.

Among the newest techniques for the analysis of the textile cultural heritage, digital radiography and Reflectance Transformation Imaging (RTI) stand out. Digital radiography in old and new valuable textiles is an important analytical technique because it is non-destructive and non-invasive, economical and very fast [11–14] which can provide morphological and physical information about the inner structure of the investigated samples [15–20]. This can be a good foundation for documentation in terms of fabric making technique, damage and repair, etc., successfully contributing to the designation of the state of conservation of materials, its evolution over time and finding optimal conservation solutions. Ultrasound images of higher resolution and contrast indicate fine details of the textile material under investigation, weaving techniques, embroidery, etc. and will be completed, when necessary, if possible, by means complementary to other three-dimensional images (e.g. those obtained with the help of a computer tomography etc.). However, it is noted that a series of radiographic exposures of historic fabrics show that excessive exposure to low energy X-rays produced no detectable changes in their mechanical integrity [21]. At the York Art Gallery, there was an exhibition with radiographic images of quilts that presented the general public not only the technical details of the fabric of the quilts, defects, possible repair techniques, but they were also valuable and appreciated for the beauty of the photographs [22].

As for Reflectance Transformation Imaging (RTI), this is an image capture and processing technique that uses multiple illumination angles to generate advanced topographic information. The most common way to implement RTI is through Polynomial Texture Mapping (PTM) [23], developed by Malzbender et al. [24], representing one of the techniques that make up the general term Reflectance Transformation Imaging (RTI) [25]. RTI allows the detailed examination of the surfaces of vulnerable objects, without direct contact with them, using light sources from different positions [26–27] and comparing luminance values of each pixel to approximate the inclination and relative depth of the analysed surface [28–29]. Interactive light control and the ability to change reflection properties increase the perception of surface structure, unlike ordinary photographs, which are static, thus enhancing the visibility of fine details and damaged areas [30–31]. In addition to the advantages offered by interactive visualization and analysis of the physical and morphological properties of different objects, RTI is a very easy to obtain and cheap technique at the same time [32].

In view of the above, the purpose of this study is to make an incursion into the application of digital radiography and Reflectance Transformation Imaging (RTI) in the analysis of old and rare textiles, for their preservation and popularization among the public. These two techniques are to be applied on a traditional Romanian shirt, about 100 years old, originating from Bihor County, Romania.

MATERIAL AND METHOD

To obtain ultrasound images, the ultrasonography technique was used, a Samsung RS 80 (Samsung Healthcare Ultrasound) device, equipped with high-resolution linear probes: L3-12A probes, with variable frequency up to 12MHz, respectively LA4-18B probes, with variable frequency up to 18MHz [8].

Applying the RTI method to the traditional shirt involved the use of a DSLR Canon EOS 90D camera with CMOS sensor, 22.3x14.8 mm in size and resolution of 32.5 mpx, fixed at the bottom of a stand, a continuous light source consisting of a 15W LED projector placed at a constant distance of two lengths from the centre of the object and two bright red balls (24 mm in diameter) located in the close proximity of the shirt. Thus, using an independent shutter, 75 raw images were captured with light sources varying in different positions (15 concentric positions containing 5 rows each, obtained between an angle of 15° and 65° formed by a straight line. perpendicular to the horizontal plane represented by the surface of the object in question). The photos obtained were introduced into the Digital Lab Notebook Inspector – RTI Version 1.0 Beta, open-source software created by Cultural Heritage Imaging [33], in order to test the accuracy of the images and correct or include those considered inappropriate in terms of quality to be further processed.

The corrected data were entered in RTIBuilder Version 2.0.2 [34] to obtain the final model. The processing pipeline is based on a semi-automatic approach in which after manually indicating the positioning of the two shiny balls, the software seeks to determine the incidence of light in each photo based on its specular reflection on the surface of the balls. Furthermore, after automatic detection of the light

Fig. 1. View of the RTI model of the traditional women's shirt in the Default mode of RTIWiever

source position and a manual redefinition required in some photos, all 75 captures were successfully interpolated in a single reference area. Interactive viewing of the created model was done in RTIWiever Version 1.1 [35] (figure 1).

RESULTS AND DISCUSSION

The internal structures of the textile materials made of natural fibres (cotton, linen, silk, etc.) are very fine; the fibres have low densities, which together with the retention of water molecules in the intermolecular cavities can attenuate X-rays, the images not always having very good contrast, have to be very good to allow examination under magnification and improve the contrast by applying specific software [22].

The heavily damaged areas in the traditional shirt were the subject of another study [8], where through digital ultrasound were highlighted the areas that have discontinuities (e.g., ruptures, thinning, etc.). In the ultrasound images (figure 2) made to capture some fine irregularities of the fabric, one can still observe a great homogeneity of the material, mostly free of ruptures or gaps in the fabric mass; a sign that it is in a good state of preservation regarding the internal properties of the material.

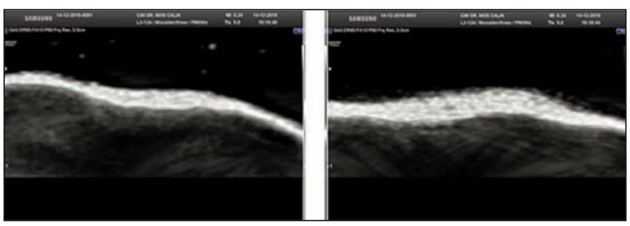

Fig. 2. Clinical Echography of the fabric of traditional shirt (ie)

The results obtained after performing the RTI on the traditional "ie" shirt were used to maximize the information transmitted and increase the volume of key details in order to determine more accurately the damaged surfaces within the cloth. The opportunity this technique offers is to separate the colour of the object from its texture and this aspect as a homogeneous surface in terms of hue favours the highlighting of degraded surfaces by observing them at different angles of light. Thus, in figure 3 can be seen multiple defects of the shirt with much higher accuracy than by the typical method of evaluation made with the naked eye, where many defects can go unnoticed due to the inappropriate incidence of light. In this respect, the image pairs A1-A2 and C1-C2 in figure 3 are edifying for the relevance of the method in terms of detecting damaged areas that stand out; here, the placement of the light source at a small angle in the upper part of the object and the modification of the specularity parameters have determined a certain shading of the two targeted areas, thus increasing the visibility of the defects. In B1-B2, the aim was to evaluate a group of small artificial damages, represented by holes in the depth of the material at the bottom of the shirt. And in this case, the interactive viewing allowed a better understanding of the degraded surfaces, the ruptures appearing more pronounced and with a greater extension than those observed with the naked eye or in default mode.

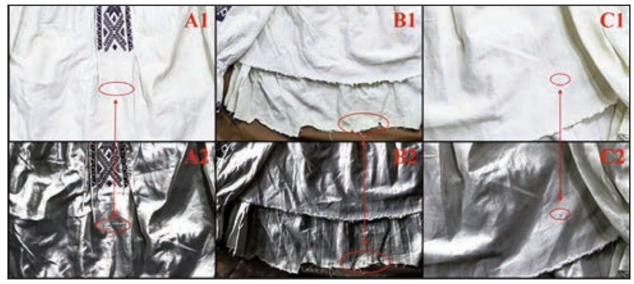

Fig. 3. Representation of the differences obtained in terms of detecting damaged areas between the default mode (A1, B1, C1) and interactive viewing through the spatial variability of light incidence and changing the parameters of specularity (A2, B2, C2)

At the same time, given the fact that the traditional motif is one of the most important and spectacular components of traditional Romanian shirts [36], the models themselves, the way they are made, the colour, etc., it is necessary to be kept and transmitted to future generations [37, 38]. In this context and considering that the qualitative photographic basis offered the possibility to generate an area of increased clarity, the traditional motif on the traditional shirt was evaluated in terms of conservation status and physical properties. The results of the analysis (figure 4) show that the motifs are in a very good state of preservation. They do not show abrasions, breaks, gaps or other discontinuities of natural or artificial origin, the models being homogeneous. The ability of RTI to arbitrarily represent geometric and diffuse shading effects, as well as to highlight details, when the light is positioned at a low angle, offers the possibility to analyse how it is made, shape, cloth, the material used and arrangement within the objects of these traditional motifs. This is fundamental for the preservation of motifs, the creation of physical and/or virtual prototypes and their application on new materials [39–41].

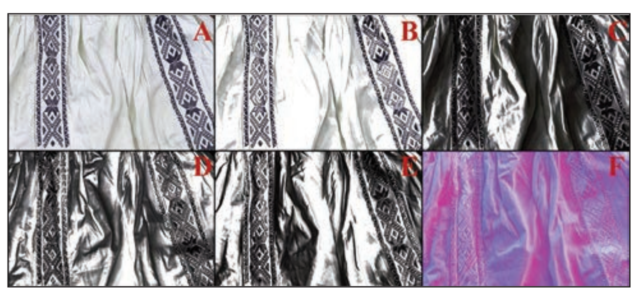

Fig. 4. Evaluation of the traditional motifs of the women's shirt under a spatially variable light source in RTIWiever: *A* – default view; *B* – specular enhancement with the light source positioned at the top; *C* – specular enhancement with the light source positioned at the left; *D* – specular enhancement with the light source positioned at the bottom; *E* – specular enhancement with the light source positioned at the right side; *F* – normal visualization

Interactive viewing from several angles of incidence of light (figure 4, *B*, *C*, *D* and *E*) and from different lighting positions, encourages an increased perception of the surface and the arrangement of the models from the overview (default mode) (figure 4, *A*). While the normal visualization mode (figure 4, *F*) creates a false-colour rendering at the pixel level, where X, Y and Z are represented by red, green and blue, thus highlighting the orientation and contour of the surfaces. This mode is very useful both in determining the contour of the traditional pattern on the shirt and the angle of inclination of the surface in question.

CONCLUSIONS

Radiographic technique and Reflectance Transformation Imaging are non-invasive evaluation methods that can be used successfully in the field of textile cultural heritage. Their aim was to highlight fine details of the fabric, which under normal conditions are not visible to the naked eye with the possibility of tracking the evolution of vulnerable areas over time and finding long-term conservation solutions. Following the application of the radiographic technique on the traditional women's shirt, a relative homogeneity was observed in terms of the internal particularities of the material, the degradations being mostly artificial and showing in separation. Using the free manipulation of the light source provided by the RTI models, the damaged surfaces were carefully examined in order to better understand the nature of the discontinuities for the future preservation of the piece of clothing. This integrated approach has proven to be very practical in identifying the degraded areas, with the great advantage of not being invasive. At the same time, the techniques involve minimal interaction with the original, they are fast both in terms of acquisition and processing, very easy to use even by non-experts, and in addition to the equipment needed to acquire data (even low-cost equipment performs well), the software dedicated to processing and visualization are open-source.

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The effect of wavelet transform for fabric defect classification

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ABSTRACT – REZUMAT

The effect of wavelet transform for fabric defect classification

An automatic control system during fabric production improves production quality. For this reason, the number of automatic systems developed is increasing day by day. These systems use different methods, different data sets, and different approaches. We investigate the effects of wavelet transform using four different feature sets (wavelet-based Principal Component Analysis, wavelet-based Gray Level Co-occurrence Matrix, Principal Component Analysis and Gray Level Co-occurrence Matrix). The methods of K-Nearest Neighbor (KNN) and Support Vector Machine (SVM) are used as classifiers. Experiments have been carried out for six different fabric defects (fly, dirty warp, tight-loose warp, fibrous weft, rub mark and weft stack) on 57 images. The experimental results performed show that wavelet-based PCA (Principal Component Analysis) and KNN have been optimal methods for achieving the highest success rate. We have achieved a 92.9825% accuracy rate by using them.

Keywords: *defect classification, fabric defect, textile, wavelet transform, woven fabric*

Influența transformării wavelet pentru clasificarea defectelor țesăturii

Un sistem de control automat în timpul producției de țesături îmbunătățește calitatea produselor. Din acest motiv, numărul sistemelor automate dezvoltate crește pe zi ce trece. Aceste sisteme folosesc metode diferite, seturi de date diferite și abordări diferite. Investigăm influența transformării wavelet folosind patru seturi de caracteristici diferite (analiza wavelet a componentelor principale, matricea de co-ocurență la nivel de gri wavelet, analiza componentelor principale și matricea de co-ocurență la nivel de gri). Metodele K-Nearest Neighbor (KNN) și Support Vector Machine (SVM) sunt utilizate ca clasificatori. Au fost efectuate experimente pentru șase defecte diferite ale țesăturii (scame, urzeală murdară, urzeală strânsă-largă, bătătură fibroasă, semn de frecare și tasarea bătăturii) pe 57 de imagini. Rezultatele experimentale efectuate arată că PCA wavelet (Analiza componentelor principale) și KNN au fost metode optime pentru a obține cea mai mare rată de succes. Am obținut o rată de precizie de 92,9825% prin utilizarea acestora.

Cuvinte-cheie: *clasificarea defectelor, defect de țesătură, material textil, transformare wavelet, țesătură*

INTRODUCTION

Defects occurring during fabric production constitute 85% of the defects encountered in the clothing industry [1]. 130 different fabric defects are included in ISO standards [2]. The reasons for these defects can be caused by raw materials, machinery or human [3]. It is difficult and costly to find 130 types of fabric defects with manpower during textile production.

According to the study of Ala and İkiz [4], the defects of broken warp, stopping mark, and warp stack are the most common defects in the textile industry. Broken warp constitutes 48.02% of the defect in their study. The ratios of stopping mark and warp stack are 15.32% and 8.69%, respectively.

Studies have been started to automate the control process based on manpower. Thus, higher success is achieved with less cost through automatic systems. However, the systems developed are still not sufficient. There are some shortcomings of the fabric defect detection (FDD) systems. There are two known databases, Parvis [5] and TILDA [6] existing in the area of automatic fabric defect control. The Parvis database is private, and the TILDA database is not free. Since there is no public and free database for fabrics, it is seen that the authors have used the datasets they have created themselves in the studies. So, they cannot be compared to each other and the effectiveness of the developed systems are discussed [7]. Other disadvantages of this shortcoming are that studies have been carried out for an insufficient amount of data and a small number of defect types. Another shortcoming is that a lot of studies have been tested on only off-line images. It decreases the applicability of the studies in real life.

Different types of wavelet transform have been used in the studies since the emergence of the idea of automating the detection of fabric defects. Wavelet-based systems have been reviewed in this study [8–19]. It is seen that hybrid studies have developed to ensure robustness when a wavelet transform is used. Features are extracted using four scale dyadic wavelet decomposition [8]. Then, these features are classified using a neural network. They emphasize that the method developed has less time complexity than the other methods through the fastness of the wavelet transform. An algorithm has been developed using wavelet theory and co-occurrence matrix in the study of Latif-Amet et al. [9]. Classification is carried out with the success of up to 90.78%. Hu and Tsai use a backpropagation neural network after selecting the best wavelet packet bases [10]. Zhi et al. develop a method with adaptive wavelet design [11]. They suggest that adaptive wavelet is better compared to orthogonal wavelet transform. Yang et al. have compared six different methods based on wavelet transform [12]. Discriminative feature extraction using adaptive wavelet has been the best method among others. It achieves the classification with an accuracy rate of 95.8%. Ngan et al. have developed the WGIS (wavelet preprocessed golden image subtraction) method [13]. The success rate is 96.7%. Gabor wavelets have been used for feature extraction, and PCA is used to reduce the dimension of features extracted in the study of Basturk et al. [14]. Jianli and Baoqi classify the defects using both textural features and geometric features [15]. Kang et al. use the combination of wavelet transform and neural network as in the study of Jianli and Baoqi [16]. It is stated that the system developed is not sufficient for smaller fabric defects. Sakhare et al. compare the performances of six approaches (statistical approach, morphological approach, Fast Fourier Transform (FFT), Discrete Cosine Transform (DCT), Wavelet Transform, and Gabor Filter) [17]. Input images are divided into four parts. The defected part is identified using the mean of these parts. First, it is investigated whether the defect is a hole or not. Second, the other types of defects are investigated for classification if the defect is not a hole. Tests have been performed to classify four different types of defects in the study. According to the experiments, the best performance has been obtained using FFT. In addition to that, the second most successful method has been DCT. Hanbay et al. use the methods of co-HOG (Co-occurrence Histograms of Oriented Gradients), wavelet transform and grey-level co-occurrence matrix to extract the features [18]. They use an artificial neural network to train the system in their study. When using the wavelet transform, defects are classified with a 90% success rate. Also, it is seen that the cost has decreased considerably. Kure et al. investigate homogeneity in fabric images [19]. They use local neighbourhood analysis to measure homogeneity.

A comparison between wavelet transform, gabor transform and the system developed has been made. According to the experiments, the cross-validation accuracy of the system is higher than the others (96.40%).

In this study, it is aimed to automate the process of detection and classification of fabric defects. The defects of fly, dirty warp, tight-loose warp, fibrous weft, rub mark and weft stack have been tried to classify. It has been investigated how wavelet transform affects the results. Different feature extraction methods (Principal Component Analysis and Gray Level Co-occurrence Matrix) have been tested. Besides, the performances of the K-Nearest Neighbor and Support Vector Machine have been compared. This paper is organized as: in the second section, we provide information about the methods we use in our study. The proposed system and experimental results are given in the third section. Finally, the fourth section presents conclusions.

BACKGROUND

The information about the methods has been provided in this section. Two-dimensional discrete wavelet transform has been used before feature extraction. The methods of principal component analysis and grey level co-occurrence matrix have been used as feature extraction methods, and their performances of them have been compared. The methods of K-Nearest Neighbor and Support Vector Machine have been used for the classification process of the extracted features.

The two-dimensional discrete wavelet transform (2D-DWT)

The 2D-DWT is a commonly used technique in image processing. Images are transformed from the spatial domain into the frequency domain through the 2D-DWT [20]. By using it, one scaling function ($\varphi(x,y)$) and three wavelet functions ($\Psi_H(x,y)$, $\Psi_V(x,y)$, $\Psi_D(x,y)$) can be obtained. $\varphi(x,y)$ is calculated as in equation 1. $\Psi_H(x,y)$, $\Psi_V(x,y)$, $\Psi_D(x,y)$ are the horizontal, vertical, and diagonal wavelet functions, respectively (equations 2, 3, 4).

$$\varphi(x,y) = \varphi(x)\varphi(y) \quad (1)$$

$$\Psi_H(x,y) = \Psi(x)\varphi(y) \quad (2)$$

$$\Psi_V(x,y) = \varphi(x)\Psi(y) \quad (3)$$

$$\Psi_D(x,y) = \Psi(x)\Psi(y) \quad (4)$$

The decomposition steps for images are given in figure 1. 3N + 1 different frequency bands are obtained with decomposition at the N level [21].

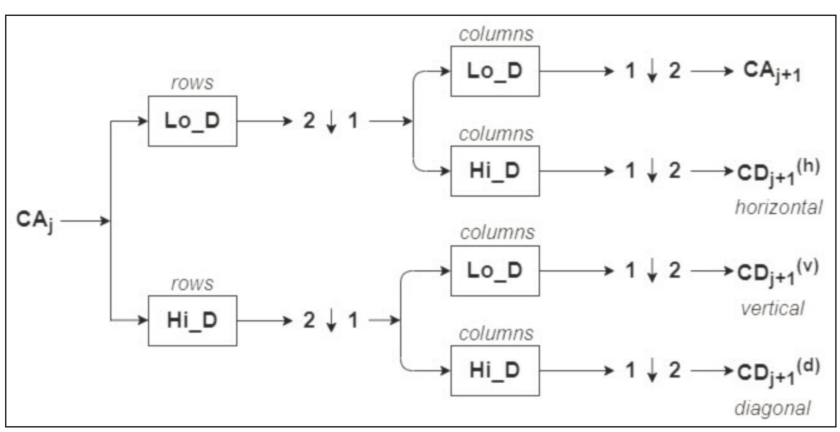

Fig. 1. 2D-DWT [21]

Feature extraction methods

Different textures can be found by revealing the texture characteristics [22]. In this study, texture characteristics have been extracted using the methods of Principal Component Analysis, and Gray Level Co-occurrence matrix.

The Principal Component Analysis (PCA)

PCA is a statistical method widely used in areas such as face recognition, image compression, and pattern recognition [23]. Using the PCA, many variables are converted into a small number of variables that are unrelated to each other. The small number of variables obtained is called the basic components of the data.

The steps for applying the PCA to a dataset are as follows:

```
Step 1. Preparation of the data set
Step 2. Calculating the average
Step 3. Subtraction the average from each
        element in the data set
Step 4. Calculation of covariance matrix C
Step 5. Calculation of Eigenvalues λ and
        eigenvectors V of C
Step 6. Creation of new reduced data set
```

Suppose, X is a dataset. x_i is the i^{th} element in the dataset X (i = 1, …, M). Average of all elements in the dataset X is calculated. Then, the calculated average is subtracted from each element. Thus, the normalized data set X' is achieved. Covariance matrix C is calculated using the elements in X' and their transposes. After calculating λ and V, a new data set is obtained using V and X'.

The Gray Level Co-occurrence Matrix (GLCM)

The GLCM [24] is based on the studies of statistical measures. A matrix of the pixels in the image is created using it [25]. The differences between the grey values of any two pixels are compared in the matrix. The created matrix can be calculated at different angles and different distance values. The features of the image are extracted from it.

The equation of GLCM is given in equation 5. $f(x,y)$ is the matrix of image. H indicates the height of the image. W indicates the width of the image. θ is inter-pixel orientation. $d = (d_x, d_y)$ is the distance between the pixels. Current pixel in the image with grey level i and neighbour pixel with grey level j are checked in GLCM [26].

$$P_{i,j}(d,\theta) = \sum_{x=0}^{H-1} \sum_{y=0}^{W-1} \begin{cases} 1, \text{ if } f(x,y) = i \text{ and } f(x+d_x, y+d_y) = j \\ 0, \text{ otherwise} \end{cases} \quad (5)$$

In this study, four features (contrast, correlation, energy, homogeneity) have been extracted using the GLCM. M is an input image in gray level space with matrix form. Local variations in M is calculated using the equation 6. Linear dependency in M is calculated using the equation 7. σ is a standard deviation, and mean μ is calculated (equation 8). The values of energy and homogeneity in M are calculated as in equation 9 and 10, respectively.

$$Contrast = \sum_{i,j} |i-j|^2 M(i,j) \quad (6)$$

$$Correlation = \sum_{i,j} \frac{(i-\mu_i)(j-\mu_j)M(i,j)}{\sigma_i \sigma_j} \quad (7)$$

$$\mu_i = \sum_{i,j=0}^{N-1} i M(i,j), \quad \mu_j = \sum_{i,j=0}^{N-1} j M(i,j) \quad (8)$$

$$Energy = \sum_{i,j} M(i,j)^2 \quad (9)$$

$$Homogeneity = \sum_{i,j} \frac{M(i,j)}{1+|i-j|} \quad (10)$$

Classification algorithms

K-Nearest Neighbor (KNN)

The KNN is the most known supervised learning algorithm. In this algorithm, it is tried to find out the class of the test element based on the training set. The first step is finding K nearest neighbors. There are more than one metrics that can be used to find distances between the elements. The metrics of Minkowski (equation 11), Euclidean (equation 12), and Manhattan (equation 13) are among the most known metrics. $x = (x_1, x_2, \ldots, x_n)$ and $y = (y_1, y_2, \ldots, y_n)$ are two elements. Euclidean distance and Manhattan distance are the customized version of the Minkowski distance for p=2 and p=1, respectively.

$$d_{Minkowski}(x,y) = \left(\sum_{i=1}^{n} |x_i - y_j|^p\right)^{1/p} \quad (11)$$

$$d_{Euclidean}(x,y) = \sqrt{\sum_{i=1}^{n} (x_i - y_j)^2} \quad (12)$$

$$d_{Manhattan}(x,y) = \sum_{i=1}^{n} |x_i - y_j| \quad (13)$$

Then, the test element is assigned to the class which is most frequent for K nearest neighbors.

Support Vector Machine (SVM)

The SVM is a supervised learning algorithm like KNN. The basics of SVM are based on statistical learning theory. It was developed by Vapnik for the problems of pattern recognition and classification [27]. The purpose of SVM is to find the hyperplane that can optimally distinguish two classes from each other. The optimal hyperplane is the farthest plane to the nearest data points of the classes.

SVM has been designed primarily for the problem of classification of two-class and linear data, and then it has been developed for the classification of multi-class and nonlinear data.

PROPOSED SYSTEM AND EXPERIMENTS

Experimental tests have been performed on 57 images belonging to six different fabric defects presented in the study of Kısaoğlu [28]. Some of these images have been obtained by applying data augmentation methods. The defects we try to classify are fly, dirty warp, tight-loose warp, fibrous weft, rub mark and weft stack. The purpose of this study is to assign the image included to the system to the class it belongs to. There are seven different classes. One of these classes is for non-defected fabric

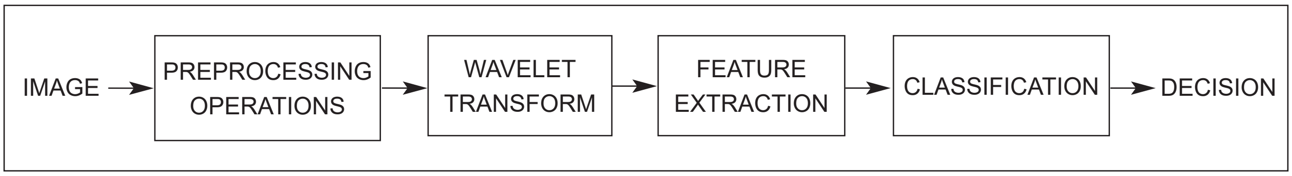

Fig. 2. The steps of Fs1 and Fs2

images. The remaining six classes are for six different types of defects. All tests were implemented using MATLAB2019a on a personal computer (Intel (R) Core (TM) i7-6700HQ CPU @2.60 GHz).

After preprocessing of images, feature extraction is made from these images. In this study, four different feature sets have been used for the classification process (Fs1, Fs2, Fs3, Fs4). The properties of them are given in table 1. The Fs1 has been created using PCA of wavelet energies. The Fs2 has been created using GLCM of wavelet energies. PCA has been used for extracting the features for the Fs3. GLCM has been used for extracting the features for the Fs4. Then, a classification method is applied to the features extracted. The classification methods of KNN and SVM have been used to classify the fabric images. The basic steps for these feature sets are given in figures 2 and 3.

In PCA, the number of parameters was changed between 5 and 17, and the results were examined. It was seen that the best results were obtained when the first 13 parameters were used. Since it shows the highest accuracy, the first 13 parameters have been selected for the PCA method. Then, these parameters have been introduced to the classifier.

Table 1

THE PROPERTIES OF FEATURE SETS			
Parameter	**Wavelet-based**	**PCA**	**GLCM**
Fs1	X	X	
Fs2	X		X
Fs3		X	
Fs4			X

The accuracy rates calculated in this section have been found using 10-fold cross-validation (CV). The accuracy rate is calculated using the values of TP (True Positive), TN (True Negative), FP (False Positive), and FN (False Negative) (equation 14). Table 2 shows the values of TP, TN, FP, FN for a two-class data set (defected and non-defected). If there is a defect in the fabric sample and the classification method is classified as defected, the number of these samples gives the *TP* value. If non-defected samples are classified as non-defected, the number of these samples gives *TN.* The number of defected fabric samples classified as non-defected determines the *FN* value. The number of non-defected fabric samples classified as defected determines the *FP* value.

$$Accuracy = \frac{TP + TN}{TP + FP + TN + FN} \tag{14}$$

Table 2

PERFORMANCE OF THE SYSTEM		
Parameter	**Classified as Defected**	**Classified as Non-defected**
Defected	TP	FN
Non-defected	FP	TN

Accuracy rates for four different feature sets are given in table 3. KNN is the most successful classifier in all feature sets. The average accuracy rate of KNN is 88.1579%, and the average accuracy rate of SVM is 81.1404%. Fs1 has been the feature set with the highest accuracy rate. When PCA is used as a feature extraction method, Fs1 has been more successful (92.9825%, 89.4737%) than Fs3 (89.4737%, 78.9474%) for both classifiers (KNN and SVM). When GLCM is used, fs4 has given more successful results (87.7193%, 82.4561%) than fs2 (82.4561%,

Table 3

ACCURACY RATES OF THE FEATURE SETS (USING CV)			
Parameter	**KNN (%)**	**SVM (%)**	**Average (%)**
Fs1	92.9825	89.4737	91.2281
Fs2	82.4561	73.6842	78.0702
Fs3	89.4737	78.9474	84.2106
Fs4	87.7193	82.4561	85.0877
Average	88.1579	81.1404	-

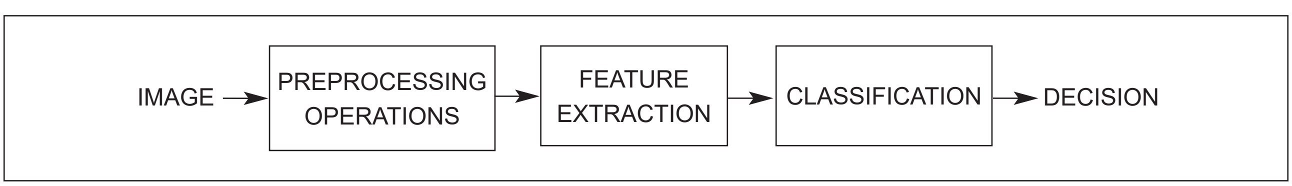

Fig. 3. The steps of Fs3 and Fs4

73.6842%). Among the feature sets, the most successful set has been fs1, while the most unsuccessful set has been fs2. The PCA is a feature extraction method that gives more successful results compared to the GLCM (table 4).

Table 4

ACCURACY RATES OF THE PCA AND GLCM (USING CV)			
Parameter	**KNN (%)**	**SVM (%)**	**Average (%)**
PCA	91.2281	84.2106	87.7194
GLCM	85.0877	78.0702	81.5790

Additionally, execution times for four different feature sets have been investigated (table 5). When the wavelet transform is used, the execution time increases. The average execution times of KNN and SVM are 1.3878 seconds and 9.798 seconds, respectively. The accuracy rates with the execution times of these sets are drawn in figure 4. As seen in the figure, KNN has been the best method in terms of accuracy rate and execution time.

Table 5

EXECUTION TIMES		
Parameter	**KNN (sec.)**	**SVM (sec.)**
Fs1	2.211	9.768
Fs2	1.072	13.434
Fs3	1.362	7.890
Fs4	0.906	8.100
Average	1.3878	9.798

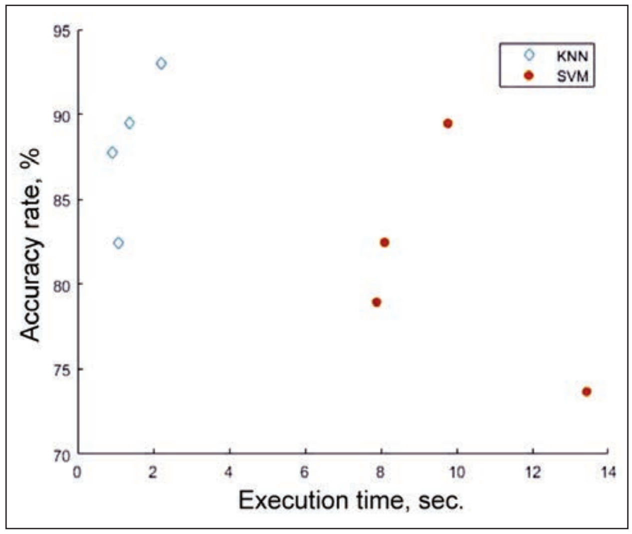

Fig. 4. Accuracy vs. Execution time

CONCLUSIONS

Four different feature sets and two different classifiers (KNN and SVM) have been used for the classification of six fabric defects (fly, dirty warp, tight-loose warp, fibrous weft, rub mark and weft stack). The feature sets used are based on PCA (Fs1, Fs3) and GLCM (Fs2, Fs4). The effect of wavelet transform on feature extraction methods has been investigated. According to the experiments on 57 images, wavelet-based PCA (Fs1) gives the highest average accuracy rate (91.2281%). GLCM method does not work well with wavelet transform for the data set, considering the accuracy rates of the feature sets. It has the lowest average accuracy rate (78.0702%).

The classifier method which has the highest accuracy rate among the two classification methods used is KNN (88.1579%). It provides the classification with the highest accuracy both when wavelet transform is used and is not used.

It is concluded that KNN results in a higher accuracy rate in less time when execution times are investigated. The execution time when using SVM is about seven times the execution time of KNN (for our samples).

In this study, which was carried out to detect and classify fabric defects, which reduced the quality of the fabric, the defect classification accuracy rate has been up to 93%. While a trained staff in the field of quality control can detect only 70% of fabric defects [29], the defects are detected and classified in our study with a success rate of 92.9825%. Hence, this system improves production quality.

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Total factor productivity and convergence of China's textile industry

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ABSTRACT – REZUMAT

Total factor productivity and convergence of China's textile industry

The scale of China's textile industry has grown to be the largest in the world with massive factor input. There is a strong demand China's textile industry, and as a traditional industry, should improve total factor productivity (TFP) to realize technology-driven and sustainable development. TFP is a commonly used indicator to measure the level of technological progress. But regional textile industry development in China is seriously unbalanced and regional TFP is quite different from each other. It is worthwhile to estimate the textile industry TFP of China and different regions, analyse the changing trend and test for their convergences. This paper firstly uses the nonparametric DEA-Malmquist index method to measure and analyse the TFP and its evolution of China's textile industry during 2007–2018 at the nation, region and province levels. Then it uses the coefficient of variation to test for σ-convergence of China's and regional textile industry TFP. It also constructs an absolute β-convergence regression equation and panel data model, respectively to test for absolute β-convergence and conditional β-convergence and determine whether the TFP of each region will also converge to its own steady-state or not. The research results help explore the future development model of China's textile industry and provide corresponding policy suggestions for the upgrading and sustainable development of the industry.

Keywords: *China's textile industry, convergence, DEA-Malmquist index method, efficiency-driven development, total factor productivity*

Productivitatea totală a factorilor și convergența industriei textile din China

Industria textilă din China a devenit cea mai mare din lume, cu aport masiv de factori. Există o cerere puternică în industria textilă din China și în calitate de industrie tradițională, ar trebui să-și îmbunătățească productivitatea totală a factorilor (TFP), pentru a realiza o dezvoltare sustenabilă și bazată pe tehnologie. TFP este un indicator utilizat frecvent pentru a măsura nivelul progresului tehnologic. Dar dezvoltarea regională a industriei textile din China este serios dezechilibrată, iar TFP regională este destul de diferită. Merită să estimăm TFP industriei textile din China și din diferite regiuni, să analizăm tendința în schimbare și să testăm convergențele acestora. Această lucrare utilizează în primul rând metoda neparametrică a indicelui DEA-Malmquist pentru a măsura și analiza TFP și evoluția acesteia în industria textilă din China în perioada 2007–2018 la nivel de țară, regiune și provincie. Apoi folosește coeficientul de variație pentru a testa convergența σ a TFP din China și industria textilă regională. De asemenea, construiește o ecuație de regresie a convergenței β absolute și un model de date panou, respectiv pentru a testa convergența β absolută și convergența β condiționată și pentru a determina dacă TFP fiecărei regiuni va converge, de asemenea, la propria sa stare de echilibru sau nu. Rezultatele cercetării ajută la explorarea modelului de dezvoltare viitor al industriei textile din China și oferă sugestii de politici corespunzătoare pentru modernizarea și dezvoltarea durabilă a industriei.

Cuvinte-cheie: *industria textilă din China, convergență, metoda indicelui DEA-Malmquist, dezvoltare bazată pe eficiență, productivitate totală a factorilor*

INTRODUCTION

After decades of development, the scale of China's textile industry has grown to be the largest in the world, with a share exceeding 1/2 of the global market, making an important contribution to China's economic growth. Traditionally, factor input is considered the main driving force of economic growth. The growth of China's textile industry, like other industries, mainly relies on large-scale investment and cheap factor input. However, factor input will be difficult to sustain as the marginal productivity decreases. At present, China's textile industry dominated by labour-intensive enterprises is facing a series of production and operation pressures. The prices of raw materials, electricity, water and other factors are constantly rising, and the supply of industrial land is becoming increasingly tight, which severely limits the sustainable profitability and development of China textile industry.

The endogenous growth theory considers technological progress as the main contributor to economic growth and can maintain the sustainable development of an industry. In the face of the challenges above, there is little doubt China's textile industry will transform from a factor-input development model to a technology-driven model and keep sustainable development by improving total factor productivity (TFP). Due to different economic foundations, industrial foundations and regional environmental conditions, the textile industry development of different regions in China is seriously unbalanced and regional TFP is also quite different from each other. How will the regional textile industry TFP change with time? Will the regional gap gradually narrow until it tends towards convergence? If there is convergence, which convergence mode is it? Hence, it is worthwhile to estimate the textile industry TFP of China and different regions, analyse the changing trend and test for their convergences.

TFP is a commonly used indicator to measure the level of technological progress in academics, which refers to the contribution of technological and non-technological factors to economic growth after labour and capital inputs are ruled out, which includes technological progress, management improvement and institutional innovation. Since the concept of total factor productivity was put forward, TFP has always been a hotspot of academia and there are fruitful research results in this field. Based on Baumol [1] and Robert's [2, 3] research on the convergence of economic growth, Stephen [4] systematically proposed an analytical framework of TFP convergence and tested TFP convergence for OECD countries. Then the academia has carried out various researches on TFP convergence at the nation level [5, 6] and industry level [7, 8] with this framework. By contrast, the research on TFP of China's textile industry is relatively limited and no literature on TFP convergence has been retrieved. Feng [9] measured and analysed the TFP and its change in the provincial textile industry in China during 2004–2014. Fu [10] found that both export and FDI have positive technology spillover effects on the TFP of China's textile and garment industry. Xie [11] suggested that the supply-side structural reforms could also improve the TFP of China's textile and garment industry. But there are some issues in the current research, such as the failure to distinguish the textile industry from the garment industry, the missing of research at the regional level and the lack of study on convergence of the textile industry TFP.

Given the shortcomings and limitations of the previous research, this article divides China into four regions: eastern, central, western and north-eastern according to the region classification standards of the National Bureau of Statistics of China. This paper firstly uses the nonparametric DEA-Malmquist index method to measure and analyse the TFP and its evolution of China's textile industry during 2007–2018 at the nation, region and province level. Then, it tests for σ-convergence and β-convergence of TFP in China and various regions. The results will help explore the future development model of China's textile industry and provide corresponding policy suggestions for upgrading and sustainable development of the textile industry. The textile industry studied in this paper refers to the textile industry (double-digit industry code: 17) by the national economy classification standard (GB/T 4754-2011), excluding the textile and garment industry (18).

MEASUREMENT METHODOLOGY OF TFP

This paper uses the nonparametric DEA-Malmquist method to measure the TFP of China's textile industry. At a given technology frontier, TFP change is measured by calculating the ratio of the Shephard distance function of two production units. To avoid the arbitrary selection of technology frontier, Fare [12] constructed the TFP Malmquist index (TFP index) from t to t+1 period:

$$M_0(x_t, y_t, x_{t+1}, y_{t+1}) = \left[\frac{D_0^{t+1}(x_{t+1}, y_{t+1})}{D_0^{t+1}(x_t, y_t)} \times \frac{D_0^{t}(x_{t+1}, y_{t+1})}{D_0^{t}(x_t, y_t)}\right]^{1/2} \quad (1)$$

TFP index is the ratio of TFP in period t+1 and period t. If $M_0(x_t, y_t, x_{t+1}, y_{t+1}) > 1$, it indicates that TFP increases from period t to period t+1, otherwise decreases.

TFP index can be decomposed into the product of technological efficiency index (TE) and technological progress index (TP), representing the technological efficiency change and technological change respectively. TP reflects a frontier shift trend at different periods. TE can be further decomposed into pure technological efficiency index (PE) and scale efficiency index (SE). So, the decomposition of the TFP index can be expressed as:

$$TFPch = TEch \times TPch = PEch \times SEch \times TPch \quad (2)$$

Two sets of input data (labour and capital) and one set of output data (effective output) are collected to calculate the TFP index. Gross industrial output value represents the effective output. An average number of regional textile industry workers is used to represent the labour factor. Capital stock represents the capital factor and is calculated by the perpetual inventory method.

TFP OF CHINA'S TEXTILE INDUSTRY

After calculation, this paper obtains the TFP index and its composition of China's textile industry at the nation, region and province levels during 2007–2018 (table 1). Due to space limitations, table 1 only lists the average TFP index and its composition.

The mean TFP indexes of China's textile industry at the nation, region and province levels are all greater than 1 (table 1), showing that China's textile industry TFP has maintained a steady growth. At the national level, the mean TFP index, TP index and TE index of China's textile industry are 1.216, 1.233 and 0.988, which indicates the average growth rates (AGRs) of TFP, TP and TE are 21.6%, 23.3% and –1.2% respectively. It can be concluded that the major contributor to China's textile industry TFP growth is technological progress and the TFP growth is technology-driven. The average annual contribution of technological efficiency to TFP growth is negative, which implies that the textile industry still has a long way ahead before shifting into efficiency-driven development mode.

Table 1

MEAN TFP INDEX AND ITS COMPOSITION OF CHINA'S TEXTILE INDUSTRY DURING 2007–2018											
Area	**TE**	**TP**	**PE**	**SE**	**TFP**	**Area**	**TE**	**TP**	**PE**	**SE**	**TFP**
China	0.988	1.233	1.000	0.988	1.216	Hainan	0.845	1.512	0.844	0.998	1.219
Eastern	1.000	1.186	1.000	1.000	1.186	Western	0.983	1.290	0.967	1.012	1.254
Beijing	1.000	1.362	1.000	1.000	1.362	Inner Mongolia	1.024	1.511	1.053	0.974	1.506
Tianjin	0.971	1.488	0.965	1.000	1.374	Guangxi	0.835	1.512	0.840	0.994	1.204
Hebei	0.914	1.495	0.942	0.972	1.303	Chongqing	0.958	1.482	0.955	1.007	1.363
Fujian	0.812	1.520	0.848	0.957	1.185	Sichuan	0.874	1.503	0.879	0.992	1.256
Guangdong	0.866	1.459	0.990	0.880	1.244	Guizhou	0.863	1.517	0.901	0.957	1.262
Hainan	1.136	1.475	1.158	0.969	1.597	Yunnan	0.899	1.509	0.959	0.937	1.279
Jiangsu	0.861	1.519	0.999	0.862	1.255	Tibet	0.852	1.494	1.000	0.852	1.285
Shanghai	0.977	1.379	1.000	0.977	1.339	Shaanxi	0.912	1.503	0.904	0.999	1.309
Zhejiang	0.860	1.519	1.000	0.860	1.257	Gansu	0.954	1.492	0.967	0.985	1.352
Shandong	0.907	1.502	1.028	0.878	1.301	Qinghai	1.030	1.487	1.092	0.945	1.481
Central	0.946	1.280	0.946	1.000	1.204	Ningxia	0.821	1.504	0.827	0.992	1.172
Shanxi	0.975	1.504	0.980	0.994	1.385	Xinjiang	0.839	1.497	0.826	1.017	1.196
Anhui	0.837	1.509	0.858	0.972	1.206	Northeastern	1.021	1.330	1.000	1.021	1.352
Jiangxi	0.830	1.497	0.818	1.014	1.197	Liaoning	0.982	1.512	1.003	0.975	1.436
Henan	0.853	1.503	0.882	0.966	1.220	Jilin	1.274	1.499	1.284	0.994	1.806
Hubei	0.837	1.506	0.861	0.968	1.195	Heilongjiang	1.027	1.496	1.021	1.007	1.445

At the region level, textile industry TFP growth in each region has a negative correlation with its economic development. The AGRs of north-eastern, western, central and eastern textile industry TFP are 35.2%, 25.4%, 20.4% and 18.6% respectively. Those of the north-eastern and western regions are both greater than that of the entire nation (21.6%), followed by the central region. As the most developed region, the AGR of the eastern region has lagged behind the nation and is the smallest of all the regions. The AGRs of SE in eastern and central regions are 0% and –0.05%, indicating that in the context of backward overcapacity and rising factor cost, it will hinder TFP growth to some extent if continuing to improve industrial agglomeration level in these regions.

At the province level, technological progress is also the major source of TFP growth, consistent with the overall trend of China. The mean TP indexes of all provinces are also greater than 1, while TE indexes of only six provinces are greater than 1. The mean TFP indexes of Shandong, Jiangsu, Zhejiang, Henan and Guangdong (the five most developed provinces in the textile industry) are 1.301, 1.255, 1.257, 1.220 and 1.244 respectively, higher than that of the nation (1.216). It shows that the technological progress of these provinces still plays an important role in promoting China's textile industry TFP growth.

CONVERGENCE TEST OF CHINA'S TEXTILE INDUSTRY TFP

Interestingly as a leader, the eastern textile industry is the most developed, but its TFP growth is the least as shown in table 1 and is closely followed by other regions, especially the western region. Does this mean the regional gap of the textile industry TFP will gradually narrow? Is there a possibility of convergence in regional textile industry TFP? If there is convergence, what's the mode of convergence? To answer these questions, referring to the analysis framework of TFP convergence proposed by Stephen [4], this paper studies the TFP convergence of China's textile industry. Convergence denotes that in a closed and effective economic environment, there is a negative correlation between the initial static indicators and economic growth rates of different economies (such as a country, a region, or a certain family). There are two types of convergence: σ-convergence and β-convergence. According to whether the economies converge at the same stable state, β-convergence falls under two categories: absolute β-convergence and conditional β-convergence. The absolute β-convergence takes other economies' steady state as the reference frame, each economy will reach the same growth rate and growth level over time. While the conditional β-convergence takes its steady-state as the reference frame.

σ-convergence

This paper uses the coefficient of variation to test for σ-convergence of China's and regional textile industry TFP. The coefficient of variation is calculated as follows:

$$CV_{i,t} = \frac{\sigma_{i,t}}{\overline{TFP}_{i,t}} \tag{3}$$

$CV_{i,t}$, $\sigma_{i,t}$ and $\overline{TFP}_{i,t}$ are the coefficient of variation, standard deviation and mean value of textile industry TFP index in region *i* at period *t* respectively.

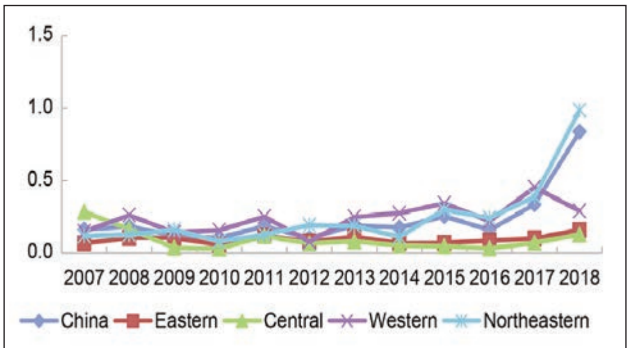

Fig. 1. The coefficient of variation of China's and regional textile industry TFP index

Figure 1 presents that the CV of China's and regional textile industry TFP index are in the fluctuating growth trend and the CV of 2018 is the largest. So, it can be concluded that China's and regional textile industry TFP during 2007–2018 don't show significant σ-convergence and there are complicated changes and restructuring within China's textile industry during that period. The evolutions of CV in eastern and central regions have remained the same, indicating that textile industry restructuring in these two neighbouring regions has been keeping close linkage and coordination. The CV in the western region fluctuates greatly, which may be related to the rapid development of the western textile industry, especially in Xinjiang. However, the CV of the north-eastern region displays greater time-varying volatility and its change trend is also different from the others. This could be attributed to the fact that there are only three provinces in the north-eastern region and the sample is too small.

Absolute β-convergence

Absolute β-convergence tests whether China's and regional textile industry TFP will converge towards the same steady-state. That is, whether the TFP growth rate is negatively correlated with its initial level and whether there is the "catch-up effect" between the backward and developed regions. This paper constructs the absolute β-convergence regression equation as below:

$$\ln\left(\frac{TFP_{i,t+T}}{TFP_{i,t}}\right) / T = \alpha + \beta \ln TFP_{i,t} + \varepsilon_{i,t} \qquad (4)$$

$TFP_{i,t}$ and $TFP_{i,t+T}$ are the textile industry TFP index in province *i* at period *t* and *t*+*T* respectively. *T* is the time span. α is the constant, β is the convergence coefficient and $\varepsilon_{i,t}$ is the random disturbance. If the β<0, it indicates evidence of absolute β-convergence. As the absolute β-convergence analysis method is cross-sectional regression at only one period, it may not be able to explain the continuity of convergence and its regression results are highly sensitive to the time span. Therefore, this paper divides the sample time span into two periods (2007–2012 and 2013–2018) and tests for absolute β-convergence of the two periods respectively. At the same time, in order to reduce the influence of outliers, this paper equally divides the sample time span (2007–2018) into six periods and takes the average value of every two years' TFP index as the TFP index of each period. Then it tests for absolute β-convergence. The convergence results are shown in table 2. The absolute β-convergence coefficients of China, eastern, central and western regions are –0.117, –0.113, –0.098 and –0.209 respectively (table 2). They're all negative and have passed the significance test at the corresponding level, indicating evidence of absolute β-convergence in the textile industry TFP index among China and these three regions. This means that the textile industry TFP growth rate of each province is negatively correlated with its initial level. Provinces with low TFP demonstrate a significant "catch-up effect" towards high TFP provinces. The provincial TFP gap will gradually decrease and eventually converge towards the same steady-state. Convergence test results in different periods also confirm this conclusion, except for the result of the central region in 2013–2018. At the same time, it can also be discovered that the absolute β-convergence coefficients of China, eastern, central and western regions in 2013–2018 are bigger than those in 2007–2012, revealing that the "catch-up effect" of the provincial textile industry TFP in 2013–2018 is greater than that in 2007–2012 and TFP of backward

Table 2

THE ABSOLUTE β-CONVERGENCE TEST RESULTS

	2007–2018		2007–2012		2013–2018	
	β	Adj-R^2	β	Adj-R^2	β	Adj-R^2
China	–0.117***	0.385	–0.174***	0.669	–0.374***	0.477
Eastern	–0.113***	0.919	–0.190**	0.422	–0.288***	0.650
Central	–0.098***	0.853	–0.143***	0.909	–0.176	0.160
North-eastern	0.738	0.895	–0.397	0.865	–1.085	0.461
Western	–0.209**	0.426	–0.149***	0.745	–0.239***	0.542

Note: ***, **, * represent significance levels of 1%, 5% and 10%, respectively.

Table 3

THE CONDITIONAL β-CONVERGENCE TEST RESULTS					
	China	**Eastern**	**Central**	**North-eastern**	**Western**
β	-0.919^{***}	-0.476^{***}	-0.466^{***}	-0.764^{**}	-1.072^{***}
Adj-R^2	0.318	0.234	0.285	0.099	0.527
F-statistics	6.118	34.356	25.552	4.502	11.044
Model	RE	RE	RE	RE	FE

Note: ***, **, * represent significance levels of 1%, 5% and 10%, respectively.

provinces grows faster during this period. In addition, the north-eastern region does not exhibit evidence of absolute β-convergence.

Conditional β-convergence

After studying absolute β-convergence, this paper constructs the following panel data model to test for conditional β-convergence of China's and regional textile industry TFP and determine whether it will also converge to its own steady-state or not. The panel data model has the advantages of a large sample size, more reliable parameter estimation and reduced multicollinearity. This paper first uses the Durbin-Wu-Hausman test to examine the fixed effect and random effect of textile industry TFP of China and each region, then determine which estimation model is more appropriate, the fixed-effect model (FE) or random effect model (RE). The results are shown in table 3.

$$\ln\left(\frac{TFP_{i,t+1}}{TFP_{i,t}}\right) / T = \alpha + \beta \ln TFP_{i,t} + \varepsilon_{i,t} \qquad (5)$$

$TFP_{i,t}$ and $TFP_{i,t+1}$ are the textile industry TFP index in province i at period t and t+1 respectively. α is the constant, β is the convergence coefficient and $\varepsilon_{i,t}$ is the random disturbance. If $\beta<0$, conditional β-convergence occurs.

The conditional β-convergence coefficients of China and the eastern, central, north-eastern and western regions are –0.919, –0.476, –0.466, –0.764 and –1.072 respectively (table 3). They're all negative and all of them have passed the significance test at the corresponding level, indicating that there are conditional β-convergence in the textile industry TFP index of China and all four regions. When a region has the higher textile industry TFP in the former period, its latter TFP growth rate will gradually slow down. Textile industry TFP index in China and all four regions will ultimately converge to their own steady state.

CONCLUSIONS

This paper estimates and analyses the TFP and its evolution of China's textile industry during 2007–2018 by using the nonparametric DEA-Malmquist index method at the nation, region and province levels respectively. Then, it tests for σ-convergence and β-convergence of TFP at the nation and region level. The research results are as follows: Textile industry TFP of the entire country, each region and each province have maintained a steady growth. The major contributor of TFP growth is technological progress and the contribution of technological efficiency to TFP growth is basically negative. Textile industry TFP growth in each region has a negative correlation with its economic development. The TFP growth rates of north-eastern and western regions are both greater than that of the nation, followed by the central region. As the most developed region, the growth rate of the eastern region has lagged behind the nation.

Convergence test results show that there are absolute β-convergence and conditional β-convergence, but no σ-convergence in textile industry TFP of China, eastern, central and western regions. The provincial TFP gap will gradually decrease and will not only converge towards their own steady-state but will eventually converge towards the same steady-state. Convergence test results at different periods provide evidence that the absolute β-convergence coefficients of these regions in 2013–2018 are greater than those in 2007–2012, which indicates that the "catch-up effect" of provincial textile industry TFP in 2013–2018 is greater than that in 2007–2012 and the textile industry TFP of backward provinces grow faster at this period. It also concludes there is only conditional β-convergence in the north-eastern region.

The above research results suggest that China should continue to promote the technological progress of the textile industry, improve its TFP to drive it to transfer to the efficiency-driven and sustainable development at last.

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Does financial reporting quality affect the investment efficiency of listed textile sector firms in Pakistan? A myth or reality

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ABSTRACT – REZUMAT

Does financial reporting quality affect the investment efficiency of listed textile sector firms in Pakistan? A myth or reality

The study investigates the relationship between financial reporting quality and investment efficiency in Textile sector firms listed on the Pakistan Stock Exchange, due to the reason of being the highest-ranked sector with a maximum number of listed firms in Pakistan. We use financial reporting quality as an independent variable, investment efficiency as a dependent variable, and the firm's annual cash, assets tangibility, and return on assets as control variables. We analyse 100 randomly selected firms for the period 2005 to 2019. The study applies various estimators, namely Pooled OLS, Fixed Effects, and Random Effects to identify which model better predicts results. The results demonstrate that firm's financial reporting quality and ROA have a positive significant effect on the investment efficiency of these selected firms in all three models, but Random Effects Model estimates better coefficients than the counterparts. While the firm's annual cash predicts a positive insignificant effect on the investment efficiency in the case of all competing models. Asset's tangibility shows a negative significant effect on the investment efficiency of these firms. The study will help the academicians in their researches, decision-makers, and top management of this particular manufacturing sector in getting insight into framing and formulating their financial strategies.

Keywords: *FRQ, investment efficiency, textile sector, random effect, Pakistan*

Calitatea raportării financiare influenţează eficienţa investiţiilor în firmele din sectorul textil din Pakistan listate la bursă? Mit sau realitate

Studiul investighează relația dintre calitatea raportării financiare și eficiența investițiilor în firmele din sectorul textil listate la Bursa de Valori din Pakistan, datorită faptului că este sectorul cel mai înalt clasat cu numărul maxim de firme listate în Pakistan. Folosim calitatea raportării financiare ca variabilă independentă, eficiența investiției ca variabilă dependentă și numerarul anual al firmei, activele corporale și randamentul activelor ca variabile de control. Analizăm 100 de firme selectate aleatoriu pentru perioada 2005–2019. Studiul aplică diverși indicatori de estimare și anume Pooled OLS, Fixed Effects și Random Effects pentru a identifica modelul care preconizează mai bine rezultatele. Rezultatele demonstrează că ROA (randamentul activelor) și calitatea raportării financiare a firmei au o influență pozitivă semnificativă asupra eficienței investițiilor acestor firme selectate în toate cele trei modele, dar Random Effects Model estimează coeficienți mai buni decât omologii săi, în timp ce numerarul anual al firmei preconizează o influență pozitivă semnificativă asupra eficienței investiției, în cazul tuturor modelelor concurente. Activele corporale arată o influență negativă semnificativă asupra eficienței investiționale a acestor firme. Studiul îi va ajuta pe academicieni în cercetările lor, pe factorii de decizie și pe top managementul acestui sector de producție special să obțină o perspectivă în încadrarea și formularea strategiilor lor financiare.

Cuvinte-cheie: *FRQ, eficiența investițiilor, sectorul textil, efect aleatoriu, Pakistan*

INTRODUCTION OF THE STUDY

Financial reporting quality entails the capability of financial statements in disclosing, providing, and transmitting the firm's financial and non-financial information as well as a comprehensive forecast of the future expected cash flows to the investors. Promulgation of high accounting standards keeps rank high of financial reporting which resultantly help the investors. The positive accounting theory suggests that financial reporting quality has two prominent dimensions i.e. signalling about the market and monitoring the managerial behaviour [1]. The repute of FRQ and accounting standard is attributed to various key factors, i.e. audit committee experience, and devotion, strict promulgation of the international Accounting standard board, creative mindset, and attitude of management [2]. The Financial reports are the key determinants of the accounting system which help the users in providing sufficient information in framing their economic decisions regarding the firm's performance. This dimension of the accounting system helps to examine past activities and operations efficiently and to forecast the possible future dimensions in this regard [3]. The quality of financial reports is a predictor of a well-communicated information system of any firm which provides users more interested and accurate information of the firm's cash flow information. The Financial Reporting Quality helps in establishing the Standards of Accounting, which promote useful information for the decision-makers [4]. Financial accounting information can be very useful in fostering investment efficiency by providing meaningful insight to the decision-makers and thereby enhancing the performance of the firm, the trust, and the confidence of the stockholders and shareholders. Disclosure of high-quality information reduces the cost of financing and market inefficiency and yields long-term returns [5]. The drastic change and innovation in technology have caused a new scenario for the customers and entrepreneurs in socio-economic disposition. It helps in changing the behaviour through excellent management of the organization's rivalries. The firm's management needs to be dynamic, innovative, and creative as the world is shifting towards a knowledge economy, where wisdom, innovation, and creativity are vital for survival and helps inaccurate information and communication which change the dynamics of the firm and efficiency is encouraged in the firm's systems [6].

Accounting Information System is vital to deliver timely and accurate information, which helps the decision-makers to efficiently convey information to the public outside the firm [7]. The information provided in financial statements is the key source that helps to analyse asset quality in the decision process for financial reporting [8]. In designing an information system, it is important to evaluate various subsystems, which resultantly uplift the organization system of information. All firms are more driven towards adequate information and a true picture of the firm that will help managers in their decision-making process and would cause efficient and accurate decisions. Adequate information and making a decision based on this information resolve the issue of the firm regarding their accurate decision making, which eventually helps to achieve the firm's objectives [9]. Similarly, Choe [10] views that the best accounting information system will have a huge effect on the firm's overall performance. A well comprehensive strategy in terms of information disclosure over competitors will give a competitive edge to the dominant firm [11]. Similarly, Hassan [12] argues that management needs to provide financial reporting information that helps the users in their forecasting about cash flow from their investment. While Lobo and Zhou [13] assert that many world top scandals occurred due to low Financial Reporting as shareholders always demand a high quality of financial reports and accurate information. In a similar study, Khalifa, Othman [14] focus on the reporting quality as a tool to encourage efficiency in organization and provide strength to the portfolio of financial instruments of the firm.

Similarly, McNichols and Stubben [15], also explained the outcomes of the financial reporting quality in the way it helps to maximize the trust of the stockholders as well as stakeholders and promote efficiency in the firm's set of activities and operations. We conduct this study with the view that such studies are rarely found in the context of developing nations like Pakistan. Hence, it is a new emerging area, especially exploring firms in the Textile sector. Most of the research in the developed world consider financial reporting quality as a prominent indicator or determinant of financial performance, which provides a firm with a competitive advantage. Most of the studies on the subject have explored the developed part of the globe and provided suggestions for developing nations. Pakistan is a developing country where firms are desperate for the implementation of accounting standards and procedures with the spirit for the best interest of its corporate sectors to encourage transparency and the disclosure of information to ascertain the desired objects in terms of efficiency at both markets and firm-level. Some of the researches verified different results in the context of developing countries than the developed world [16]. We do not follow the blind eye technique for the data analysis; rather we test the data for the best suitable model it supports. In this regard, we use Pooled OLS, fixed effects, and random-effects models to predict results. There is no such study in developing markets, exploring the nexus of FRQ and investment efficiency, especially in the Pakistani context. Moreover, we examine the textile sector firms as representatives of the manufacturing sector which have not been previously explored in the context of Pakistan in such a composite manner. The study aims to measure and evaluate the financial reporting quality practices of the Textile sector firms to ascertain their strength and weaknesses and to investigate the relationship between Financial Reporting Quality and Investment Efficiency in these listed selected firms.

LITERATURE REVIEW

The area of financial reporting has been widely explored in the developed world, and the empirical literature can be found with greater frequency. Biddle and Hilary [17] examined publicly traded firms in the United States and argued that financial reporting quality significantly affects the firm's investment efficiency. Similarly, some of the researchers confirmed that FRQ can encourage the disclosure of information and motivation of the stockholders [10]. While some believe that FRQ helps to get a competitive edge over others in the same market and industry [11]. Mendoza and Yelpo [18] certified the importance of FRQ and proclaimed that accounting transparency is playing a significant role in the firm's performance. Likewise, Li and Wang [19], also confirmed the importance of financial reporting quality in boosting the organizational size and performance and argued that FRQ practices with higher and greater frequency can affect the corporate real investment decisions. Admitting the positive outcomes of FRQ, Yeganeh and Taran [4] pointed out financial reporting as the strength of the firm, which can affect the firm size, performance, and investment decisions. Kinyariro [20], also confirmed the positive significant correlation between financial reporting quality and investment, which supports the findings of that school of thought, viewing FRQ as the tool to uplift the firm, s efficiency. Healy and Palepu [21] argue that accurate information is attributed to FRQ, as due to it, a better picture is shown, which is highly trusted by investors. And the true cash flow disclosure helps investors in making their accurate decisions. KHODAEI and YAHYAEI [22] reported insignificant nexus between FRQ and investment efficiency. In a similar study, Chen, Hope [23] confirmed the contribution of FRQ in a firm's audit quality, management of leverage structure, and evaluation of financial structure. While, Flannery [24] argued that information efficiency will have a positive effect on the economy of the country in general, and the firm in specific. Berger and Udell [25], also validated a positive relationship between financial reporting and investment efficiency. While in contrast to those who believe that FRQ is positively and significantly associated with investment, Ortiz-Molina and Penas [26] reported an insignificant relationship between FRQ and investment efficiency. Similarly, Diamond [27], also reported an insignificant relationship between these two variables. Meyer, Becker [28] explored Chinese firms and argue that investment efficiency can be enhanced with proper financial reporting quality to boost the confidence and motivation of the stockholders. The same was confirmed by Child and Rodrigues [29] pointed out financial reporting as the strength of the firm, which can affect the firm size, performance, and investment decisions. Saghafi and Arab [30] found an insignificant effect of the FRQ on investment efficiency and similar results were obtained by another researcher [31]. Bharath, Sunder [32] asserted that financial reporting quality can enhance investment efficiency and help decision-makers. While some of the researchers argue that Financial Reporting Quality vitally contributes to the firm's financial standstill and builds the investors, trust [31]. Most of the researchers reported that financial reporting can make the decisions easy for the top management and help to enhance the volume of a firm's assets and performance Noravesh, Karami [7], also examined Iranian firms and found that FRQ can positively affect the investment efficiency. Likewise, Lai [33] argued that financial reporting quality is very vital for the firm's success and carries a significant effect on the firm's investment volume.

RESEARCH METHODOLOGY

Hypotheses of the study

H_1: There is a positive significant relationship between financial reporting quality and investment efficiency.

H_2: There is a positive significant relationship between return on assets and investment efficiency.

H_3: There is a positive significant relationship between the tangibility of a firm's assets and investment efficiency.

H_4: There is a positive significant relationship between corporate cash holdings and investment efficiency.

Data, sampling and sources

This research investigates the Textile sector firms, so all listed firms in the Textile sector are the population of the study. The sample size represents the entire population for saving the time and resources of the researchers [34]. In the current research, the simple random sampling technique has been adopted. The study uses the data of 100 Pakistani Textile sector firms out of 145 listed firms on Pakistan Stock Exchange with maximum asset value for the period 2005 to 2019. The study covers the criteria of Roscoe [35], for the sample size and sufficiency, who argued that 10 times observations for each variable in the study are good enough. In the current research secondary data has been collected from the firm's annual reports.

Specification of the econometric models

We use the panel data modelling approach due to the nature of the data. Hsiao [36] argues that panel data is superior to time series and cross-sectional data, due to its district characteristics. Panel data outline unobserved heterogeneity and provide a maximum number of data points, which resultantly causes more degree of freedom and drop down the issue of collinearity among explaining variables. Moreover, it combines both time series and cross-sectional data [37]. We follow previous studies that have used simple pooled OLS, Fixed Effect Model, and Random Effects Model [38]. Pooled OLS in an appropriate estimator to capture the individual effect as well as observable and unobservable variables. Moreover, pooled OLS generates efficient and consistent estimates of the explanatory variables [39]. We always expect a difference in the values of various variables across various firms in the same industry. If there are unobservable effects caused by heterogeneity, which are not isolated, they will keep volatile (inflating) the regression's and capture heterogeneity, fixed-effects or random-effects models are used [38]. We apply the following pooled OLS, fixed effect, and random effect models.

Pooled OLS Model

$$y_{it} = \beta x_{it} + a z_i + \varepsilon_{it} \quad (1)$$

$$Investment\ eff = \beta_0 + \beta_1 FRQ + \beta_2 Annual\ Cash + + \beta_3 ROA + \beta_4 Assets\ Tang + \varepsilon_i \quad (2)$$

Fixed Effects Model

$$y_{it} = \beta x_{it} + \alpha_i + \varepsilon_{it} \quad (3)$$

$$Investment\ eff = \beta_0 + \beta_1 FRQ + \beta_2 Annual\ Cash + + \beta_3 ROA + \beta_4 Assets\ Tang + \varepsilon \quad (4)$$

Random Effects Model

$$y_{it} = \beta x_{it} + a + \mu_i \varepsilon_{it} \quad (5)$$

$$Investment\ eff = \beta_0 + \beta_1 FRQ + \beta_2 Annual\ Cash + + \beta_3 ROA + \beta_4 Assets\ Tang + \mu + \varepsilon \quad (6)$$

Operational definitions and measurement

We use-dependent, independent and control variables in this study, i.e., investment efficiency as the dependent variable, financial reporting quality as an independent variable, and cash, asset tangibility, and ROA as control variables. The study measures Investment Efficiency as the increase in the firm's tangible plus intangible assets divided by the total assets of the firm. We follow the fundamentals of the previous researchers, who also similarly measured it [17]. We establish the following equation for investment efficiency:

$$Inv = \beta_0 + \beta_1 SG + \mu \qquad (7)$$

where *Inv* is the sum of total investment and tangible assets increase over the period, *SG* – the change in sales growth. The Financial Reporting Quality in this research is measured through the Profit management calculation model, formally proposed by [15]. We ensure dividing all variables by the value of total assets at the beginning of the year. Residual of this equation represents a change in accounts receivable, which is not for a change in the sale. We use the absolute value of this figure multiplied by –1, describing the *FRQ*. A larger value in our case means higher *FRQ*. In this study, *ROA* is calculated as net profit/total assets. While cash is measured as the ratio of cash to total assets and Tangibility of assets predicts the ratio of fixed assets to total assets.

RESULTS DISCUSSION

Diagnostic tests

To satisfy the data for the feasibility of the analysis, heteroscedasticity, and autocorrelation were checked, in this regard, the following tests have been performed. The tests, s results demonstrate that there is no issue of heteroscedasticity and autocorrelation in the data, and the data is normal as all the reported results of these tests are insignificant which confirms no such issues in the data (table 1).

Table 1

DIAGNOSTIC TESTS

Tests	X2	Prob. Chi Sq.
Breusch-Godfrey Serial Correlation LM test	0.062	0.121
Breusch-Pagan-Godfrey Heteroscedasticity test	0.842	0.537
Jarque-Bera test (Normality)	0.512	0.401

Pearson correlation analysis

Table 2 shows the correlation between a dependent variable and the independent variable of the study. Correlation is a statistical measure that talks about the direction and strength of the association between two variables. The results suggest that financial reporting quality positively significantly correlated with investment efficiency ($r = 17$), meaning that an increase in financial reporting quality will enhance the investment efficiency of Textile sector firms in Pakistan. Similarly, cash and ROA also show a positive correlation with the firm's investment efficiency, however assets tangibility shows a negative significant correlation with the investment efficiency of these listed firms ($r = –0.15$). Cohen [40] has stated the level of significance of correlation that starts from 0.1 and further elaborated its various dimensions i.e., weak, moderate, and strong correlation.

Table 2

PEARSON CORRELATION ANALYSIS

Variables	InvtEff	F.R.Q	Annual Cash	ROA	Assets Tang
Invt Effc	1.0000				
F.R.Q	0.3476	1.0000			
Annual Cash	0.0689	0.0234	1.0000		
ROA	0.3245	0.0564	0.0389	1.0000	
Assets Tang	–0.4148	0.0312	0.3209	–0.1467	1.0000

Regression analysis

Table 3 shows the regression analysis of the study. The results validate random effect as the best estimator that is why we consider the values of this model. The results demonstrate that firm financial reporting quality has positive significant effect on the Investment Efficiency ($\beta = 0.1903$, $p<0.05$), the same kind of significantly positive effect on the firm's investment efficiency, has been documented by all three models. The results are in line with the findings of previous studies that argued that FRQ has a positive significant effect on a firm's investment efficiency [41]. The results predicting a positive but insignificant effect of cash, annually hold by these firms on the investment efficiency ($\beta = 0.0679$, $p>0.05$), in all three models. The findings of the study are confirming the results of some previous studies, which obtained a positive insignificant results for the annual cash [42]. The results also demonstrate that ROA has positive significant effect on the investment efficiency of these selected firms, as the corresponding probability value is significant at 5% ($\beta = 0.2439$, $p < 0.05$) in all three models, verifying the significant effect of financial performance proxy ROA on the investment efficiency of these Textile sector firms in Pakistan. Some previous studies also validated similar results [43]. The results predicting a negative significant effect of assets tangibility on a firm's Investment efficiency, as the beta value and t-value are negatively and significant at 5% probability level ($\beta = –0.3675$, $p<0.05$) in the models used in this study, verifying the negative significant effect of the asset tangibility on the investment efficiency of these sample firms. The results confirm the findings of some similar studies [43]. The R-squares reported are 26.187, 32.386 and 38.971 respectively by pooled OLS, Fixed Effects and Random Effects Model, validating that the random-effects model has better

Table 3

RESULTS OF POOLED OLS, FIXED EFFECTS, AND RANDOM-EFFECTS MODELS			
Variables	**Pooled OLS**	**Fixed Effect**	**Random Effect**
F.R.Q	0.1903	0.2206	0.2654
	(3.2101)	(3.6701)	(3.9600)
Annual Cash	0.0353	0.0568	0.0679
	(0.0561)	(0.0789)	(0.0800)
ROA	0.1134	0.1327	0.2439
	(3.1301)	(2.9810)	(3.6700)
Assets Tang	–0.1851	–0.2963	–0.3675
	(–3.059)	(–4.1500)	(–4.3200)
R-Square	26.187	32.386	38.971
F-Statistics	23.197 (0.001)	32.672 (0.000)	-
Wald Chi	-	-	45.977 (0.000)
LM test	212.309		
(Pooled vs FE or RE)	(0.006)		
	Fixed Effect or Random Effect is more appropriate than pooled OLS, as the reported value is significant at the 5% probability level.		
Hausman test	3.456		
(RE vs FE)	(0.103)		
	Random Effect is appropriate as the reported value of the test is insignificant at a 5% probability level		

explanatory power than the rest of the two models. The Wald chi value of the Random Effects Model is highly significant in comparison to the F-values of the counterpart models, this justifies and confirm that the Random Effects Model is a preferred model over the rest of the two models.

CONCLUSION

Financial reporting quality can enhance investment efficiency by declining asymmetries of information and developing the trust and confidence of the investors. In this competitive business world, financial reporting and corporate disclosures are vital for the efficiency and competitive performance of a firm. Pakistan Textile sector is one of the biggest sectors in terms of the number of listed firms. This study aimed to investigate the effects of financial reporting quality on investment efficiency. The study analysed Textile sector firms as representative of the manufacturing sector. We used various control variables along with the independent variable financial reporting quality. The study measured and calculated financial reporting quality and investment efficiency as per the models proposed by [17]. The Findings of the study are very much consistent with results documented by previous studies. The results demonstrate that a firm's financial reporting quality and ROA have a positive significant effect on the investment efficiency of these selected firms, verifying the findings of past studies that predicted similar results [44]. While the firm's annual cash predicts a positive insignificant effect on the investment efficiency confirming the results in line with previous studies [45]. However, asset tangibility shows a negative significant effect on the investment efficiency of these firms [46]. As the results in our study claimed the significant effect of the financial reporting quality on the investment efficiency, therefore firms in Pakistan should practice well adequate and internally certified accounting and reporting systems to entice investors' confidence in buying the equity of the firm. Such attempts will help the profit maximization strategies of firms listed in the textile sector, and will be an eye-opener for the rest of the firms in other sectors to focus on their reporting quality. Central Bank should interfere in this regard to make the financial reporting quality of the firms more adequate and transparent. Based on the findings the Security and Exchange Commission of Pakistan should make various dimensions of corporate disclosure mandatory for listed firms in general, and the textile sector in particular. Moreover, the compliance of accounting standards that are acceptable internationally must be ensured in the prevailing financial reporting of these selected firms. Also, non-compliance regarding quality financial reporting must lead to the de-listing of the firm as a penalty announcement if found their failure during conduct of an audit by the professional auditor. Future studies should use the combination of both accounting base attributes i.e., accrual quality, persistence, predictability, and smoothness, and market base attributes i.e., conservatism, timelines, and value relevance in the context of Pakistan. Similar studies if conducted in the future can use the moderating and mediating effect of corporate governance, audit quality, and corporate disclosure. Moreover, in similar studies comparison of the manufacturing sector and financial firms can also be a vital addition to the literature. While SEM is also a better choice in future studies to cover the advanced modelling perspective. Moreover, a comparative study of Pakistani textile firms and Bangladeshi textile firms will also be a novel work. Our study is confined to textile sector firms which is why the results will not be generalizable to other sector firms. Secondly, different measurement techniques of the variables and a huge sample size may affect the results.

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Silk weaving business sustainability as a cultural heritage of Indonesia: a case study in Wajo Regency, South Sulawesi

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ABSTRACT – REZUMAT

Silk weaving business sustainability as a cultural heritage of Indonesia: a case study in Wajo Regency, South Sulawesi

This study was designed to probe into the sustainability of the silk weaving business as a cultural heritage in Wajo Regency, South Sulawesi, Indonesia, which is seen from the aspects of opportunities and challenges. To enact such a purpose, a case study was used in this research. Participants involved were silk entrepreneurs in Wajo Regency, South Sulawesi, Indonesia. Data were garnered through three stages: 1) observation, 2) documentation, and 3) semi-structured in-depth interviews. Findings suggest that the silk weaving business as a cultural heritage continues to grow and gives an identity to Wajo Regency as a city of silk and a centre for selling silk fabrics in Indonesia. This is evidenced by a large number of silk weaving business units and the large number of workers absorbed, especially women, who can contribute to regional income and economic growth. This finding is influenced by several factors that provide opportunities, such as family economic education which continues to be passed down from generation to generation, capital assistance from banks, gender equality for weavers, and the adaptability of silk entrepreneurs. However, there are challenges in the sustainability of the silk weaving business in terms of limited local raw materials and the use of the Gedogan traditional loom which is rarely used even though it is a typical loom in silk weaving and is a cultural heritage in weaving. Based on the findings, the study suggests adaptive skills training for silk entrepreneurs and making silk weaving as an educational tourbe.

Keywords: *Gedogan traditional loom, Alat Tenun Bukan Mesin (ATBM), adaptability, gender, informal economy education*

Sustenabilitatea afacerilor cu țesături din mătase ca moștenire culturală a Indoneziei: un studiu de caz în regența Wajo, Sulawesi de Sud

Acest studiu a fost conceput pentru a investiga sustenabilitatea afacerii cu țesături din mătase ca moștenire culturală în regența Wajo, Sulawesi de Sud, Indonezia, care este analizată din punctul de vedere al oportunităților și provocărilor. Pentru a realiza un astfel de obiectiv, în cadrul cercetării a fost utilizat un studiu de caz. Participanții implicați au fost antreprenori în domeniul mătăsii din regența Wajo, Sulawesi de Sud, Indonezia. Datele au fost colectate în trei etape: 1) observație, 2) documentare și 3) interviuri detaliate semi-structurate. Rezultatele sugerează că afacerea cu țesături din mătase ca moștenire culturală continuă să crească și dă o identitate regenței Wajo, ca oraș al mătăsii și centru pentru vânzarea țesăturilor din mătase în Indonezia. Acest lucru este dovedit de un număr mare de unități de producție a țesăturilor din mătase și de numărul mare de muncitori absorbiți, în special femei, care pot contribui la veniturile regionale și la creșterea economică. Această constatare este influențată de mai mulți factori care oferă oportunități, cum ar fi educația economică a familiei, care continuă să fie transmisă din generație în generație, asistența de capital din partea băncilor, egalitatea de gen pentru țesători și adaptabilitatea antreprenorilor din domeniul mătăsii. Cu toate acestea, există provocări în sustenabilitatea afacerii cu țesături din mătase, în ceea ce privește materiile prime locale limitate și utilizarea războaielor de țesut tradiționale Gedogan, destul de rar, deși acestea sunt războaie de țesut tipice pentru țeserea mătăsii și reprezintă o moștenire culturală în domeniul țeserii. Pe baza constatărilor, studiul sugerează formarea abilităților de adaptare pentru antreprenorii din domeniul mătăsii și realizarea țeserii mătăsii ca un tur educațional.

Cuvinte-cheie*: război de țesut tradițional Gedogan, Alat Tenun Bukan Mesin (ATBM), adaptabilitate, gen, educație în economia informală*

INTRODUCTION

The silk weaving business is one of the world's industries that produces luxury fabrics [1]. In particular, the silk weaving business of Wajo Regency, South Sulawesi, Indonesia, is an intangible cultural heritage that has been endorsed by the Ministry of Education and Culture [2]. This is in line with the opinion of the Creative Economy Agency [3] that traditional woven fabrics are cultural heritage works that are the pride of society and are intellectual works of the nation's children that need to be preserved as they have a major impact on local identity and have a close relationship with creative industries [4]. Thus, the silk weaving business needs to be preserved since it is a local cultural heritage [5].

Silk woven cloth has been used for generations and has become the mandatory clothing for the Bugis people in traditional activities such as weddings and other traditional activities [6]. Silk cloth has religious motifs and colours that can describe the social status of the community. In addition, the silk weaving business is a local potential that cannot be found anywhere else. Although it has the same main material, namely silk, each region has its characteristics that contain a profound philosophy and are influenced by the geographical environment and the potential of natural resources [7]. Silk fabrics in South Sulawesi have traditional motifs, namely Balo tettong, Mallobang, Ballo Renni, Cobo, and bombang.

The silk weaving business is one of the economic activities of the Wajo community, apart from farming and gardening. Initially, silk weaving business activity became a side job. This can be seen from the working hours which are generally carried out at night. After the household, activities are finished and weaving is done by women. Along with its development, the silk weaving business has become the main source of livelihood for the Wajo people. There are 22 large and medium industries in Wajo Regency, and 13 were oriented to the silk industry [8]. This indicates that the silk industry in Wajo plays an important role because it can create new jobs and absorb labour. Therefore, it needs to be maintained and developed so that the silk weaving business can provide benefits to the community in a sustainable manner [9].

Recently, silk entrepreneurs have to compete fiercely in business competition with modern clothing, although the use of traditional clothing is part of preserving culture [10]. Thus far, previous research has only focused on the production process of silk weaving and how to acquire knowledge of weaving without paying attention to the sustainability of the silk weaving business as a cultural heritage. To fill such a void, the present study looks into the exploration of the silk weaving business as a cultural heritage that focuses on challenges and opportunities. This is done considering that silk weaving is one of the cultural heritages that need to be preserved [5].

METHOD

This study employed a qualitative approach with a single case study design. The analysis technique used qualitative analysis techniques [11], including data reduction, data presentation, concluding, and verification. This study specifically looks into the challenges and opportunities of the issue of sustainability in the silk weaving business as a related cultural heritage. The research was conducted in Wajo Regency, South Sulawesi, Indonesia. Five silk entrepreneurs consisting of the silk weaving business which has the largest and oldest business were invited to attend semi-structured interviews. Data in this study were collected within three stages: 1) observation, 2) documentation, and 3) semi-structured in-depth interviews.

Observations were conducted to observe various phenomena that occur during the study. These observations were done in the form of direct visits to the object and research subject to see how silk weaving business activities were carried out and to explore the living conditions of silk entrepreneurs within the research sites. Documentation was done by collecting data through written information related to the research questions. Data obtained from related agencies such as the Wajo Regency Industry Service in 2015–2019 was also documented.

In-depth semi-structured interviews were conducted using the participant's national language while the transcripts were then translated into English. This research interview led to the depth of information obtained through direct dialogue with research participants about how the silk weaving business as a cultural heritage focuses on challenges and opportunities.

RESULTS AND DISCUSSION

The silk weaving business in Wajo Regency, South Sulawesi, Indonesia, has increased annually, as seen from the growth in silk business units and labour as well as regional income. Such data is outlined in table 1.

Table 1

DEVELOPMENT OF THE SILK INDUSTRY IN WAJO REGENCY, SOUTH SULAWESI, INDONESIA

Year	Business unit	Labour	Locally-generated revenue
2015	5806	17396	100 M
2017	5940	18308	118 M
2018	6093	18510	135 M
2019	6116	18510	134 M

Source: Central Statistic Agency, Wajo Regency, South Sulawesi, Indonesia, 2015–2019.

Based on table 1 [12–15], the silk weaving business can absorb labour and contribute to regional income and increase economic growth [16]. The silk weaving business in Wajo continues to develop and gives impacts the welfare of silk entrepreneurs and local communities. This business also plays an important role in the economic development throughout the country. This fining portrays how the silk weaving business sustainability as a cultural heritage and how it deals with challenges and opportunities within the business activity. The detailed findings are discussed in the following sections.

What are the challenges in the sustainability of the silk weaving business as cultural heritage?

The present study portrays challenges in the sustainability of the silk weaving business, such as the availability of raw materials, which is an essential factor in the manufacture of silk fabrics. Although several places in Wajo Regency provide raw materials, they have not yet been able to meet the demand for silk production. Also, the price of imported raw materials is inexpensive than the local raw materials. This encourages entrepreneurs in Wajo Regency to use the imported raw materials. This finding is evident by the interview data with the participants: *"For silk fabrics, I mostly use imported raw materials because they are cheaper, easy to obtain and available in large quantities. It is different from local raw materials which are more expensive and available in limited quantities so that they cannot meet the demand for silk thread".*

About this issue, the role of the government, especially MSMEs and the Cooperative Office, is required to preserve silk cloth as a cultural heritage, as silk weaving is a leading sector in Wajo. Thus, it needs serious attention in the supply of raw materials since it is a problem that often occurs [16]. Further, entrepreneurs need to be given knowledge about the production of silk raw materials to compete with imported raw materials with the quality and quantity that suits their needs. This can hamper local entrepreneurs to be dependent on imported materials, even when disaster hits the regions.

This study also documents that the use of looms used by silk entrepreneurs, which are dominated by ATBM (Alat Tenun Bukan Mesin)/non-machine loom, is also another challenge [17]. Meanwhile, the traditional Gedogan loom, which produces high-quality silk and is an original cultural heritage loom, is only used for special orders (figure 1). This is seen from the interview with the local entrepreneurs. They share that: *"For looms, I use ATBM because it is more efficient and practical. Even if I use the traditional Gedogan weaving tool, only if there is a special order because the processing time is quite long, namely a month to only produce one silk sarong, although in terms of quality it is much better".*

The use of traditional Gedogan looms should be by the use of ATBM. This is because silk entrepreneurs only focus on production without paying attention to the sustainability of the silk weaving business, which has a distinctive competency that can produce genuine silk fabrics of good quality [18]. In addition, the use of traditional looms is an effort to preserve cultural heritage [19].

What are the Opportunities for the Sustainability of Silk Weaving Business as a Cultural Heritage?

In the sustainability of the silk weaving business in Wajo, South Sulawesi, several factors become opportunities, such as family economic education where the knowledge of weaving silk cloth is naturally unstructured and unsystematic. It occurs in a family environment without being limited by the time [20]. Children are directly involved in weaving activities, such as providing raw materials and marketing, leading to an economic learning process [21]. In providing weaving knowledge, there is no compulsion so that children are more comfortable and easier to understand. This is shared by the participants in the interview: *"The process of weaving culture inheritance I got indirectly. Where initially I was invited to help manage a silk weaving business after school or in my spare time. I was taught from spinning silk threads so that I could produce silk fabrics of different patterns and colours, and I was involved in exhibition activities. So, at first, I didn't understand, gradually I understood".*

The economic behaviour of silk entrepreneurs is indirectly formed from economic education in the family. This leads to the existence of the silk weaving business and is one of the main sources of livelihood for the Wajo community because the inheritance process continues from generation to generation, this has directly become a form of cultural inheritance.

The activity of weaving silk cloth is generally only done by women so some women become the backbone of the family [21]. The silk weaving business is a sustainable and labour-intensive economic activity for women [22] since women can develop ideas in producing silk motifs and colours in the management of the silk weaving business. Thus, it can be said that the role of women in the weaving business is proven to have a significant effect on the business world and welfare [23]. This is in line with interviews with most of the participants in this study: *"Weavers that are*

a

b

Fig. 1. Photo of looms used by silk entrepreneurs in weaving silk fabrics:
a – Gedogan traditional looms; *b* – Alat Tenun Bukan Mesin (ATBM)

employed are women because weaving is a woman's activity that has been going on for generations. Weaving is also the identity of Bugis women so it should not be done by men because it must be done gently and with feeling".

Women have a big share in the silk weaving business because weaving has become an identity for Bugis women. Along with the development of the business, silk weaving entrepreneurs have empowered men as weavers from the island of Java. This was done to open the mindset of the Wajo people who consider weaving as a women's activity. By involving men, the work will be more efficient and effective, considering that they are stronger and faster than women because weaving silk requires greater energy. In addition, it has an impact on reducing unemployment in Wajo. As time goes by, recently there are male weavers from Wajo whose numbers are fairly minimal. This is based on the results of an interview with one of the participants: *"Most of the weavers who work come from the surrounding community, which consists of house neighbours and village neighbours. However, some come from outside the island of Sulawesi. For weavers from outside Sulawesi, I employ men because they are more agile, strong. Apart from that, I hope that the male weaver I recruited can change the mindset of society that thinks silk weaving is women's work. And this is successful because there are already two male weavers who come from Wajo".*

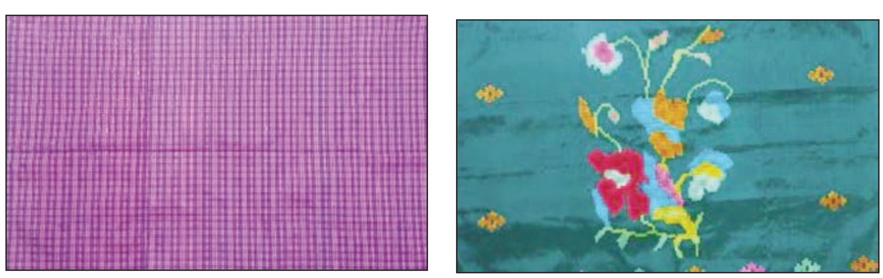
There is a cultural shift where weaving activities, which are generally only carried out by women, currently involve men even though the numbers are very minimal. Thus, it is necessary to understand that gender inequality is not only economically inefficient but also has social impacts that will affect the development of a nation [24]. This is because an effective workforce plays a positive role in determining economic growth [25]. This is an opportunity for the sustainability of the silk weaving business as a cultural heritage.

Apart from informal economy education and Human Resources (HR)/Weavers, capital is an opportunity for the sustainability of the silk weaving business. Initially, the capital is owned personally. Then, silk entrepreneurs received capital assistance from banks to develop a silk weaving business. This was demonstrated by the establishment of a silk Village BNI in Wajo. However, over time, many entrepreneurs have been able to develop their businesses with their capital. This was confirmed by the participants in the interview: *"In the beginning, this business used personal capital. After a few years, I got a loan from a bank that collaborates with a silk entrepreneur and establishes a silk village. With the given capital, I can develop a bigger business. But over time, I have now used my capital in developing a silk weaving business. So, I have to be careful to look at the market share so that the capital I spend can provide maximum profit".*

Capital is one of the important aspects in the sustainability of the silk weaving business as a cultural heritage. The existence of capital assistance from both the government and the banking sector has proven to be able to advance the silk industry amidst competition and support sustainable economic development [26].

The adaptability of silk weavers is an opportunity for the sustainability of the silk weaving business in Wajo. In a globalized world, a mixture of cultures tends to occur. Thus, it needs the ability to adapt to other silk entrepreneurs. In this case, local wisdom can balance technology and market tastes by considering regional characteristics, climate, and environmental conditions [27]. The silks produced in the silk weaving business are not only original motifs but adapted to market tastes. Like the Lagosi motif, the modified motif is currently the most popular. Silk woven products are not only silked fabrics but in the form of wallets, tissue holders, and party bags that are tailored to the tastes of the market (figure 2). For wallets and tissue holders, most silk entrepreneurs use unused silk cloth. This has an impact on reducing the textile waste generated by the silk weaving business. This is in line with the issue of circular economy which proposes the reuse or recycling of unused woven fabrics to reduce their impact on the environment and recycling these items give a different appearance to cultural heritage [28, 29].

Silk product marketing in Wajo Regency is marketed through various media, starting from individual marketing, exhibitions to online marketplaces such as the internet, web, and social media. Thus, marketing is more practical. Utilizing online marketplaces in business activities can increase sales [30], thereby encouraging sellers to effectively integrate themselves into the global marketplace [31]. The use of social media can increase marketing, and online marketing has a positive impact on the marketing of the textile industry [32]. The internet changed the way silk entrepreneurs did business, making it easier for customers to access and select items to buy anytime and anywhere [33]. In addition, silk entrepreneurs who have good skills and are willing to innovate will



a ***b***

Fig. 2. Photo of silk fabric motif: *a* – Balo Renni (Traditional/Original silk fabric motif); *b* – Lagosi Motifs (Modification silk cloth motif)

increase silk weaving sales and increase profits [34]. Silk products have been marketed throughout the archipelago, such as Jakarta, Bali, Jogjakarta, Sumatra, the island of Java, and other regions and even abroad. This is conveyed in the interview by the participants: *"For the silk motifs that I make, most of them are adapted to consumer demand, for example, the Lagosi motif. Apart from silk cloth, I also sell bags, tissue holders and wallets made of unused silk. For the marketing itself, there are those from around Sulawesi, Java Island, and even abroad such as Singapore, Malaysia, Japan, and Thailand. So that silk products are not only sold in stores but also through exhibitions and social media which make it easier for consumers to buy".*

The adaptability of silk entrepreneurs by utilizing social media makes the silk cloth marketing process more effective and efficient, which is not limited by time and space. The adaptability of silk entrepreneurs not only adapts to market tastes but has an impact on the use of semi-modern looms in the production process. The use of semi-modern looms provides an opportunity for the sustainability of the silk weaving business as a cultural heritage in Wajo. It is shared in the interview as follows: *"Currently, some of the looms I use semi-modern machine looms, although only on a small scale and are dominated by ATBMs because it is faster and more practical to produce 15 meters of silk in a day so that silk fabrics can be made in the form of clothes, not limited to fabrics. only".*

The use of semi-modern looms in the production of silk fabrics provides changes both in terms of quantity and time efficiency because the use of sophisticated machines in the silk fabric production process can increase production [35].

Nonetheless, silk entrepreneurs still have to use Gedogan traditional looms in the process of making silk fabrics. The ability to adapt has an impact on the sustainability of the business from time to time [36], The silk weaving business is no exception so that the adaptability of silk entrepreneurs makes the silk weaving business able to compete and preserve the cultural heritage that exists in Indonesia because good culture is a culture that can adapt to changing times and can provide prosperity for people who is in it.

The present study documented that the sustainability of the silk weaving business is inseparable from internal aspects such as education in the family, raw materials, capital and Human Resources (HR)/ weavers and external aspects such as the ability to adapt to the face of globalization and be able to take advantage of opportunities so that the silk weaving business can continue to exist which can improve people's welfare and economic growth in Wajo Regency (figure 3). Therefore, the silk weaving business needs attention from the government, as the silk weaving business can have an economic impact and preserve cultural heritage since maintaining local wisdom is one way to preserve the values that exist in society [37]. The silk weaving business in Wajo Regency indirectly contributes to supporting the Sustainable Development Goals (SDGs) [38] (figure 4). SDGs 1 (poverty alleviation) can be seen from the standard of living of silk entrepreneurs, both in terms of adequate income and fulfilment of consumption. SDGs 5 (Gender Equality) can be seen

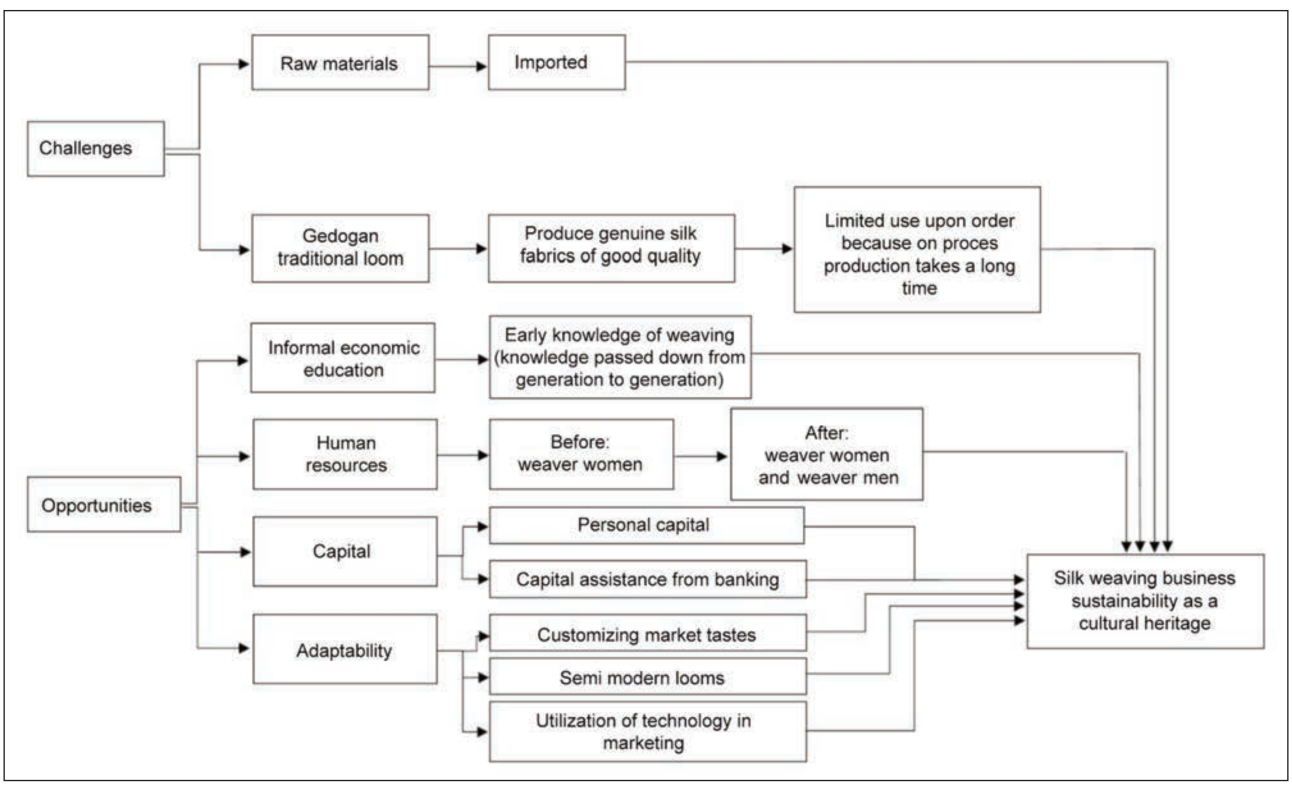


Fig. 3. Visualization of the sustainability of silk weaving business as a culture heritage

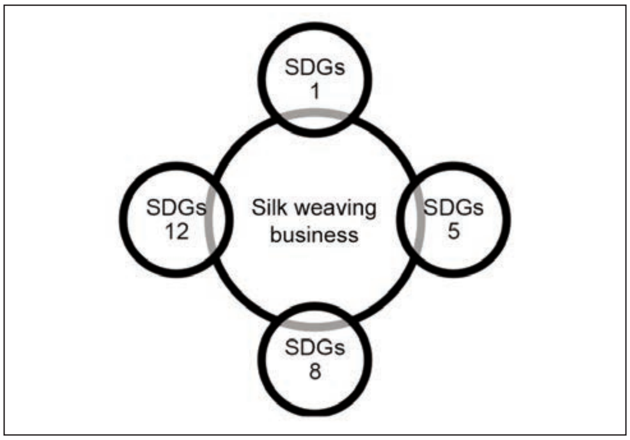


Fig. 4. Sustainable Development Goals (SDGs)

from the participation of men and women in the process of weaving silk, SDGs 8 (Decent work and economic growth) can be seen from the weaving silk indirectly that promotes sustainable economic growth and can create decent jobs. In the production process, the remaining unused silk cloth is used as something of value for money, such as a wallet which indirectly also answers the objectives of SDGs 12 (responsible consumption and production).

CONCLUSIONS

The present study has attempted to portray challenges and opportunities that emerged in the sustainability of the silk weaving business in Wajo Regency. The good adaptability in the era of globalization encourages the sustainability of the silk weaving business in Wajo Regency. Adaptation is one of the factors that provide opportunities for the sustainability of the silk weaving business, such as family economic education, capital assistance, and gender equality in weavers. In this case, weavers are not only women but also men. However, there are several obstacles, such as limited raw materials and the use of the traditional Gedogan loom which is rarely used, even though it is a typical loom in producing silk.

Therefore, the silk weaving business needs serious attention from the government because the silk weaving business plays an important role in economic development and gives Wajo's identity as a strategic silk city for the marketing of silk woven fabrics. In developing the silk weaving business in the future, adequate planning is necessary to support the economy and become alternative educational tourism that has an impact on society and the government.

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Research on the acceptability of the dual model of education in the textile industry sector

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ABSTRACT – REZUMAT

Research on the acceptability of the dual model of education in the textile industry sector

For the purpose of the research on the acceptability of the dual model of education in higher education, 30 companies from the textile sector were selected. The obtained results show that the respondents accept the dual model of education in a large percentage, ranging from 80% to 83.33%. From the answers related to decision-making on accepting the dual model of education in their companies, the respondents showed a positive attitude in the percentage ranging from 56.66% to 73.33%. A lower percentage of eligibility indicates that respondents will not make an immediate decision without additional information. From the answers related to the large administration and the number of documents for the inclusion of the company, the respondents believe that this administration is unnecessary. Only 13.33% of respondents believe that the existing administrative conditions are not an obstacle to companies' acceptance of dual education.

Keywords: *dual model of education in higher education, textile industry, Government of the Republic of Serbia*

Cercetare privind acceptabilitatea modelului dual de educație în sectorul industriei textile

În scopul cercetării privind acceptabilitatea modelului dual de educație în învăţământul superior, au fost selectate 30 de companii din sectorul textil. Rezultatele obținute arată că respondenții acceptă modelul dual de educație într-un procent mare, variind de la 80% la 83,33%. Din răspunsurile legate de luarea deciziilor privind acceptarea modelului dual de educație în companiile lor, respondenții au manifestat o atitudine pozitivă în procentaj, variind de la 56,66% la 73,33%. Un procent mai mic de eligibilitate indică faptul că respondenții nu vor lua o decizie imediată fără informații suplimentare. Din răspunsurile legate de birocrație și numărul de documente pentru implicarea firmei, respondenții consideră că această activitatea este inutilă. Doar 13,33% dintre respondenți consideră că aspectele administrative existente nu reprezintă un obstacol în calea acceptării de către companii a educației duale.

Cuvinte-cheie: *model dual de educație în învățământul superior, industria textilă, Guvernul Republicii Serbia*

INTRODUCTION

In the last three decades, the European fashion sector in the fields of textiles and clothing has undergone a great transformation. This industry, which is dominated by small and medium enterprises, has largely abandoned the low values of mass production. Significant to the success is that this industry has largely opened up a wide range of new areas of application for textile materials around the world, practically to all industrial and consumer sectors. Thus, European industry in this sector has successfully maintained positions with higher added value in the supply chain. Those that are typically related to knowledge, advanced technological capabilities and highly specialized skills. This includes research, development, testing, and highly flexible, strictly controlled production of functional textile materials for complex components or products in the textile sector. It also includes design, efficient custom production and fast delivery of textiles with high fashion content and outstanding added value of clothing for demanding markets.

The European textile and clothing industry has traditionally been regionally grouped, usually under the influence of available raw materials, processing aids as well as human resources or relevant end markets. The sectoral innovation community, that is, research and educational institutions and industry is organised to develop the fashion industry. The dual model of education occupies a significant place in developed European countries [1, 2].

The Serbian textile industry faces similar challenges. This industry today has 64,156 employees. It had realized exports in the period January – October 2020 in the amount of 747.3 million dollars. According to the export results, the textile industry has long been at the top of Serbian exporters [3].

HUMAN RESOURCES AS A BIG CHALLENGE OF THE TEXTILE INDUSTRY

A great challenge, that the whole fashion sector in all EU regions has, is the lack of interest of young people to pursue their careers in this sector. Despite the ETF (European Technology Platform) research which predicts that around 600,000 new jobs will be created in the fashion sector by 2025, this sector is of little interest to young people. The exceptions are design and fashion marketing. The education system at all levels in the EU, except for rare examples, reduced the number of their students. Research shows that, in Eastern European countries, young people's interest in joining the sector is far greater than in other regions. Therefore, all regions see a solution to this problem in organizing a campaign to attract young people to this sector similar to the existing successful Go Textile campaign in Germany [4–6].
Research by the European Skills Council – Textile Clothing Leather & Footwear shows that in addition to experts with a higher level of education in technology, management and creative disciplines, there is an acute need for staff for manufacturing occupations, technicians and similar jobs. The survey shows that 93% of all textile and clothing companies in Europe employ no more than 20 people. This shows that flexibility and multiple skills are largely needed. Therefore, it appears as a necessary need to organize ways to acquire skills for certain jobs in the fashion sector. The real situation shows that these specialization training are not yet firmly accepted in all European textile regions. The potential is especially unused in parts of southern and eastern Europe.
The Serbian textile industry faces similar challenges. In the 21st century, young people should adopt the philosophy of education as their philosophy of life. Rapid technical-technological development brings with it new challenges and the question is how to overcome those challenges today. Among other things, it brings awareness to young people that education is a pillar of building a successful professional career [1, 2].

Dual model of education as one of the solutions

A skilled workforce is one of the key resources not only for the Serbian economy but also for all economies in the world. The systemic connection between the world of work and the world of education, therefore, appeared necessary. To that end, the introduction of dual education in the system of secondary and higher education and in the textile sector has begun in Serbia. This is expected to use the potential to advance the transition from school to the world of work and offer young people a career planning perspective. Innovation and investment in education are considered to be key preconditions for preparing society for the future [1].
Introducing a dual education system is no easy task. This system cannot only be copied to Serbia from countries such as Germany, Austria or Switzerland. In order to achieve sustainable results, a lot of work must be done on adapting the dual system from those countries to the existing conditions that currently exist in Serbia in the education system as well as in the economy [7].
Dual education in Serbia started with GIZ. Almost 20 years ago, GIZ, the German Agency for International Cooperation in the Field of Economic Development, with the consent and support of the ministry in charge of education, began implementing a project piloting the application of dual education in Serbia through educational profiles such as locksmith welder [8].
The Ministry of Education, Science and Technological Development has committed itself to educational reforms in the light of accession to the European Union. Education reform is focused on the modernization of general, vocational and higher education, digitalization, entrepreneurship, coverage and quality of preschool education. Serbia has launched an ambitious skills development agenda, taking into account skills that will be needed in the future. The Ministry of Education, Science and Technological Development has expanded its capacity to meet national priorities, establishing the Sector for dual education and the Sector for digitalization in education and science [9–20].

METHODOLOGY OF RESEARCHING THE ATTITUDES OF BUSINESSMEN

In order to spread the idea of the acceptability of the dual model of education, an analysis of the attitudes of businessmen in domestic textile companies was performed. The research was realized on the basis of a specially designed instrument – an expert interview. The expert interview was conducted in order to come to preconditions for establishing guidelines for improving the acceptability of the dual model of education in the field of the clothing industry, in the function of developing the competitiveness of domestic companies in conditions of intensifying competition in the international market. This research involved designing a questionnaire and a sample of respondents. The interview is direct and structured and its role is to enable relevant views to be obtained in this area. The questionnaire is designed to include questions of the benefits of the dual model of study for all participants as well as questions related to the administrative procedures provided for employers to admit a student to their companies [21].
The research of the attitudes of businessmen was conducted in the period from the beginning of December 2020 to the end of January 2021 on the territory of the Republic of Serbia, with the aim of obtaining the opinion of businessmen from domestic companies. In addition to the owners of the company, the research also includes managers who are expected to be involved in working with students who opt for a dual model of learning in that company.
During the research, it was noticed that the attitudes of all entrepreneurs do not differ from each other to a greater extent. Namely, from the answers of entrepreneurs, it could be concluded that they have

similar attitudes, regardless of whether the entrepreneurs are from small, medium or large companies. For that reason, the research sample was designed for a size of 30 units. Based on the answers of businessmen from domestic companies (mainly medium and large companies), the basic assumptions that creatively influence the process in modern training of students according to the dual model of education were reached in the survey. This research was done in order to develop the national economy, especially providing quality staff for the economy and increasing their employment, which would all lead to improving the competitiveness of domestic textile companies.

Using statistical methods in the analysis of responses in order to obtain relevant data on the conceptual form of certain quantities, as determinants and attributes for modelling management processes, a certain set of attitudes is given that give the basic characteristics of the management model. All relevant factors in the research were analysed through a survey where businessmen of domestic companies gave their opinion on the basis of which attitudes emerged that will serve as a basis for improving the dual model of student training, which aims to determine the process management strategy.

PRESENTATION OF RESEARCH RESULTS

The total number of analysed companies is 30. Of that number, 7 companies have up to 10 (micro-companies) employees, 19 companies have up to 50 employees (small companies), 4 companies have up to 250 employees (medium companies) and two companies have over 250 employees (large companies). All companies are privately owned. Regarding the structure of the respondents, 12 of them are business owners, while the rest are managers in various jobs of technical preparation and production.

1. When asked if you think that this dual model of education is good because it allows students to acquire real knowledge in an industrial environment, respondents answered with: Yes – 80%; Partly good – 10% and No – 10%.
2. Most of the respondents (83.33%) agree that the dual model of education is a better way of choosing staff than the existing one, 16.66% agrees partially, while 0% disagrees.
3. 73.33% of respondents agree that this is a good way for you to provide deficient staff, 10% agrees partially, while 16.66% disagrees.
4. 66.66% of respondents think that this is a good opportunity to solve their staffing problems, 16.66% of them partially agrees that this is a good opportunity, while 16.66% thinks that it is not.
5. Sixty percent of respondents think that better quality staff can be produced this way, 23.33% partially agrees, while 16.66% does not agree.
6. Most of the respondents (56.66%) consider that the change of generations in their company can be successfully done in this way, 26.66% partially agrees, while 16.66% disagrees.
7. Results of the survey show that most of the respondents (80%) agree that the dual model of education represents an improvement of the previous way of education, 16.66% agrees partially, while 3.33% does not agree with this statement.
8. When asked if you think that students in your company, through work-based learning, will increase their motivation because they will have the opportunity to learn from older future colleagues, who at that early age can be role models who influence their future decisions and professional orientation, respondents answered with: Yes – 93.33%; Partially – 6.66% and No – 0%.
9. The majority of respondents expressed a negative attitude towards administrative barriers: 73.33% agreed that seeking a large amount of evidence that companies meet the requirements for learning through work is an administrative barrier, 13.33% partially agreed, while 13.33% disagreed with the given attitude.

The most significant research results

The most significant research results are the following:

1. To the questions under ordinal numbers 1, 2 and 7 which refer to the general opinion on dual education, the respondents answered positively and in a large percentage ranging from 80% to 83.33%;

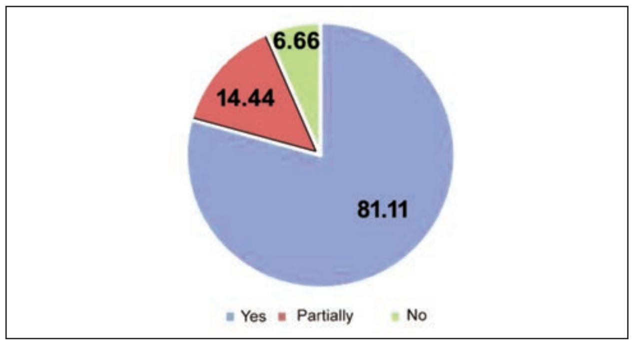

Fig. 1. Attitudes of respondents about the acceptability of the dual model of education

2. A large number of respondents, question number 8, believe that students in their company can successfully be trained. As many as 93.33% answered positively, 13.33% partially and no one answered negatively;
3. To the questions under ordinal numbers 3, 4, 5 and 6, which refer to the direct acceptance of students and solving their personnel problems, the respondents answered positively, from 56.66% to 73.33%. This shows that the respondents are not ready to immediately, without more detailed information, enter the dual model of education in their own company. This indicates that respondents do not have enough information to specifically apply dual education in their company. This requires the need to further promote dual education in order to make it clearer what are the benefits provided by dual education.

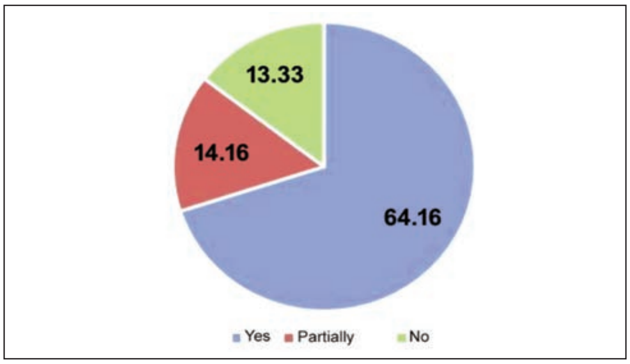

Fig. 2. Attitudes of respondents to include their own enterprise into a dual model of education without additional information

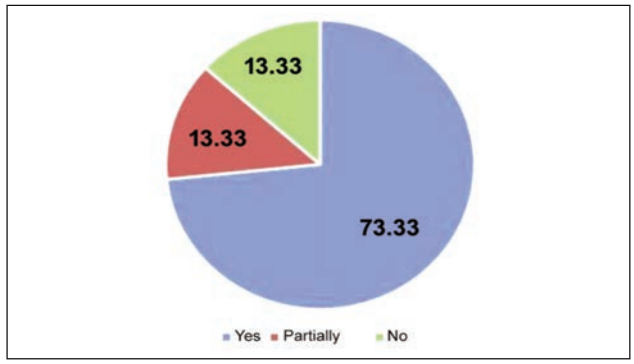

Fig. 3. Respondents' attitudes about administrative barriers to accepting the dual model

4. To the question, under number 9, a large number of respondents believe that unnecessary administration, which is reflected in the submission of a large amount of evidence, is an obstacle for companies to more easily accept the dual model of education. Only 13.33% of respondents believe that the existing administrative conditions are not an obstacle to accepting dual education.

CONCLUSION

Serbia is making significant efforts to provide skilled labour for the economy. To that end, the introduction of dual education in the higher education system has begun. This is expected to use the potential to advance the transition from school to the world of work and offer young people a career planning perspective. Innovation and investment in education are considered to be key preconditions for preparing society for the future.

In this paper, 30 companies from the textile sector were selected to investigate the acceptability of the dual model of education in higher education. The obtained results show that the respondents accept the dual model of education in a large percentage, ranging from 80% to 83.33%. From the answers related to decision-making on accepting the dual model of education in their companies, the respondents showed a positive attitude in the percentage ranging from 56.66% to 73.33%. This shows that respondents will not make an immediate decision without additional information. From the answers related to the large administration of enterprise involvement, the respondents consider that administration to be unnecessary. Only 13.33% of respondents believe that the existing administrative conditions are not an obstacle to companies' acceptance of dual education.

The results of the work indicate that in the future it is necessary to work more on informing companies about the advantages that dual education offers. The results also indicate that special attention should be paid to further simplification of administrative documentation that allows companies to join the dual system.

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Influence of sewing parameters on the energy consumption of the sewing machines

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ABSTRACT – REZUMAT

Influence of sewing parameters on the energy consumption of the sewing machines

The clothing industry due to the rapid changes in the technological and economical fields faces continuously new challenges like efficient machine and process settings' changes for individual production orders for smaller quantities; increased product and materials variety and increased competitiveness through higher quality and lower production costs.

Energy consumption is very important because, besides the varying costs (material, labour), the costs of energy are one of the key factors affecting the manufacturing costs, which is the main factor affecting the final price of the clothing products. It is well known that energy costs constitute 10–15 % of the overall manufacturing costs in the apparel industry.

In the present study, the correlation of the various sewing parameters with the energy consumption and thus the energy costs are examined. In order to obtain this goal, a data collection system has been designed in order to meet the needs and the nature of the measurements. Sewing experiments were carried out on different samples using various sewing parameters and the consumption of the electrical power was monitored. Additionally, the measurements obtained during the experiments were sent and stored in a computer for the processing of the signals and their statistical evaluation.

Keywords: *sewing parameters, energy consumption, efficiency, performance, sewing machines*

Influența parametrilor de coasere asupra consumului de energie al mașinilor de cusut

Industria de îmbrăcăminte, din cauza schimbărilor rapide din domeniile tehnologic și economic, se confruntă în continuu cu provocări noi, precum modificări eficiente ale setărilor echipamentelor și proceselor pentru comenzile individuale de producție în cantități mai mici; o varietate crescută de produse și materiale și creșterea competitivității prin calitate superioară și costuri de producție mai mici.

Consumul de energie este foarte important deoarece, pe lângă costurile variate (material, manoperă), costurile cu energia reprezintă unul dintre factorii cheie care influențează costurile de fabricație, fiind principalul factor care afectează prețul final al produselor de îmbrăcăminte. Este bine cunoscut faptul că aceste costuri reprezintă 10–15% din costurile totale de producție în industria de îmbrăcăminte.

În studiul de față, se analizează corelarea dintre diferiți parametri de coasere, consumul de energie și costurile energiei. Pentru a atinge acest scop, a fost conceput un sistem de colectare a datelor care să răspundă nevoilor și naturii determinărilor. Experimentele de coasere au fost efectuate pe diferite probe, folosind diverși parametri de coasere și a fost monitorizat consumul de energie electrică. În plus, determinările obținute în timpul experimentelor au fost trimise și stocate într-un computer pentru procesarea semnalelor și evaluarea statistică a acestora.

Cuvinte-cheie*: parametri de coasere, consum de energie, eficiență, performanță, mașini de cusut*

INTRODUCTION

The competitive character of clothing manufacturing enables continuous actions towards the improvement of several factors like the optimization of the process parameters, the use of new materials, the adaptation of the manufacturing concepts towards the quick response for small batches and new products. This trend poses certain requirements on the production systems and equipment: both have to be flexible and reliable. In the case of the equipment, it means shorter set-up times upon material changes and much more efficient quality assurance procedures.

The response to that critical situation using the traditional empirical machine set-up and process planning methods is difficult and it does not ensure the achievement of the goals. Better control and predictability of the processes are required. Additionally, in the new and thriving segment of technical textiles, defects may cause the failure of product functions. Also, they increase the demand for new methods providing more holistic and knowledge-based management and control of the processes [1]. In order to decrease the production costs, a general emphasis was given on the material and labour costs and they concentrate mainly on the different methods are applied for minimization. Energy costs aren't considered yet with these headings.

Energy consumption is an important issue for optimization, as, besides varying costs (material, labour), the cost of energy is one of the key factors forming the total manufacturing cost, thus determining the price of any article of clothing. It is well known that energy costs constitute some 10–15% of the overall manufacturing costs in the garment industry [2].

There are several studies correlating sewing speed, needle selection, needle penetration and withdrawal forces and energy consumption. Lojen published a study in 1995 about stitching velocity. Stitching velocity is one of the parameters in the technological operation of sewing which influence both total sewing time and quality of stitch form [3]. According to Stjepanovic, the selection of a suitable sewing needle was proved to be one of the most important parameters in the production of garments' joints. Needle thickness is an important parameter and should correspond to thickness, respectively surface mass of sewing material and sewing thread [4].

Rogale and Dragcevic have developed the first measurement and data acquisition system for sewing machines in 1998. The system was capable to measure simultaneously a number of parameters (sewing speed, average sewing speed, maximum sewing speed attained, sewing acceleration, number of stitches in a seam etc.). It could be also linked with some other measuring equipment for the investigation of other processing factors. It can rightly be considered a universal tool for investigating processing parameters in real in-plant conditions, and, as such, a necessary tool for clothing engineering [5].

Silva et al. have studied the compression force and the displacement waveforms from the presser foot bar, as well as the admissible displacement limits used to monitor (on- and offline) fabrics' feeding efficiency [6]. Rogale et al. studied the energy consumption of sewing machines in 2005. According to their study, consumption of electrical energy is of high importance in garment sewing processes and selection of a proper method of work can result in reducing the time necessary to perform the operations, simplification of the operation structure, higher average stitching speed and higher sewing machine utilization [2].

In 2006, Bayraktar and Kalaoğlu have developed an online measurement and monitoring system to measure dynamic yarn stresses and presser force during the sewing process [7]. Carvalho et al. aimed to develop real-time control and monitoring devices, as well as offline process planning tools for industrial sewing by evaluation of needle penetration forces [8].

The energy consumed during the sewing process is the biggest part of the total energy consumption for the garment industry. Needle penetration and withdrawal forces vary according to sewing parameters and the materials used. These forces contribute to the mechanical load of the machine and consequently to the total energy consumption. The present study approaches the energy consumption issue in a different frame. It is aimed to determine the effect of various sewing parameters such as fabric features, sewing needle size, seam length and sewing speed on the penetration and withdrawal forces and finally on the energy consumption. A measurement and data collection system were developed for the measurement of the energy consumption during the sewing process under variable sewing parameters.

The thorough study and the understanding of the factors affecting the energy consumption during the sewing process is the target of the paper because it is the main way to optimize it and to obtain the minimization of the energy costs. It is worth mentioning that even a small decrease of the energy consumed during the sewing process results in a huge amount of total energy saving if it will be considered that all over the world decades of millions of sewing machines are in daily operation. Therefore, the current study has an additional vision towards the respective environmental benefits.

MATERIALS AND METHOD

Materials

For the sewing experiments, three different types of knitted fabrics have been chosen; two knitted-based laminated fabrics with different lamination characteristics. The laminated fabrics are affecting the sewing machine load because of fabric hardness and higher needle penetration force. Therefore, two different types of laminated single jersey fabric were compared with each other and also with a cotton jersey knitted fabric was used as reference material.

The fabric types used for the experiments are shown in figure 1.

The sewing experiments were made on a full automatic 301 lockstitch machine, equipped with a direct drive servo motor.

Two different needle sizes of the types DP*5 (134R) 80 Nm and DP*5 (134R) 110 Nm were used since the size of the needles is considered as one of the main sewing parameters. These needles have the same (SUK) needlepoint shape. A standard 150 dtex*2 core-spun PES sewing thread was used for all sewing experiments.

The physical characteristics and the properties of the fabrics were measured using instruments and testers

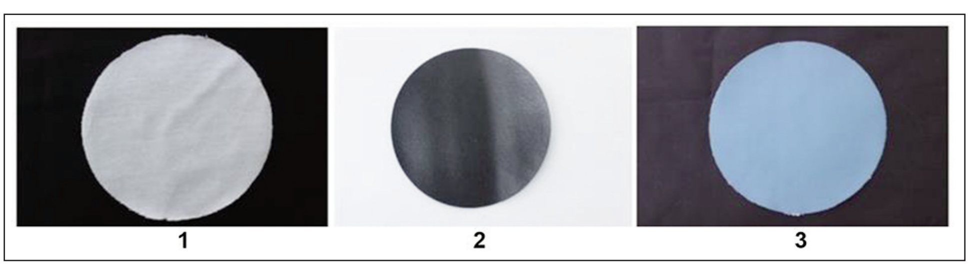

Fig. 1. Fabric types: *1* – 100% Cotton Single Jersey (CO); *2* – PES Single Jersey with PE-PUR lamination (PES-PE/PUR); *3* – PES Single Jersey with PUR lamination (PES-PUR)

like a precision balance, Shirley hardness tester, loop length and L&M Sewability tester for the measurement of the fabric weight per unit area, fabric density and sewability correspondingly. These values are related to machine sewing load and needle penetration force. Measurements were taken using these devices in order to correlate the increasing machine load with energy consumption.

Method

In this study, the effect of needle size, seam length, sewing speed and their interactions to energy consumption has been examined. The investigation was based on the use of the data logger system connected to the sewing machine. Factorial trials design was chosen for the design of the experiment.
The mechanical and physical properties of the fabrics were investigated in order to characterize the fabric types used in this study. After the definition of the fabric properties, sewing operations were performed with different parameters. Energy consumption was measured and the data were collected by the developed system. The data collected were analysed statistically, after the sewing experiments.
The sewing experiments were based on four variable groups:
• 3 different fabric types;
• 2 different needle sizes (80 and 110 Nm);
• 2 different seam lengths (20 and 40 cm);
• 2 different sewing speeds (1500 and 3000 rev/min).
Seam length and sewing speed values were kept constant through the control system of the sewing machine. After adjustments, 2 layers of fabrics have been sewn linearly, through lengthwise grainline (wales) direction. Electric energy data (operating current and voltage of the machine) were measured and collected under these different sewing conditions. Since the operating voltage is constant, the electric power and energy consumed have been estimated based on the measurement of the electric current.
A data collection system has been specially designed for the measurement of the actual electrical performance of the sewing machine under real conditions, during the sewing process. The system consists of the following units:
• Current sensor;
• Voltage sensor;
• Data logger unit;
• Interface and communication unit;
• Personal computer.
The current and voltage measuring and data collection system (data logger) were set up between the machine and the power supply during the sewing operations (figure 2). The data logger was designed to get 350 samples per second. A data cable was connecting the data logger and the computer for the data transfer. The data were transferred and saved in text format using the Hyperterminal program.
The stored data were imported into the Excel program for further data processing. The saved non-valid data before the start of the sewing operations and the corresponding data after the end of the sewing operations, which contain thread trimming and presser foot lifting, were deleted (figure 3). The average electrical current value was calculated for every single test and for each experimental group.
The measurements were repeated five times for each of the 24 fabric samples combinations according to the experiment design in order to perform the variation analysis. The statistical analysis of the 120 obtained waveforms corresponding to the respective sewing tests has been performed using PASW 25.0 software package.

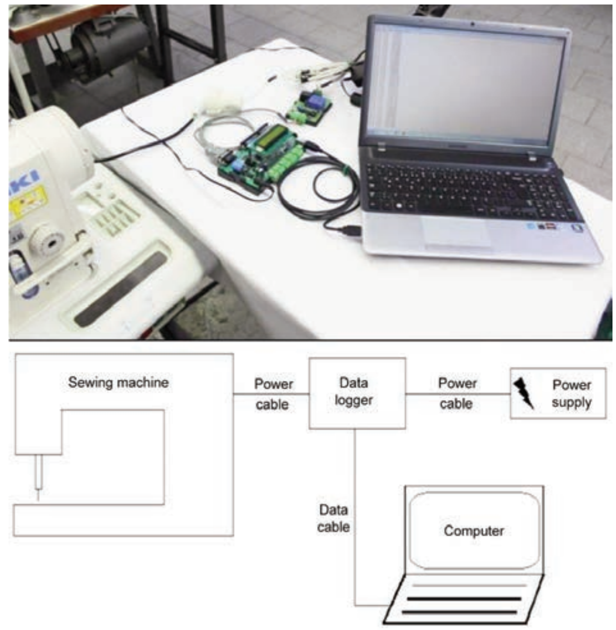

Fig. 2. General and schematic view of the data logging system

RESULTS AND DISCUSSION

The technical characteristics of the three different fabric types used for the sewing experiments, such as fabric mass per unit area, the density of wales and courses and sewability values are shown in tables 1 and 2.
The average current values, used for statistical analysis, resulted from the measurements during the actual sewing process. The current fluctuation during the actual sewing process corresponds to area 1 in figure 3. The average current values given in table 3

Table 1

STRUCTURAL CHARACTERISTICS OF FABRICS			
Sample	**1**	**2**	**3**
Fabric composition	CO	PES-PE/PUR	PES-PUR
Fabric mass per unit area (gr/m²)	144.15	194.7	376.2
Wales density (wales per cm)	14	13	11.5
Courses density (courses per cm)	21	17	8.5

Table 2

THE SEWABILITY VALUES OF FABRICS			
Sample	**1**	**2**	**3**
Fabric composition	CO	PES-PE/PUR	PES-PUR
Threshold value (gf)	50	50	150
Average sewability value	45.33	100	98.67
Average penetration force (gf)	118.67	446	234.33

include only the data of that area. The non-valid data before and after sewing operations corresponding to the thread trimming and presser foot lifting were filtered and removed before any calculation.

The average current values of the measurements on the five specimens per sample for the various combinations of fabric type, needle size, sewing speed and seam length are given in table 3.

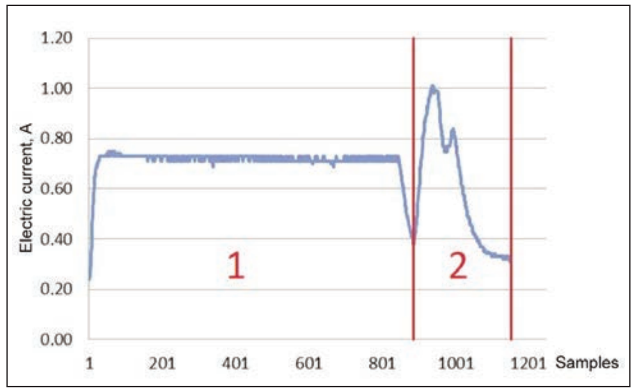

Fig. 3. Typical layout of the current waveform (testing group 1); actual measurements (1) and thread trimming-presser foot lifting area (2)

Table 4 shows the statistical data of the current values on the total of the 120 individual specimens for the various combinations of the independent variables.

Table 3

AVERAGE CURRENT PER EXPERIMENTAL GROUP						
Group	**Sample no.**	**Composition**	**Needle size (Nm)**	**Sewing speed (rev/min)**	**Seam length (cm)**	**Average current values (A)**
1	1	CO	80	1500	20	0.71
2	1	CO	80	1500	40	0.73
3	1	CO	80	3000	20	1.10
4	1	CO	80	3000	40	1.14
5	1	CO	110	1500	20	0.76
6	1	CO	110	1500	40	0.77
7	1	CO	110	3000	20	1.11
8	1	CO	110	3000	40	1.16
9	2	PES - PE/PUR	80	1500	20	0.71
10	2	PES - PE/PUR	80	1500	40	0.70
11	2	PES - PE/PUR	80	3000	20	1.09
12	2	PES - PE/PUR	80	3000	40	1.13
13	2	PES - PE/PUR	110	1500	20	0.75
14	2	PES - PE/PUR	110	1500	40	0.76
15	2	PES - PE/PUR	110	3000	20	1.10
16	2	PES - PE/PUR	110	3000	40	1.14
17	3	PES - PUR	80	1500	20	0.73
18	3	PES - PUR	80	1500	40	0.72
19	3	PES - PUR	80	3000	20	1.10
20	3	PES - PUR	80	3000	40	1.15
21	3	PES - PUR	110	1500	20	0.75
22	3	PES - PUR	110	1500	40	0.75
23	3	PES - PUR	110	3000	20	1.11
24	3	PES - PUR	110	3000	40	1.17

Table 4

DESCRIPTIVE STATISTICS OF THE CURRENT VALUES						
Parameter	**No. of specimens**	**Min value**	**Max value**	**Average**	**Std. Dev.**	**Variance**
Electric current (A)	120	0.69	1.18	0.93	0.20	0.04

Table 5

ANALYSIS OF VARIANCE	
Data Source	**Significance p**
Corrected Model	0
Intercept	0
Fabric type	0
Needle size	0
Sewing speed	0
Seam length	0
Fabric type * Needle size * Sewing speed * Seam length	0.003
Fabric type * Needle size * Sewing speed	0
Fabric type * Needle size * Seam length	0.684
Fabric type * Sewing speed * Seam length	0.003
Needle size * Sewing speed * Seam length	0.46
Fabric type * Needle size	0
Fabric type * Sewing speed	0.022
Fabric type * Seam length	0.145
Needle size * Sewing speed	0
Needle size * Seam length	0.051
Sewing speed * Seam length	0

The univariate analysis of variance is presented in table 5 and from the data given; the significant influence of the parameters and the combinations of them is resulting.
The following parameter combinations correspond to higher values of the significance p:
- Needle size & Fabric type & Seam length $p = 0.684$
- Needle size & Sewing speed & Seam length $p = 0.460$
- Seam length & Fabric type $p = 0.145$
- Needle size & Seam length $p = 0.051$

meaning that their interactions are insignificant at the error level of 5%, i.e., they don't have any effect on current values. Nevertheless, a p-value of 0.051 for the "Needle size & Seam length" effect is sufficient to suggest that this interaction has no effect on electric current values, but the characterization can be considered as marginal.
On the contrary, the significance p has lower values for the following parameters and their combinations:
- Needle size $p = 0$
- Sewing speed $p = 0$
- Seam length $p = 0$
- Fabric type $p = 0$
- Fabric type & Needle size & Sewing speed & Seam length $p = 0.003$
- Fabric type & Needle size &Sewing speed $p = 0$
- Fabric type & Sewing speed & Seam length $p = 0.003$
- Fabric type &Needle size $p = 0$
- Needle size &Sewing speed $p = 0$
- Sewing speed & Seam length $p = 0$.

These p values indicate that the related factors are important at the level of 1% ($p < 0.01$), i.e., these variables affect the dependent value of the electric current.
Additionally, for one combination of parameters
- Fabric type &Sewing speed $p = 0.022$

the p-value shows that this interaction has an effect on the electric current value at a 5% error level.
According to the previous detection of the most significant factors, an investigation of the corresponding experimental results has been made. The obtained data have been studied in order to examine the nature of the dependence between the various factors and the energy consumption on the physical level apart from the statistical one.
In terms of nominal amplitude current values, the most intense variation was caused by the change of the sewing speed. By the increase of the sewing speed, a respective increase of the electric current appears. A representative example is given in figure 4. In qualitative terms double sewing speed doubles, the nominal electric current.

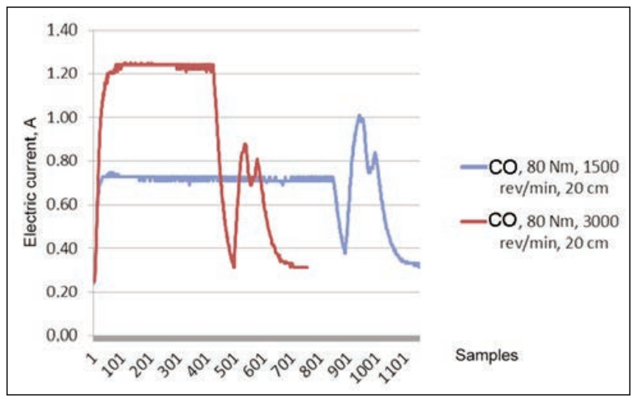

Fig. 4. Electric current vs sewing speed

This finding at a first glance is of minor importance since the energy consumed in both cases is the same, since the double speed and the double electric current consumption results in the completion of the sewing phase in half of the time needed for the low speed. However, a more detailed quantitative investigation gives interesting results. In the following table 6, I_{1500} and I_{3000} denote the electric current consumption of the sewing machine at 1500 and 3000 revolutions per minute.
Table 6 presents the electric current consumption in different combinations of materials, needles and lengths for 1500 and 3000 rpm for every case. Although it was expected that the ratio I_{3000}/I_{1500} should be 2, however, the nature of the transient phenomena and the machine mechanical characteristics, mass and inertia results in a lower ratio of the currents. According to that data, the operation of the sewing machine at higher speeds for the same material, same needle and same sewing length is less energy-consuming.
Concerning the effects of seam length, the respective measurements are given in table 7. It is obvious that

Table 6

ELECTRIC CURRENT VS SEWING SPEED			
Parameters	I_{1500}(A)	I_{3000}(A)	I_{3000}/I_{1500}
CO, Needle: 80 Nm, Length: 20 cm	0.71	1.1	1.55
CO, Needle: 80 Nm, Length: 40 cm	0.73	1.14	1.56
CO, Needle: 110 Nm, Length: 20 cm	0.76	1.11	1.46
CO, Needle: 110 Nm, Length: 40 cm	0.77	1.16	1.51
PES – PE/PUR, Needle: 80 Nm, Length: 20 cm	0.71	1.09	1.54
PES – PE/PUR, Needle: 80 Nm, Length: 40 cm	0.7	1.13	1.61
PES – PE/PUR, Needle: 110 Nm, Length: 20 cm	0.75	1.1	1.47
PES – PE/PUR, Needle: 110 Nm, Length: 40 cm	0.76	1.14	1.50
PES – PUR, Needle: 80 Nm, Length: 20 cm	0.73	1.1	1.51
PES – PUR, Needle: 80 Nm, Length: 40 cm	0.72	1.15	1.60
PES – PUR, Needle: 110 Nm, Length: 20 cm	0.75	1.11	1.48
PES – PUR, Needle: 110 Nm, Length: 40 cm	0.75	1.17	1.56

Table 7

ELECTRIC CURRENT VS SEAM LENGTH			
Parameters	I_{20cm}(A)	I_{40cm}(A)	I_{20cm}/I_{40cm}
CO, Needle: 80 Nm, 1500 rpm	0.71	0.73	1.03
CO, Needle: 80 Nm, 3000 rpm	1.1	1.14	1.04
CO, Needle: 110 Nm, 1500 rpm	0.76	0.77	1.01
CO, Needle: 110 Nm, Length: 40 cm	1.11	1.16	1.05
PES – PE/PUR, Needle: 80 Nm, 1500 rpm	0.71	0.7	0.99
PES – PE/PUR, Needle: 80 Nm, 3000 rpm	1.09	1.13	1.04
PES – PE/PUR, Needle: 110 Nm, 1500 rpm	0.75	0.76	1.01
PES – PE/PUR, Needle: 110 Nm, 3000 rpm	1.1	1.14	1.04
PES – PUR, Needle: 80 Nm, 1500 rpm	0.73	0.72	0.99
PES – PUR, Needle: 80 Nm, 3000 rpm	1.1	1.15	1.05
PES – PUR, Needle: 110 Nm, 1500 rpm	0.75	0.75	1.00
PES – PUR, Needle: 110 Nm, 3000 rpm	1.11	1.17	1.05

the ratio of the electric current for the two different sewing lengths of 20 and 40 cm is close to the unity with marginal deviations of a maximum of 5%, which can be explained as belonging to the extent of the random occurring deviations and measurements errors.

It is shown in the following figure 5, the graph of the variation of the electric current of a representative testing case for Cotton, needle 110 Nm and 1500 rpm. During the use of different needles 80 and 110 Nm considerable variation of the average current consumption. The thicker the needles, the higher the mechanical resistance during the penetration of the needle, so the load on the machine and the average current is increased.

According to the data of table 8, it is verified that the electric current consumed when bigger needles are used is systematically higher than when a smaller needle is used. However, the increase of the mean power consumed is in the range of 1–9% (figure 6).

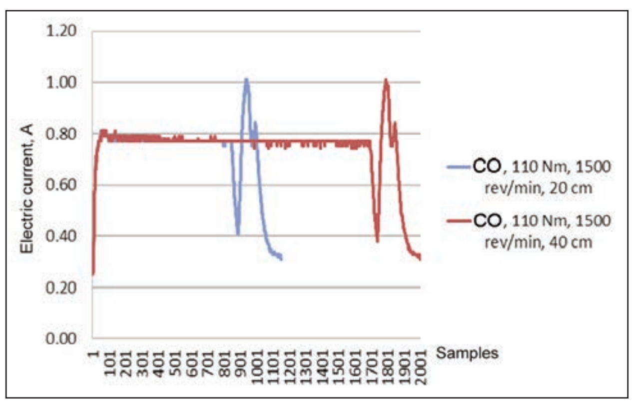

Fig. 5. Electric current vs seam length

The dependency of the electric current and consequently the power consumed depends also on the mass per unit area of the fabrics. Table 9 presents the related data.

The received data indicate that the electric current i.e., power consumed, is almost constant for the

Table 8

ELECTRIC CURRENT VS NEEDLE SIZE			
Parameters	I_{80Nm}(A)	I_{100Nm}(A)	I_{80Nm}/I_{100Nm}
CO, Length: 20 cm, 1500 rpm	0.71	0.76	1.07
CO, Length: 40 cm, 1500 rpm	0.73	0.77	1.05
CO, Length: 20 cm, 3000 rpm	1.1	1.11	1.01
CO, Length: 40 cm, 3000 rpm	1.11	1.16	1.05
PES – PE/PUR, Length: 20 cm, 1500 rpm	0.71	0.75	1.06
PES – PE/PUR, Length: 40 cm, 1500 rpm	0.7	0.76	1.09
PES – PE/PUR, Length: 20 cm, 3000 rpm	1.09	1.1	1.01
PES – PE/PUR, Length: 40 cm, 3000 rpm	1.13	1.14	1.01
PES – PUR, Length: 20 cm, 1500 rpm	0.73	0.75	1.03
PES – PUR, Length: 40 cm, 1500 rpm	0.72	0.75	1.04
PES – PUR, Length: 20 cm, 3000 rpm	1.1	1.11	1.01
PES – PUR, Length: 40 cm, 3000 rpm	1.15	1.17	1.02

Table 9

ELECTRIC CURRENT VS MASS PER UNIT AREA			
Parameters	**CO**	**PES - PE/PUR**	**PES - PUR**
Length: 20 cm, 1500 rpm, Needle 80 Nm	0.71	0.71	0.73
Length: 20 cm, 1500 rpm, Needle 110 Nm	0.76	0.75	0.75
Length: 20 cm, 3000 rpm, Needle 80 Nm	1.1	1.09	1.1
Length: 20 cm, 3000 rpm, Needle 110 Nm	1.11	1.1	1.11
Length: 40 cm, 1500 rpm, Needle 80 Nm	0.73	0.7	0.72
Length: 40 cm, 1500 rpm, Needle 110 Nm	0.73	0.7	0.75
Length: 40 cm, 3000 rpm, Needle 80 Nm	1.14	1.13	1.15
Length: 40 cm, 3000 rpm, Needle 110 Nm	1.11	1.1	1.11

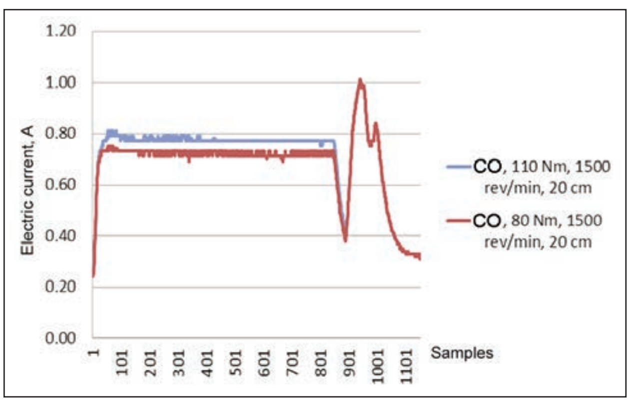

Fig. 6. Electric current vs needle size

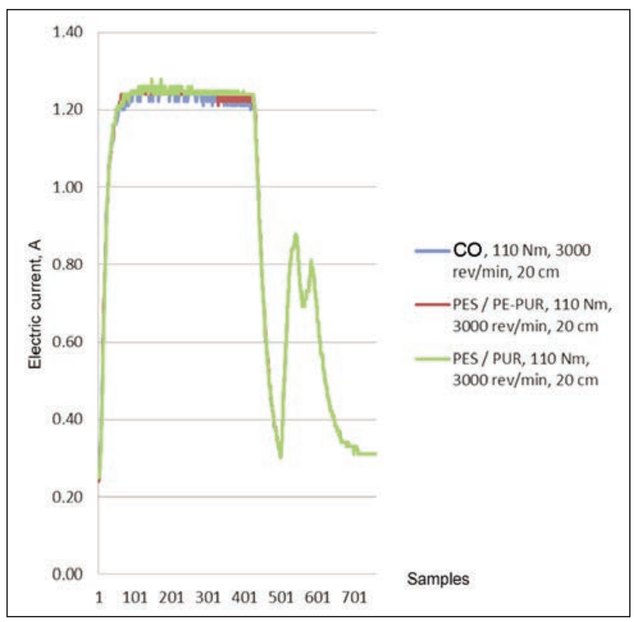

Fig. 7. Electric current vs fabric type

three categories of fabrics and for every combination of the other parameters. It seems that the mass of the moving parts of the sewing machine and the related inertia is of a size that permits the operation of the sewing machine in a sense that the load variations due to the different mass per unit area values do not affect considerably the power consumption (figure 7). In the above graph of a representative case (3000 rpm, 20 cm sewing length and needle type 110Nm) the similarity of the three curves is obvious. That similarity covers not only the steady-state regions but also the transient phenomena.

Studies in the literature have focused on the correct material matching (especially thread – fabric – sewing needle). In this study, the effects of the correct material and parameter selection on energy consumption were examined besides the material matching before sewing. Material selection is more than just an issue affecting production quality. The correct use of energy resources in increasing production rates is important in terms of both production costs and environmentally friendly production.

CONCLUSION

The sewing tests have included the total of the major parameters influencing the operation of the sewing machine. A general result of the evaluation and the statistical elaboration of the power measurements indicate that the sensitivity of the electric power versus the various parameters is extremely limited. The only valuable difference comes in the case of the sewing speed, where the higher speed results in lower power consumption.

The nature of the results and the evaluation of the data received, enable the further investigation of the process and it promotes the importance of the electronic measurement system developed. The system made possible the detection of the real operating conditions of the sewing machine and it will be used in future experiments.

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Development of a hat style recognition system based on image processing and machine learning

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ABSTRACT – REZUMAT

Development of a hat style recognition system based on image processing and machine learning

The purpose of this paper is to investigate the recognition mechanism of hat styles and develop a corresponding hat style recognition system (HSRS). An image processing and machine learning integrated method (IPML) is proposed and validated for automatic hat style recognition. First, 4 kinds of hat styles (borderless knitted hats, berets, top hats and peaked hats) with 800 pictures are employed as research objects and divided into two categories: the first 400 serve as the training set and the rest 400 as the test set. Then, IPML is proposed to obtain a hat silhouette. Curvature feature points are extracted from hat silhouette and further used as parameters for the automatic hat style recognition. In the real recognition process, a new case is compared with the pre-set 400 samples in the training set regarding these characteristic parameters. A Hausforff distance-based similarity measurement tool is used in the comparison process. The experimental results show that when the curvature feature points are 70 and the output results are 3, the average recognition accuracy rate can reach 90.5%, of which the value of borderless knitted hats is the highest with 98% and followed by the top hats with 95%. This work can be used for hat recommendation systems. It can also be extended to support the area of personalized industrial product design such as fashion design, furniture design and advertisement design.

Keywords: *image processing, hat style, Hausdorff distance, curvature characteristic, automatic recognition*

Dezvoltarea unui sistem de recunoaștere a stilului de pălărie bazat pe procesarea imaginilor și învățarea automată

Scopul acestei lucrări este de a investiga mecanismul de recunoaștere a stilurilor de pălărie și de a dezvolta un sistem de recunoaștere a stilului de pălărie (HSRS). Este propusă și validată o metodă integrată de procesare a imaginii și învățare automată (IPML) pentru recunoașterea automată a stilului de pălărie. În primul rând, 4 tipuri de stiluri de pălării (tricotate fără bor, berete, jobene și chipie) cu 800 de imagini sunt folosite ca obiecte de cercetare și împărțite în două categorii: primele 400 servesc ca set de instruire, iar restul de 400 ca set de testare. Apoi, se propune IPML pentru a obține o siluetă de pălărie. Punctele caracteristice de curbură sunt extrase din silueta pălăriei și utilizate în continuare ca parametri pentru recunoașterea automată a stilului. În procesul de recunoaștere reală, un nou caz este comparat cu cele 400 de eșantioane prestabilite din setul de instruire, în ceea ce privește acești parametri caracteristici. În procesul de comparare este utilizat un instrument de măsurare a similitudinii bazat pe distanța Hausforff. Rezultatele experimentale arată că, atunci când punctele caracteristice de curbură sunt 70 și rezultatele de ieșire sunt 3, rata medie de acuratețe a recunoașterii poate ajunge la 90,5%, dintre care valoarea căciulilor tricotate fără bor este cea mai mare, cu 98% și urmată de jobene cu 95%. Această lucrare poate fi folosită pentru sistemele de recomandare a pălăriilor. De asemenea, poate fi extinsă pentru a sprijini zona de design personalizat a produselor industriale, cum ar fi designul vestimentar, designul mobilierului și designul publicitar.

Cuvinte-cheie: *procesarea imaginii, stil de pălărie, distanță Hausdorff, caracteristică de curbură, recunoaștere automată*

INTRODUCTION

In recent years, with the rapid development of e-commerce, the transaction scale and penetration rate of online clothing shopping have been continuously improved [1]. The sales of online clothing mainly depend on the quality of product images to show and transmit product information [2–4]. Consumers choose their favourite styles and products according to the pictures provided by the merchants [5]. However, the current search on the online shopping platform is still based on text, which has wasted a lot of time and labour on the text labelling of products. Besides, the ability of text to describe products is limited and the text does not have a uniform standard, especially for non-standard consumer products such as clothing [6]. These reasons not only decrease the efficiency of online shopping but also make consumers more bored and even give up shopping during an online search. Therefore, it is necessary to realize the image retrieval of products to identify the clothing styles that the consumers want, which greatly improves the convenience of online shopping and enhances the consumers' desire to purchase [7].

Nowadays, the development of digital image technology has made this demand possible. There are many studies focusing on how to use image technology to realize the automatic recognition of clothing styles. For example, Juan and her co-workers combined the clothing local histogram of oriented gradients (HOG) features with key dimensions to realize the style classification [8]. An et al. proposed a fast and reliable method by adopting wavelet Fourier descriptor, liner discriminant analysis and extreme learning machine to handle multi-class fashion flat sketches classification problems [9]. Hou et al. used the combination of Hu invariant moments and Fourier descriptors to describe the contour features of the garment [10]. However, these shape feature descriptors cannot visually correspond to the contour of the garment. To solve this problem, Li et al. detected the peak value of each point curvature of the garment contour and selected the point with the largest peak to form a feature point set to describe the garment, which achieved the recognition of the clothing style [11]. On the other hand, there have been some studies on image recognition of clothing styles, but few methods have involved computer automatic identification of clothing accessories [12, 13]. Accessories play an indispensable role in clothing. Among them, the hat is one of the most popular clothing items for women. Therefore, the research on automatic recognition technology of hat style not only promotes the efficiency and practical values of image recognition technology in e-commerce but also contributes to the development of clothing intelligent matching recommendation system.

METHODOLOGY

In this paper, an image processing (IP) and machine learning (ML) integrated method (IPML) is developed to support the recognition process. In the recognition process, an IP method will be first used to obtain the contour curve of the pending hat image. After this procedure, a clean and smooth curvature of the involved hat can be obtained. Then, an extraction method will be applied to obtain the feature points of the pending sample. Then these feature points will be processed through a ML method and compared with the feature points of the pre-processed samples in a pre-defined Learning Sample Library (LSL). The style information of the learning sample in the LSL that has the most similar feature points will be utilized as the result of the pending sample.

Working principle of the proposed system

The working principle of the proposed hat style recognition system (HSRS) is based on IPML. The general working process of the proposed system is presented in figure 1.

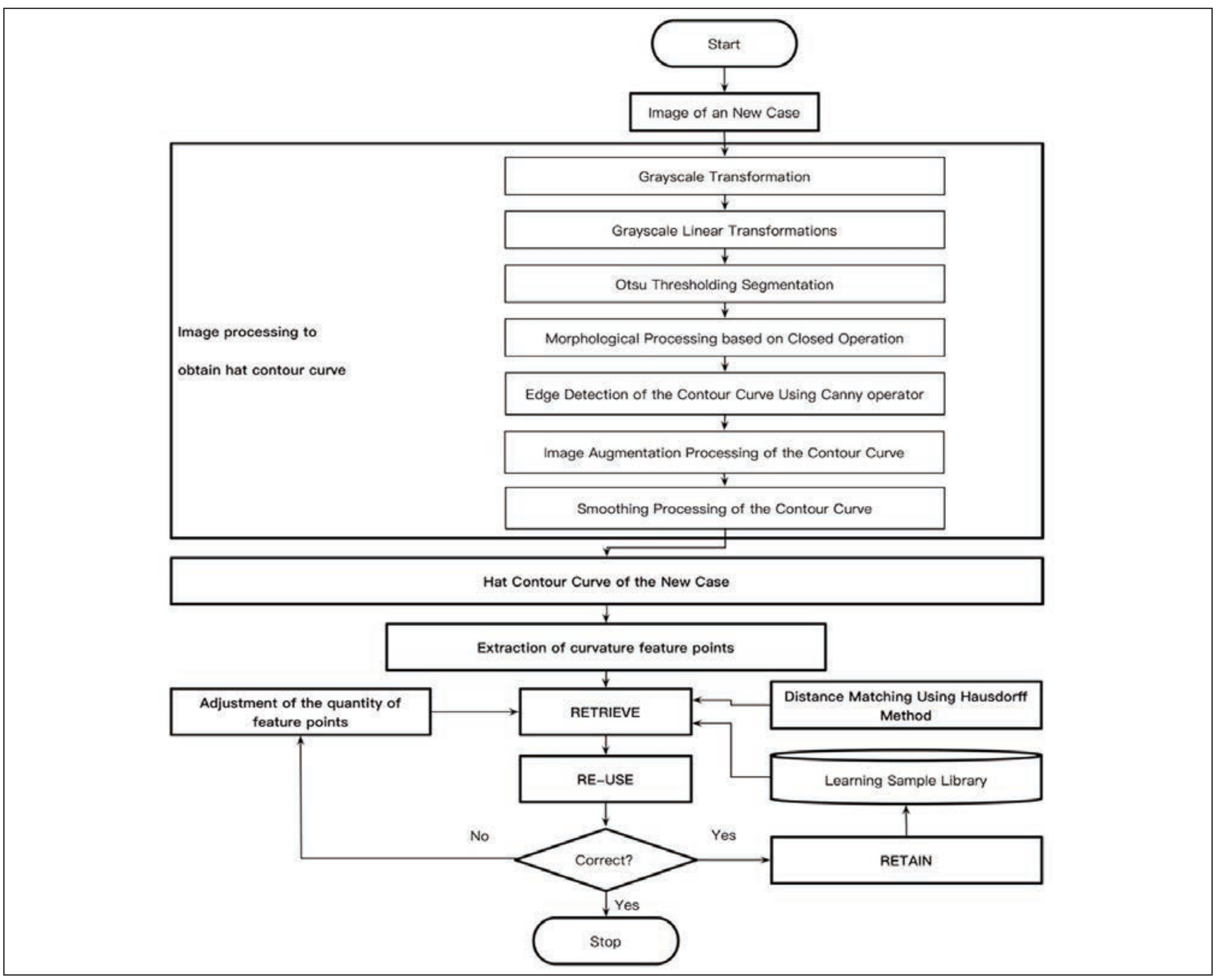


Fig. 1. Flow chart of automatic recognition process of hat style

The IP method includes Greyscale Transformation, Greyscale Linear Transformations, Otsu Thresholding Segmentation, Morphological Processing Based on Closed Operation, Edge Detection Using Canny operator, Image Augmentation Processing, Smoothing Processing of the Contour Curve, and Feature Points Extraction Method. Through these operations, we can first obtain a clean and smooth contour curve of the pending images of any hat, and then the feature points of the contour curves of these hats can also be obtained. There are two functions of the IP method: (1) processing the learning samples in the LSL, and (2) processing the new pending case.

In the recognition process, the IP method will be used to obtain the contour curve of the pending hat image. After this procedure, the feature points of the pending sample can be obtained. Then ML method will be used. There is a pre-defined LSL and the pre-processed hat samples together with their corresponding feature points will be stored inside the LSL. In the real recognition process, the Hausdorff distance method will be used. The pending sample will be compared with those samples which are stored in the LSL. The sample with the highest similarity will be utilized as the learning sample, whose style will be used as the result of the pending sample. When the similarity is below the threshold of 80%, the number of extracted feature points and output results will be adjusted until it is higher than 80%.

Related concepts, processing methods and their principles

The principles, detailed steps and corresponding results of IP used in the HSRS are shown in figure 2. The greyscale transformation process is performed at the beginning stage of the image processing procedure. It is carried out in order to highlight the hat part in the hat image, and also fade the extra background part [14]. Through the greyscale transformation procedure, the image to be processed will be only with black and white pixels, which is easier to facilitate the image segmentation between the hat part and the background, as shown in figure 2, (A). The greyscale transformation is realized in MATLAB R2014a. The greyscale transformation classifies the pixels of the image through the threshold setting. The selection of different threshold settings will affect the effect of greyscale transformation. Let $f(x, y)$ be the image to be processed, and we need to find a threshold A to divid this image. Using the pre-defined threshold A, the image to be processed can be divided into two parts:

$$g(x, y) = \begin{cases} a_0 & f(x, y) \leq A \\ a_1 & f(x, y) \geq A \end{cases} \quad (1)$$

If we let $a_0 = 0$ (black) and $a_1 = 1$ (white), the image to be processed will be converted into an image with only black and white pixels. The greyscale liner transformation process is carried out after the greyscale

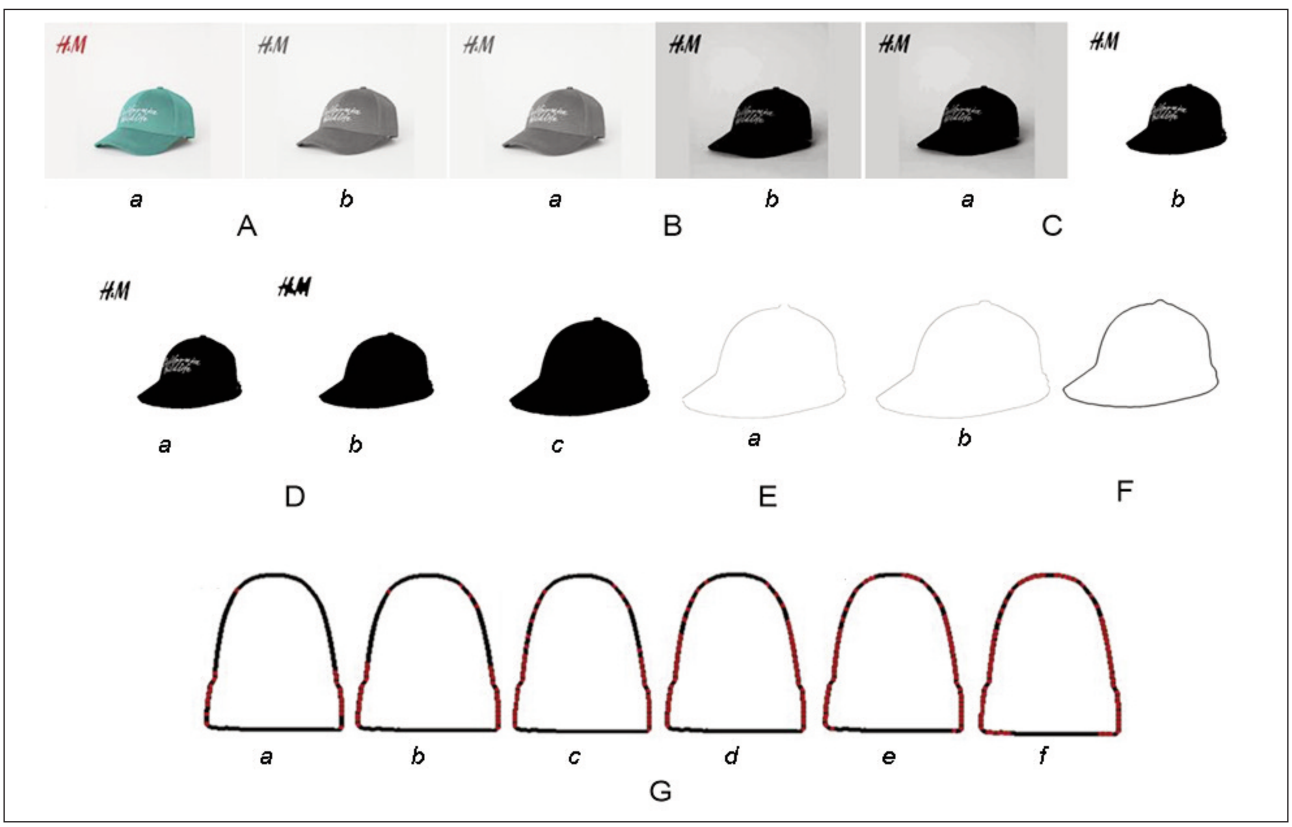


Fig. 2. (A) Greyscale transformation of hat image: *a* – original image; *b* – greyscale; (B) Greyscale liner transformation of hat image: *a* – before; *b* – after; (C) Otsu thresholding segmentation of hat image: *a* – greyscale linear image; *b* – binary image; (D) Morphological process based on closed operation of hat image: *a* – binary image; *b* – morphological closure image; *c* – maximum area image; (E) Image augmentation processing: *a* – before; *b* – after; (F) Contour after curve smoothing process; (G) Extracted feature points of borderless knitted hat: *a* – 20; *b* – 30; *c* – 40; *d* – 50; *e* – 60; *f* – 70

transformation process. The grey value of the image obtained by the greyscale transformation process is sometimes concentrated in a small range due to underexposure or overexposure, resulting in the situation where the grey level of the image is not obvious, and the image clarity is not high [15]. This procedure aims to use linear functions to extend the pixels of the image to improve the blurry situation of the image and make the greyscale of the image clear, as shown in figure 2, (B). The greyscale liner transformation is performed in MATLAB R2014a. If the greyscale range of $f(x, y)$ is $[a, b]$, the greyscale range of the transformed image of $g(x, y)$ will be extended to [c, d], then the linear transformation can be expressed as:

$$g(x, y) = \frac{d - c}{b - a}[f(x, y) - a] + c \qquad (2)$$

Where a and b are the minimum and maximum values of the image brightness, respectively; c and d respectively correspond to the maximum value after the transformation. Set the maximum grey level of the image as L. In order to enhance the display effect of the image, the grey value in the $[a, b]$ can be converted to the $[c, d]$ as follows:

$$g(x, y) = \begin{cases} c & 0 \le f(x, y) < a \\ \frac{d - c}{b - a}[f(x, y) - a] + c & a \le f(x, y) \le b \\ d & b < f(x, y) < L \end{cases} \qquad (3)$$

After the greyscale liner transformation of the hat image, the hat and the image background occupy different greyscale ranges. In order to realize the division of hat and background, thresholding segmentation technology can classify the greyscale value of the hat image by dividing the pixels with the same greyscale range into the same area. This process is achieved using the maximum inter-class method (also known as Otsu method) to obtain the image threshold, which is a widely used, easy to calculate, stable and effective method [16]. The main principle is to divide the image histogram into two groups at a certain threshold. When the variance of these two groups is the largest, the threshold of segmentation is obtained. This process can separate the hat from the background, by converting the background with a lower greyscale to white, while the hat with a higher greyscale value is retained, as shown in figure 2, (C). Closed operation is one of the basic operations of morphology, which can eliminate the narrow discontinuities and gaps and fill the small holes in the image. Meanwhile, the maximum area of the hat image needs to be extracted based on closed operation in order to filter unnecessary information, such as logo pattern and facilitate the next contour extraction, shown in figure 2, (D). The morphological processing based on the closed operation is also realized in MATLAB R2014a. The edge is one of the most basic features of the image. It exists at the junction of one area of the image and another attribute area. It is the most concentrated place of image information, and often contains most of the information of an image [17]. The edge detection process is performed at the middle stage of the image processing procedure. It is a necessary and important step to identify the hat style in this study because the edge can outline the shape of the hat, which is convenient for subsequent processing. The Canny operator has been widely used due to its excellent performance [18]. It uses a Gaussian filter to reduce noise on the image, which makes the position error of the actual edge and the detected edge very small and then performs non-maximum suppression, which can exclude some non-edge interference, and finally uses a double threshold to determine whether to keep the edges, which can ensure that false edges are not detected. The edge detection using Canny operator is carried out in MATLAB R2014a. The image augmentation process is performed after the edge detection of hat image using Canny operator. When extracting contour lines of the hat image, it is easy to produce discontinuous edges of the image. Therefore, it is necessary to augment the surroundings of the image to ensure the integrity of the extracted curve, as shown in figure 2, (E). The image augmentation process is performed in MATLAB R2014a.

Due to the influence of noise and image digitization errors, the extracted contour lines will appear to be not smooth. In order to prevent these impacts on subsequent experiments, the extracted contour curve obtained after the augmentation processing needs further to be smoothed. The smoothing of the curve can be obtained by spatial domain filtering and frequency domain filtering, but the latter is widely used because it is not affected by the image size. Here, the two-dimensional discrete Fourier transform in the frequency domain is used to smooth the curve, since it can convert the image from the spatial domain to the frequency domain, and has been widely used in image enhancement, image edge detection, and image denoising [19]. The hat outline image of $f(x, y)$ with the size $M \cdot N$ is defined by its two-dimensional discrete Fourier transform $F(u, v)$ as follows:

$$F(u, v) = \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x, y)\, e^{-j2\pi(ux/M + vy/N)} \qquad (4)$$

Where $u = 0,1,2,\ldots, M-1$ and $v = 0,1,2,\ldots, N-1$ determine the size of the frequency region $M = N$, $F(u, v)$ represents the value of each frequency point (u, v). The definition of inverse Fourier transform is as follows:

$$f(x, y) = \frac{1}{MN} \sum_{u=0}^{M-1} \sum_{v=0}^{N-1} F(u, v)\, e^{j2\pi(ux/M + vy/N)} \qquad (5)$$

The smooth process is performed in MATLAB R2014a. As can be seen in figure 2, (F), the contour image after the frequency domain filtering process keeps the original details and becomes smooth without small fluctuations and noise, which is conducive to the extraction of characteristic points of the curve later. The contour feature points are the most basic elements representing the shape of the object. The shape can be accurately described by the contour line, and the curvature is an important feature for determining the shape of the curve [20]. Therefore, the extracted curvature of hat image is selected as the feature vector for hat style recognition. The number of curvature feature points is marked as n. After a series of processing of hat images, the obtained contour curves are stored in the form of pixel coordinates in the computer. The coordinates of the contour point is shown as $d(k) = (x_k, y_k)$, where x_k represents the abscissa of pixel point, and y_k represents the ordinate of the pixel point. The curvature value of feature points can be obtained by calculation. The curvature K of the curve $y = f(x)$ at point M is:

$$K = \frac{|y''|}{(1 + y'^2)^{3/2}} \tag{6}$$

Where y' and y'' represent the first and second derivatives of the curve at point M, respectively. The calculated formula is as follows:

$$Y' = \frac{(y_{k+1} - y_k)}{(x_{k+1} - x_k)} \tag{7}$$

$$Y'' = \frac{(y'_{k+1} - y'_k)}{(x'_{k+1} - x'_k)} \tag{8}$$

The extraction process of the curvature feature points is as follows:

1) Perform the first and second order derivation of the hat outline according to equations 7 and 8, and obtain the curvature value of each point on the contour line by equation 6;

2) Detect the peak curvature values and arrange the results in descending order;

3) Select the largest curvature peaks with 20, 30, 40, 50, 60, 70, 80, 90 points as n to test the recognition accuracy of system, respectively. The highest correctness rate is selected as the extracted feature point. Take the borderless knitted hat as an example, figure 2, (G) shows the result of extracting 20 to 70 feature points (red dots). The extraction of curvature feature points is obtained in MATLAB R2014a.

Hausdorff distance has been widely used as a similarity measure function, since it has strong anti-interference ability and fault tolerance [21]. It can describe the distance between sets. The smaller its value, the similarity between point sets [22]. The Hausdorff distance between two sets A and B can be described as follows:

$$H(A, B) = max\,(h(A, B), h(B, A)) \tag{9}$$

$$\begin{cases} h(A,B) = max\,(a \in A)\, min\,(b \in B)\, \|a - b\| \\ h(B,A) = max\,(b \in B)\, min\,(a \in A)\, \|b - a\| \end{cases} \tag{10}$$

Equation 9 is the basic form of the Hausdorff distance, $H(A,B)$ represents the larger value between $h(A,B)$ and $h(B,A)$; $h(A,B)$ and $h(B,A)$ are the one-way Hausdorff distances between the two sets A and B in formula (10). $h(B,A)$ represents the distance between each point a_n in the A set and the point b_m in the set B closest to the a_n, then sort the closest distances $\|a_n - b_m\|$. The maximum value of $\|a_n - b_m\|$ is the value of $h(A,B)$. Take a hat as an example. A hat image first needs to be pro-treated by a series of IP method on the computer. Then, the feature point set B is obtained and matched with the feature point set A of known samples in the training set by calculating the Hausdorff distance. According to the distance from small to large, the first hat style judgment results with the smallest distance from the point set B are sequentially output. The number of hat style output results is expressed by P. Assume that the P is 5. If there are 4 peaked hats and 1 top hat, the output result of the hat style is peaked cap, which means that the highest proportion of the category is the final recognition result. Besides, considering the fact that the output results are easy to appear with 1:1 at $P = 2$, 3 is chosen as the minimum value of output result to avoid this.

Hats can be divided into many categories according to different criteria, such as seasons and materials, etc. The most common classification of hat is determined by the style. Therefore, we firstly build a hat image sample of four common styles including peaked hats, berets, top hats and borderless knitted hats. 800 pictures as samples are obtained from the internet resource (www.taobao.com). There are 200 pictures in each type of hat. 100 of them are randomly selected as the training set, and the remaining 100 sheets are used as test sets. In order to facilitate the research, a solid color background and a flat single-piece hat is selected.

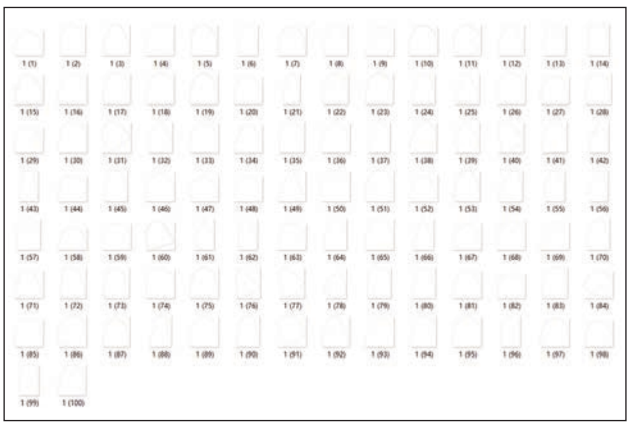
EXPERIMENTS

The purpose of the proposed HSRS is the automatic definition of any hat with four hat styles. In order to realize the proposed system, two experiments are performed. The first one is designed to establish the Learning Sample Library (LSL). The second is intended to evaluate the recognition accuracy of HSRS by testing the stored samples in LSL.

Experiment I: establishment of the Learning Sample Library

There are four common styles of hats, including peaked hats, berets, top hats and borderless knitted hats. In this study, we define the proposed LSL with four sub-libraries: peaked hat library (PL), beret library (BL), top hat library (TL) and borderless knitted hat library (BKL). For each sub-library, we stored 200 samples. 100 of them are randomly selected as the training set, and the remaining 100 sheets are used as test sets. The first 100 training samples first are processed by IP method. Through these operations, the clean and smooth contour curves and corresponding feature points of these hats are obtained. The BKL as an example are shown in figure 3, *a* and *b*. Then, the rest 100 samples are processed and used to validate the learning process. The results show that the overall accuracy of the validation samples for PL, BL, TL and BKL were 83%, 78%, 86% and 91%, respectively. It indicates that the overall accuracy of the learning process is in a generally high level. Next, the unqualified samples for each sub-library are removed from the different libraries

a



b

Fig. 3. Graphical representation of: *a* – original sample images of 100 borderless knitted hats as training set; *b* – extracted contour curves of 100 borderless knitted hats as training set

because they are not representative and it will affect the accuracy of the system for future learning processes. Finally, 100 training samples and the qualified learning samples are all stored in the LSL.

Experiment II: Determination of the quantity of feature points and hat style output

In order to optimize the efficiency of the proposed system, we must determine the quantity of the feature points in the retrieve process. There are two key variables, the curvature feature points (n) and hat style output (P), that will affect the recognition accuracy of the proposed system. Therefore, we use 200 new cases (50 samples for each style) to investigate the ideal quantity of feature points and hat style output. The result is the average accuracy value of the four types of hats, as shown in figure 4. When n is fixed and used to calculate the Hausdorff distance, the first 3, 5, 8 and 10 judgment results with the smallest distance are selected as the final recognition results. As shown in figure 4, the recognition accuracy gradually decreases with the increase of P. The highest recognition accuracy (each value is above 84%) is achieved at $P=3$, while when $P=10$, the recognition accuracy is the most unsatisfactory. This is because the farther the distance is, the smaller the similarity is. Meanwhile, if the output number is too much, it will cause interference on the judgment result, thus affecting the recognition accuracy. When P remains unchanged, the influence of n on the recognition accuracy is investigated by selecting 20, 30, 40, 50, 60, 70, 80 and 90, respectively. In addition, the recognition accuracy for different P fluctuates obviously as the curvature feature points increase. It can be clearly seen that the highest recognition accuracy is achieved with 90.5% at $P=3$ and $n=70$. It may be explained that if there are too few feature points, the extracted image contour is incomplete and the recognition accuracy will be reduced; If there are too many selected feature points, the recognition accuracy will be disturbed by the unimportant points. Therefore, $P=3$ and $n=70$ are used as the final parameter of the identification system.

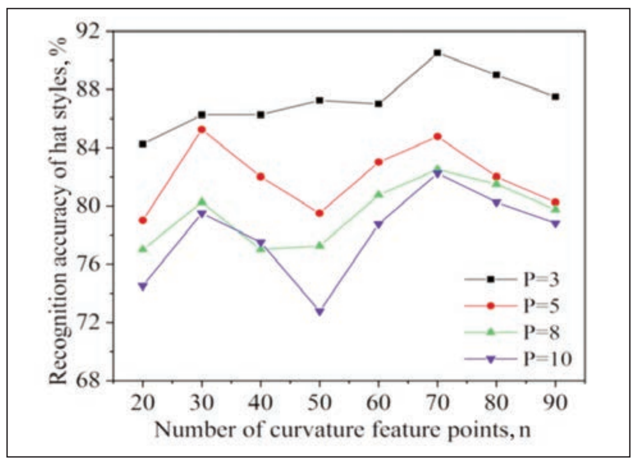


Fig. 4. Recognition results of different parameters

CASE STUDIES

In order to validate the effectiveness of the proposed HSRS, two different cases are discussed. The first case is discussed to show the general working process of an unknown case. The second case study is presented to show how the system will work when the system encounters a recognition result with low accuracy.

Case study I: the presentation of the working process of the recognition of an unknown case

In this case, the proposed system enables to realize a correct recognition of the specific hat style for an unknown hat by IPML. The whole process is as follows: the unknown hat is first processed through the series of operation of the IP method. Then the contour curve and its feature points ($n=70$) of the hat are obtained. Next, these feature points are matched with samples stored in the LSL using the Hausdorff distance method. After the comparisons of all 186 cases in the BKL, BKL93 (figure 5) has the highest similarity with the tested hat with the similarity of 92%, which is higher than the pre-defined threshold of 80%. At the same time, this case will be stored in the BKL as the sample of BKL187. When a new case is similar to BKL187, the BKL186 will be called.

a *b*

Fig. 5. Sample images of: *a* – BKL93; *b* – tested hat

Case study II: the working principle of the system when the system encounters a recognition result with low accuracy

This case is presented to explain the working principle of HSRS when it encounters a recognition result with low accuracy. There are two new samples to be tested and evaluated (named as C1 and C2). The whole process is similar to Case study I. Then, their feature points are obtained and matched with samples stored in the LSL using the Hausdorff distance method. $P=3$ and $n=70$ are used as the discriminant parameters of the proposed system. However, the recognition accuracy of C1 and C2 is 74% and 78%, respectively, which is below the pre-defined threshold of 80%. In order to improve the recognition accuracy, the number of hat style output remains unchanged ($P=3$) and the number of feature points (n) is adjusted by first increasing the number of feature points, such as 75, 80, 85, etc., and then reducing the number of feature points, such as 65, 60, 55, etc. When its recognition accuracy is higher than 80%, stop adjusting and make a judgment. The results show that the recognition accuracy of C1 with 80 feature points and C2 with 65 feature points is 85% and 86%, respectively. Besides, the two samples will be stored in the corresponding library for the next judgment.

Evaluation of the proposed Hat Style Recognition System

In order to evaluate the accuracy of the proposed system, 400 new samples (100 for each style) are carried out and analysed. When $P=3$ and $n=70$, the recognition results of the four hat types are shown in figure 6, (A). It can be seen that the recognition accuracy of the borderless knitted hat is the highest with 98%, followed by the top hat with 95%, while the recognition accuracy of the peaked hat and beret is relatively low, 88% and 81%, respectively. This is due to the fact that the contour curve of the beret is round and simple with fewer inflexion points, and its overall shape is similar to that of the top hat, resulting in recognition errors, as shown in figure 6, (B) [23, 24]. In addition, the peaked cap is easily misidentified as a beret or top hat, because it has more shape and style, compared with those of the other three caps. At the same time, the contour curve of the peaked hat is variable, which leads to great uncertainty in the identification process, thus affecting the final recognition result.

CONCLUSIONS

To achieve the automatic recognition of hat styles, an image processing and machine learning (IPML) integrated method is proposed. 4 kinds of hat styles with 800 pictures (borderless knitted hats, berets, top hats and peaked hats) are created as research samples, including 400 training sets and 400 test sets. After obtaining a smooth and complete contour curve by a series of pre-processing, the curvature feature points of the hat profile are extracted as the feature values

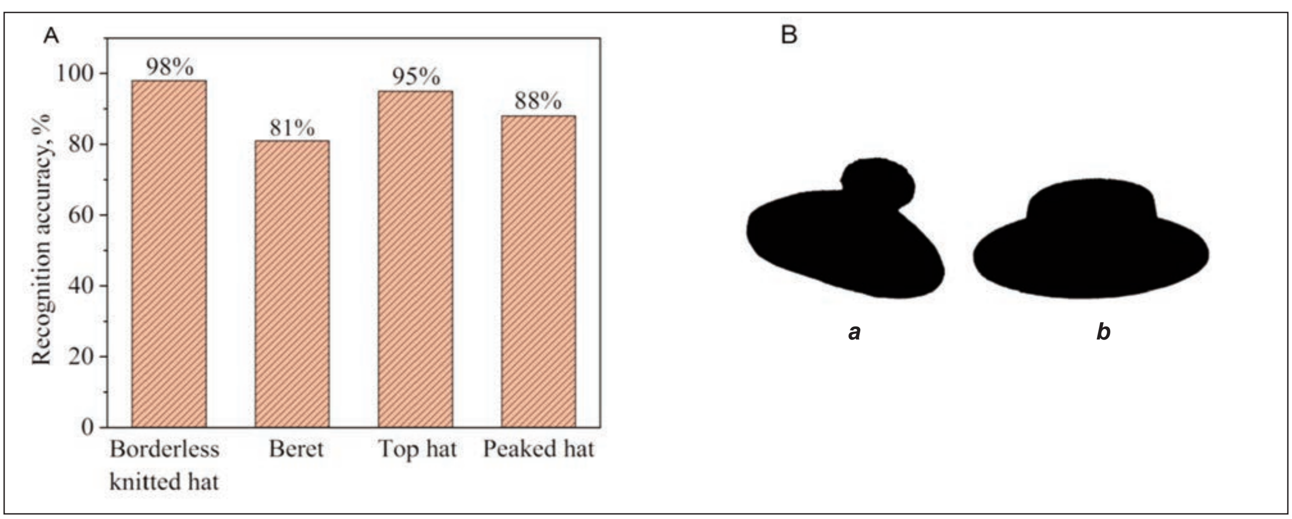


Fig. 6. Graphical representation: *A* – Recognition accuracy of four types at $P=3$ and $n=70$;
B – The contour curve of: *a* – beret; *b* – top hat

of the style recognition. Then, the Hausdorff distance is calculated and used to match the similarity between the samples and the training set. The identifying results are output by similarity from high to low and the highest output proportion is taken as the final recognition result. The experimental results are as follows:

- When $P=3$ and $n=70$, the average recognition accuracy of the four types of hats is the highest, reaching 90.5%.
- Different types of hats have different recognition accuracy. When $P=3$ and $n=70$, the highest recognition accuracy is 98% for the borderless knitted hat, followed by the top hat with 95%, while the low recognition accuracy of the peaked hat and beret is 88% and 81%, respectively.
- The automatic recognition system is suitable for the simple outline hat like the borderless knitted hat and top hat. However, for hats with complex contours and large differences in shape, a single curvature feature point cannot fully characterize the hat image shape. The recognition accuracy of this method needs further study.

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Diabetic foot ulcers, a comprehensive approach – Review

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ABSTRACT – REZUMAT

Diabetic foot ulcers, a comprehensive approach – Review

Diabetic foot ulcer represents a very severe complication of diabetes mellitus, often requiring foot amputation, leading to morbidity and higher mortality rates. Around one in six diabetic patients develops foot ulcers over their lifetime. Promoting a series of preventive measures including systemic control of diabetes and other comorbidities along with local foot care proved to be a valuable strategy. In addition to rigorous, active prevention, multidisciplinary therapeutic management of diabetic ulcers includes offloading techniques, ulcer debridement, advanced dressings and diabetic foot surgical treatment. In this article, we analyze each component of this sequential treatment plan, with emphasis on current indications and resources, having as main goals decreasing complication rate and morbidity, improving the quality of life and life expectancy of diabetic patients.

Keywords: *diabetic foot ulcers, treatment, dressings, surgery, prevention*

Ulcerul piciorului diabetic, o abordare exhaustivă – Sinteza literaturii

Ulcerele piciorului diabetic reprezintă o complicație foarte severă a diabetului zaharat, adeseori necesitând amputația segmentului afectat, determinând morbiditate severă și creșterea ratei mortalității în această populație. Aproximativ unul din șase pacienți diabetici dezvoltă ulcere la nivelul piciorului pe parcursul vieții. Promovarea unor serii de măsuri preventive, cum ar fi controlul sistemic strict al diabetului și al altor comorbidități, împreună cu îngrijirea locală a piciorului sunt strategii eficiente în reducerea morbidității. Prevenția activă și riguroasă și abordarea multidisciplinară terapeutică a ulcerelor diabetice include tehnici de descărcare a presiunii de pe membrul afectat, debridarea ulcerelor, pansamente moderne și tratamentul chirurgical al piciorului. În acest articol, analizăm fiecare componentă a planului terapeutic secvențial, cu accent pe indicații curente, având drept obiectiv principal reducerea ratei complicațiilor și morbidității, cu creșterea calității vieții și speranței de viață a pacienților cu diabet zaharat.

Cuvinte-cheie: *ulcerul piciorului diabetic, tratament, pansamente, chirurgie, prevenție*

INTRODUCTION

The foot is highly susceptible to mechanical trauma, due to its weight load absorbing properties during locomotion. Involving the most distal part of the neurovascular network, chronic wounds may result in patients with conditions such as peripheral vascular disease, biomechanical deformities, but most importantly in those with diabetes mellitus. Non-healing chronic wounds can potentially determine loss of the limb. In addition, these types of wounds were proven to increase mortality risk independent of other factors [1].

Diabetes mellitus represents a severe chronic condition leading to significant systemic complications and quality of life impairment, being the seventh cause of death in the United States population [2, 3]. According to the International Working Group on the Diabetic Foot a diabetic foot amputation occurs every 20 seconds and affects over 1 million individuals each year. There were 425 million people with diabetes worldwide in 2017, a number anticipated to rise to 629 million by 2045 [4]. Around 15% of diabetic patients develop foot ulcers over their lifetime [5]. Arteritis and small vessel thrombosis, neuropathy (potentially ischemic in origin) and big vessel atherosclerosis are the three basic components of diabetic vascular disease. When combined, these are almost certain to produce impairment in weight-bearing regions [6, 7]. Diabetic foot ulcers are generally deeper and more commonly infected than other leg ulcers, reflecting the diabetic's usual experience with severe end vascular ischemia and opportunistic infection [8]. The duration of the condition will raise the disease's incidence and mortality risk due to uncontrolled infection [8, 9]. It is known that associated infection is the most common cause of diabetes-related admission to the hospital and remains one of the major pathways to lower-limb amputation [4]. Non-healing diabetes ulcers associating soft tissue infection may complicate with severe bone infection-osteomyelitis, requiring aggressive surgical treatment and associating a higher risk of major lower limb amputation necessity [10].

THERAPEUTIC STRATEGY

Treatment of diabetic foot ulcers involves a multidisciplinary team consisting of general practitioner, diabetologist, podiatrist, orthotic devices specialist, infectious disease doctor and surgical specialists-vascular surgeon, general surgeon, plastic surgeon and orthopedic surgeon [7]. Preventive measures are mandatory, an essential strategy being patient education on adequate systemic treatment of diabetes and self-care of affected foot [7, 11]. Controlling diabetes, smoking and obesity, as well as frequent foot inspections, callosity removal (in neuropathic foot), daily moisturizing, regular toenail trimming, and well-fitting footwear, are all important measures in preventing diabetic foot complications [12, 13]. In diabetic patients, glucose level should be strictly monitored (including glycosylated hemoglobin HbA1c), as it was observed that inadequate glycemic control represents a primary determinant for the occurrence of diabetic ulcers [7, 14].

In addition to continuous, active prevention, the following represent the main components of the therapeutic management of diabetic ulcers: offloading techniques, ulcer debridement, advanced dressings and diabetic foot surgery.

Offloading

Many foot ulcers have a biomechanical component as part of the etiology. Increased plantar pressure has been linked to a variety of structural abnormalities in the foot. Claw toe deformity, hammer foot, hallux valgus or Charcot's neuro-arthropathy are the most common anomalies in patients with diabetes and they can cause severe disruption to the foot's architecture, as well as a higher occurrence in local foot pressures [7, 15–17]. Repetitive damage to the foot must be prevented by lowering pressure and shear forces on the sole of the foot, allowing existing wounds to heal and high-risk regions to be protected against recurrent ulcers. The importance of ulcer offloading is growing, since it has been noted that if the foot is not appropriately offloaded (in high-pressure areas), even after the ulcer has healed, therefore increasing the risk of recurrence [18, 19]. Furthermore, even in a well-perfused limb, poor off-loading of the ulcer has been shown to be a key cause of ulcer healing delay [20, 21].

The International Working Group on the Diabetic Foot (IWGDF) recommends a non-removable knee-high offloading device as a first choice offloading treatment for healing a neuropathic plantar forefoot or midfoot ulcer in a diabetic patient. Second and third choices, in case of contraindications and patient non-compliance, removable knee-high and detachable ankle-high offloading could be used. The fourth choice of offloading therapy implies appropriately fitting footwear paired with felted foam [22]. If non-surgical offloading fails, surgical offloading interventions (internal offloading) are recommended [19].

Debridement

Debridement of all chronic wounds is recommended to remove surface debris and necrotic tissues. It promotes granulation tissue development and can be accomplished surgically, enzymatically, biologically or through autolysis. Debridement lowers bacterial count while increasing local growth factors production. This approach also diminishes pressure, assesses the wound bed status, and promotes wound drainage [7, 20, 23].

Mechanical debridement includes abundant washing, high-pressure irrigation or pulsed lavage, used as the initial step of the surgical procedure, facilitating necrosis removal [7]. Surgical debridement performed in sterile conditions, in the operating room is the gold standard procedure; hyperkeratosis and dead tissue are quickly and effectively removed until a healthy bleeding ulcer bed is created. If significant ischemia is suspected, vigorous debridement should be delayed until vascular evaluation and, if required, a revascularization treatment should be conducted [24, 25].

Collagenase, papain, a mixture of streptokinase and streptodornase, and dextrans are agents used for enzymatic debridement. These can remove necrosis while causing minimal damage to healthy tissue. Enzymatic debridement is recommended for ischemic ulcers, despite its high cost, in case of exceeding pain sensation during surgery [26]. Compared to saline moistened gauze and selective sharp debridement, biochemical debridement using Clostridia collagenase ointment resulted in a statistically significant decrease in wound surface after 12 weeks [27].

Endogenous proteolytic enzymes disintegrate sloughy, necrotic tissue in a natural process known as autolytic debridement, a process enhanced by dressings such as hydrocolloids, hydrogels and films. The use of dressings that produce a moist wound environment allows host defence systems (neutrophils, macrophages) to remove devitalized tissue utilizing the body's enzymes, such as collagenase, elastase, myeloperoxidase, acid hydroxylase, and lysozymes [7, 28].

Dressings

Dressings have improved wound management and healing of diabetic foot ulcer. These dressings should initiate and promote the production of healthy granulation, as well as accelerate the epithelization process [7, 29]. Thus, the main properties of such dressings should be the provision of moisture, capability to enhance growth factors production, antiseptic capacity, oxygen permeability, the ability to stimulate autolytic debridement, long and efficient time of action with sustained drug release [7, 30]. Since ulcer differ in location, depth, scarring, contraction, infection, pain, as well as the patient’s biological status, multiple types of dressings may be employed, either passive, active or interactive. Passive ones provide protection and ensure exudate absorption. Active and interactive dressings stimulate local cellular and growth factor activity. These are beneficial in chronic wounds, with high adaptability, providing a more suitable environment. Categories of diabetic foot ulcer dressings can be split into hydrogels, hydrocolloids, alginates, foams, silver-impregnated, textiles and films [7, 30, 31]. Table 1 presents current advanced dressings useful for treating diabetic foot ulcers [7, 32–35].

Table 1

SOME CHARACTERISTICS OF PROTECTIVE OVERALLS USED IN THE STUDY [10]

Dressing type	Action mechanism and advantages	Indication	Disadvantages	Examples
Alginate	Absorbs wound exudate Induces autolytic debridement Provides moisture control Conforms easily to wound bed Absorbs wound exudate	Highly exuding wounds Bleeding wound bed Cavities Can be combined with silver dressings	Should not be used on dry/necrotic wounds or friable tissues Can be adherent during removal	Sorbalgon (HARTMANN USA, Inc.) Algicell Alginate Wound Dressings (Integra LifeSciences Corp) High Gelling alginate (3M Health Care)
Film	It provides a "breathable" barrier, blocking bacteria, while allowing oxygen Wound can be properly inspected due to its transparency Can be combined with alginate or hydrogel dressings	Low exuding wounds Cavities	Removal may be difficult; therefore, one should be attentive to damaged skin around the wound Not to be used in infections Provides no absorption Exudate may accumulate underneath, prompting removal	Tegaderm Transparent Film Dressing (3M Health Care)/ Adhesive Transparent Dressings (Comfort Release) Mepore Film Dressing (Mölnlycke Health Care US, LLC)
Foams	Enhanced absorption of wound exudate Provides moisture control Provides thermic and mechanical protection Ease of use Long-lasting up to seven days Conforms easily to wound bed	Highly exuding wounds Cavities	May cause maceration May cause dermatitis induced by adhesive compounds It can be bulky	Mepilex (Mölnlycke Health Care US, LLC) ALLEVYN (Smith+Nephew, Inc. HydroCell Foam Dressing (Integra LifesSciences Corp)
Hydrocolloid	Provides moist environment Induces autolytic debridement Absorbs exudate Long lasting	Low/moderate exuding wounds	May cause maceration May cause excess granulation tissue Not to be used on dry/necrotic high exuding wounds Can cause unpleasant odor Should not be used in infections	Cardinal Health Hydrocolloids (Cardinal Health) GentellDermatell (Gentell) Hydrocolloid Dressing (Smith+Nephew, Inc.)
Hydrogel	Absorbs wound exudate Provides wound hydration Cooling subjective sensation Induces autolytic debridement Can be used with silver dressings for further antimicrobial activity	Low/moderate exuding wounds Dry wounds	May cause maceration Should not be used in infections, especially anaerobic	DermaPlex Gel (MPM Medical) Dermagran Amorphous Hydrogel Dressing (Integra LifeSciences Corp)
Silicone	Protects newly formed tissues Provides comfort Are amongst most atraumatic dressings	Low/moderate/ high exuding wounds Can dry out if left too long	May cause silicone induced sensitivity	Mepiform Soft Silicone Gel Sheeting ((Mölnlycke Health Care US, LLC) Silicone Gel Sheet (Smith+Nephew, Inc.)
Silver	Provides antiseptic effect Can be combined with other dressings Reduces odor Improves subjective pain sensation Can be used for prolonged periods	Low/moderate/ high exuding wounds Infected wounds	May cause sensitivity to dressing May cause discoloration	PolyMem Silver Non-Adhesive Dressing (Ferris Mfg. Corp) Atrauman Ag (HARTMANN USA, Inc.)
Textile dressings	Used as primary or secondary sterile dressing Protect wound from contamination Absorb exudate Allow wound specific treatments with antiseptic or antimicrobial solutions	Low/moderate/ high exuding wounds Infected wounds	Require more frequent dressing changes Pain and bleeding in case of wound adherence	Woven and non-woven fibers: cotton, polyesters Sterile gauze pads

Textile dressing

Textile dressings provide the advantage of being highly available, allowing for wound secretion inspection, being easy to use by all healthcare workers and being affordable due to the low cost. Thus, they provide a very reliable form of dressing for patients with chronic diabetic foot ulcers. Textile dressings are to date the most often used type when treating diabetic foot ulcers. In order to gain an optimal wound healing environment, efforts were made to define and establish accurate parameters for each class of textile dressings.

Functional model of hemostatic material based on conventional technology (weaving)

The calculation of the design parameters of the woven structure is achievable by considering the field of material use and the values generated by its theoretical design, respectively: degree of corrugation, structure phase, special structure phases (a and b), geometric densities of warp and weft yarns, critical geometric densities, minimum geometric density/structure phase (including special phases), simultaneous minimum geometric density, critical technological density. The input data for the calculation of the parameters listed above, as well as the values obtained, are presented in tables 2 and 3 and figure 1.

Table 2

INPUT DATA AND DESIGN PARAMETERS		
Input data	**Unit**	**Values**
Length density of warp//weft yarns	-	280 dtex × 2/54f/150Z// 300dtex × 2/54f/100Z
Diameter of warp//weft yarns	mm	0.216//0.224
Geometric density in warp//weft	mm	0.476//0.476
Critical geometric density	mm	0.440
Simultaneous minimum geometric density	mm	0.38105
Critical technological density	yarn/10 cm	227.3
Wave height for warp//weft yarn in phase "a"	-	0.06129//0.37871
Wave height for warp//weft yarn in phase "b"	-	0.37871//0.06129
Phase number "a"	-	2.3809
Phase number "b"	-	7.6191
Design parameters	**Unit**	**Values**
Density in warp//weft	yarns/10 cm	210//210
Fabric width	mm	120
Total number of warp yarns	yarns	265 yarns (252 background+ 8 edge and weaving + 5 reserve)
Pattern	-	ajour (according to the programming scheme – fig. 1) base (RB2/2; P3 3/ 3 3)
No. heald frames	-	8
Encrypted drawing	-	-(1-2-2-1-3-4-4-3-5-6-6-5-7-8-8-7)-
Encrypted card	-	-(2-3-6-7/3-4-7-8/2-3-6-7/1-4-5-8/1-2-5-6/1-4-5-8)-
Weaving machine type	-	Jakob Mueller/150mm/cams/max.12 heald frames

Table 3

MINIMUM GEOMETRIC DENSITY ON STRUCTURE PHASES				
Structure phase	**h_U (mm)**	**h_B (mm)**	**l_U (mm)**	**l_B (mm)**
I	0	0.4400	0.4400	0
II	0.0540	0.3860	0.4366	0.2111
a	0.0612	0.3780	0.4357	0.2252
III	0.0810	0.3590	0.4324	0.2543
IV	0.1620	0.2700	0.4090	0.3474
V	0.2160	0.2160	0.3833	0.3833
VI	0.2700	0.1620	0.3474	0.4090
VII	0.3590	0.0810	0.2543	0.4324
b	0.3780	0.0612	0.2252	0.4357
VIII	0.3860	0.0540	0.2111	0.4366
IX	0.4400	0	0	0.4400

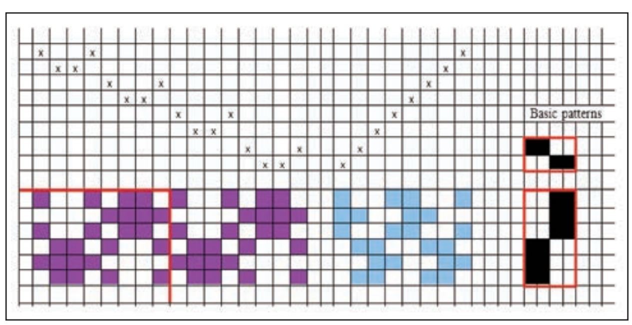

Fig. 1. Schematic diagram for combined ajour connection

Functional model of hemostatic material based on unconventional textile technology

Unconventional textile materials (non-woven fabrics) are based on textile support (consisting only of fibres) which is subjected to a consolidation process with or without consolidation materials, reinforcing bodies or sources of consolidation.

Taking into account the requirements imposed by the field of clinical use, researchers from INCDTP, Romania have designed and achieved a functional model of hemostatic material, on a technological flow that includes the following phases: mixing bed formation, detachment, mixing, carding – folding and mechanical consolidation – interweaving. It should be noted that the interweaving is performed only with the fibrous layer, so without depositing on woven textile support, because the fibres have low tensile strength and elongation at break: max. 1 cN, respectively max. 2%. The consolidation of the fibrous layer was achieved by mechanical interweaving procedure using interweaving needles, GROZ-BECKERT type, with the specification 15 x 16 x 36 x 3½ R221 G 82012.

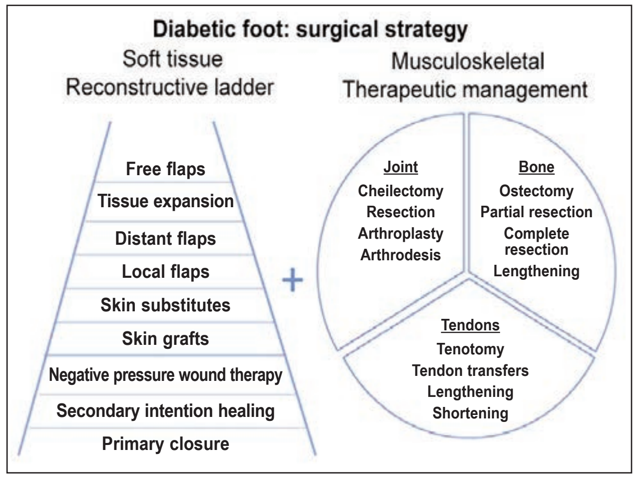

Fig. 2. Surgical strategy for diabetic foot

Negative pressure wound therapy (NPWT)

Negative pressure wound therapy (NPWT) is a novel therapeutic option for diabetic foot ulcers. It uses a special pump (vacuum-assisted closure) to apply intermittent or continuous sub-atmospheric pressure to a resilient open-celled foam surface dressing, silver coated, with an adhesive drape to maintain a closed environment [36, 37]. NPWT is now approved for complicated diabetic foot wounds, although it is not recommended for patients who have an ongoing bleeding lesion. This technique results in a larger proportion of healed wounds, a shorter time for wound closure, a more rapid granulation, lowering the risk of secondary amputation [37–39]. Over the first four weeks of therapy, negative pressure wound dressings reduces wound size more efficiently than saline gauze dressings. NPWT is a cost-effective, simple-to-use, and patient-friendly approach of treating diabetic foot ulcers that aids in early wound closure, reducing complications, and therefore ensuring a better outcome [37].

Surgical treatment

The surgical approach ranges from minor interventions for foot ulcers to extensive reconstructive procedures for Charcot deformities and soft tissues related anomalies. The most important step is to diagnose and treat as soon as possible soft tissue and bone infections. Nonvascular foot surgery, vascular foot surgery, and in some cases, necessity amputation are all options for diabetic foot surgical management [7, 40].

A thorough evaluation should be performed, analysing the complexity of soft tissue defects and musculoskeletal pathological features. Vascular status of the foot is the main concern and should be always addressed prior to any reconstructive attempt. Corroborating the aforementioned findings, a comprehensive approach is presented in figure 2, integrating the surgical options for diabetic foot [41–43].

The reconstructive ladder represents the surgeon's therapeutic options ranging from the simplest procedures (primary closure and secondary intention healing), step by step to the most complex (microsurgical transfer free flaps). An alternative reconstructive paradigm is represented by the reconstructive elevator, directly selecting the most appropriate surgical procedure, taking into consideration particular patient characteristics in order to obtain optimal form and function [42, 44].

A sequential approach is usually employed to restore foot architecture through musculoskeletal interventions. The main therapeutic goal is to obtain the diabetic patient satisfactory ambulating status, having in mind an individualized approach for each patient. For long term immobilized patients, without gait rehabilitation potential, amputation should be considered, to avoid long hospitalization and morbidity [41, 45]. In selected active patients, adequate quality of life may be restored with a leg amputation rather than having a sequel limb. On the other hand, in patients with severe systemic status and multiple comorbidities, unable to ambulate with a prosthetic device, limb salvage is indicated, ensuring a better quality of life than amputation [45]. Amputation indication should be thoroughly assessed, given that it was observed that major amputations are associated with a higher mortality rate [45, 46].

Conceptually surgical interventions can be classified as elective, preventive, curative and emergent nonvascular foot surgery, all aiming at correcting abnormalities that may increase plantar pressure [47, 48]. Each class of foot surgery is distinguished not only by its wound status but also by its risk of subsequent amputation [48]. Elective surgery (Class I) refers to reconstructive procedures used to address deformities or excessive plantar pressures in people without neuropathy or a history of ulceration. In the absence of open wounds, prophylactic (Class II) operations are performed in neuropathic patients to limit the risk of ulcers or repeated ulceration. When open wounds are present, Curative surgery (Class III) is frequently used for regions with chronically elevated peak pressure, or as an alternative to partial foot amputation by performing joint resection, eliminating underlying bone prominences (surgical decompression), osteomyelitis and draining underlying abscesses. To limit

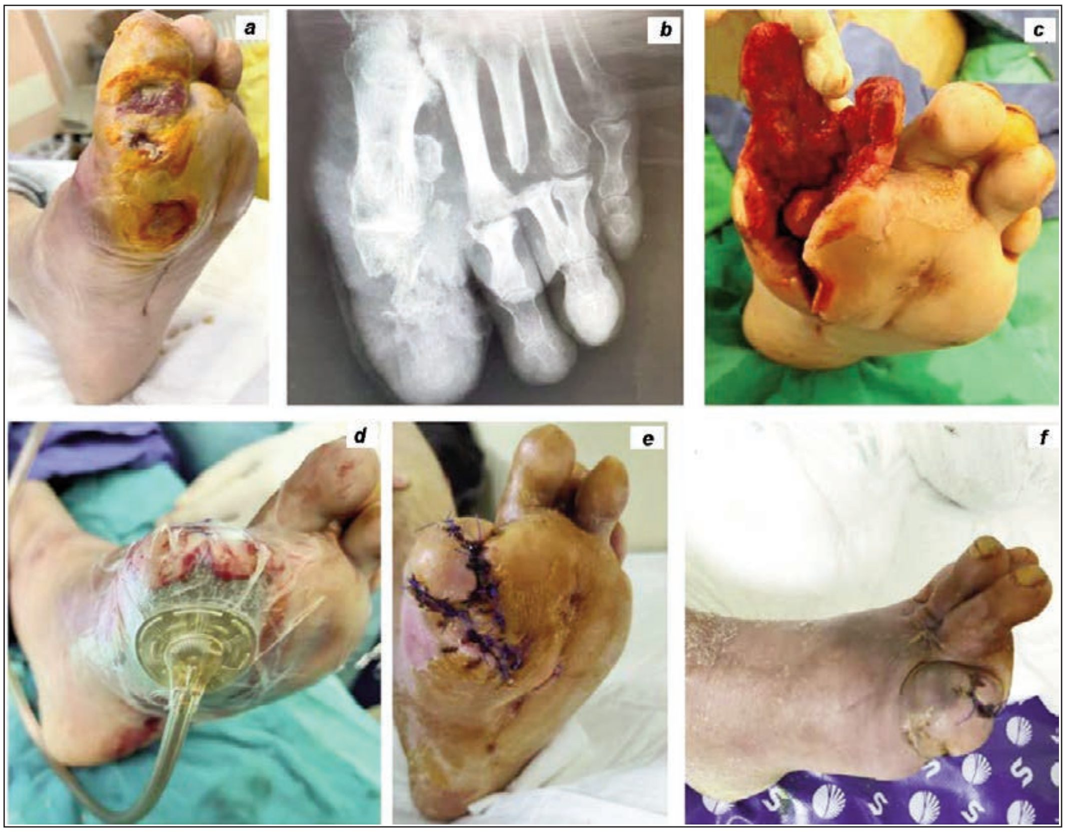

Fig. 3. Photography of: *a* – clinical aspect of extensive osteomyelitis of left hallux in a type II diabetes patient; *b* – radiologic aspect revealing bone lysis; *c* – aspect after surgical debridement imposing left halluces amputation; *d* – negative pressure wound therapy was further used; *e* and *f* – foot aspect after secondary closure when the wound was stabilized and the infectious process was eradicated

the course of infection, emergent interventions (Class IV) are done for severe or ascending infections (wet gangrene, necrotizing fasciitis, etc) [7, 47–50]. As the name implies, the latter of the aforementioned procedures are performed in an emergency setting and typically consist of open amputations at the foot level with additional fasciotomies [51]. Figure 3 presents the case of a patient needing emergency treatment, with amputation necessity for the first ray of left foot and subsequent surgical treatment.

CONCLUSIONS

Therapeutic management of diabetic foot ulcers implies a systematic, multidisciplinary approach in order to reduce severe complication, avoid lower limb amputation and decrease overall morbidity and mortality rates. The current strategy able to provide optimal results includes adequate preventive measures (patient education, strict control of blood glucose levels, self-care of the foot) and prompt initiation of specific treatment including wound correct debridement, offloading, topical use of advanced dressings, negative pressure wound therapy and surgical treatment which ranges from minor interventions for foot ulcers, to extensive reconstructive procedures for vascular restoration, bone deformities and soft tissues related anomalies.

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