INTERACTIVE SYSTEM FOR LEARNING THE BRAILLE ALPHABET AND THE FINGERSPELLING SIGNS

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Abstract: In this paper, an interactive system formed of a tactile display and an artificial fingerspelling hand - both interfaced with a computer, is presented. The system is dedicated for learning the Braille alphabet - by children with seeing disability and the finger spelling signs - by children with communication disability. The proposed system is an intelligent environment for social assistance in the field of sensorial and communication rehabilitation.

1. INTRODUCTION

The importance of sensorial and communicational functions results from the fact that the human organism is an open biosystem, in a permanent exchange of energy and information with the environment. The human being receives information from the environment: 1% by taste, 1.5% by tactile sense, 3.5% by smell, 11% by hear and 83% by sight, [14].

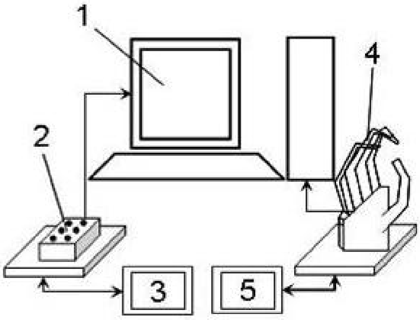


Fig. 1 The principle scheme of the system

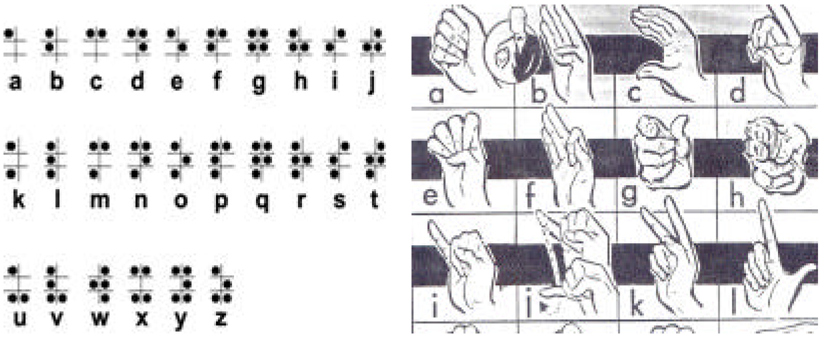


Fig. 2 The Braille alphabet and examples of dactilemes

Working in the field of sensorial functions rehabilitation, the authors' objective is to design an interactive system for learning the Braille alphabet by children with disabilities of sight and the dactilemes used in the International Sign Language by children with disabilities of view and speech. Using this system ensures a more efficient process of rehabilitation concerning communication functions, conducting to a more rapid integration in society and family of children with sensorial disabilities.

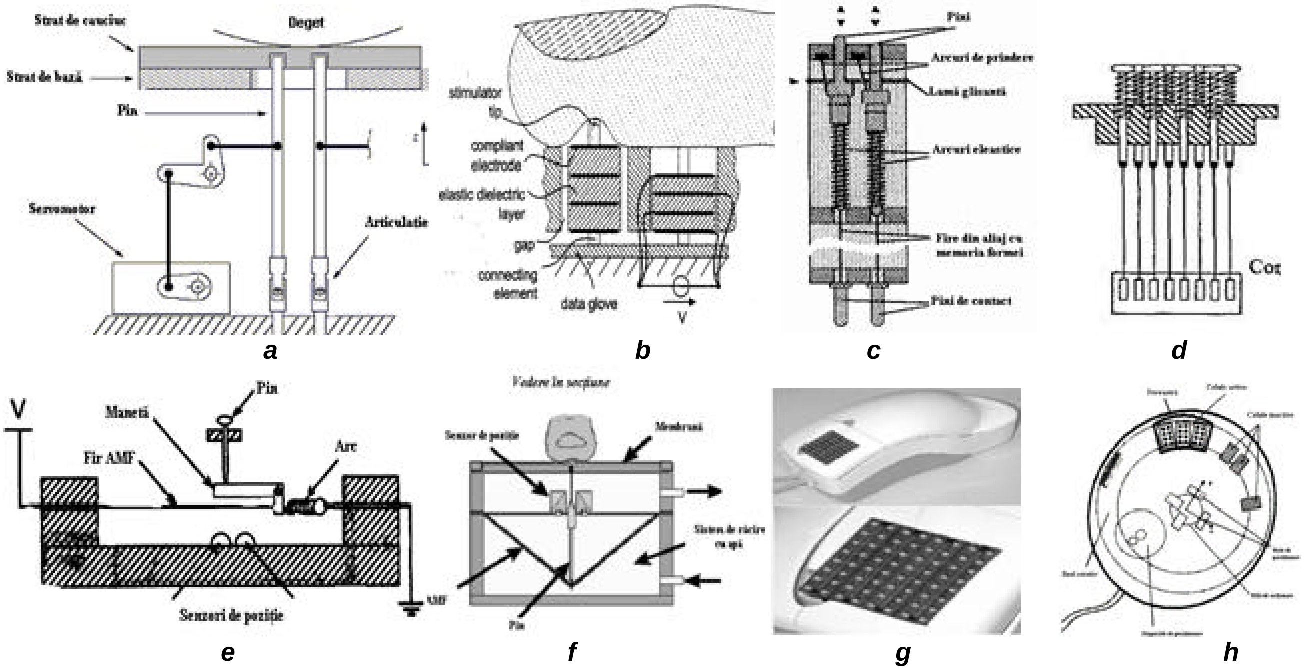
The principle scheme of the proposed system is presented in figure 1. The central control system *1* is in connection with the tactile display (TD) *2* and the artificial hand (AH) *4*. With *3* and *5* the control and actuating subsystems were annotated. These subsystems are used for the TD and AH. In the process of learning the Braille alphabet, the educator inserts the character wanted and at the TD the pins are being arranged in the configuration matching the character, for being seen by the user. The visual feed-back (interface at screen *1*) is destined exclusively to the educator. In the process of learning of the mimico-gesticular language, the educator or user inserts the desired character, and hand *4* disposes in the configuration specific to the character, and also, at screen *1*, the virtual model of a natural hand is watched, in the same character's configuration.

2. COMPARATIVE STUDY OF SOME TACTILE DISPLAYS

The tactile display is the system artificially created, in which a human subject can interpret information concerning the shape and surface of some objects. According to this definition, a tactile display has the role to stimulate receptors within the tegumentary tissue, for generating the contact sensation. Also, this term is used for naming the systems that offers tactile feedback from the interaction with virtual objects (haptic feedback). In certain situations, the tactile display is interpreted as a surface capable of changing shape on the background of control from a computer, [2], [6].

Considering the nature of skin receptors, it results that the stimulus generated by the tactile displays must be categorized as follows:

- vibrations (offers information concerning the surface's texture, flow, impact and punctual contact (the domain of frequency of vibration varies from few Hz, to few hundred Hz);
- distribution of pressure and reproduction of shapes at low scale (this situation needs a pin network, closely positioned one to each other, which can be in contact with finger tip, individually, so that they can approximate a desired shape);
- sensation of a thermic parameter (it represents a new domain, thermic perception can be based on a combination of some parameters like: temperature, thermic conductivity, etc.);
- other modalities: electric cutanated stimulation, devices with electro-rheologic fluids for converting the information concerning compliance and others.



a b c d e f g h

Fig. 3 Examples of tactile displays

In figure 3 some examples of tactile displays are presented, [3], [8], [16], [17]. In figure 3a is put on view an alternative with four pins in oscillatory movement, each of the four pins being tied from the base by a spherical articulation and being put on move by two d.c. servomotors.The pins apply a cutting force over the fingers which they come in contact. Examples 3 b-f are characterized by the vertical movement of the pins with different options of mini/microactuators. The actuating system in figure 3b is based on chemical actuators with dielectric polymers. When a tension is applied, they narrow and grow their surface. When the tension is no longer applied, the polymer resizes to its initial shape and surface. For realizing a considerable movement of the pin, more stacks of dielectric material and electrodes are required. The solutions in figures 3c, d, e and f are useful for actuating pins based on memory-shape alloy, with active elements, wire-typed, the resizing being ensured by the elastic elements. These actuators offer the optimum conditions for miniaturizing. The alternative in figure 3d consists of eight modules, each of them with two pins. The pin's movement in figure 3e is produced by activating a wire with shape memory alloy, whose stroke is amplified within an articulated element. The display in figure 3f contains 10 pins linearly disposed. A mouse with tactile display is presented in figure 3 g. In figure 3 h there is a display for reading in the Braille alphabet. It consists of 20-80 cells which are disposed in a circle; three of them are active, being situated near de access window. Each cell has eight pins, disposed on two columns, each column containing four pins actuated by the electromagnets.

The most important functional parameters, specific to the tactile displays are: normal pressure applied on finger tips; the frequency of excitation; the power density; the active element density; the number of pins; the distance; the maximum frequency; the force on the pin ; the pin diameter; the distance between the centers of two consecutive elements. No tactile display is destined to learn the Braille alphabet. For those who know this alphabet, displays like in figure 4 are in the market, [19], [20], [22]. These vary by the method of actuating the pins but are very expensive.

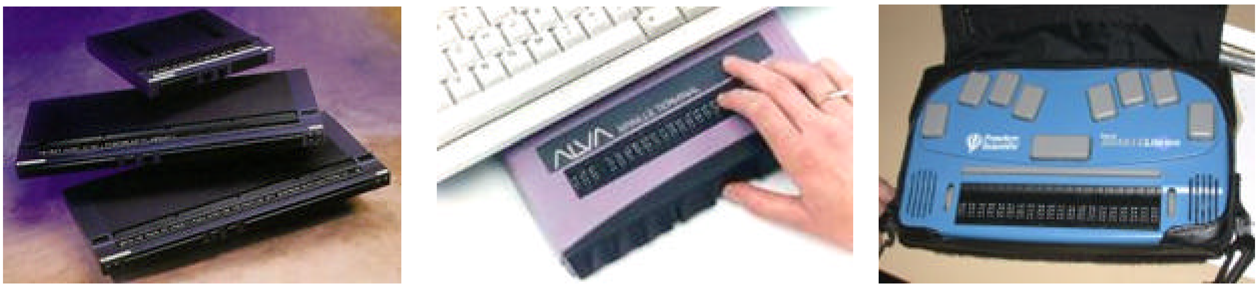


Fig. 4 Examples of commercial displays for the Braille alphabet

3. COMPARATIVE STUDY OF SOME FINGERSPELLING HANDS

Research in the field of artificial anthropomorphic hands has its origin in robotics and prosthetics. Once with the improvement of actuating and control systems, hands which copy in great measure the sizes and functions of the natural hand were realized. In figure 5, some examples of anthropomorphic hands are presented, [4], [9], [10]. The main researched aspects are: solutions for ensuring dexterity; miniaturizing for reducing weight and ensuring dimensions similar to the human hand; new actuating systems; automatic control of the grasping force. A new direction is represented by microcontroller-based systems. Anthropomorphic hands were developed, having pneumatic, artificial muscles, hydraulic, electrical actuating system, and recently, with shape memory alloy actuators.

Nowadays, there are several techniques for modeling and animating a hand, according to the dactilemes, like in figure 6a, [5] . The application is used for text-to-speech converting system. The most advanced researches are conducted in the field the so-called fingerspelling hands, meaning artificial hands, for blind and deaf people, who can communicate only by these devices.

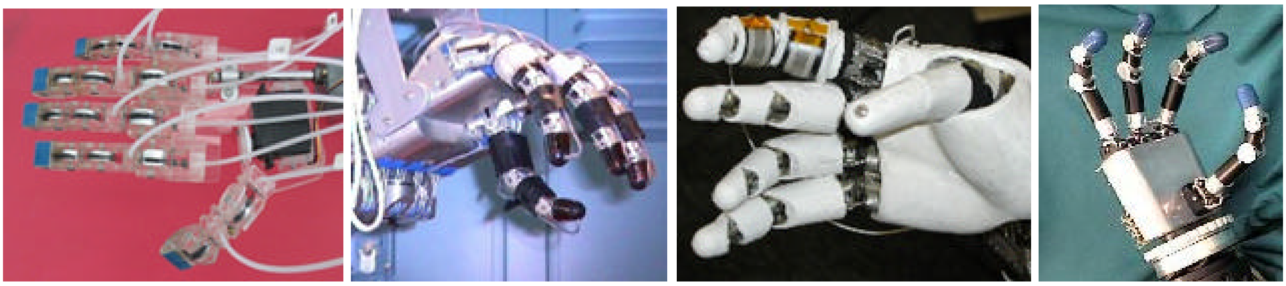


Fig. 5 Examples of anthropomorphic hand.

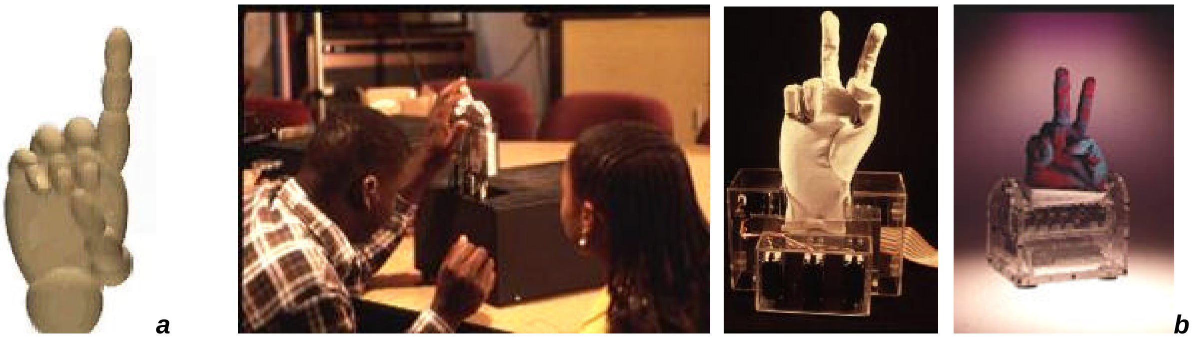


Fig. 6 Examples of Fingerspelling hand.

In figure 6, there are presented several examples, [1], [7]. There common characteristic is five-finger structure with the thumb in opposition, with articulated phalanges. D.c. motors are used to actuate their mechanisms. Their overall size is similar to that of a natural hand. This kind of equipment ensures an alternative channel for the sensorial perception (tactile sense, instead of seeing and hearing).

4. LEARNING SYSTEMS FOR DISABLED CHILDREN

The rehabilitation of children with communication disabilities is an educational and rehabilitational activity. This activity has greater and more rapid effects, as early as it starts. The methodology used in teaching children with speech problems how to communicate is based on mimico-gesticular method, on the tactile sense and on the lip-reading method. The ICT is currently proposed by all the European countries to be applied in different medical problems, especially in rehabilitation, [18]. Unfortunately, ICT wasn't largely used in the field of special education. The most efficient for children with special educational needs and for teachers are still searching for.

Through CMC (Computer Mediated Communication), people with hearing and seeing problems are offered numerous opportunities, by combining the text communication with the audio-video one. Paper [1] presents the new aspects connected with usage of the vocal synthesizer and of Braille displays. One of their conclusions is that access to this kind of facilities allows persons with disabilities to learn more in less time. An interesting study was realized by a team of researchers from Austria, Spain and Great Britain whose goal is the initiation of this category of persons in using informational facilities like fax and Internet, because, in their opinion, people with hearing disabilities are endangered to stand outside the informational society. The previous research's purpose is to develop a multimedia course for learning of written language. At New South Wales University, intelligent gloves, capable of feeling the hands' gestures on which they stand and to transmit the signal to a computer were created. Special software displays on the screen the text in English, according to the finger-spelling signs. During this recent experiment, the system translates the desired text with a precision of 90 percent. One of the problems in the development of this device is concerning the complexity of gestures which express several characters or words, being difficult to harmonize the finger-spelling signs with usual speech. Thus, one of the aims of using information technology in the field of special education is the offering an adequate technical infrastructure to respond to the individual needs of the user.

5. CONTRIBUTIONS IN THE FIELD OF TACTILE DISPALYS

The functional and constructive parameters of the developed tactile display are: pin diameter: 1.5 mm, center-to-center spacing of the pins: 2.5 mm, force at each pin: 2 N, vertical displacement of the pins: 1.5 mm. We selected shape memory alloy (SMA) wires as actuators because of their very high force-to-volume and force-to-weight ratios. Electrical current heats the SMA wires, which undergo a phase transformation and shorten, thus pushing the pins up. In figure 7, some actuating posibilities by SMA wires are given. The mechanical design of one element of the tactile display that we have chosen is shown in figure 7 c. Based on the input data and on the SMA wire actuators design methodology, presented in [13], [14], we determined the necessary length and diameter of the wire, the elastic force of the biasing spring.

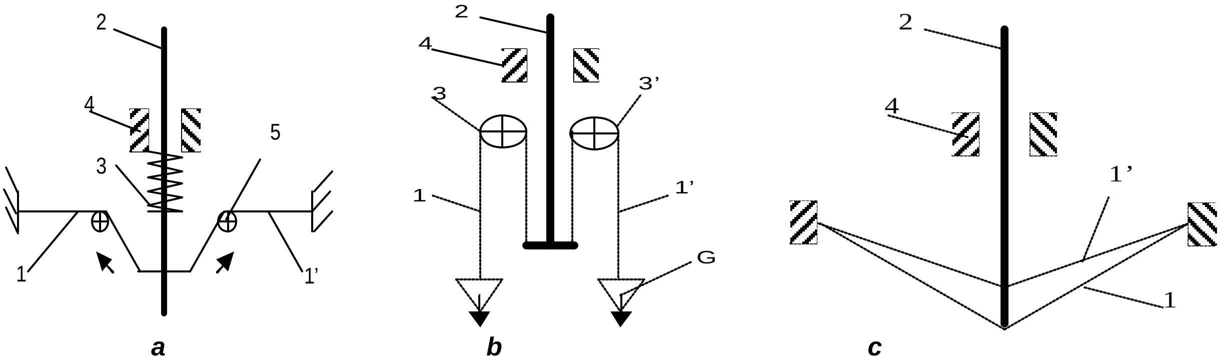


Fig. 7 Different solutions to actuate the pins by SMA wire actuators

We adopt the distance between the ends of the wire (Fig. 8 a): AB = 50 mm and the high of the pin: DC = 25 mm. It results the length of the wire at low temperature, in the martensite phase: l = 71 mm. For a shape memory effect about 3 %, results the length of the contracted wire at high temperatures, in the austenite phase: l' = 68.8 mm. These lengths assure the imposed pin displacement.

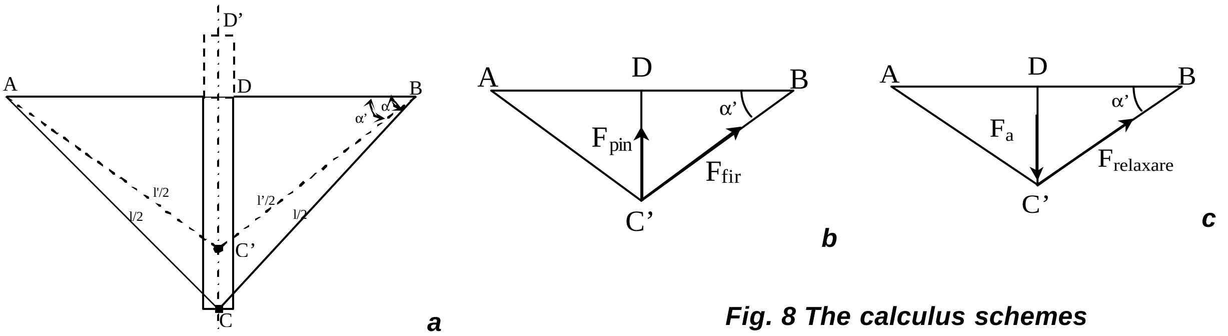


Fig. 8 The calculus schemes

Based on figures 8b and 8c, according with [12], the force exerted by a pin, F_{pin} , the force developed by the wire when it “remembers” its the initial length, F_f., the restoring or relaxation force F_{relax} which extends the cooled wire and the necessary force to be developed by the bias spring, were calculated for different wires diameters, (Table 1).

Based on the force F_a we established the diameter *d*, the average diameter *D*, the number of active coils *n* and the spring rate *c* for the restoring (relaxation) spring.

Table 1 The forces for different wire diameters.

Diameter of the wire [mm]	F_f [N]	F_{pin} [N]	F_{relax} [N]	F_a [N]
0,05	0,39	0,26	0.068	0.045
0,1	1,57	1,05	0.27	0.18
0,15	*3,53*	*2,36*	*0.61*	*0.40*
0,25	9,81	6,57	0.71	1.14

The tactile system in our prototype consists of a line of four individually actuated pins that are raised against the fingerpad. The 3D model without the SMA wires is given in figure 9.

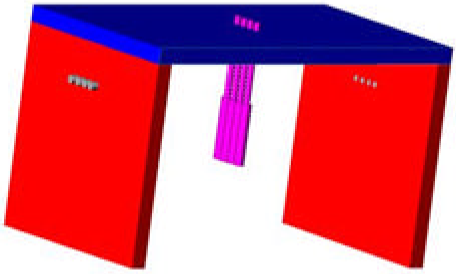


Fig. 9 The 3D model of the developed prototype

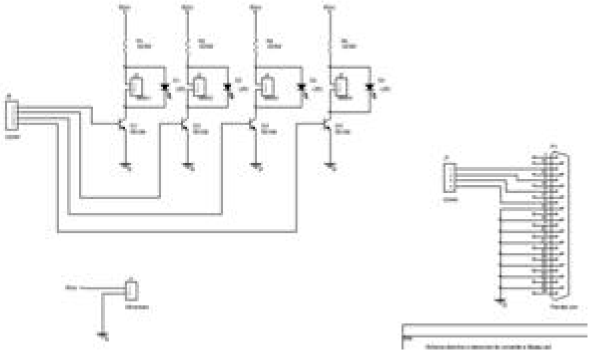
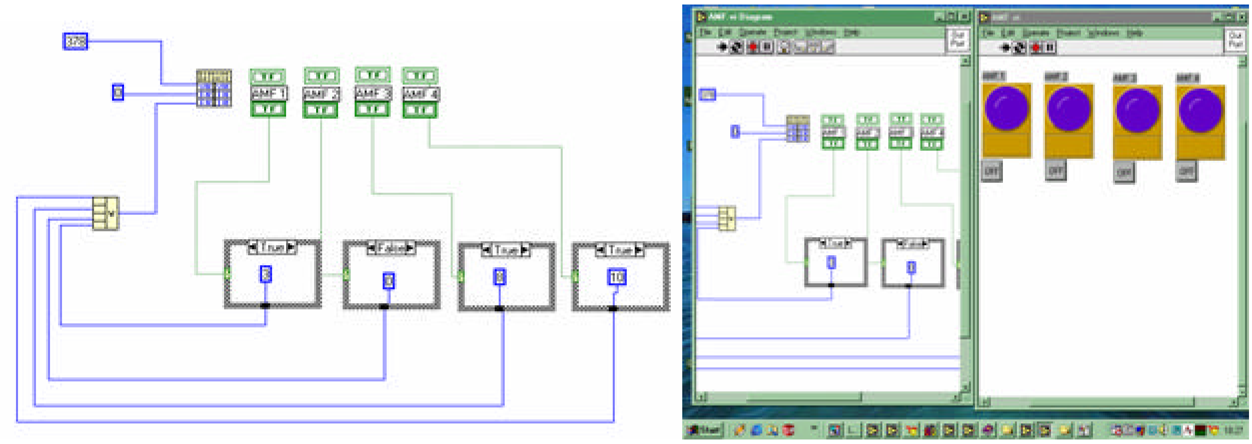


Fig. 10 The electronic scheme of the prototype

For the developed prototype, the actuation system of SMA wires is realized through parallel port of a P.C. Electrical schematics uses as command elements four transistors BD139 which were choosen according with power consumption required by the wires. Because the maximum current for activation is 400mA (recommended for 0,15 mm wire diameter) were used four limiting elements of 10 Ω at an active power of 2W.



a ***b***

Fig. 11 The program and interface for the command of the prototype

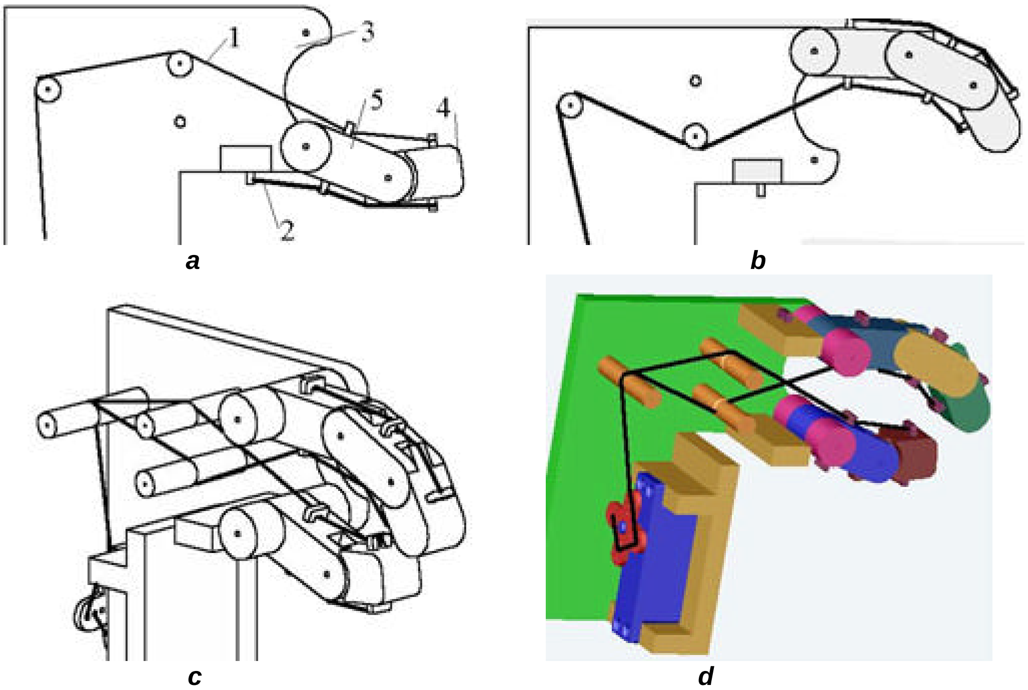
The command in the base of transistors is realised by using the 2, 3, 4, 5 pins of the parallel port connector DB25 pins; those pins belongs to data register 378h. (fig. 10), [12]. The source of the program for the developed prototype was written in LabView. In the figure 11 is presented a snapshot picture of the program source.

6. CONTRIBUTIONS IN THE FIELD OF FINGERSPELLING HANDS

Taking into account its functional role, a fingerspelling hand must be an antropomorphic one. The synthesis of its mechanisms has at its basis the analogy with the natural hand, materialized in the following synthesis criteria [13], [15]: imitating form and size of the natural hand; the adaptability to the form and size of the grasped objects.

The first synthesis criterion determines the following structural characteristics: the size of palm, fingers and phalanges, number of fingers, the relative position of fingers and the distance between them, while the second determines: the type of joints that connect the fingers to the palm, the type of fingers, the number of phalanges for each finger, the mobility, the morphology of the mechanisms. The adaptability can be achieved by: the articulation of the phalanges; the coordination of the phalanges movement of each articulated finger; the coordination of the movement of several fingers; the opposition and the coordination of the movement of the thumb and changing the prehension configuration.

Ensuring these functions through the tendon driven-mechanisms leads to the following advantages: light weight, small size, actuators can be installed at a certain distance, low backlash, no shocks, overloading protection, silent functioning and good efficiency. The small size of the tendons permits large bending radius and thus large flexion-extension of the fingers.



a b

c d

Fig. 12 The developed anthropomorphic hand

The proposed model of an anthropomorphic hand is composed of two fingers corresponding to the thumb and the index of a natural hand. The thumb, with two articulated phalanges, is placed in opposition to the index, which has three articulated phalanges. The joints between phalanges and between the proximal phalanx and palm correspond to metacarpo-phalangeal and inter-phalangeal joints of a natural hand (Figure 12). The coordination of the movements of phalanges is secured by the tendon mechanisms shown in figures 12a (for the thumb) and 12b (for the index). The role of this coordination is to offer the fingers flexion and extension, a character as closed to the natural movements as possible. The tendon pulling determines the flexion of the fingers. The extension is ensured by elastic strips placed on the dorsal side. In figure 12 a, following notations are used: 1– tendon (cable), 2– elastic strip, 3– palm, 4, 5 – phalanges. The 3-D model of the hand is presented in figure 12d. The used actuator (Standard HS-311 DC servomotor) requires 3-5 V peak to peak square wave pulse. Pulse duration is from 0,9 ms to 2,1 ms with 1,5 ms as center. The pulse refreshes at 50 Hz (20 ms). It can be operated within a 4,8 – 6 V range.

CONCLUSIONS

The assistive devices are very diversified due to the diversity of affections, having a strong adaptability to each user. The learning systems are now in a beginning stage, there are no researches only for children with special needs. A prototype of a tactile display, consisting in tactile pins reproducing sensations related to normal contact forces has been developed. The actuators are based on a shape memory wires. First tests showed encouraging results. The development of anthropomorphic hand able to replicate the motion capabilities of the natural hand represents a condition for a fingerspelling hand system.

REFERENCES

1. Beumer, J.J, de Haan, A. , Implications for designing a CMC system to support Visually Imapired Persons (VIPs), in Computers Helping People with Special Needs, Vollmar, R., Wagner, R. (eds.), Osterreichische Computer Gesellschaft, 2000, pg. 51-58.
2. Bronzino, J.D. (editor), Biomedical Engineering Handbook, CRC Press & IEEE Press, Hartford, 1997.
3. Brenner, W., Micro-Actuation Principles for Hight Resolution Graphic Tactile Displays, 2000, available at: www.rm.mce.uec.ac.jp\study-shumj\TactilDisplay\.
4. Caldwell, D.G., Biomimitic systems for limb prosthetics using pneumatic muscle actuators, Proc. Int. Conference ACTUATOR 2002, Bremen, pp. 658-661.
5. Davidson, M.J., Improved hand animation for American sign language, avalable at: http://rose.iinf.polsl. gliwice.pl/~ kwadrat/www.csun.edu/cod/conf2001/proceedings/0092davidson.html
6. Fritschi,M.,Design of a Tactile Shear Force Prototype Display, 2003, available: http://www.tuch-hapsys.org
7. Gilden, D., Dexter, A Robotic Hand Communication Aid for Deaf-Blind, International Journal of Rehabilitation Research, 2004, 11 (2), 188-189.
8. Howe, R.D., Shape Memory Alloy Actuator Contoller Design for Tactile Displays, Proc. of the 34th IEEE Conf. on Decision and Control, New Orleans, 1995, pag. 1-5.
9. Kyberd, P.J., The design of anthropomorphic prosthetic hands: A study of Southampton Hand, Robotica, vol. 19, pag. 593-600, 2001.
10. Kuribayashi, K, An upper extremity prosthesis using SMA actuators, IEEE Int. Workshop on Robot and Human Communication, pp.52-57.
11. Mandru, D., Rusu, C., Noveanu, S., Research concerning the development of a robotic system for rehabilitation exercises, Mecatronica, nr. 2, ISSN 1583-7653, pag. 55 – 60, 2004
12. Mandru, D., Crisan, R., Buiga, S., Research concerning the development of a Tactile Display, 2004, Buletinul Stiintific al Universitatii de Nord, Baia-Mare, seria C, volumul XVIII, pag. 195-200, ISSN 1224-3264.
13. Mandru, D., Ingineria protezarii si reabilitarii, Editura Casa Cartii de Stiinta, Cluj-Napoca, 2001.
14. Maties, V., Mandru, D., Balan, R., Tatar, O., Rusu, C. – Tehnologie si educatie mecatronica, Editura Todesco, 2001, ISBN 973-8198-05-4
15. Mandru, D., Crisan, R., Hand prosthese: two different aproaches, A IX-a Conferinta Internationala de Mecanisme si Transmisii Mecanice, MTM 2004, 10-12 iunie, Cluj-Napoca, in Acta Technica Napocensis, series Applied Mathemathics and Mechanics, 47, vol. II, ISSN 1221- 5872.
16. Nobels, T., *Design* of High Power Density Electromagnetic Actuators for a Portable Braille Display, Proc. of 2002 Conf. on New Actuators, Bremen, pag. 596-599.
17. Taylor, P.M., The Design and Control of a Tactile Display based on Shape Memory Alloys, Proc. of the 1997 IEEE Int. Conf. on Robotics / Autom., Albuquerque, 1997.
18. Raportul Agentiei Europene pentru Dezvoltare in domeniul Educatiei Speciale, editori: Cor Meijer, Victoria Soriano, Amanda Watkins, 2003, ISBN 87-90591-77-1, www.european-agency.org, pg. 37-57;
19. http://robotics.eecs.berkeley.edu/~gmoy/tactiledisplay/main.html
20. http://faculty.washington.edu/chudler/gif/braille.gif
21. http://www.ncaonline.org/monographs/monograph_images/Braille-Cell.gif
22. http://www.freedomscientific.com/fs_products/displays_focus40-80.asp