# Aspects regarding vital functions monitoring through an adaptive textile system

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ANGELA DOROGAN
IOANA CARPUS
DIMITRIE NANU
MIRCEA IGNAT

**REZUMAT – ABSTRACT**

**Aspecte privind monitorizarea funcțiilor vitale printr-un sistem textil adaptiv**

*În prezent, există aproximativ 80 de milioane de persoane cu diverse tipuri de dizabilități în Uniunea Europeană, dar acest număr este de așteptat să crească în următorii ani, în principal ca urmare a proporției crescânde a cetățenilor în vârstă.*
*La nivelul Uniunii Europene, dizabilitatea este văzută ca o problemă a întregii societăți. Aceasta presupune pregătirea și adaptarea continuă în toate sferele vieții, pentru primirea și menținerea acestor persoane în curentul principal al vieții sociale, pentru asigurarea tuturor facilităților. Sunt stimulente puternice pentru cercetare și inovare în domeniul social (servicii în folosul oamenilor), medical (boli cărora nu li se cunoaște originea, protocoale medicale personalizate, instrumente neconvenționale de monitorizare, etc.) sau tehnologic (robotică, informatică, textile, etc.), deopotrivă. Un rol important revine îmbrăcămintei adaptive caracterizate prin confort, accesibilitate, siguranță și stil. Lucrarea include aspecte privind realizarea unor modele experimentale de elemente textile cu funcții elctronice destinate sistemelor de monitorizare a unor funcții vitale.*

*Cuvinte-cheie: dizabilitate, funcții vitale, textile adaptive*

**Aspects regarding vital functions monitoring through an adaptive textile system**

*Currently, there are about 80 million people with various types of disability in the European Union, but this number is expected to grow in the coming years, mainly due to the increasing proportion of older citizens.*
*At European Union level, disability is seen as a problem of the whole society. This requires continuous training and adaptation in all spheres of life, for receiving and maintaining these persons in the mainstream of social life, in order to ensure all the facilities. There are powerful incentives for research and innovation in the social field (services for the benefit of people), medical field (diseases whose origin is unknown, customized medical protocols, non-conventional monitoring instruments etc.), or technology field (robotics, informatics, textiles etc.) in an equal manner. An important role is played by the adaptive clothing characterized by comfort, accessibility, safety and style. The paper includes aspects regarding the making of some experimental models of textile elements with electronic functions intended for vital functions monitoring systems.*

*Keywords: disability, vital functions, adaptive textiles*

*"More than one billion people in the world live with some form of disability, of whom nearly 200 million experience considerable difficulties in functioning. In the years ahead, disability will be an even greater concern because its prevalence is on the rise. This is due to ageing populations and the higher risk of disability in older people as well as the global increase in chronic health conditions such as diabetes, cardiovascular disease, cancer and mental health disorders"*

*Dr. Margaret Chan, General Director, World Health Organization*

## INTRODUCTION

Professor Stephen W. Hawking mentions: "It is my hope that, beginning with the Convention on the Rights of Persons with Disabilities, and now with the publication of the World report on disability, this century will mark a turning point for inclusion of people with disabilities in the lives of their societies" [1]. In analyzing the needs of the people with disabilities, it is important to see the interaction between the individual and the environmental factors – from impairments, activity limitations and participation restrictions, to the highest level of functioning that a person may attain, probably, at one moment and which defines their capabilities in different areas of activity and participation. Improving living and working conditions for people with special needs and the elderly has convergence points, these are powerful incentives for research and innovation in the social field (services for the benefit of people), medical field (diseases whose origin is unknown), or technology field (robotics, informatics, textiles etc.) in an equal manner. Disability is a social state and not a medical condition. Clarity and precision are needed to define different concepts [2]. According to the decision-makers in the field, disability has different definitions and a sum of characteristics specific to each of them [3–4]. According to **Disabled Peoples' International (DPI)**, disability is defined as the "results from the interaction between persons with impairments and attitudinal and environmental barriers which they confront".

**The World Health Organization** proposes the following definition of disability: “restriction or lack (resulting from an impairment) of ability to perform an activity in the manner or within the range considered normal for a human being”. **The United Nations Organization (UNO),** based on the Convention on the Rights of Persons with Disabilities, uses the following definition: “Persons with disabilities include those who have long-term physical, mental, intellectual or sensory impairments which in interaction with various barriers may hinder their full and effective participation in society on an equal basis with others”. Disability for CIF/CIF-CY (The International Classification of Functioning, Disability and Health CIF and CIF for Children and Youth: an umbrella term for the deficiencies in the functions and structures of the body, activity limitations and participation restrictions. Disability is perceived and approached through two models: medical and social [5–8]. *The medical model* defines people with disabilities from the perspective of their disease or medical condition. In this model, disability is perceived as the individual’s problem, the latter being dependent on the others and requiring appropriate treatment for their problem.

*The social model* is promoted by the European Union and focuses on the social environment that is not adapted to the needs of the people with disabilities, hence the difficulties they face. Thus, the social model no longer perceives disability as an individual problem, but as a social fact, generated by politics, practice, attitudes and the environment. Disability is not an attribute of an individual, but a complex of conditions created by the social environment. Considering the main characteristics that define the social model vs. the medical model (table 1), it can be emphasized that the purpose of the social model was to eliminate the obstacles, so that the people with disabilities benefit of equal opportunities, in order to have an independent existence being treated by virtue of their qualities and not defects.

Table 1

| Medical model | Social model |
|---|---|
| Disability is a personal problem | Disability is a social problem |
| The person with disabilities must adapt | People with disabilities must be provided with facilities |
| “Disability” has an individual identity | People with disabilities have a collective identity |
| People with disabilities need help | People with disabilities need rights |
| Individual adaptations | Social changes |

Source: [http://www.eupd.ro/wp-content/uploads/2011/09/Curriculum.pdf]

A third *model* is the *biopsychosocial* one adopted by the World Health Organization (WHO) and constitutes an integral framework of the medical and social model in what regards incapacity. In the biopsychosocial model, incapacity is approached as an interaction between biological, psychological and social factors [9], the functioning of an individual in a certain field is a complex interaction or relation between their health condition and contextual factors (for example, environmental factors and personal factors). The human being is a complex biopsychosocial entity; therefore, regardless of the nature and the action of an external factor, whether harmful, aggressive or beneficial, the human individual, their body reacts as a whole on all its manifestations: physical, physiological, neuroendocrine, psycho-emotional, behavioral and social. An important role in the implementation of the biopsychosocial models is given to the adaptive/ interactive clothing. The trend in the textile sector to include consumer requirements in the technical aspects of the product is the key to the sustainable development of the sector. Theoretically, meeting customer requirements and the technical aspects (functionality, ergonomic aspects, comfort etc.) are just as important in ensuring the success of the product [10]. Companies have quickly learned that clothing should be functional, versatile and durable. There are two product-making philosophies: a so-called “product-out” one in which the manufacturer’s decision takes into account the product technological and design specifications and another one, “market-in”, that embraces the consumer’s requirements in the product making process [11]. In this manner, textile products that goes beyond the normative body type is created, which approaches the spectrum of the body types and ensures comfort, accessibility and style in the conditions of a certain functionality.

## EXPERIMENTAL PART

The making of an interactive textile system is dealt with in several phases, in which the contribution of different transdisciplinary departments is, in turn, of utmost importance. Of these phases, we mention:

a) detection of a need and its transposition into technical requirements;
b) establishing the specifications of each component of the interactive textile system;
c) researching and designing the new system;
d) designing, making and validating the system.

Given the variety of the problems imposed by the interactive textiles systems and the multiple solutions for solving them, it is difficult to establish a generally valid template according to which we can conduct the design activity. For these reasons it can be argued that there can be no method to be applied based on a logical scheme, starting from an initial point, going through a number of procedures and arriving at the end point with a determined number of return loops and ramifications. If this were possible, with the existing computer technologies, programs could be developed to solve the task of the design engineer.

Generically, the design process consists of a structured set of planned, ordered and controlled activities aimed at making products that meet market demands. The search for solutions can be done heuristically or based on logical methods [12]. Modern design, focused on meeting market demands, implies the application of some global concepts such as: *simultaneous or convergent engineering, total design, ecological engineering, product life cycle engineering* etc. The balance between functionality, durability, economicity, ergonomicity and beauty for the textile systems that change the quality of life and add value is the result of implementing the textile design of interaction. The textile design of interaction proposes a new space for the designing (spatial and temporal) of the dynamic elements that combines the fields of textile design and interaction design. There are also taken into account the user's actions (micro-interactions) that can trigger another action on the part of the device, and each of these interactions rely on a man centered design concept based on a new qualitative level of the science, technology and art correlation. The algorithm for designing the exprimental models of interactive/adaptive textile products has been finalized following a corrective-type modeling activity that included the logical interpretation/analysis of:

– the processing capacity of selected yarns;
– the relations of interdependence between the physical & mechanical characteristics and the functional characteristics of the textile structures;
– the "architecture" of the textile system with customized areas, with specific functionalities and differentiated advantages;
– the factors that influence the "anatomical form" of the product;
– the physical and mechanical potential of the textile structures produced on textile machines with systems which design the structure in "anatomic cuts" for comfort at movement and action;
– the potential field of use requirements.

To make a textile element with embedded electronic functions (fig. 1), there are used:

• at the textile product level:
  – an adjustment band according to the perimeter of the signal pickup area, by means of a velcro demountable joint;
  – a modular undershirt incorporating the band-type module, mentioned above; the other modules of the undershirt may include other components for monitoring some physiological parameters in the context of providing a predefined well-being state.
• at the textile support level:
  – a woven fabric with structures that expose a large surface of contact in order to take over the physiological signal; examples of structures are highlighted in the images in figure 1. The functionality embedded in the textile structure, in relation to the yarns systems that define it, lies in the direction of the weft yarns. The unidirectional, continuous or discontinuous arrangement ensures the generation of an electrical circuit, in which the interferences that might occur are avoided, only by intersecting the yarns from the two yarns systems of the woven fabric.
• at the yarn level;
  – a multi-component yarn that provides a "mantle" effect for the yarn with the electrical conductivity functionality.

The yarns used are recognized in the specialized media existing research.

The novelty in this research at national level refers to the incorporation of conductive yarns with the role of monitoring some physiological signals, in order to maintain a preset/ predefined well-being state, and at an international level, respectively, it refers to two aspects:

a) the confirmation by preliminary experimentation of the referential, taken from an experience declared in the specialized media,

b) the development of the research, by defining some optimized surfaces for arranging the functionalised yarns, respectively, by selecting certain woven fabrics specific structures that ensure a more faithful take-over, as a specific law, amplitude, frequency, corresponding to a selected **physiological signal.**

The interactive thread used is of double type, between a spun cotton yarn and a monofilament based on copper (lithium). The joining of the two yarns has technical reasoning, workability and comfort in wearing, after being part of a fabric/fabric. The selection of the textile support, the fabric, compared to a knit or nonwoven, has technical reasoning of dimensional stability, minimizing elongations under the traction load, by itself known as the elasticity of a fabric (under certain conditions of thread and bond) is minimal. The interactive thread can be embedded in the

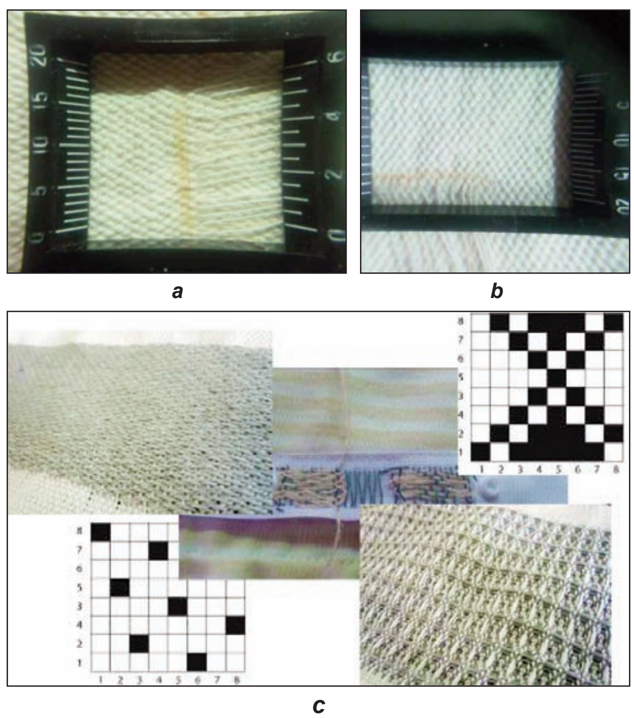


Fig. 1. Variants of embedding the functionalized yarn for monitoring physiological signals a) and b) detail about the embedding of functionalized yarns – the beige-orange yarns, to highlight the frequency of their deposition, compared to the sewing – embroidery deposition, where the yarn density is inferior; c) variants of structures for surfaces woven with embedded functionalized yarns

weaving structure, in a normal weaving process, preferably on machines with unconventional insertion. This aspect has both positive parts (providing a non-stressed fabric, considering that there is a conventional or multifilamentary textured or non-textural thread and the interactive thread that contains a lithic component (ie stretching and flexibility much inferior to conventional wires).

Taking into account that an important role in maintaining health is played by *the heart rate and respiratory rate*, the static testing of the electronic functions for the textile element dealt with the identification of the independent conductors in the textile structure.

The importance of the vital functions mentioned [13–15] is supported by the following aspects:

*Cardiac rhythm*: The primary function of the heart is to ensure the transport of blood and nutrients in the body. Regular heart beats, or contractions, ensure the transport of blood in the body. Each beat of the heart is controlled by a nervous impulse that circulates through the heart at regular intervals. There are several heart rate diseases (for example: a malfunctioning of the sinus node or interruption of the electrical stimuli system; arrhythmia makes your heart beat either too quickly or too slowly or determine its irregular rate; tachycardia occurs when the heart rate exceeds 100 beats per minute, if the number of the beats of the heart per minute reaches 150 or above, the person in question suffers from supraventricular tachycardia; bradycardia is a condition in which the heart rate is too low, below 60 beats per minute, that may be the result of problems with the sinoatrial nodule or heart damage following a heart attack or cardiovascular disease). The cause of these rate disorders is usually a coronary artery disease that nourish the patient's heart, a myocardial infarction or heart failure. Patient monitoring is very important given that the symptoms are very varied: most often, the patient feels nothing, but there can appear palpitations, vertigo and loss of consciousness and, also, irregular rate.

*Respiratory rate* is another parameter used in patients monitoring. Respiratory failure is not a disease, but a functional disorder caused by various pathological causes. Respiration is a vital function of the human body, which is continuous and cyclical and has the role of ensuring the bi-directional exchange of gases between the body and the air in the atmosphere. Respiratory failure is the body's inability to maintain the normal gases exchange at the cellular level and, consequently, to maintain the aerobic metabolism. Sleep apnea is the respiration interruption during sleep. Sleep apnea may be associated with: arterial hypertension, myocardial infarction, heart failure, irregular beats of the heart (arrhythmias); strokes; drowsiness throughout the day; increased risk of road accidents. The hyperventilation syndrome refers to the respiration acceleration, causing an increase in the amount of air that ventilates the lungs. Hyperventilation can cause dizziness and weakness, feeling of lack of air, loss of balance, muscle spasms in the hands and legs, tingling around the mouth or in the fingers. The causes are multiple: fear, asthma; chronic obstructive pulmonary diseases; congestive heart failure; costochondritis or the Tietze syndrome; deep vein thrombosis and pulmonary embolism; myocardial infarction; hyperthyroidism; pregnancy; central nervous system disorders (stroke, encephalitis, meningitis), drug overdose, fever, infections (pneumonia or septicemia), lactic acidosis, metabolic acidosis, the chronic altitude disease, stress, pulmonary edema, pleural effusion, severe shock, severe anemia etc. [18].

Considering the above mentioned, the experimentation of the experimental model – a textile element with electronic functions as part of the system for monitoring some vital functions – was made by means of capacity measurements (table 2 and figure 2), in static state, using the RLC ESCORT ELC-132A bridge rectifier (the measurements were made at the Electrical Engineering Institute ICPE-CA).

On the analyzed textile structure independent conductors were identified and the capacity measurements were made in static state. Considering the flexibility of the textile element, the distance between the yarns giving electronic properties can be modified in correlation with the phases of the respiration process (at rest, the diaphragm is curved upwards and tends to flatten when contracting, thus increasing the vertical diameter of the thoracic cavity). If the distance increases, the capacity decreases and vice versa.

The results obtained following the static state measurements demonstrate:

– the potential of the textile element to monitor respiration or heart rate as a result of the capacitive microsensors introduced into the textile structure;

Table 2

| Connections | Capacity [pF] |
|---|---|
| 1-1[a] | 2,5 |
| 2-2[a] | 2,4 |
| 3-4 | 2,2 |
| 3-5 | 2,1 |
| 4-5 | 2,6 |

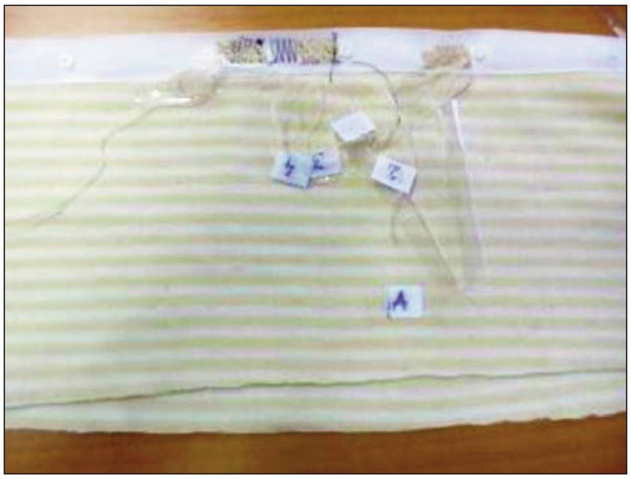

Fig. 2. Textile element with electronic properties

– the networks or the independent conductors can be used as microsensors that may have applications regarding both the appearance of the biological fluids and the evolution of humidity and the capacity permittivity (depending on the characteristic of the liquid) changes with the appearance of the fluid.
– considering the flexibility of the textile element, the distance between the yarns giving electronic properties can be modified in correlation with the phases of the respiration process (at rest, the diaphragm is curved upwards and tends to flatten when contracting, thus increasing the vertical diameter of the thoracic cavity).

## CONCLUSIONS

- The social policies promoted at the national level are those of inclusion, which opens new perspectives for the multidisciplinary research.
- The human being is a complex biopsychosocial entity; therefore, regardless of the nature and the action of an external factor, whether harmful, aggressive or beneficial to the human body, this reacts as a whole on all its manifestations: physical, physiological, neuroendocrine, psycho-emotional, behavioral and social.
- The human body controls a multitude of complex interactions to maintain its balance or to make the systems function at a normal rate. An important role in maintaining health is played by the heart rate and respiratory rate.
- The performances imposed on the interactive/adaptive textile systems can be ensured by applying the "triple propeller" model, a neo-evolutionary model of the innovation process that describes the multiple reciprocal relations at different points in the knowledge accumulation process.
- The results obtained following the static state measurements demonstrate the potential of the textile element to monitor respiration or heart rate due to the capacitive microsensors introduced into the textile structure.

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**Authors:**

ANGELA DOROGAN[1]
DIMITRIE NANU[2]
IOANA CARPUS[2]
MIRCEA IGNAT[3]

[1]The National Research and Development Institute for Textiles and Leather
[2]Univ. of Medicine and Pharmacy "Carol Davila"
[3]National Institute for Research and Development for Electrical Engineering – ICPE-CA

**Corresponding author:**

ANGELA DOROGAN
e-mail: angela.dorogan@certex.ro