NEW POSSIBILITIES FOR CONTROL OF MECHATRONICAL REHABILITATION SHOES TUKE

Miroslav Gorlický[1], Dušan Šimšík[2]

[1]Ing. Miroslav Gorlický, Department of Automation, control and human-machine interaction, Technical university of Košice, Slovak Republic

[2]prof. Ing. Dušan Šimšík, Ph.D., Department of Automation, control and human-machine interaction, Technical university of Košice, Slovak Republic

Abstract
Article discusses possibilities of new control system of mechatronical rehabilitation TUKE version shoes. Originally they were developed as a part of the international FP7 project SMILING. We describe new mechanical concept of shoes with new simplified control system. That directly modifies chaotic signals, provides motor control of actuators and sensors of swing phase. Processing of data from the sensors of swing phase, generator of chaotic signals and transmit commands for motor control of actuators, provides microprocessor on an open electronic platform ARDUINO. Output data from the sensors, generator of chaotic signal and motor control, as well as the actual value of position controlled actuators, are also recorded and processed by a computer.

Keywords
ARDUINO, rehabilitation shoes, sensors, generator of chaotic signals

I. Introduction

Mechatronical rehabilitation shoes with TUKE mechatronical unit (Fig. 1) were developed in the project SMILING - Nb.215493 (2008-2010). It is a complex mechatronical system, which requires the interaction of sensors, data, mechanical parts and human activity. [3]

SMILING project was aimed at creating a complex rehabilitation system for training walk through SMILING shoes. This unconventional rehabilitation system is not focused on a number of exercises to increase muscle strength and nature of joint mobility, as almost all the traditional exercises, but the dynamic behaviour of the human motion system while walking and the process of learning a new gait patterns due to age reduced response capabilities. [1, 2, 3, 4]

By changing the shoe's base along the frontal and sagittal planes during the swing phase, always chaotically into other angles, a user achieves a dynamic response of the platform while walking, and has the feeling of imbalance at each step. This feeling makes him to get back into balance. Due to the fact that each step is therefore unique, the user is forced to align their every step walking and thereby trains his brain to unforeseen situations, such as for example in a real environment crashes caused by late responding to obstacles while walking.

The result of the project was the creation of a new rehabilitation program, which included a new concept clinical testing, creating training program, development of rehabilitation devices [1,2,3,4,5]. After finishing SMILING project, we continued in development and experiments with TUKE version shoes aiming at shoes convenient for autonomous home use.

II. Mechatronical rehabilitation shoes TUKE

Mechatronical rehabilitation shoes TUKE use different mechanical principle, but operate on the same

principle - changing inclination and height of shoe's base along the frontal and sagittal planes with 4 actuators as SMILING shoes (Fig. 1).

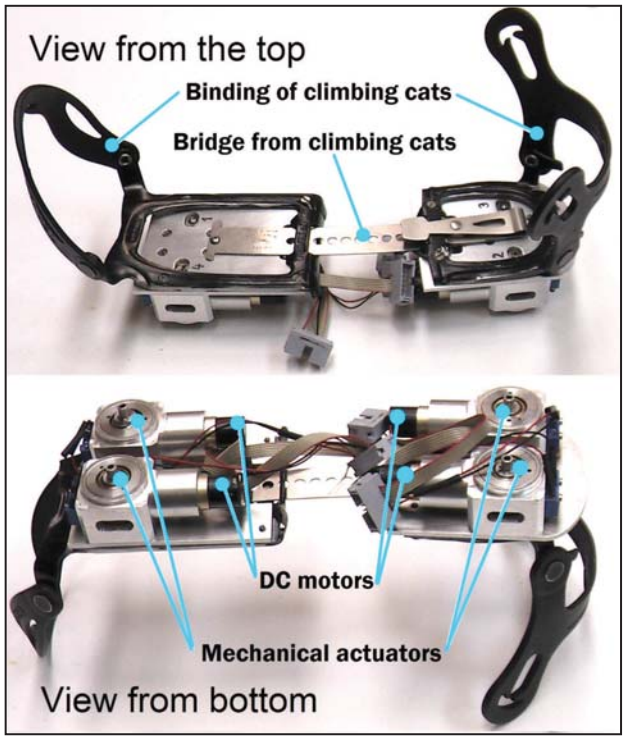

Fig. 1: Mechatronical rehabilitation shoes TUKE version [1].

A. Mechanism of SMILING shoes STRATH

SMILING rehabilitation shoe mechanism with the University of Strathclyde design (STRATH) uses crank in the shape of a dynamic involute driven through composite mechanical transmission, consisting of four levers, ram and chain drive [2]. Each shoe contains four of these complex mechanisms, which move with crank in two directions proportionally giving the total range of movement 15-20 mm. Changes in the range of the opening of all actuators results in changes of inclinations and heights of shoes´ basis. User has to react by changes in ankle angles in frontal and sagittal planes. [3, 4]

B. Mechanism of SMILING shoes TUKE

The essence of the mechanism TUKE is deployment of the three-course thread screws, using rotation nut axially secured around its axis through a rectangular toothed gear (Fig .2).

Due to the axial movement of the screws each of these four mechanisms inclinations and heights of the shoes basis change. Mechanism is more simple, with less components than STRATH one.

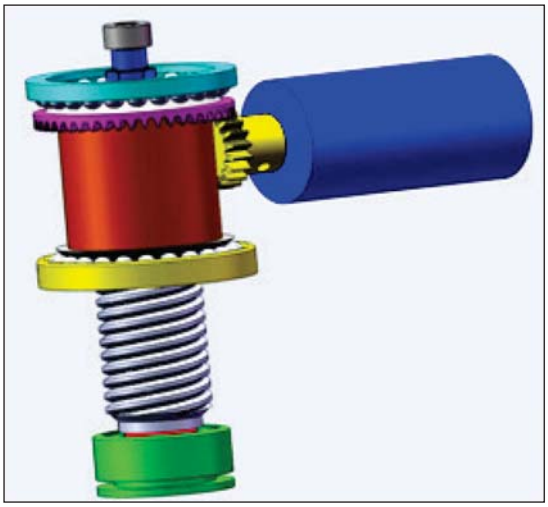

Fig. 2: Model of mechanism of the rehabilitation shoes TUKE.

III. Arduino system

Arduino is an open-source platform based on ATMega microcontroller from Atmel and graphical development environment that is based on Wiring and Processing environment. It enables rapid prototyping and fast learning the basic principles of electronics and programming.

Arduino development board (Fig. 3) contains an 8-bit microcontroller family of from Atmel AVR and many other supporting devices. It has programmed directly from a computer via the USB interface without using an external programmer.

Official release of Arduino, which manufactures and sells Italian company Smart Projects, using ATMega chips. Each board has most of the I/O pins accessible through precise socket into which you simply connect additional circuits, which in the world of Arduino says "Shields".

Fig. 3: Development board Arduino Duemilanove with microcontroller ATMega328P.

The development board usually consists of some LEDs, reset button, plug for ICSP programming, power connectors, an oscillator and circuit to enable communication over USB.

The basic version of Arduino, Arduino Duemilanove, is providing a total of 14 I/O digital pins and 6 analog pins. Six digital pins can also be used for software-controlled PWM output [6, 7].

IV. design of the new control system for the TUKE shoes

The prototype of the new control system of TUKE shoes consists of: development board with Arduino Duemilanove microcontroller ATMega 328P (Fig. 3), 9DOF sensor mo-dule (Fig. 4), module of 4 DC motors control (Fig. 5), module for read and write to the SD card (Fig. 6) and the communication module Bluetooth Transceiver - RS232/TTL (Fig. 7).

A. 9DOF sensor module

9DOF sensor module consists of a 6DOF sensor ITG/MPU 6050 (Fig. 4-left) (3D gyroscope and 3D accelerometer) and 3DOF compass HMC5883L (Fig. 4-right) (3D magnetometer). They are used to control actuators, and accelerations, to track current position and rotation of shoes against space in 3D while user is walking. Arduino microcontroller evaluates data from the 9DOF sensor and determines the beginning and the end of swing phase. Data from 9DOF sensor is also recorded on SD card and are transmitted to the PC via the BT module.

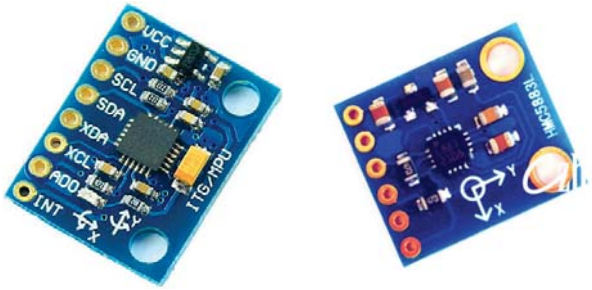

Fig. 4: 9DOF sensor module: 6DOF ITG/MPU 6050 on left and 3DOF compass HMC5883L on right.

B. Motors control module MCM

The main module to control 4 DC motors (Fig. 5) (hereinafter referred to as MCM) is used to control 4 actuators at each shoe. Module contains 2x L293D (push-pull four channel driver with diodes) controlled with 74HCT595 (8-bit serial-in, serial or parallel-out shift register with output latches; 3-state).

After determining the beginning of the swing phase from the present data from 9DOF module, Arduino sends data to MCM for new positions of all 4 actuators at each step. MCM takes care of proper adjustment of new positions according to the data set. Arduino continuously processes data from 9DOF module to determine the end of the swing phase.

If MCM did not yet finish the process of setting all actuators to new positions, and the Arduino detects the swing phase is at the end, then Arduino sends command to MCM for stop this process in the current position.

This internal control is necessary to ensure the motors against their destruction or overload circuits because motors are unable to make sufficient torque to overcome the weight of the user's feet on the floor.

Fig. 5: 4 DC motors control module MCM.

C. SD card module

SD card module (Fig. 6) is used to store the measured data from 9DOF module, as well as data provided by Arduino, like positions of actuators for each finding the beginning and the end of swing phase and the actual positions of actuators. These data also enable to analyze the user gait and testing of a prototype for identifying weaknesses, and for additional tuning and optimization program.

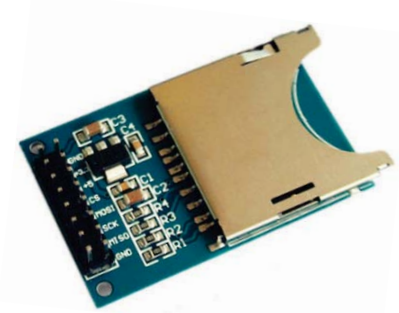

Fig. 6: SD card module

D. Communication module

Communication Bluetooth module (Fig. 7) is used to receive current data to a computer for further analysis. Data processed by Arduino are sending 10 times per second. BT module is used to receive current data to a

computer for further analysis. Data processed by Arduino are sending 10 times per second in a set of values and each set contains a unique identification sequence number. This makes it possible to determine the percentage of failed transmission via BT module, which is needed for testing.

Fig. 7: Communication Bluetooth module

V. Conclusion

Arduino system for its universal application is a popular system, because possibilities of its use are widespread and suitable for the mechatronical rehabilitation SMILING shoes TUKE. Arduino project since the beginning was freely available. Documentation, Language Reference and external libraries are mostly issued under the Creative Commons, making them available to all source files and maintain certain compatibility. [7]

It therefore forced us to use maximum utility modules. We plan to simplify the resulting prototype, and place all required modules on the one PCB that should be mounted on to internal free space in the TUKE shoes to get a user-friendly effect, so that the shoes can be used for household use.

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Ing. Miroslav Gorlický
Department of Automation, control and human-machine interaction
Technical university of Košice
Letná 9, 042 00 Košice, Slovak Republic
miroslav.gorlicky@tuke.sk

prof. Ing. Dušan Šimšík, Ph.D.
Department of Automation, control and human-machine interaction
Technical university of Košice
Letná 9, 042 00 Košice, Slovak Republic
dusan.simsik@tuke.sk