ROBOTIC SYSTEM AND INTEGRATED ITC SOLUTION FOR DISABLED PEOPLE

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Abstract. This paper evidences research aspects regarding the development of innovative systems for disabled people. It is focused on the concept development for an upper limb mechatronic system and on the development of an integrated IT&C solution aimed to help teaching and training processes of the visually impaired pupils.

Key words: upper limb, robotic system, integrated IT&C solution, teaching, visuyally impaired pupils.

1. INTRODUCTION

The research involved by the topic of this paper is based on the belief that the field of disability and social inclusion has always been and continues to be a highly debated topic that includes research in different fields like: medicine, sociology, psychiatry and, not the least engineering According to World Health Organization (WHO), disability is defined as "the result of the interaction between a person with a disability and barriers related to the social and attitudinal environment he / she may encounter."

Along the history, there were so many cases when people lost parts of their bodies and got disbilities. Considering the upper limb, one of the first mentioned upper limb prosthesis is of the Roman general, Marcus Sergius Silus Ferrous who lost his right hand during the Punic war. To be able for further fighting, he had an iron hand prosthesis. In the XIXth century and the beginning of XXth century, the upper limb prostheses were mainly made of wood and leather, with customized design focused on person's needs aimed to sustain (see Fig. 1 [1]).

The high development of science and technolgies, specially the new advanced materials, the artificial intelligence and high performance modelling software stand as important tools for design and developement of high performance

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hand prostheses. These enable indepenedent and accurate motions, could be with tactile feedback and, thus, would restore muscle sense (see Fig. 2 [2, 3]). They are lightweight, look similar to real limb of the people and enable performing many every day tasks [4, 5].

Fig. 1 – Hand prosthesis with fingers motion mechanism (1920) [1].

Partial hand prosthesis [2]. Hand prosthesis [3].

Fig. 2 – Hand prostheses.

We also gave attention to people with visual impairments that must be able to learn the Braille alphabet in order to benefit from training. The alphabet over time has been enriched with the 9 principles of standardization of Braille alphabets for different countries, adopted in 1949 by UNESCO experts. The disadvantage of using the Braille alphabet is that large volumes of the printed books require large storage spaces and it is very difficult to cover all areas with them.

An advantage and help for the visually impaired people are provided by the computer. Several software tools have been developed to help the blind or partially sighted, such as screen readers and assistive software. There are various ways to implement these tools, but they do not always meet the needs of visually impaired.

JAWS is a software produced by Freedom Scientific, being a screen reader application. It is provided with Ioana's voice in Romanian and can be installed on a single computer. This software, for a large part of the users, is almost unusable as it is an installed application and it needs many customized settings. It is not cheap, meaning 2,852 RON (570 euro) per computer [6].

Another specific tool is represented by the computers produced by Apple Inc. These are designed as integrated systems for the blinds, but the minimum price for a minicomputer is 4,000 RON (800 euro) [7].

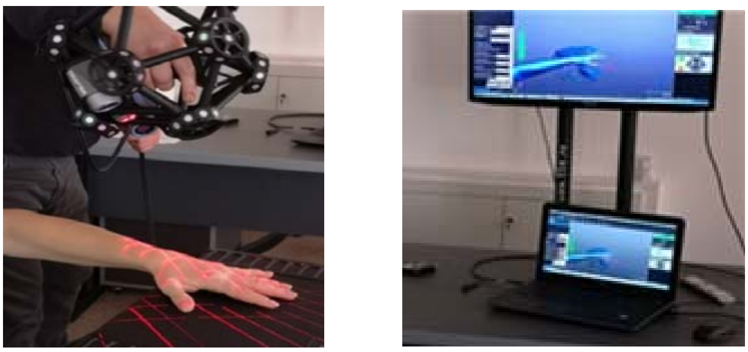
This paper further presents research results on the concept, design and modeling of a mechatronic system for the upper limb (hand prosthesis). It is estimated that the prosthesis would be light weight, with accurate motions, user friendly and, not the least, with affordable price for the social assisted people in need. Another important issue of this paper is to evidence the software components of an innovative assistive system aimed to help teaching and training the visually impaired pupils when working on the computer.

2. MODEL OF THE UPPER LIMB SYSTEM

2.1. CONCEPT AND MODEL

The idea of customized design of a prosthesis for hand, raised from the need of helping a young girl in the social assistance system to have a normal life. She lost her arm in an accident, while she was little and, can not afford a performance hand prosthesis to help her perform everyday tasks.

In order to design and, finally, prototype a fit prosthesis, it is the objective to have it look as much as possible, similar to her existing real arm. This is why, there has been applied the reverse engineering technique and, aided by the MetraSCAN laser system [8, 9], the surface model of her arm was generated (see Fig. 3). One can notice, for example, the dimensions and appearance of the fingers in the model.



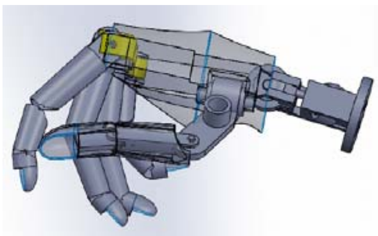
3D laser scanning with MetraSCAN

Fingers dimensions.

Fig. 3 – Reverse engineering – 3D scan.

The mechatronic system for upper limb is designed so that to enable two independent rotational motions for each of the fingers, two rotational motions of the hand (at wrist) and two rotational motions of the forearm (elbow) (see Fig. 4).

3D model of the upper limb.



3D model of the hand.

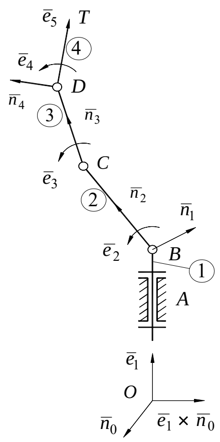
Simulation of fingers motion.

Fig. 4 – Mechatronic system's 3D models.

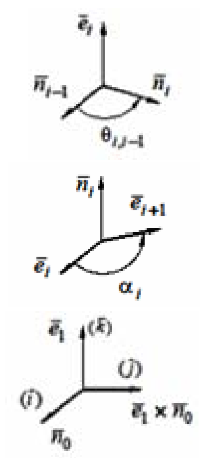
2.2. KINEMATIC ANALYSIS OF THE THUMB MECHANISM

The fundamental principle for planar mechanisms structure is Assur principle, that states that any planar mechanism is made of serial, or parallel connected modular groups (one driving link and the rest passive links) with zero mobility [10]. Kinematic analysis of a mechanism is aimed to determine the postions, speed and accelartion distributions of its each element, previously knowing their constructive characteristics and relative movement of the active link elements.

For the designed upper limb mechatronic system, schematic representation of the thumb and the trihedron axes are shown in Fig. 5.



Kinematic scheme.



Trihedron axes.

Fig. 5 – Kinematic representation of the thumb.

Associated to this kinematic scheme, the multipolar scheme is presented in Fig. 6, where the Z(0) notation stands for the drive link and the $R(i), i=1,...,4$ represents the rotational dyad (RRR).

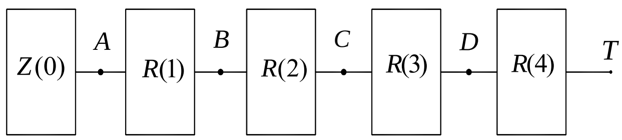


Fig. 6 – The multipolar scheme of the thumb.

The position vector for the thumb tip, T, is determined by relation (1):

$$\overline{r}_T = s_1\overline{e}_1 + a_1\overline{n}_1 + s_2\overline{e}_2 + a_2\overline{n}_2 + s_3\overline{e}_3 + a_3\overline{n}_3 + s_4\overline{e}_4 + a_4\overline{n}_4 + s_5\overline{e}_5 , \qquad (1)$$

where:

- s_i is the distance between the normals $\overline{n}_{i\text{-}1}$ şi $\overline{n}_i$, positive sign along the $\overline{e}_i$;
- a_i is the distance between the axes $\overline{e}_i$ şi $\overline{e}_{i+1}$, always positive.

Considering as given inputs the values for constructive parameters (length of kinematic elements), as well as mechanism initial positions (defined by axes angles), the vectorial equation (1) turns into relation (2):

$$\overline{r}_T = s_1\overline{e}_1 + a_2\overline{n}_2 + a_3\overline{n}_3 + s_5\overline{e}_5 . \qquad (2)$$

Projection on each of the OXYZ axes, results in relation (3), that is:

$$\begin{cases} X_T = a_2 D_2 + a_3 D_3 + s_5 A_5, \\ Y_T = a_2 E_2 + a_3 E_3 + s_5 B_5, \\ Z_T = s_1 + a_2 F_2 + a_3 F_3 + s_5 C, \end{cases} \qquad (3)$$

where the values for $D_2, D_3, E_2, E_3, F_2, F_3, A_5, B_5$ and C_5, as well as their derivatives, are determined by matrix calculation.

The calculation was done in MATLAB and an example of the fingers motion simulation is presented in Fig.7.

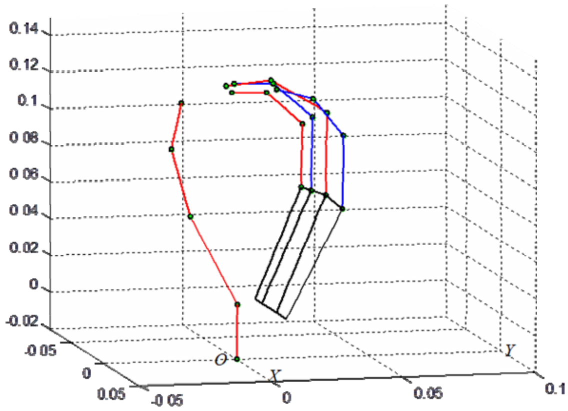


Fig. 7 – MATLAB fingers motion simulation.

3. IT&C SOLUTION FOR VISUALLY IMPAIRED PUPILS

The IT&C system can be used by people with disabilities, in Romanian language. Depending on their health problems and enthusiasm they can get to use it the best they can**.**

The integrated system, IT&C SOLUTION, is based on open source information technologies, Linux operating system with individualized application packages, designed to facilitate user access to various sources of information and training.

The installation process (see Fig. 8) is assisted vocally. For the first screen the voice speaks in English and the requirements are not understandable, but from the second screen when choosing the Romanian language everything flows in this language.

Fig. 8 – Screenshoot of the instalation process.

In the first part of installation, a basic system is obtained (see Fig. 9).

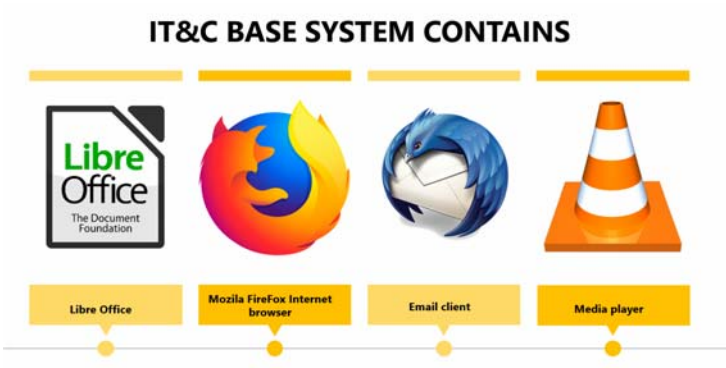


Fig. 9 – Screenshoot of the basic system components.

Existing systems (currently) do not provide an integrated solution and do not meet the education and training requirements of visually impaired people, do not provide them with integrated cloud and e-mail tools.

An important aspect considered by the authors when desgining the system, is that of costs – which should be as low as possible, so as to allow access to the integrated modular system of the young people who have low incomes (as, unfortunately is the case of so many of them, nowadays).

This system, compared to existing ones, offers an integrated solution that can be customized on request. This is an important issue and advantage of its concept and design.

The basic package is the one that will be integrated in all the distributed variants and depending on the each person disability/disabilities, customized modules will be integrated to satisfy the needs and requirements.

The tools dedicated to reading texts by the visually impaired are Daisy players and specific formats are developed for them. Within existing operating systems, the formats for Daisy systems are not integrated and therefore a visually impaired person could not use such files.

Few examples of additional packages integrated into the designed system are evidence in Fig.10.

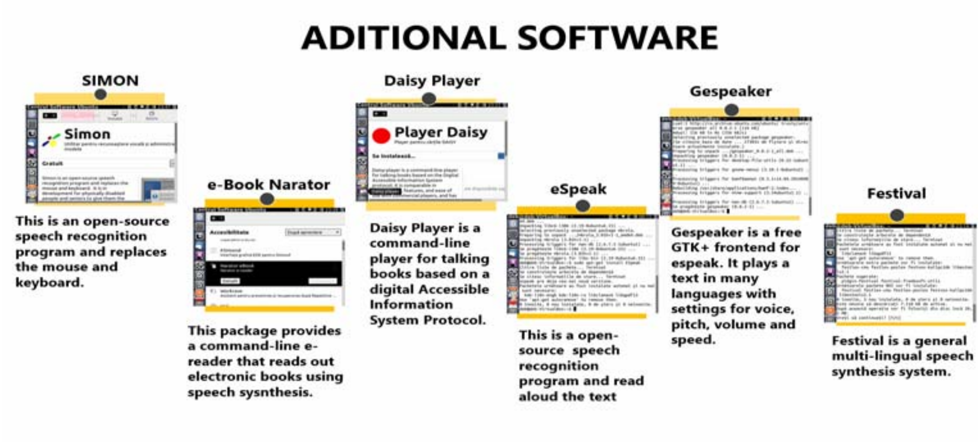


Fig. 10 – Additional software.

The integration of the additional packages involved adaptations, modifications of the different versions in order to be supported by the Kernel of the basic operating system. The interface has been modified; changes and adaptations have been made to various packages such as Simon, Festival so that they can be compatible with each other.

Some available applications / uses of the integrated modular system are mentioned next:

– personal use – at home;
– educational units – basic school, college;–
– associations of people with visual, reading and writing disabilities;
– persons who teach and train the visually impaired people.

4. CONCLUSIONS

The paper presents search results on innovative mechatronic and ITC aimed to improve the life of people with disabilities and focuses on their skills and availability to use mechatronic system, computers and IT technologies.

There are presented the concept, model and kinematic analysis for a new upper limb mechatronic system. This is a hand prosthesis and it is intended to be low weight, friendly user, to provide accurate and, even, complex motions.

The ITC system developed could be used by people with visual disabilities, in Romanian language. Designed and adapted according to their customized needs, it is an important tool in training and teaching, enabling the spelling support.

Further development of research would involve prototyping, test and validation of the upper limb mechatronic system. Also, it would involve the development and integration of new customized (for people with reading and/or writing disabilities, with average learning disabilities) modules and solution into the software system that would enable network communication, access to cloud technology. All these mentioned envisage a, relatively, normal life for people with disabilities.

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REFERENCES

1. https://ro.pinterest.com/pin/577727458433025139/, accessed on July 10, 2020.
2. https://www.armdynamics.com/our-care/finger-and-partial-hand-prosthetic-options, accessed on July 10, 2020.
3. https://www.ottobockus.com/prosthetics/upper-limb-prosthetics/solution-overview/bebionic-hand/, accessed on June 7, 2020.
4. HAAS, M., FRIEDL, W., STILLFRIED, G., and HÖPPNER, H., *Human-Robotic Variable-Stiffness Grasps of Small-Fruit Containers Are Successful Even Under Severely Impaired Sensory Feedback*, Front Neurorobot, **12**, *70*, 2018, doi: 10.3389/fnbot.2018.00070.
5. HÖPPNER, H.,, GROßE-DUNKER, M., STILLFRIED, G., BAYER, J., and van der SMAGT, P., *Key Insights into Hand Biomechanics: Human Grip Stiffness Can Be Decoupled from Force by Cocontraction and Predicted from Electromyography*, Front Neurorobot, **11**, *17*, 2017, doi: 10.3389/fnbot.2017.00017.
6. https://www.anjo.ro/cititoare-de-ecran-pentru-calculator/freedom-scientific-jaws-home-edition-pentru-utilizatori-individuali-persoane-fizice.html, accessed on October 10, 2020.
7. https://www.emag.ro/mac-mini-pc-apple-cu-procesor-intelr-coretm-i3-3-60-ghz-8gb-128gb-ssd-intel-uhd-graphics-630-int-space-grey-mrtr2ze-a/pd/D8JF64BBM/, accessed on October 10, 2020.
8. https://www.cadworks.ro/solutii/scan-3d/metrascan-3d/, accessed on June 17, 2020.
9. RADU (FRENŢ), C., ROŞU, M. M., ILIESCU, M., *Design and model of a prosthesis for hand*, *IOP Conf. Ser.: Mater. Sci. Eng.* **916** 012093, 2020.
10. SHAI, O., *Utilization of the dualism between determinate trusses and mechanisms*, Mech. Mach. Theory, **37**, *11*, pp. 1307–1323, 2002.