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# Monitoring the movement of the upper limb in the context of rehabilitation games

## Monitorowanie ruchu kończyny górnej w kontekście gier rehabilitacyjnych

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**Registration of the upper limb movement in real time is necessary to prepare interactive methods to support the recovery process of the upper limb. These types of computer programs often use three-dimensional environments and virtual reality techniques. Traffic registration can be carried out using commercially available controllers prepared for the needs of computer games, which facilitates the creation of applications supporting the rehabilitation process. The disadvantage of this approach are significant limitations in the possibilities of motion registration, in particular the movement of individual upper limb members. The solution may be to prepare a controller dedicated to the needs of therehabilitation.**
**KEYWORDS: measurement systems, virtual reality, rehabilitation support**

Development of virtual reality technology constantly shifts the limit of realism of computer simulations [1]. So far, the use of these solutions in rehabilitation has been limited due to the lack of access to inexpensive and easy-to-use devices. On the wave of popularization of screens and interfaces enabling precise tracking of the location in space, many applications aimed at medicine and rehabilitation were created [2, 3].

Virtual environments allow for precise measurement of behavioral parameters while performing complex, but safe tasks in simulations, whose realism is similar to real situations [3, 4]. In many solutions based on virtual reality technologies and computer games, feedback is provided by both visual and auditory stimuli. In the case of upper limb rehabilitation, users can interact with virtual objects directly through hand and body movement, through interfaces providing sensory feedback, and perform activities that create the impression of immersed in simulation, which increases the probability of transferring learning outcomes to natural situations [5].

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Sensory feedback can be included in the simulations of rehabilitating upper limbs using gloves or external robotic interfaces, defining the trajectory and resistance of the range of motion [6]. It should be noted, however, that modern technological solutions have many disadvantages.

Vibratory stimulation as a form of sensory feedback is an imperfect method in terms of the precision of the position and resolution of simulated sensations. However, robotic interfaces are difficult to use at home.

An important aspect of the assessment of the impact of physical training in virtual environments is to determine the correctness of the kinematics of the movements performed in the context of 2D interfaces and more immersive 3D solutions. The improvement of the motor performance of the upper limbs is most often measured by the parameters of speed, precision and fluidity and the degree of coordination between changes in the position of the individual components of the musculoskeletal system [7]. Movements of the upper limbs carried out with the use of three-dimensional interfaces are more similar to the natural ones than the same movements realized using two-dimensional interfaces. This is evidenced by the studies in which the kinematics of arm movements related to the indication of various points in the natural environment were compared, with movements performed in an immersive virtual environment, presented through a usable screen [8, 9].

### Rehabilitation games

One of the important challenges in the rehabilitation of upper limbs is control of the motion kinematic track and gradual increase of loads. These issues are among the main factors influencing the development of robotic and mechanical devices supporting rehabilitation.

Interesting solutions are inexpensive devices using the concept of tele-rehabilitation that can be used by the patient at home. They are intended to be used after a period of structural changes and mainly concern physiotherapy at the functional level. An example of such a device is the Razer Hydra controller, designed for computer games – held in the palm of your hand allows you to determine the position and orientation in three-dimensional space. The controller is suitable for use in games supporting the recovery of the upper limbs, including the shoulder, elbow or wrist joint.


Fig. 1. Examples of games: "Apples" (top photo) – added load has the form of a band weighing 1 kg, placed on the wrist; "Mag" (bottom picture) – the resistance to overcome was obtained by introducing a flexible tape


Fig. 2. Examples of games "Castle" (top) and "Blacksmith" (bottom)

Because the controller is held in the palm of your hand, it is difficult to carry out exercises aimed at preventing carpal tunnel syndrome. Nevertheless, rehabilitation games can be supplemented by overcoming the resistance and / or adding a load – e.g. in the form of a band filled with sand or an elastic band (fig. 1).

The following games were prepared for testing: "Castle" (fig. 2), "Manta", "Mag" (fig. 1), "Keys", "Blacksmith" (fig. 2) and "Apples" (fig. 1). They were tested in the rehabilitation center "Kaśmin", where information on the usefulness of this type of solution was collected. The main caveat, which also applies to other similar devices available on the market, is that they significantly limit the range of movements that can be registered – especially in the shoulder joint area – because the monitored space is narrowed to the area just before the rehabilitated person. The controller held in the palm of the hand also does not give the possibility of full control of the movements performed, because a specific hand position can be obtained in many ways, which makes proper exercise difficult. Similarly, it is not possible to monitor the movement of the fingers and the wrist itself. Specialists who evaluated the games and controller suggested that it would also be useful to measure the force exerted during the game when clamping a flexible object in the hand (an example of manta, which must shrink while passing through the gate – this action would be implemented by tightening the hand). As a result of the research, a new controller for games supporting exercises was proposed.

## Proposal of a new interface to record the movement of the upper limbs

The aim of the work was to design and manufacture a device processing data from such sensors as accelerometer, gyroscope and magnetometer, in order to determine the absolute orientation of individual members of the upper limb in three-dimensional space. In addition, a strain gauge device would measure strength when clamping an object in your hand. The use of this type of controller would also facilitate the introduction of resistance or load to the scenario of games – it would be possible due to the release of the player from the need to hold the controller in his hands. A very important feature of the designed device is a clear increase in the range of recorded movements in comparison with measurements carried out using controllers typical for computer games, e.g. Razer Hydra controller, used in preliminary tests at the "Kaśmin" center. Due to the lack of the need to hold the controller, you can change the flexion of your fingers or straighten them during exercises.

The arm equipped with a set of sensors is mounted on the arm, forearm, forearm and middle finger (fig. 3). This is an arrangement of the AHRS (attitude and heading reference system) type. The main sensor data acquisition system is attached to the shoulder *via* the I2C interface (inter-integrated circuit) and forwarding them to a PC computer *via* a Wi-Fi wireless interface.

As the AHRS sensor, the BNO055 module from Bosch was selected along with the board in the Development Board version made by Adafruit.

In the case of HA1 and HA3 modules, the standard layout address (0x28) is used, while in order to change the address in HA2 and FG systems to (0x29) it was necessary to connect 3vo and ADR pins. This solution enabled the connection of two sensors to one I2C port. From each sensor, 8 bytes are taken, which are a description of the individual components of the orientation of the three-dimensional space.

The FSR sensor (force sensor) mounted on it is used to record hand squeeze measurements. It is an analog sensor, and its operation is similar to the operation of a resistor with variable resistance.

After converting the data from the sensors, they are converted into a text format, i.e. a string of different lengths. Text data is sent to a PC computer via the Wi-Fi interface, with the option of transferring data via the USB port. The Wi-Fi interface with the ESP12f system, which communicates with the STM32C8T6 system via the UART interface, is used to send the text line.

The ESP12f system is programmed as a UDP (user datagram protocol) by the Arduino IDE tool and the FTDI (UART – USB converter) in 80 MHz mode and with an input data rate of 115 Kb/s.


Fig. 3. Laboratory version of the interface for rehabilitation games

## Conclusions

Due to the limitations of the currently used controller, a different approach to the problem of registering the movement of the upper limb was proposed.

The developed tool allows not only to record and transmit in real time data on the absolute orientation of the individual upper limb (arm, forearm, metacarpal), but also to bend the selected finger and measuring the pressure on the inside of the hand. The use of such a controller, which the player does not have to hold in his hands, would also facilitate the addition of resistance or load to the game scenario, as well as allow to perform exercises in which the flexion of the fingers changes or must be done with straightened fingers.

A very important feature of the designed device is also a significant increase in the range of recorded movements.

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REFERENCES

1. Kosinski R.J. "*A literature review on reaction time*". South Carolina: Clemson University, 2008.
2. Salcudean S., Ku S., Bell G. "Performance measurement in scaled teleoperation for microsurgery". *Lecture Notes in Computer Science*. Vol. 1205. Springer, 1997: pp. 789–798.
3. Wagner C., Stylopoulos N., Howe R.D. "The role of force feedback in surgery: analysis of blunt dissection". *Proceedings of the 10th symposium on haptic interfaces for virtual environments and teleoperator systems*. 2002: pp. 68–74.
4. Zandsteeg C.J., Bruijnen D.J.H., van de Molengraft M.J.G. "Haptic tele-operation system control design for the ultrasound task: A loop-shaping approach". *Mechatronics*. 20 (2010): pp. 767–777.
5. Euijung Yang, Dorneich M.C. "The Emotional, Cognitive, Physiological, and Performance Effects of Variable Time Delay in Robotic Teleoperation". *International Journal of Social Robotics*. 9, 4 (2017): pp. 491–508.
6. Grabowski A. „Projekt dwuramiennego robota sterowanego przez teleoperatora z wykorzystaniem technik rzeczywistości wirtualnej". *Napędy i Sterowanie*. 226 (2018): pp. 46–50.
7. Keshner E.A. "Virtual reality and physical rehabilitation: a new toy or a new research and rehabilitation tool?". *Journal of NeuroEngineering and Rehabilitation*. 1(1):8 (2004).
8. Weiss P.L., Jessel A.S. "Virtual reality applications to work". *Work*. 11, 3 (1998): pp. 277–293.
9. Sveistrup H. "Motor rehabilitation using virtual reality". *Journal of Neuroengineering and Rehabilitation*. 1, 1 (2004): pp. 10. ■

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