A dedicated wearable device integrated in textiles

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ABSTRACT – REZUMAT

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The wearable devices have a big role in increasing the quality of life that should take into account also the persons with disabilities. Our research focuses on a certain category of persons with disabilities, namely those with visual impairments. Thus, once again the technological progress must be capitalized in favour of the less fortunate. We propose an original device easy to use and integrate into any textile product. The device contains a microcontroller, sensors and actuators. The sensors collect information from the outside world and provide a "picture" of it by means of tactile and acoustic actuators. The research opens the possibility of designing of fabrics using nanotechnology to have sensors and actuators directly into the fabric.

Keywords: *model, quality of life, simulation, ultrasonic sensor, visually impaired*

Posibilități de integrare a unui dispozitiv portabil în produse textile

Rolul dispozitivelor portabile este mai ales de creștere a calității vieții, ținând cont și de persoanele cu dizabilități. În cadrul cercetării se analizează o anumită categorie de persoane defavorizate și anume cei cu deficiențe de vedere. Astfel, încă o dată progresul tehnologic trebuie să fie valorizat în favoarea celor mai puțin favorizați. Se propune un dispozitiv original ușor de utilizat și de integrat în orice produs textil. Dispozitivul conține un microcontroler, senzori și elemente de acționare. Toate acestea culeg informații din lumea exterioară și oferă o "imagine" a acesteia, prin elemente de acționare tactile și acustice. Cercetarea poate fi un punct de plecare în proiectarea unor materiale textile folosind nanotehnologii, pentru crearea de senzori și elemente de acționare direct în materialul textil.

Cuvinte-cheie: *model, calitatea vieții, simulare, senzor ultrasonic, deficiențe de vedere*

INTRODUCTION

The continuous development of the IT sector in general has influenced the quality of life. The innovative products in the textile industry propose solutions with incidence on certain areas like medicine [1] in putting forward new ways to design and produce virtual prototypes of garments adapted for people with scoliosis [2], other impairments [3] and fashion like the design of a three dimensional virtual apparel online application web page [4] or the use of 3D surface geometry for modelling and simulation purposes [5].

Due to the great development of the smartphones in recent years it has become a habit for us all to have a powerful computer in our pocket. This led to the ease of wear sensors even in clothing. Time ago any measurement of the athletic performance or health problems was possible only in specialized cabinet. Today it is usual to wear devices that give us a measure of our health. All worn devices with sensors fit in the category of wearables and their main purpose is to improve the quality of life [6].

Wearables are something usual in areas such as medicine with wearable sensors that gather a large amount of data for the clinical environment in order to have a better knowledge and communication with the patient [7–8], and also wearable accelerometers in order to assess levels of impairment and the individual's functional limitation after stroke [9]; and such as fashion with wearable devices treated as digital jewelry in order to reflect the tastes and moods, and allow to express the personalities, cultural beliefs, and values of each person [10], or the interplay of electronic textiles and wearable technology in the fashionable technology treated as the intersection between design, fashion, science and technology [11]. This has created the concept of smart clothes that cover many areas that work together to improve the quality of life, well-being and health [12].

Figure 1 highlights the state of the art both from the conceptual and the applicability point of view regarding the wearable technologies, while exploring the evolution of the concepts and approaches, identifying the place that fits our research.

As can be seen, our research is placed between medicine and fashion applied for the visually impaired individuals. The undertaken research implies a multidisciplinary approach, requiring focused market researchers, electronic engineers and textile designers.

Next, we present the pros and cons of the wearable technology from the point of view of present applications and use (figure 2).

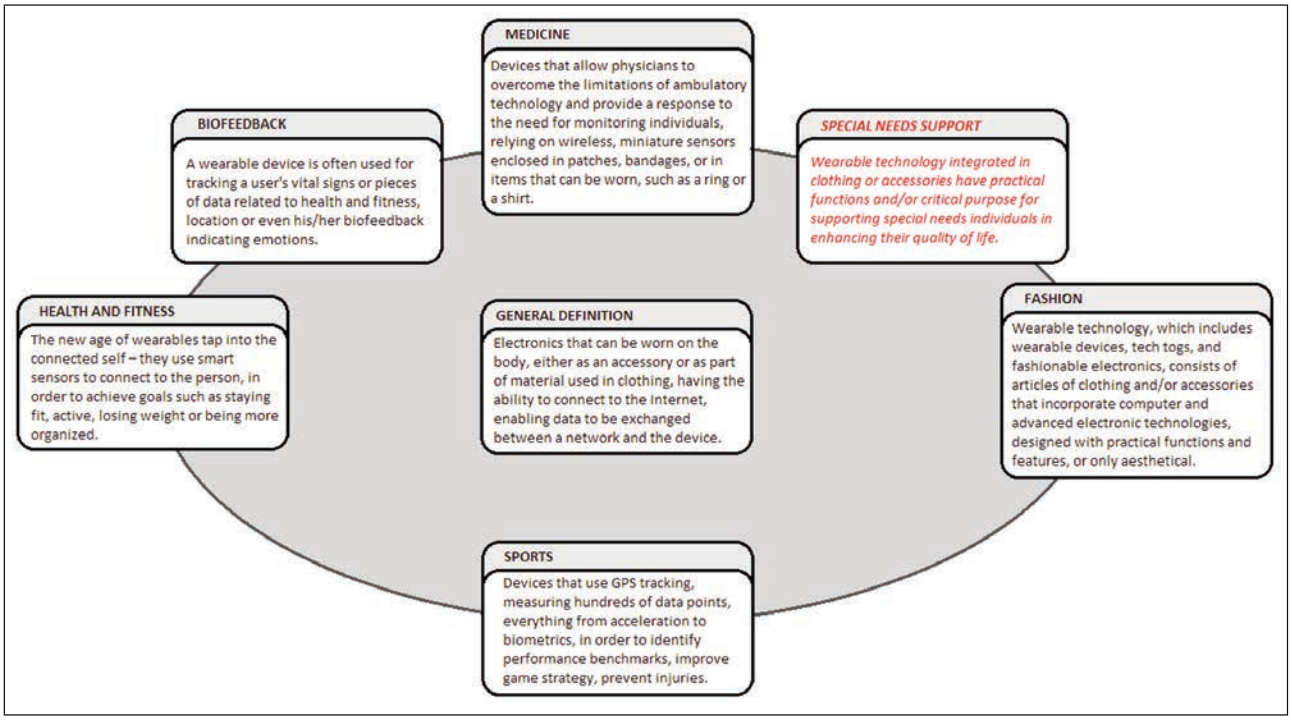

Fig. 1. Definitions of wearable technology

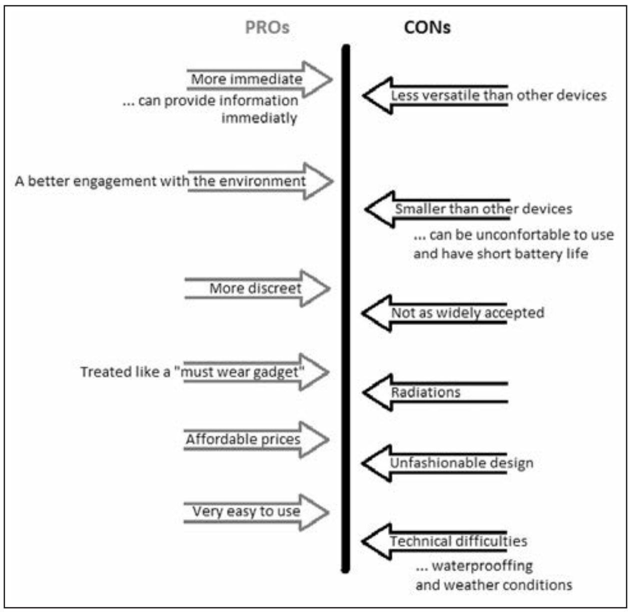

Fig. 2. Analysis of wearable technology

The goal of the general wearable technology pros and cons evaluation is to determine the characteristics of our device. Customizing our device led us to taking advantage of some pros and cutting out some of the cons. Thus, our device, from the point of view of specific application for people with special needs, is characterized by:

– More immediate having high speed sensors and actuators
– A better engagement with the environment: compensate an individual's natural sensors offering an "image" of the real world.
– More discreet: both in use and design, not making it weird to wear
– Potentially more fashionable: integrated, even hidden for certain tasks, in a cap or cloth
– Affordable prices: making a balance between price and usefulness
– User friendly: ready to use for the visually impaired persons
– Moreover, the weather conditions influence and the waterproofing are the same as the textile product's ones.

EXPERIMENTAL WORK

The research included both a part of creating a prototype, which is based on the results of the market research, and a part of modeling and simulation of the proposed prototype operation in different types of environment.
In figure 3 there is presented the electronic principle diagram of the proposed device.

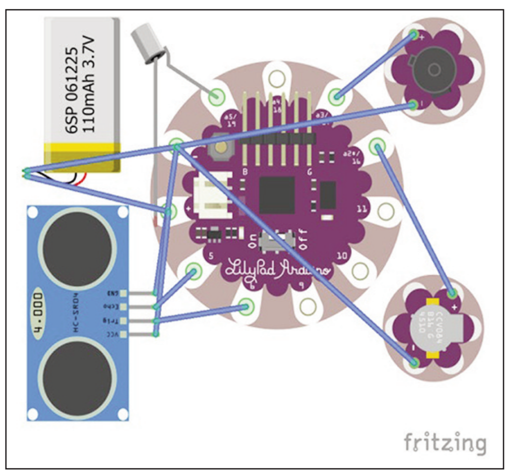

Fig. 3. Prototype design

As can be seen, we considered for this device two sensors: one tilt sensor and one ultrasound sensor, two actuators: one vibrating motor and one buzzer all controlled by a microcontroller integrated in a wearable platform powered by a LiPo battery.
This device can be placed on any type of cloth, as can be seen in figure 4.

Fig. 4. Device placement: *a* – on a cap; *b* – on a shirt

In order to validate our idea and to find out the “voice” of the client, we turned to the Associations of Visually Impaired from Romania. From the answers received there were considered relevant 78%. From these, 36% considered the device very useful and 43% of them appreciate the price as affordable and 29% of them appreciate the dimensions as acceptable. The results were encouraging. All the other categories, even those who could not evaluate (they requested further details), found it useful to design and then test the device. Regarding the category that considers that there are necessary major changes compared to the presented design, they proposed improving the functionality via a miniature camera and a system of sensors mounted on the white cane.

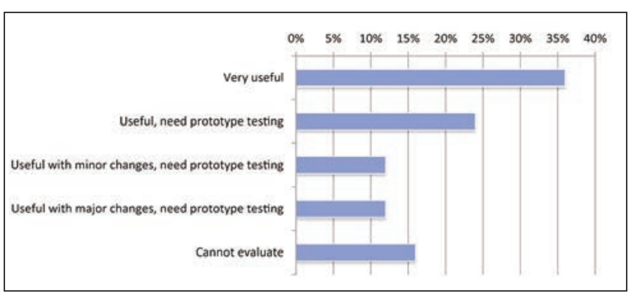

Fig. 5. “Voice” of the client

For our research we considered the case of the device applied on a cap, in order to have as input also the head movement angle to scan the environment by means of the ultrasound sensor.
The simplified diagram used to write the mathematical model is presented in figure 6.

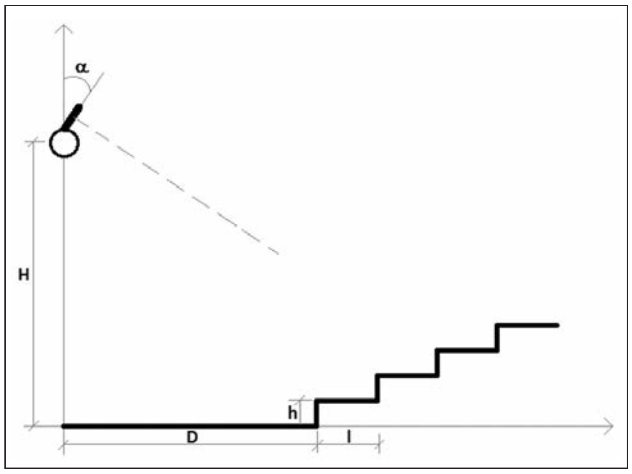

Fig. 6. Model outline

We considered for the ultrasonic sensor only the wave perpendicular to the sensor, even if it has a detection angle of 30°, as can be seen in figure 7; errors are negligible for the case study.

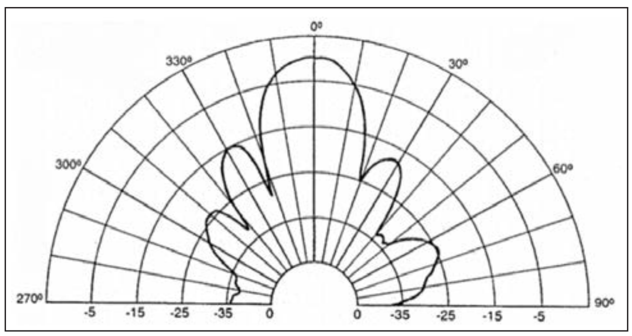

Fig. 7. Typical beam pattern ultrasonic sensor [13]

As obstacles we considered a series of steps, having the following mathematical model:

$$step(x) = \sum_{k=0}^{n} \theta\,(x - D - k \cdot l) \qquad (1)$$

where:

- θ is Heaviside function;
- D – the distance to the first step;
- l – the width of a step;
- n – the number of steps.

The equation for the sensor output is:

$$y = H - x \tan(\alpha) \qquad (2)$$

Where:

- H is the height of the person;
- α – the tilt angle of the head.

By solving the resulting equations we get:

$$x = \frac{H - k \cdot h}{\tan(\alpha)} \in [100 - (k-1) \cdot l,\ 100 - k \cdot l], \quad k = 0 \ldots n \qquad (3)$$

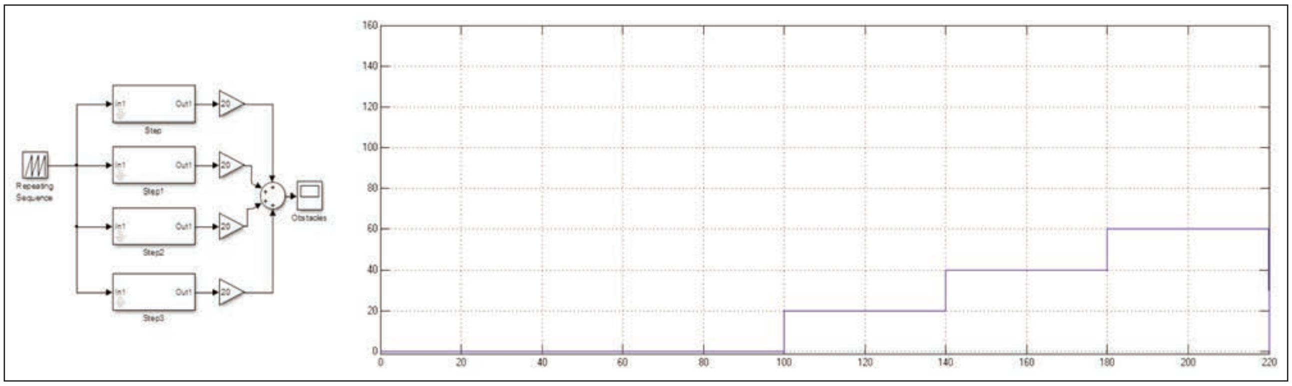

Fig. 8. Simulation of step obstacles

In our mathematical model we considered as inputs:

- Person's height H = 160 cm
- Head tilt angle α = 0...60º
- Obstacles have a straight line of 100 cm and 3 steps of l = 40 cm width and h = 20 cm height each (figure 8).

Table 1

SIMULATION PARAMETERS			
Sl no.	**Distance (m)**	**Simulated Time of flight (millisecond)**	**Theoretical Time of flight (millisecond)**
1	0.3047	1.79	1.7923
2	0.5	2.94	2.941
3	1.0	5.882	5.882
4	1.5	8.82	8.823
5	2.0	11.76	11.764

In simulation we took into account the operation mode of the ultrasonic sensor, which determines the distance to the obstacle based on response time, or time of flight (table 1 [14]).

RESULTS AND CONCLUSIONS

The model output data highlights the correlation between the detected obstacles profile on sweeping the angle α (head tilt) in the interval (0…60º) (figure 9).

As can be seen, it can identify a low height obstacle, which means obstacles very close to the ground, at a distance from 90 cm up to a distance of 300 cm. As the obstacle is higher, so the sensing distance is reduced to a minimum of 3 cm, due to the limitations of the sensor. If the usual obstacles are at very small distance and also of low height, the device can be mounted on the white cane.

Our research fits into the current trend of the concept of smart cloths that is closely related to wearable technology. It highlights the importance of wearable devices that can be used to help support personal control over the quality of life, health and well-being mostly for visually impaired individuals.

We propose a device considered useful by the Associations of Visually Impaired from Romania. This device is simple to use and provides tactile and audible feedback that allows the visually impaired to make an "image" of the surroundings. The results of performed simulations prove that this feedback is an

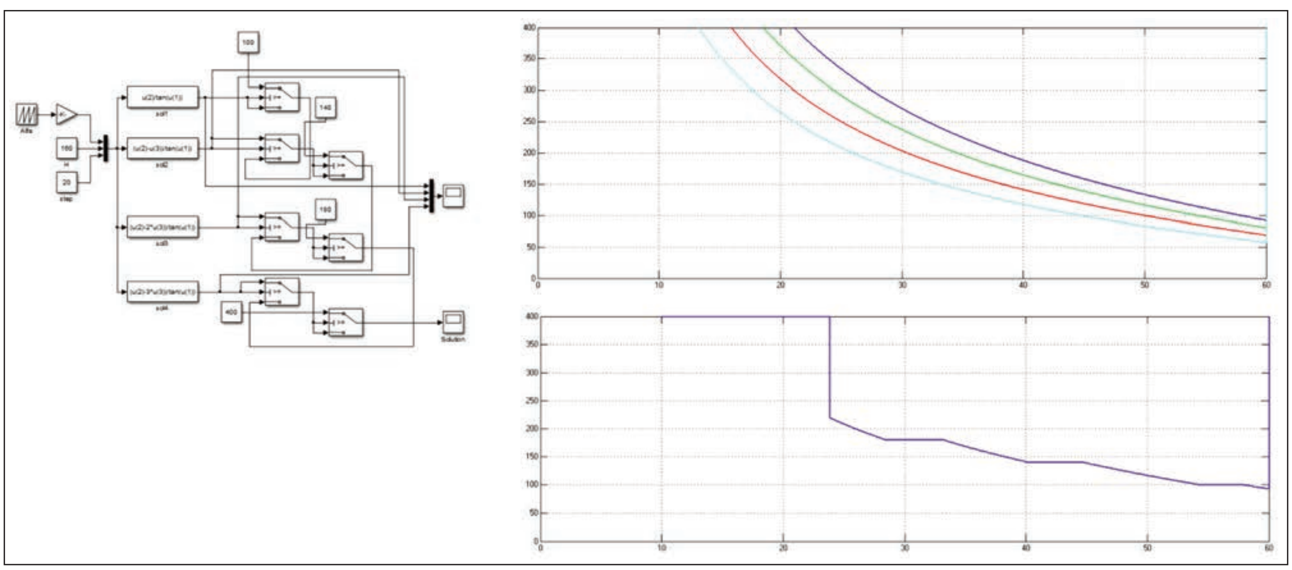

Fig. 9. Simulation results

outline of the obstacle, which is detected from 90 cm to 300 cm from the individual's position. The response time for the distance of 200 cm is about 12 ms. The fact that the used ultrasonic sensor has a tight angle (30°) for this case is an advantage because the obstacle detected is controllable from the positioning in space point of view. A sensor with a 360° angle would mean a large amount of information to be processed by the individual. Thus, our device can be used alone or in combination with other accessories for visually impaired people. Future developments may be in the following directions: miniature camera with wide angle, comparable to the view angle of humans of about 120°, to identify the contour and position of the obstacles and also the use of sensors embedded into the fabric by means of nanotechnologies, in which case even if the sensors have tight angle, by their appropriate positioning on the cloth, the obstacles can be identified similar to the case of miniature camera use.

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