TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics and Mechanics
Vol. 56, Issue III, September, 2013

WHEELCHAIR CONTROL THROUGH HEAD MOVEMENTS

Emőke SZELITZKY, Sergiu NĂSUI, Dan MÂNDRU

Abstract: *This paper describes a new control system of a mobility aid (e.g. wheelchair) for people with lower limb disabilities or those who have difficulties in long lasting displacements. The operating principle is based on the flexion - extension and abduction-adduction movements of the head, which are transmitted forward to the electrical actuators of the wheelchair. A set of four unidirectional resistive sensors are positioned strategically above the collar level of a garment, each in one of the main moving directions (forward, backward, right and left). An Arduino Mega 2560 data acquisition board reads the sensors data and sends commands for the adaptation circuitry. The operating principle is experimentally tested on a remotely controlled car.*
Key words: *Wheelchair control, resistive sensors, head movement, Arduino Mega 2560.*

1. INTRODUCTION

One of the most important ability of a human being is to be able to move, it means freedom and power. Every motion, no matter how small, is the result of a very complex activity, based on a central locomotive system. The human locomotive apparatus roughly consists of bones, ligaments, joints and the muscles as engine.

Many disabilities can affect the human motion witch main causes are lower limb abnormalities or spinal diseases. The simplest abnormalities are bone dislocations, sprains, fractures, ligament injuries while at the other end are paralysis and paraplegia. In order to restore the locomotion ability many type of products were designed over the centuries to enhance human motion. Nowadays the most used machines are the wheelchairs. In terms of control, these machine can be divided in two main categories namely, operated by the own energy of the user or by external energy source. This last category consists of electrical operated equipments.

For long distance movements a classical wheelchair, operated by the own energy of the user, can be arduous to use. This is another reason why many scientists and publications main purpose is to improve the condition of the wheelchair users mostly by using external source of energy.

The first step in this direction was the introduction of a joystick for the wheelchair control. Nonetheless the hand function may be limited for patients with sever injuries. Therefore alternative wheelchair control is needed implying other parts of the body.

A widely used method is the so called sip and puff (or sip-n-puff) approach, where the user commands the wheelchair by inhaling (sipping) or exhaling (puffing) through a pneumatic tube. Acute and fine puffs can be used for direction and speed modulation [1].

An ultrasonic head control method is presented in [2] having more than thirty years of maturity, now commercially available. The head control interface uses two transducers to measure the position of the head and mimic a joystick-type control.

Nowadays wheelchairs incorporating joystick, sip-n-puff, chin, head and tongue-operated elements are commercially available and can be easily bought on the internet at a low acquisition cost.

A short review of the scientific literature revealed the following new main control types: myoelectric, voice-related, brain control, electro oculograms and several limb or head related control possibilities.

A pattern recognition based myoelectric manipulation of an electric wheelchair is presented in [3]. This discriminates muscular activities using a support vector machine based classifier. As the authors underline, the proposed method is a reliable alternative to the classical or joystick control of a wheelchair.

A voice controlled wheelchair project is presented in [4], where with a grammar-based recognition parser a more then 97% successful recognition rate is achieved. In [5] the voice recognition system is supplemented with ultrasonic and infrared sensor system for obstacle, hole and downstairs avoidance.

As the interest in brain controlled devices increased, several articles with brain and mostly electro oculograms (EOG)-based control are tested. A recent example is revealed in [6] where conscious eye-blink EOG signals are used as wheelchair control.

An interesting approach of a wheelchair control uses on-seat pressure sensors in order to measure human intention by means of changes in the center of gravity on the seat [7]. This control is used in conjunction with a manual command mode.

Most of the wheelchair users do not show head or neck motion disabilities. By virtue of this, wheelchair control by head guidance can be provided. The scientific literature shows an example of an infrared LED array-based speed and direction controlled wheelchair [8], while another example [9] uses an inertial measurement unit (accelerometer) mounted on a cap for wheelchair control.

This article presents a new wheelchair control by means of neck motion detection using low-cost resistive sensors. Possible motions are left, right and forward, backward. In order to show the proficiency of the system a remotely controlled car is used, with an adaptor circuit between the car remote controller and the data acquisition board (DAQ). In the following sections the used resistive sensors are presented and methods description is provided.

2. METHODS

The human neck and implicit head movement measurement is carried out using resistive sensors and an Arduino data acquisition board. The signals acquired by the Arduino Mega 2560 board's analog ports are processed locally and control signals trough its digital ports are send to a control circuitry. This is empowered to control a wheelchair motor or as in our application a remotely controlled car.

2.1 Resistive sensor

The used sensors are uniflex resistive sensors acquired from Abrams Gentile Entertainment Inc. These resistive sensors change their resistance drastically during bending in the main direction. At a flat position they present a resistance between 7.5 and 12.5kOhm reaching up to 40kOhms during bending. The sensor functional characteristic is showed in Fig. 1.

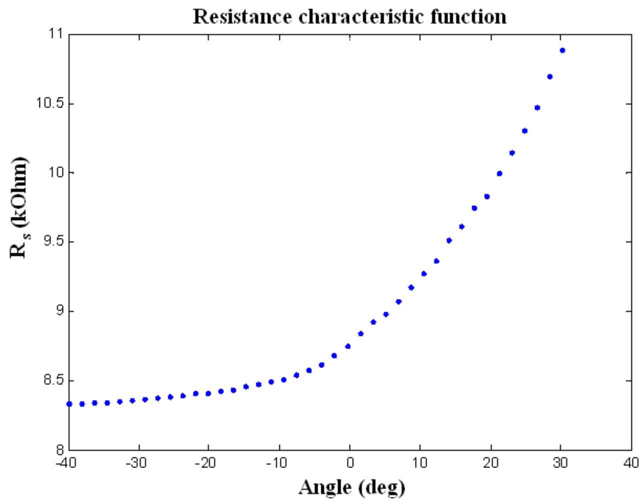

Fig. 1. Sensor functional characteristic

As the authors proved [10] this is an exponential behavior, and it can be determined with two measurements at two different angles. Its 11.4x0.6 cm dimension makes it suitable for neck motion detection, while the sensor pins facilitates the connection to an electrical board.

2.2 Sensorized shirt

In order to acquire the motion of the human neck the sensors need to be placed at the neck level. Tests using sensorized clothes [11] showed the importance of impeding the glide of the cloth above the monitored area. In the case of the neck measurements this can be achieved starting from a jumper with collar.

The sensor attachment around the neck area of the jumper is done by way of small pockets. At one end the sensor can easily glide in the pocket while at the other end the sliding is blocked with connectors as shown in FIG... For the four directions four sensor were attached to the right, left, front and back of the neck. They are mounted with the sensitive film in the inward direction (being more sensitive during bending). With this structure the sensor's resistance increases with bending.

2.3 Remote car and adaptor circuitry

The used remote controlled car works at 27 MHz radio frequency and it has two electrical motors to run. One is used for the forward and backward movements of the car, while the other to rotate the wheels to the right or left directions. In this construction there is no possibility to control the speed of the first motor, or the wheel angle trough the second motor. Fig. 2 presents the main elements of the experiment which comprises a remotely controlled car, a controller, an adaptor circuitry and a DAQ board.

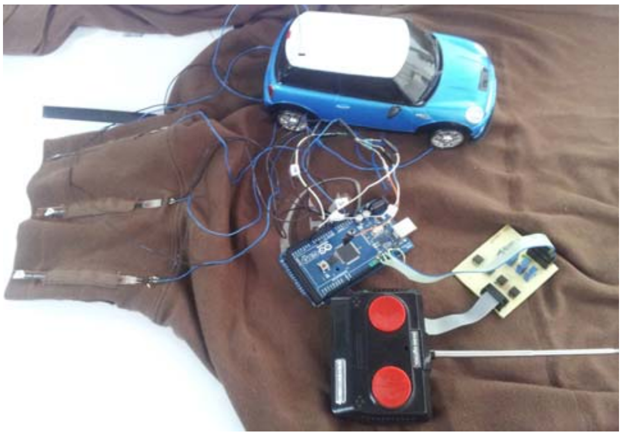

Fig. 2. The main elements of the experiment

For these experiments the authors did not modified any electrical or mechanical parameter of the car, whereas alterations of the transmitter are needed. The buttons of the transmitter are disconnected from the original command circuitry in order to allow the adaptor circuitry to simulate button pressing. By this approach the adaptor circuitry can be connected to any similar machine or wheelchair.

The adaptor circuitry comprises four optocouplers, four 10 kOhm potentiometers and two connectors, one for the remote transmitter and one for the DAQ board, as shown of Fig 3.

Using optocouplers the Arduino Mega 2560 board and the car motor control circuitry are galvanically isolated. Thus from the DAQ board's side does not present any issue how the motor control is achieved.

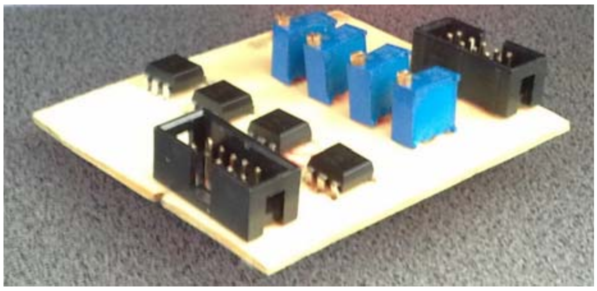

Fig. 3. Adaptor circuitry

2.4 Data acquisition board

An Arduino Mega 2560 DAQ was used for data acquisition and motor control. It's based on an ATmega 2560 microcontroller and comprises 54 digital input/ output pins (of which 15 can be used as PWM outputs), 16 analog input pins, 4 UARTs, a USB connector and a power jack. It is powered by the USB port when connected to a PC, by the power jack or trough an adaptor with a battery. For our purpose 4 analog input pins and 4 digital output pins are needed.

The sensors resistance is read by the DAQ board by means of a voltage divider circuitry. Thus the resistance value is converted to voltage in the 0 and 5V range. At the analog input port this range is converted trough a 10 bit resolution converter to a number between 0 and 1023.

2.5 Voltage divider

Fig. 4 presents the schematic of a voltage divider. In order to increase its sensitivity the resistor value (R_2) will be determined considering maximal variation of the voltage divider output, when the sensor changes its value from minimum (around 5kOhm) to maximum (around 20 kOhm).

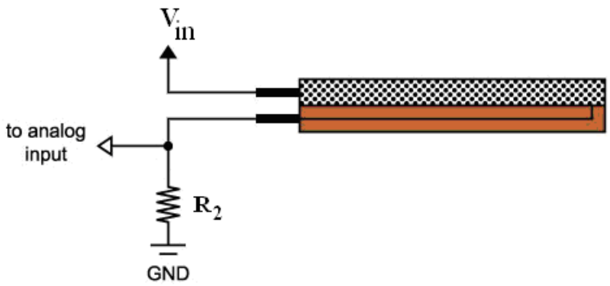

Fig. 4. The voltage devider

Starting from the general voltage divider equation (1):

$$V_{out} = V_{in} \cdot \frac{R_2}{R_S + R_2} \quad (1)$$

Supposing R_2 as a range of values between 5 and 20 kOhm and knowing the minimum and maximum expected resisivity of the sensor, we can describe the output voltage difference as:

$$V_{out} = V_{in} \cdot R_2 \cdot \left(\frac{1}{R_{s\min} + R_2} - \frac{1}{R_{s\max} + R_2} \right) \quad (2)$$

The R_2 value for which the V_{out} is maximal will be the resistance we are interested in. This will maximize the voltage variation at the DAQ board input.

Considering R_{smin} and R_{smax}, the maximum variation can be achieved with a 12.5 kOhm resistor, as it can be seen from the Fig 5.

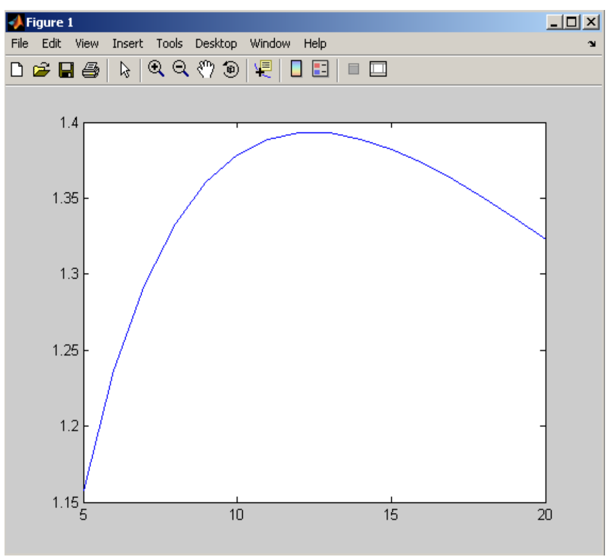

Fig. 5. Output voltage difference versus sensor resistance

3. RESULTS

The remote car can move in forward, backward, left and right directions with a constant velocity. Thereby states are: STOP, FORWARD, BACKWARD, LEFT and RIGHT while the actions: FORWARD bend, BACKWARD bend, LEFT bend, RIGHT bend and STOP. In Table 1 the motor control logic is described. Starting from different initial states, while applying all the possible actions in every state, the final statuses are defined.

As it can be seen for the forward and backward directions the subject does not have to keep his head in the moving direction, while it can be tedious, instead gives a short command which the car maintains until receiving another command.

In the case of the left and right commands the procedure is quite different. Usually the user does not want to make a long turn to right or left, but a short one. This is why is much easier to make a continuous lateral motion.

While the sensors are temperature sensitive and they are mechanically attached to the connectors, variations between tests are typical. Thus before use, a calibration procedure is needed. This consists of sensors resistance determination (by the software) and manual choose of the active level limits. All these information are included in the software.

For better performances a dead range is defined. Thereby if the read value is above a certain limit shall be considered an active command, while is between a range of maximum and minimum it is not considered at all and while is under a lower limit is considered as an inactive command.

Table 1

Motor control logic

Initial state	Action	Result	Final state
STOP	A=FORWARD bend	when **A** motor1 goes forward	FORWARD
FORWARD	A=BACKWARD bend	when **A** motor1 stops	STOP
STOP	A=BACKWARD bend	when **A** motor1 goes backward	BACKWARD
BACKWARD	A=FORWARD bend	when **A** motor1 stops	STOP
STOP	A=LEFT bend	*while* **A** motor1 goes forward and motor2 goes left	STOP
FORWARD	A=LEFT bend	*while* **A** motor2 goes left	FORWARD
BACKWARD	A=LEFT bend	*while* **A** motor2 goes left	BACKWARD
STOP	A=RIGHT bend	*while* **A** motor1 goes forward and motor2 goes right	STOP
FORWARD	A=RIGHT bend	*while* **A** motor2 goes right	FORWARD
BACKWARD	A=RIGHT bend	*while* **A** motor2 goes right	BACKWARD

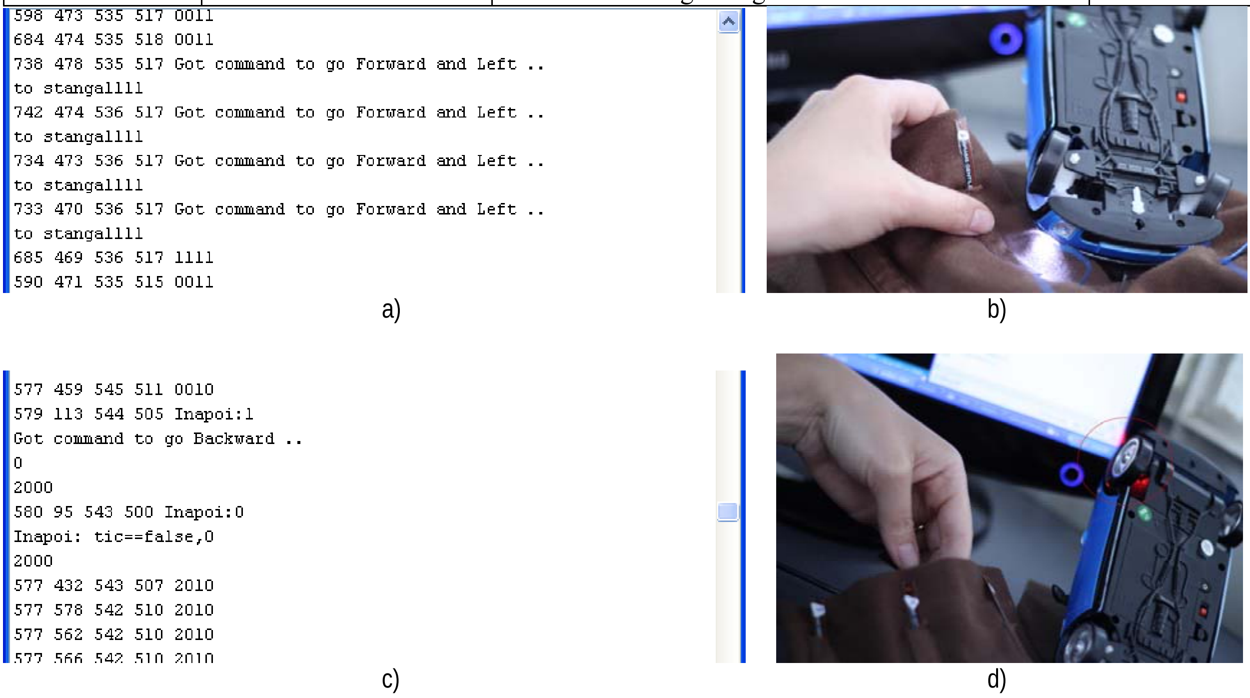

Fig. 6 Test result using a remotely controlled car

For these experiments the authors use a feedback in order to give information about the commands and states.

Fig. 6 shows the test results. In Fig. 6 a) and b) the left command can be observed. It is receiving the left command while the left sensor is activated.

In Fig. 6 c) and d) the backward command can be observed. It is enough to receive only one time the backward command.

4. CONCLUSIONS

Human locomotion is a fundamental life function which ensures independence. For the disabled people the inability to move properly is a great physical incapacity which involves a powerful psychological impact. Disabled people use several devices in order to increase their mobility.

Wheelchairs with external source are electrical powered, being useful for both disabled and elderly people, who cannot propel a classical wheelchair for long distance.

As a short literature review shows the classical wheelchair control is gradually replaced by keyboard, joystick, myoelectric, voice, sip and puff, and head movement based control systems due to their numberless advantages.

In this paper the authors present a head based control system by means of four unidirectional resistive sensors for the four main motion directions. This approach does not require a broad movement of the head for control being very sensitive to bending, a great advantage in terms of ergonomics.

While the sensors are influenced by temperature, connections and life cycle the system needs to be calibrated before use. This is achieved by measuring the sensors resistance in two different positions as limits.

Based on an Arduino board, the system can be expanded easily by means of wireless transmission. As this, the user can control the wheelchair in order to bring it beside the bed and possible get in it, without the help of another person.

5. ACKNOWLEDGEMENT

This paper was supported by the project "Improvement of the doctoral studies quality in engineering science for development of the knowledge based society-QDOC" contract no. POSDRU/107/1.5/S/78534, project co-funded by the European Social Fund through the Sectorial Operational Program Human Resources 2007-2013.

This research was partially supported by the European Commission under contract FP7-247688 3DLife.

6. REFERENCES

[1] *ATWiki, "Alternative wheelchair control", http://atwiki.assistivetech.net/index.php/Alternative_wheelchair_control.*

[2] D. L. Jaffe, *An ultrasonic head position interface for wheelchair control*, J. Med. Syst., vol. 6, no. 4, Aug. 1982, p. 337–342.

[3] Oskoei, M.A., Hu, H.: *Myoelectric based virtual joystick applied to electric powered wheelchair*. In: IEEE/RSJ International Conference on Intelligent Robots and Systems, 2008. IROS 2008 IEEE/RSJ International Conference on Intelligent Robots and Systems, IROS 2008, 2008, p. 2374–2379.

[4] Nishimori, M. et al.: *Voice controlled intelligent wheelchair*. In: SICE, 2007 Annual Conference SICE, 2007 Annual Conference. 2007, p. 336–340.

[5] Mazo, M. et al.: Wheelchair for physically disabled people with voice, ultrasonic and infrared sensor control. *Auton Robot*, **2** (3), 1995, p. 203–224.

[6] Ning, B. et al.: *Human Brain Control of Electric Wheelchair with Eye-Blink Electrooculogram Signal*. In: Intelligent Robotics and Applications (Editors: C.-Y. Su et al.). Springer Berlin Heidelberg, 2012, p. 579–588.

[7] S. Jia, J. Yan, J. Fan, X. Li, and L. Gao, *"Multimodal intelligent wheelchair control based on fuzzy algorithm,"* in 2012 International Conference on Information and Automation (ICIA), 2012, p. 582–587.

[8] Kupetz, D.J. et al.: *Head motion controlled power wheelchair*. In: Bioengineering Conference, Proceedings of the 2010 IEEE 36th Annual Northeast Bioengineering Conference, Proceedings of the 2010 IEEE 36th Annual Northeast. 2010, p. 1–2.

[9] Aleksandar, P., Branko, D.: Wheelchair control by head motion. *Serbian Journal of Electrical Engineering*, **10** (1), 2013, p. 135–151.

[10] Szelitzky, E. et al.: Flexible rezistive sensor modelling suitable for human movement assesment-Initial results. *Automation Computers. Applied Mathematics.(ACAM)*, 2012.

[11] Szelitzky, E. et al.: *Spine movement monitoring and visual feedback*. Q-DOC Project – Doctoral students' session. Cluj-Napoca, Romania, 2013.

Controlul miscării persoanelor cu dizabilități

Rezumat : Acest articol descrie o nouă modalitate de locomoție pentru persoanele cu dizabilități sau pentru cei care prezintă dificultăți în deplasările de lungă durată. Principiul de funcționare se bazează pe captarea mişcărilor de flexie-extensie si abductie-adductie ale capului, în plan sagital şi frontal şi transmiterea comenzilor catre motoarele electrice ale unui fotoliu rulant. Un ansamblu de patru senzori rezistivi unidirecționali sunt pozitionați strategic la nivelul gulerului pe o îmbrăcăminte senzorizată în cele 4 direcții de mişcare (înainte, spate, dreapta, stânga). O plăcuță de achiziție date Arduino Mega 2560 citeşte datele de la senzori şi trimite comenzile spre un circuit de adaptare. Principiul de funcționare este testat experimental pe o maşinuță cu telecomandă.

Emőke SZELITZKY, Eng., PhD Student, emoke.szelitzky@mdm.utcluj.ro, 0264-401645.
Sergiu Ciprian NĂSUI, BSc Student, sergiu.nasui@yahoo.com
Dan MÂNDRU, Prof. Dr. Eng., dan.mandru@mdm.utcluj.ro, 0264-401646, Technical University of Cluj Napoca, Faculty of Mechanical Engineering, Department of Mechatronics and Machines Dynamics.