An Interactive Technology to Support Education of Children with Hearing Problems

Aleksandar Krastev, Anna Lekova, Maya Dimitrova, Ivan Chavdarov

Abstract: *The paper presents a "design and simulation of gesture"-based model to support education of children with hearing problems. To engage the child's attention and control their own learning according to the individual skills, a framework is proposed for interaction with an artificial hand in the form of a game with rewards for correct answers. The anthropomorphic hand, designed for the purpose in 3D, is both realistic and able to produce all fingerspelling signs of the international sign language. The novelty of the present work is in the proposed integration of biologically feasible movements of the hand and the cognitive ability to display meaningful signs to support teaching novel concepts to children with hearing problems.*

Key words: *Education, Gesture-based Technology, Arm/Hand Model, Children with Hearing Problems, Interactive Technology.*

INTRODUCTION

The future of education is in technology-based classrooms where gesture-based technological models will be integrated. According to Microsoft, gesture-based computing can be a valuable tool in maintaining and focusing students' attention, and promoting interactive classrooms [13]. In passive learning students listen and do not participate in the content of a lesson or in other activities. Gesture-based technology promotes active learning methods where the user's attention is more engaged and the manipulation of the information in the virtual environment is more intuitive. By introducing gesture-based interaction with the computing technology in the classroom the learners can have better control of their own learning preferences and tempo of acquiring new knowledge.

In most general terms, the cognitive function of the gesture is two-fold: to support the speech or to replace it [14]. Supporting the spoken language can help the formation of concepts that are faster and deeper learned than by speech alone [2]. This promotes the introduction of gesture based technologies in the classroom (i.e. tablets and virtual reality), on the one hand, and teaching systems for people with special educational needs (the system Makaton, for example [8]), on the other. In any case, the development of gesture-based technologies for the classroom will have enormous role and influence in future education, for design of natural human-robot interaction and intuitive human-robot interfaces [4], [8], [16].

Non-less important is the issue of designing novel gesture interfaces for people with hearing problems and introducing them in the classroom. It has been established that children of deaf parents are exposed to intensive fingerspelling training from very early age [1]. This helps to acquire large vocabulary very early and the amount of learned words and concepts is comparable to the vocabulary of spoken words by children, who have no difficulty of hearing. If a child has hearing problems, but her parents do not use fingerspelling because they can hear, the child's vocabulary is smaller than in the typical or the other hard of hearing children. This is one of the cases when a gesture-based computing and robotic technology can play a crucial role in helping the child learn fingerspelling, especially in cases when her parents are not deaf or hard of hearing. This ability correlates strongly with the reading ability, so interactive gesture-based technologies can provide invaluable help to the child's cognitive development [1], [3].

Another important role of an interactive technology for gesture production in the classroom is being an assistant to the teachers, who have to bring heavy manuals and picture materials in order to explain gestures [12, 17]. An interactive or robotic technology can reduce the physical burden of the teacher and will make the lessons enjoyable to the learners.

The next sections present a novel framework for design of realistic gesture-based interfaces, aiming to be introduced further in robotic technology. The framework implements a "design and simulation of gesture" - based model to support education of children with hearing problems.

INTERACTIVE TECHNOLOGY BASED ON GESTURES (ITG)

We propose an interactive technology based on gestures (ITG) to support education of children with hearing problems. It is established that early learning of sign language in children with hearing difficulties is observed around 13 months of age and the first word is fingerspelled at the age of 2 years [1], very similar to the stage of cognitive development of children without hearing problems.

On figure 1 a framework for teaching fingerspelling via a robotic hand is presented. We have used patterns, videos and pictures for each letter performed by the human hand for relevant interpretation of each sign with a 3D model of a robotic hand. Children with hearing problems can see the gesture on the monitor and learn with the ITG technology.

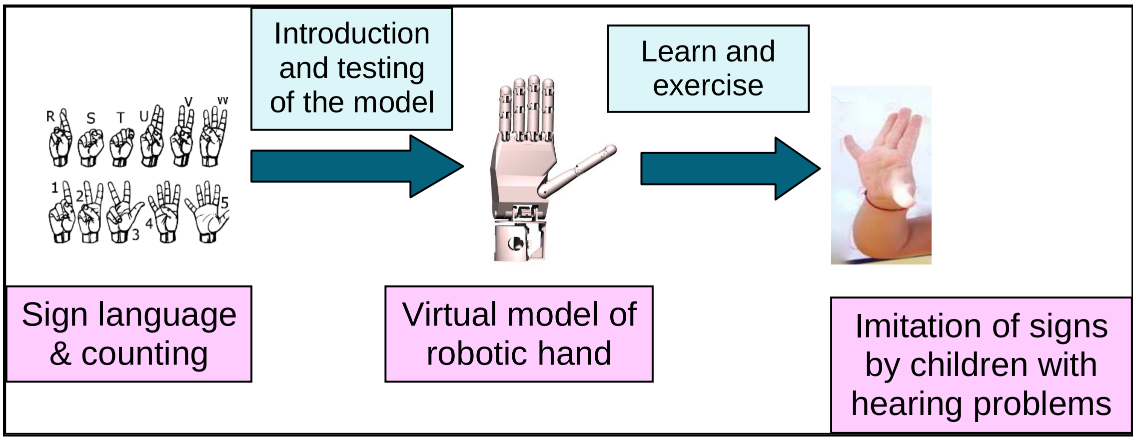


Fig. 1. A framework for teaching fingerspelling via robotic hand implementing ITG

The anthropomorphic hand, designed in 3D, is both realistic and able to produce all fingerspelling signs of the international sign language. It can be introduced very early in the child's education and will help in maintaining the normal tempo of cognitive development.

To engage the child's attention and control their own learning according to the individual skills, we propose that the framework for interaction with the artificial hand is in the form of a game with rewards for correct answers (fig. 1). The assigned reward points according to their answers are displayed in each child's profile page.

TECHNICAL DETAILS

A series of experiments with the robotic hand has been conducted for imitating of finger signs of the International dactyl alphabet for people with hearing difficulties. We have used patterns, videos and pictures for each letter performed by the human hand for a relevant interpretation of each sign from [3]. This is reflected in series of experiments and simulations with the product MSC.visualNastran 4D [11]. We have designed a different configuration of kinematics joints for moving of the robotic hand by tuning the place and number of the rotary motors and all constraints for them, such as time, moving angles and interpolations for smooth animation. Based on a medical measurement system of the real human hand in norm and pathology (provided by www.dpkids.org) and the obtained results from the simulation, we have made changes in the hand by increasing the length of the thumb phalanges, and also a new motor has been placed at the base of the thumb. Thus we achieved realism and closeness in the imitation of the dactyl alphabet by our hand.

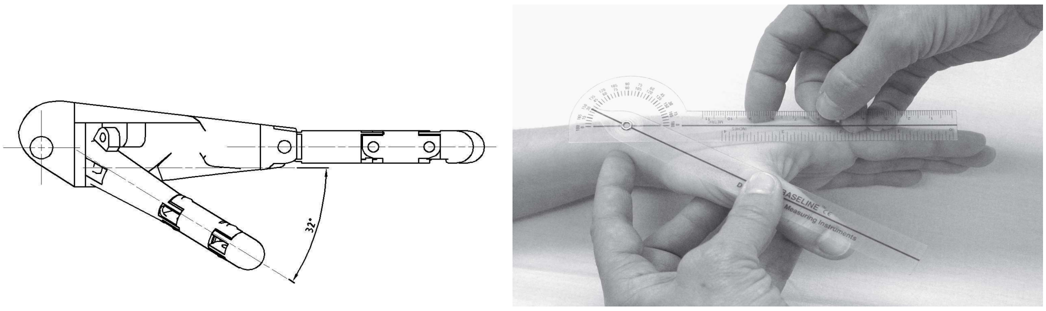


Fig. 2. a) 3D virtual model of the robotic arm b) medical measurements of a real hand

A coordinate system in the centre of each part of the model that has to be controlled is placed in order to move the robotic arm in a simulation mode. “Cord” tool bar from “Edit” toolbar is used. When a coordinate system is selected, a set of kinematics links of type “rotary motor” for each controlled object (phalanges and wrist) are defined by “Revolute motor” menu “Create constraint”. The control of each rotary motor is carried out by its orientation after filling in the field “Orientation” in the “Motor type”. From the “Value” menu an “Edit Table” is selected for tabular input of the discrete values of control parameters. In the corresponding kinematics joint “Control of angle as a function of time” is selected. The measurement unit for time is “second”, while the unit for controlling of the degree is “angle”. The interpolation between the discrete values is of type “Piecewise linear”. Tuning the other rotary motors is the same. In “World menu” is selected the option “Simulation settings” to set the time of the simulation. In case of wrong direction of the movement of one of the movement motors (as opposed to the normal direction of the natural hand movements), a correction is made by clicking on the icon of the motor with the right mouse button by selecting “Swap cords”. To achieve high-quality visualization of the robotic arm before running of each simulation, several tools are used to rotate and zoom the image in several views, which show clearly the gesture of the alphabet.

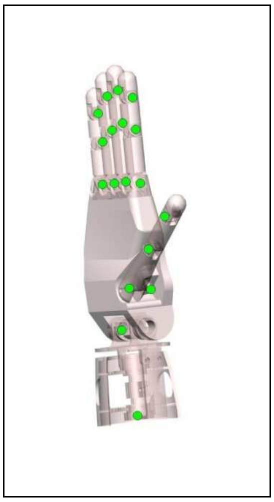
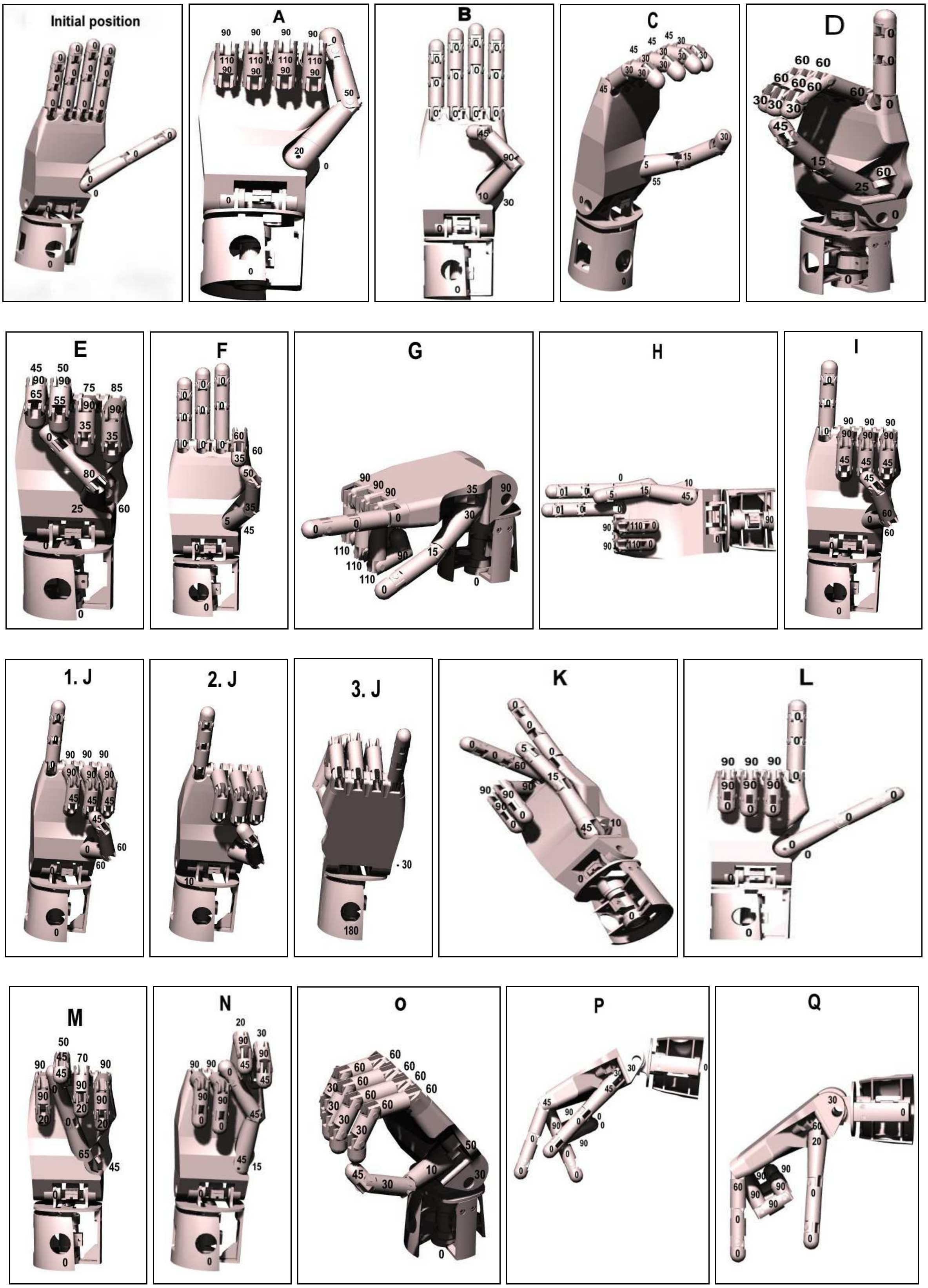


Fig. 3. Kinematics joints in the 3D robotic hand model

After achieving a successful simulation for every gesture of the alphabet one or more images are generated by the program when the wrist is rotating. The image quality is controlled in the menu "Rendering", where the number of pixels in width and length are set. Some special effects as "Shadows" and "Reflections" can also be made.

Labels and numbers in Fig. 4 indicate the changes in the degrees for the rotary movement motor positioned in the kinematics joints to control the robotic arm.



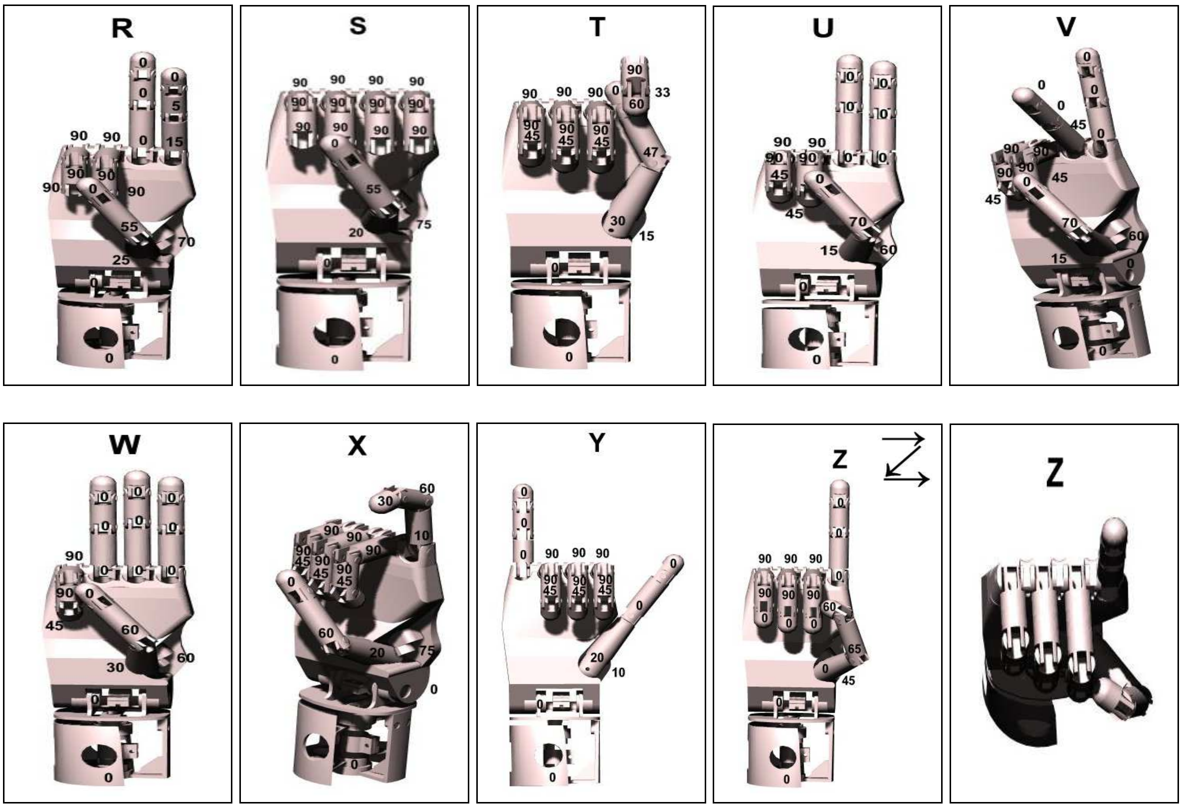
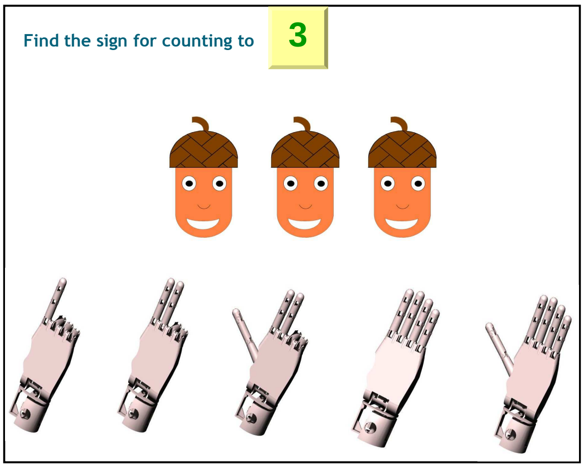


Fig. 4. Robotic hand simulations of the International fingerspelling alphabet

RESULTS AND DISCUSSION

The results of the simulations have proven that the 3D virtual model of the robotic arm can be successfully used to mimic hand gestures, both in static and dynamic mode. Most letters are static except the letters J and Z. For the letter Z there is an additional movement in the area of the elbow and shoulder.



Find the sign for counting to 3

Fig. 5. Example of the test phase of the interactive system

Depending on the child's own skills of learning new signs of the alphabet the framework provides repetitive simulations for the current letter until correct gesture imitation is made by the child (Fig. 5). Our framework ITG presents a realistic sign simulation by the robotic hand. It is intended to be a substitute for the robot in cases the robot is broken or unavailable. Besides, it enhances the acquisition of abstract knowledge that is generalized across types of sign presentations – by human or robot hands.

The present hand simulation is appropriate for virtual reality implementation, for 3D printing, as well as for implementation in anthropomorphic robotics.

RELATED WORK

Robotic hands are widely used in rehabilitation medicine. The first robotic finger-spelling hand is developed especially for the dactyl alphabet and is designed by the Southwest Research Institute (SWRI) in San Antonio, USA in 1977 [9]. The system allows people with impaired vision and hearing to learn new information by examining a robotised hand, displaying signs, sent by other people via a keyboard. With the development of the technologies in the next years enhanced versions of such robotic hands of a new generation have been developed, e.g. “Dexter” (1985), “Dexter-II” (1988) and “RALPH” (1992).

At present, with the advancement of 3D printing technology, hand prostheses are being designed which are affordable and at the same time individualized [6], [7]. This technology will lead to a boom in the production and replacement of prosthetic hands for children – both for learning sign languages and for object manipulation. The effort to achieve realism in the structure and function of the hand, like the proposed in the present paper, will have big influence and role in the future 3D printer technologies for rehabilitation medicine.

The present approach is compatible with the design of flexible fluidic actuators [15], as well as with antagonistic joints [5], so that the interactive technology based on gestures can include gesture interface with either real or robotic hand that can be realistic, functional and affordable for all at the same time.

CONCLUSIONS AND FUTURE WORK

The contributions of the proposed work are: 1) An attractive and interesting way of teaching children in the form of a game; 2) Personalization of learning according to the child's time preference and perception abilities; 3) Setting the time for simulation and the possibility of multiple repetition of a movement supports the way of studying through imitation of the fingerspelled signs according to the perception abilities of the child.

The proposed gesture-based method of teaching promotes the design of children-focused technology rather than teacher-centred. The framework will be tested with real children in the future. The proposed method is sufficiently general to be applied in other learning activities related to gesture-based computing and its future role in education.

REFERENCES

[1] Backer, S. The Importance of Fingerspelling for Reading. Visual Language and Visual Learning Science of Learning Center (Research Brief No. 1). Washington, DC, 2010, p. 8.

[2] Cook, S., M. Tanenhaus. Embodied Communication: Speakers' Gestures Affect Listeners' Actions. Cognition, vol. 113 (1), 2009, 98-104.

[3] Fingerspelling, http://www.signingsavvy.com/browse-fingerspelling

[4] Gleeson, B., K. MacLean, A. Haddadi, E. Croft, J. Alcazar. Gestures for Industry: Intuitive Human-Robot Communication from Human Observation. ACM/IEEE HRI'13, Tokyo, Japan, 349–356.

[5] Grebenstein, M., P. van der Smagt. Antagonism For a Highly Anthropomorphic Hand–Arm System. Advanced Robotics, vol. 22, 2008, 39-55.

[6] http://arstechnica.com/information-technology/2013/02/robohand-how-cheap-3d-printers-built-a-replacement-hand-for-a-five-year-old-boy/

[7] http://www.asme.org/engineering-topics/articles/mechanisms-systems-devices/3d-printing-helps-kids-grasp-life

[8] Huang, C.-M., B. Mutlu. Modeling and Evaluating Narrative Gestures for Humanlike Robots. Proceedings of Robotics: Science and Systems (RSS) Conference, Berlin, Germany, 2013, 26-32.

[9] Jaffe, D. Evolution of Mechanical Fingerspelling Hands for People Who are Deaf-Blind. Journal of Rehabilitation Research and Development, Vol. 31 (3), 1994, 236–244.

[10] Makaton, http://www.makaton.org/

[11] MSC.visualNastran 4D, http://www.mscsoftware.com

[12] Oramas, J., K. Chiluiza, A. Moreno. Potential Benefits in the Learning Process of Ecuadorian Sign Language Using a Sign Recognition System. E-Minds, Vol. 2 (7), 39-57.

[13] Osborne, C. Gesture-based Tech: A Future in Education. March, 2012, http://www.zdnet.com/blog/igeneration/gesture-based-tech-a-future-in-education/15514

[14] Rossini, N., D. Gibbon. Why Gesture without Speech but Not Talk without Gesture? Proceedings of Gesture and Speech in Interaction - GESPIN, Bielefeld, Germany, http://coral2.spectrum.uni-bielefeld.de/gespin2011/final/Rossini_Gibbon.pdf

[15] Schultz, S., C. Pylatiuk, G. Bretthauer. A New Ultra-Light Anthropomorphic Hand. Proceedings of IEEE International Conference on Robotics and Automation, Seoul, Korea (2001), 2437-2441.

[16] Stiefelhagen, R. H.K. Ekenel, C. Fügen, P. Gieselmann, H. Holzapfel, F. Kraft, K. Nickel, M. Voit, A. Waibel. Enabling Multimodal Human-Robot Interaction for the Karlsruhe Humanoid Robot. IEEE Transactions on Robotics, Special Issue on Human-Robot Interaction, Vol. 23, No. 5, 2007, 840-851.

[17] Zamfirov, M., S. Saeva. Sign Language on Human and Nature, Physics and Astronomy. Altera Publisher, Sofia, 2004 (in Bulgarian).

ABOUT THE AUTHORS

Research Fellow Aleksandar Krastev, PhD, Department of Hybrid Systems, Institute of Systems Engineering and Robotics, BAS, Phone: +35928732614, E-mail: aikrastev@yahoo.com.

Associate Professor Anna Lekova, PhD, Head of Department of Hybrid Systems, Institute of Systems Engineering and Robotics, BAS, Phone: +35929793232, E-mail: alekova@iser.bas.bg.

Associate Professor Maya Dimitrova, PhD, Department of Hybrid Systems, Institute of Systems Engineering and Robotics, BAS, Phone: +35929792054, E-mail: dimitrova@iser.bas.bg.

Associate Professor Ivan Chavdarov, PhD, Department of Robotics, Institute of Systems Engineering and Robotics, BAS, Phone: +35929792422, E-mail: ivan_chavdrov@dir.bg