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Wheelchair prototype controlled by position, speed and orientation using head movement

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ABSTRACT

A prototype that simulates a wheelchair was built using electronic commercial devices and software implementation with the aim to operate the prototype using head movement and analyzing the system response. The controllers were simulated using MATLAB® toolbox and Python™ libraries. The mean time response of the system with manual control was 37,8 s. The mean orientation control response with constant speed was 36,5 s and the mean orientation control response with variable speed was 44,2 s in a specific route. The variable speed response is slower than constant speed due to head motion error. The system was rated such as" very good" by 10 participants using a System Usability Scale (SUS).

Specifications table

Hardware name	*Wheelchair prototype controlling by head movements through graphic user interface*
Subject area	*Engineering and assistance technology* *Rehabilitation* *Robotics* *Sensors* *Intelligent control*
Hardware type	*Field measurements and sensors* *Electronic engineering and computer science*
Open source license	*Creative Commons license*
Source file repository	*González, Ximena (2021), "Wheelchair prototype design files AXGC", Mendeley Data, V2, doi: 10.17632/ys9s9pgvbg.2, URL:* https://data.mendeley.com/datasets/ys9s9pgvbg/2

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Hardware in context

Electric-powered wheelchairs have been designed since years ago improving the hardware system using different types of instrumentation instead of classic joystick as indicated by Callejas-Cuervo et al. [1]. in the State of the Art about electronic instrumentation and wheelchair control. In the literature review, published articles between 2016 and 2019 developed wheelchair control devices using head movements. One of the devices used for movement acquisition is Inertial Measurement Unit (IMU), which is an electronic unit that acquires and sends data of angular velocity and body movement."Inertial sensors measure acceleration and angular velocities and are used in applications of movement analysis. It is common to use magnetometers to get in a complete manner the orientation variables analysis. Accelerometers are transducers that produce an output signal related to acceleration, and the more common are the piezoelectric. The gyroscope is a sensor which measures angular velocity. Its operation is based on two parallel oscillating masses that are always in opposite directions and at the same velocity. When an angular velocity is applied, the masses move, varying an internal capacitance. The sensor output is proportional to the difference between the two capacitance variations, and any change of position produces a variation when the user changes the position." [2]. Moreover, MicroElectroMechanical Sistems (MEMS) can be placed on the body or on the wheelchair with the aim to measure body movements [1].

Head movements can be acquired using MEMS sensors (accelerometer, gyroscope and magnetometer) such as mentioned by Ruzaij et al. [3] by means of Orientation Detection (OD) units. The first OD reads the wheelchair orientation, and the second OD unit is fixed on the user's head and used to control the speed and direction of the system. The head orientation is measured using Euler angles (Roll, Pitch and Yaw). The system uses an ARM cortex M3 microcontroller to perform the control of the application. The orientation detection unit consists of two orientation detection modules BNO055 which includes MEMS sensors and are combined together in one chip with ARM cortex M0 processor. The BNO055 is a nine Degree Of Freedom (DFO) module. The system also has an LCD display for monitoring the control system response. The system was tested in a caterpillar robot." The ARM microcontroller sends the control commands to the BMS5005 robot controller. Sabertooth 2x25 motor driver unit realizes the final motor control action. One of the orientation modules is fixed on the robot chassis to give reference orientation if there is any slope or not straight portion of the road. The robot has two DC motors and is operated at 24 V/7.5 A" [3].

Another work of Ruzaij et al. [4] designs and realizes a speed compensation algorithm that enhances the head tilts controller performance in case of non-straight roads and passing ramps. It is designed to compensate the lost speed in one or both of the wheelchair motors depending on the value of the road slope angle and the user weight. The authors use the same structure described in [3]. Additionally, the authors improved several functions of the performance of the head tilt controller such as command confirmation function for removing involuntary effect in head motion and a stop emergency button. The system was implemented in a physical wheelchair." The command confirmation function has been tested by ten users for six motion commands which are forward, forward-left, forward-right, left and right... The test results revealed a successful performance for the function with increasing the starting reaction time for $\approx$ 100 ms [5].

Marins et al. [2] used an IMU to capture head movements and operate a wheelchair. The extraction and processing data was made using Arduino Uno and data classification using MATLAB®. The information is acquired using accelerometer and gyroscope of an IMU using Roll and Pitch angles. It is not necessary Yaw angle information, then, the" x" and"y" axes are implemented. The design was not implemented in a wheelchair or prototype.

Otherwise, Errico et al. [6] proposed a sensory-headwear-based system for self-access to environmental control. The system has motion sensors, transmission and reception electronic units, radio-frequency trans-receivers, software with a simplified graphical user interface and hardware actuators. The communication between the sensors and the Multipoint Control Unit (MCU) takes place via an Inter-Integrated Circuit (I^2C) interface. The communication between MCU and the RF transmission chip is through in-circuit serial programming (ICSP). A battery-pack supplies 4.5 V regulated by an MT3608 with constant 1.2 MHz frequency, and current mode step-up converter. The MT3608 output voltage was set to 5 V. The wireless transmission takes place on a dedicated pipe at 2.4 GHz. The CPU runs a graphical user interface developed using the creation engine for gaming Unity©, version 2017.3 and C# programming language [6].

Gomes et al. [7] developed an interface based on head movements providing continuous direction and speed commands to operate a wheelchair based on null-position of head, according to the natural posture of the user. The Head Motion Unit (HMU) consists of an IMU (BNO055) and WiFi module (ESP8266) connected via I^2C bus. A Wheelchair Processing Unit (WPU) consists of an Arduino Mega, IMU, WiFi module and several range sensors for the safety modules. IR sensors are used to detect distance of the head to the headrest and two micro laser sensors (VL53L0X) to detect frontal objects in the wheelchair's way. The system also integrates a biaxial joystick connected through the analog ports of the Arduino. The power system consists of power driver and controller (Roboteq HDC2450), and two DC motors coupled to the rear wheels of the wheelchair.

Another system designed using accelerometers was developed by Dey et al. [8] moving the wheelchair in five different directions according to different head gestures. Two DC motors have been incorporated to move the wheels in another position. Arduino UNO controls the wheelchair direction using relays as the motor driver. The wheelchair has been powered by solar panel thus providing emphasize on the use of green energy. Light Dependent Resistor (LDR) has been used as light detection sensor, for situations as, when the light is inadequate and the user cannot operate the wheelchair. Ultrasonic sensor has been used as obstacle detector for making the movement safer.

Mahmud et al. [9] developed a multi-modal human machine interface for the larger domain of people with disabilities to control the wheelchair. The interface comprises joystick, smart hand-glove, head movement tracker and eye tracker. The raspberry pi unit works as a main controller of this multi-modal interface. The system has 2-axis joystick with high accuracy and efficiency. The hand glove has flex-sensors, which calculates the amount of deviation/deflection. An Arduino Nano is attached the hand gloves tracking the hand gestures based on the resistance value of the flex sensors. A camera is used to detect eye gaze movement. The system is processed by means of a Convolutional Neural Network (CNN) architecture. An IMU tracks head movements. The IMU is connected to an Arduino nano and it processes the signals received from the IMU, providing the final direction in which the raspberry pi operates the wheelchair. The communication between the raspberry pi and arduino module happens wirelessly as there is a Bluetooth module attached to the arduino nano.

Kader et al. [10] developed a head motion-controlled semi-autonomous wheelchair by means of 3-axis accelerometer, two DC motors, sonar sensors to detect obstacles, and SMS through GSM modem with location information. The motion sensor is placed at the top of the head, and in the normal orientation of the head, which is parallel to the earth's surface. When the head of the user tilts in different angles, the orientation is changed. The unit control is Atmega328P (Arduino Nano) microcontroller to receive data. The microcontroller communicates with the GSM modem by some attention (AT) commands using Universal Asynchronous Receiver and Trans- miter (UART) communication protocol. The serial communication speed is 115,200 bps. The system also has a Bluetooth (BT) module, which receives head orientation data and provides it to the microcontroller.

On the other hand, the literature review presents the results about fuzzy logic controllers that were implemented in different wheelchair systems such as [11], [12] and [13]. Zhang et al. [11] developed a fuzzy logic structure for an electric powered wheelchair based on an iterative linear matrix algorithm. The control attenuates the influence of the unknown nonlinear of the dynamical systems. The fuzzy controller evaluates the speed error and the accelerate error such as inputs and the control decision is the output of the system. 65 s elapsed to stablish the position and velocity tracking of the wheelchair. Lee et al. [12] implemented a fuzzy wall-following control based on ultrasonic sensors with conditionals of distance for each fuzzy rule. The fuzzy input was the distance and the fuzzy output was the wheelchair angle. Maatoug et al. [13] made a fuzzy logic controller with distance and angle inputs to operate the wheelchair. The fuzzy variables are based on the error. The controllers do not take into account the obstacles and the wheelchair make a trajectory since an initial position. The controller us a zero-order Takagi-Sugeno type.

The literature review shows different types of fuzzy controllers taking into account the error and the input sensors measurements but the review does not present a fusion of fuzzy controllers with position, speed and orientation variables. In this research, the objective was to make the fuzzy controllers for each variable and finally, the fusion controllers.

Hardware description

The prototype was designed taking into account the wheelchair characteristics to transport a person with physical disabilities. The prototype has sensors, unit control, communication system, actuators, frame and configuration head motion capture system. The inputs and outputs system, unities control and communication elements are shown in Fig. 1. The blocks

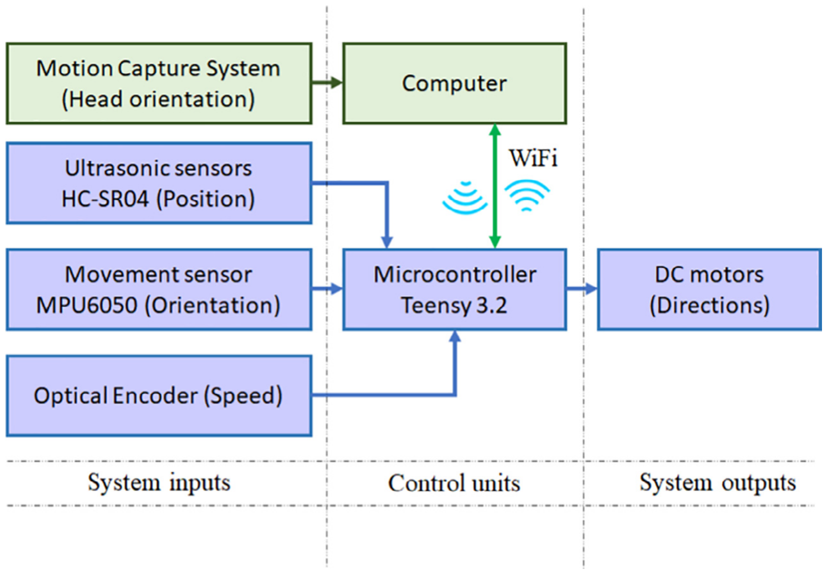

Fig. 1. Block diagram of the electronic devices located on the wheelchair prototype.

in blue color mention the elements of the wheelchair prototype and the blocks in green color mention the external elements such as the computer and the cup where the motion capture system was implemented.

Sensors: The prototype has sensors to measure distance, speed and orientation. The sensors implemented are: Ultrasonic module HC-SR04 for measuring distance between the prototype and the obstacles near to itself, which are located on the front and sides of the prototype; the speed sensor is composed of an optical encoder located on the wheels to measure the number of turns and obtain the angular velocity of the system. The optical encoder model is HC-020 K. The movement sensor is MPU-6050, which is used for knowing the prototype orientation and determine possible risks of collision or inclination that affects the stability of the prototype.

Actuators: The actuators are two DC gearmotors of 25 mm with a nominal speed of 20 rpm and a turning radius of 217.0:1. The model motor is 225–801 of Makeblock company and the maximum power output is 1090 mW. The actuators are connected to a L298N driver used to control the speed and direction of the wheels.

Unit Control: The microcontroller Teensy 3.2 of PJRC company is the unit control of the prototype system, which has an ARM Cortex-M4 processor, Flash memory of 256Kbytes, Random Access Memory (RAM) of 256 KBytes, and Electrically-Erasable Programmable Read-Only Memory (EEPROM) of 2 Kbytes. The physical part has 34 digital input/output pins and twelve Pulse Width Modulation (PWM) output pins. The communication systems are composed of three serial pins, one Serial Peripheral Interface (SPI) and two Inter-Integrated Circuit (I^2C) pins. The microcontroller is programmable using Arduino libraries.

The elements mentioned above are shown in a block diagram in Fig. 2.

Frame: The structure has four wheels, a base and caterpillar links. The structure was developed by Makeblock, with the Starter Kit Bluetooth 90020. The structure is shown in Fig. 3.

Communication system: The system uses a User Datagram Protocol (UDP), which exchanges datagrams on the network. The Open System Interconnection (OSI) model utilizes the UDP protocol in the transport layer. UDP supplies data transport with low overhead due to datagram header size that is small and it does not have network management traffic. This protocol has an interface between network and application layers of the OSI model. It does not guarantee that the message will be delivered, but does guarantee the speed of sending and receiving data [14]. The prototype communication allows transferring data between the head motion capture system and the computer, receiving head motion angles. The wheelchair prototype sends and receives information. The prototype sends the sensors data such as distance, speed, movement angles and temperature and receives control actions to operate it. Fig. 4 shows a bidirectional communication between the unit control and the prototype and, the unidirectional communication between the head motion capture system and the computer.

Configuration head motion capture system: The user can activate the control system by means of a Graphic User Interface (GUI) and start the different control types developed by using a head motion capture system. The capture system generates Euler angles (Pitch, Yaw and Roll) to send to the computer for processing and produce control actions to operate the wheelchair prototype. The capture system also has an initial configuration and data calibration for sending Euler angles and connecting to the WiFi network. For another hand, the capture system has a power system to charge it when the light red of the system is turned-off. Fig. 5 shows the different head movements made by the user and the direction of the wheelchair prototype in response to these movement.

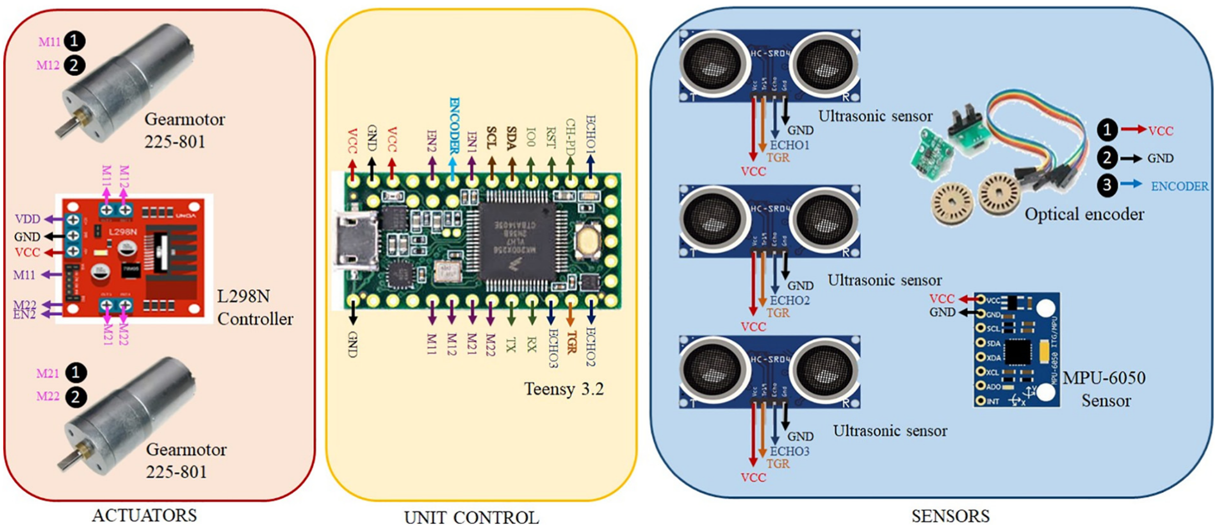

Fig. 2. Elements of the wheelchair prototype: actuators, unity control and sensors.

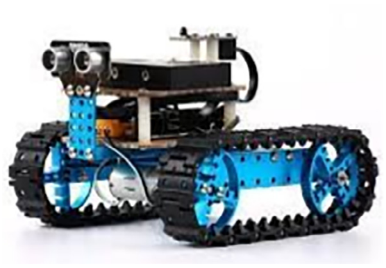

Fig. 3. Structure used for prototype implementation of the system.

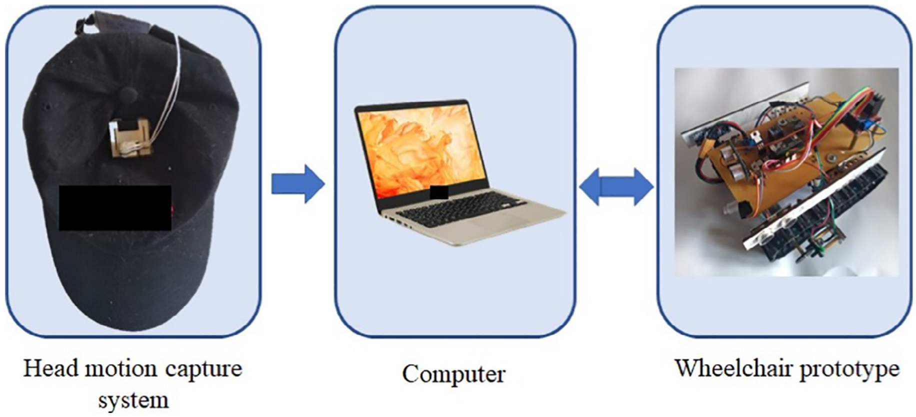

Fig. 4. Bidirectional communication between the prototype and the computer and unidirectional communication between the head motion capture system and the computer.

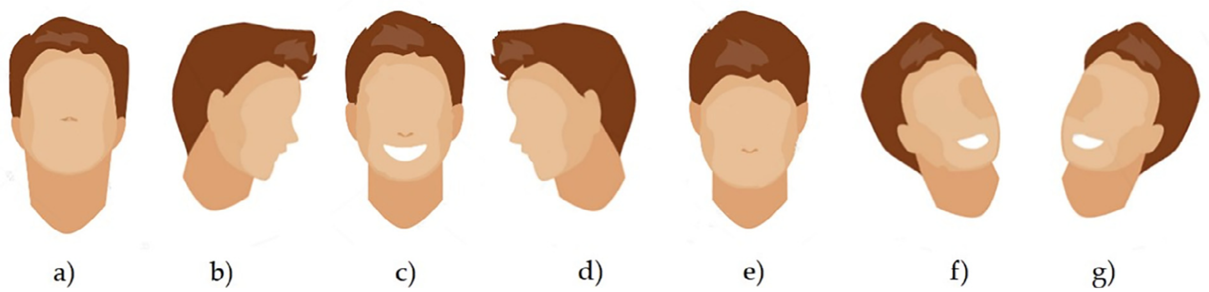

Fig. 5. Head motion to operate the wheelchair prototype in seven directions: (a) backward movement; (b) left movement; (c) stop; (d) right movement; (e) forward movement; (f) right-back movement; (g) left-back movement.

Design files

The design files section is divided in hardware and software files where the hardware section illustrates the schematics and PCB layouts of the system and the software section describes the main algorithms of the fuzzy controllers, graphical interface and communication using block diagrams for a better comprehension.

Electronics

The schematics of each component is mentioned below. The schematic for ultrasonic sensor, optical encoder, movement sensor, WiFi module and microcontroller inputs and outputs are shown in the Figs. 6-10. Fig. 6 illustrates the sensor HC-SR04 using 5 V for operating.

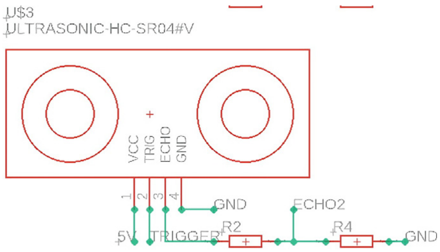

Fig. 6. HC-SR04 ultrasonic sensor schematic made in EAGLE.

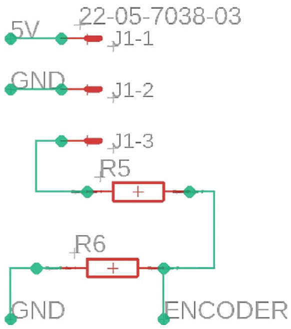

Fig. 7. Optical encoder schematic made in EAGLE.

The schematic of Fig. 7 illustrates the connections of the speed sensor at 5 V and an output analog signal that is processed with the microcontroller using an equation to calculate the speed in RPM. The output signal needs an voltage divider using an input signal of the microcontroller.

The movement sensor sends and receives data using I^2C protocol. The pins used for this protocol are SDA (data line) and SCL (clock data). The sensor sends information about the prototype movement and the microcontroller processes and obtains the Euler angles that describe this movement in three axis. The schematic is shown in Fig. 8.

The WiFi module voltage is 3,3 V and uses serial communication through RX (reception data) and TX (trans- mission data) pins. The module also has a reset pin controlled by the microcontroller for communication reset. The schematic is shown in Fig. 9.

Fig. 8. MPU6050 movement sensor schematic made in EAGLE.

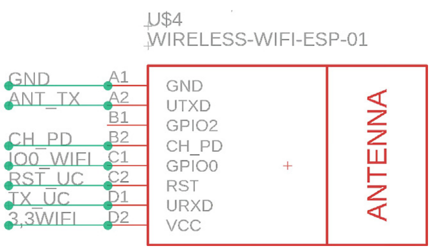

Fig. 9. WiFi module ESP8266 schematic made in EAGLE.

The microcontroller has the inputs and outputs signals for the sensors and actuators. The schematic is shown in Fig. 10.

The L298N is used for motor control using 5 V. The input signal voltage is 3.3 V because the microcontroller generates this level. The input signals are enabled for each motor, and two signals for each motor, which operates the direction of motor rotation. The PCB layout was generated using one layer taking into account the schematics mentioned above. The PCB contains voltage divider for the optical encoder and ultrasonic sensors. Fig. 11 shows the PCB layout of the wheelchair prototype.

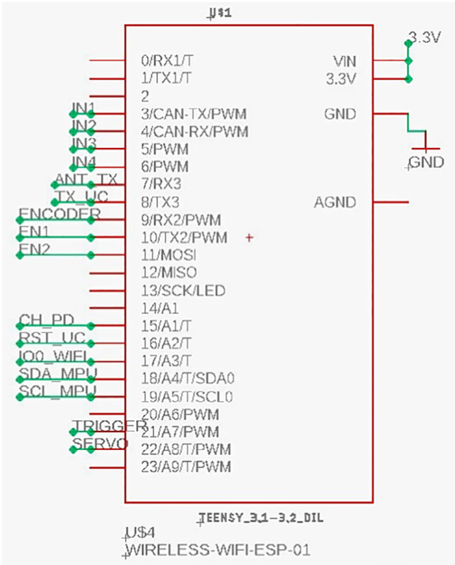

Fig. 10. Teensy 3.2 microcontroller with inputs and outputs.

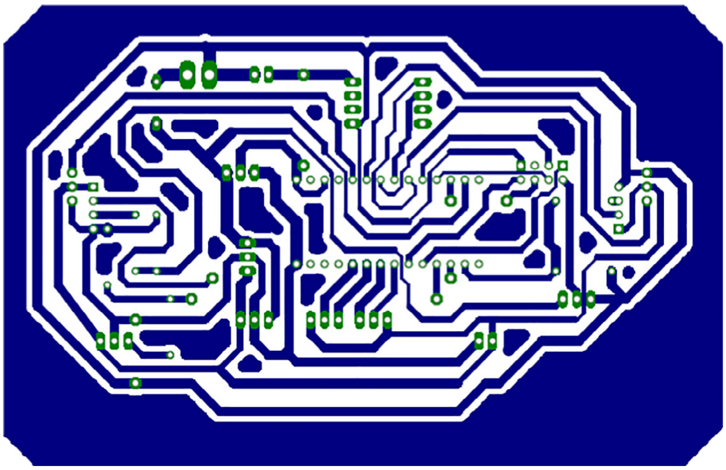

Fig. 11. PCB Layout of the wheelchair prototype using EAGLE.

Software and firmware

The software developed in this design includes the communication algorithm, the GUI algorithm for manual and fuzzy controllers, and the control algorithm using Python™. Table1 shows the different commands utilized for sending to the microcontroller for each direction and speed desired.

Communication algorithm: The communication algorithm between the computer and the prototype is described using a block diagram that is shown in Fig. 12, where the command sent is"@" to know the sensors data located in the prototype.

Table 1
Commands to send to the prototype to stablish speed and direction.

Command	Speed[PWM]	Direction
@	–	–
0	255	Forward
1	255	Right
2	255	Left
3	0	Stop
4	255	Backward
5	100	Forward vel1
6	140	Forward vel2
7	180	Forward vel3
8	210	Forward vel4
9	240	Forward vel5
a	255	Turn on its axis
b	100	Right vel1
c	140	Right vel2
d	180	Right vel3
e	210	Right vel4
f	240	Right vel5
g	100	Left vel1
h	140	Left vel2
i	180	Left vel3
j	210	Left vel4
k	240	Left vel5
l	100	Backward vel1
m	140	Backward vel2
n	180	Backward vel3
o	210	Backward vel4
p	240	Backward vel5
q	255	Backward right
r	255	Backward left

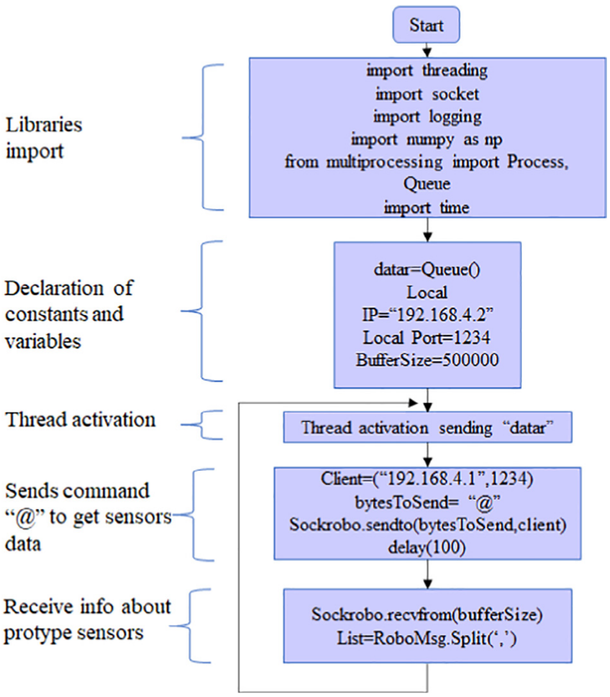

Fig. 12. Block diagram of the communication algorithm between the computer and the prototype.

GUI algorithm: The GUI algorithm shown in Fig. 13 shows a main window of the application with the manual control importing the control and graphical libraries, and choosing the control type to be executed. In this case, the user chooses the desired speed and executes the application using the buttons of the interface to operate the prototype.

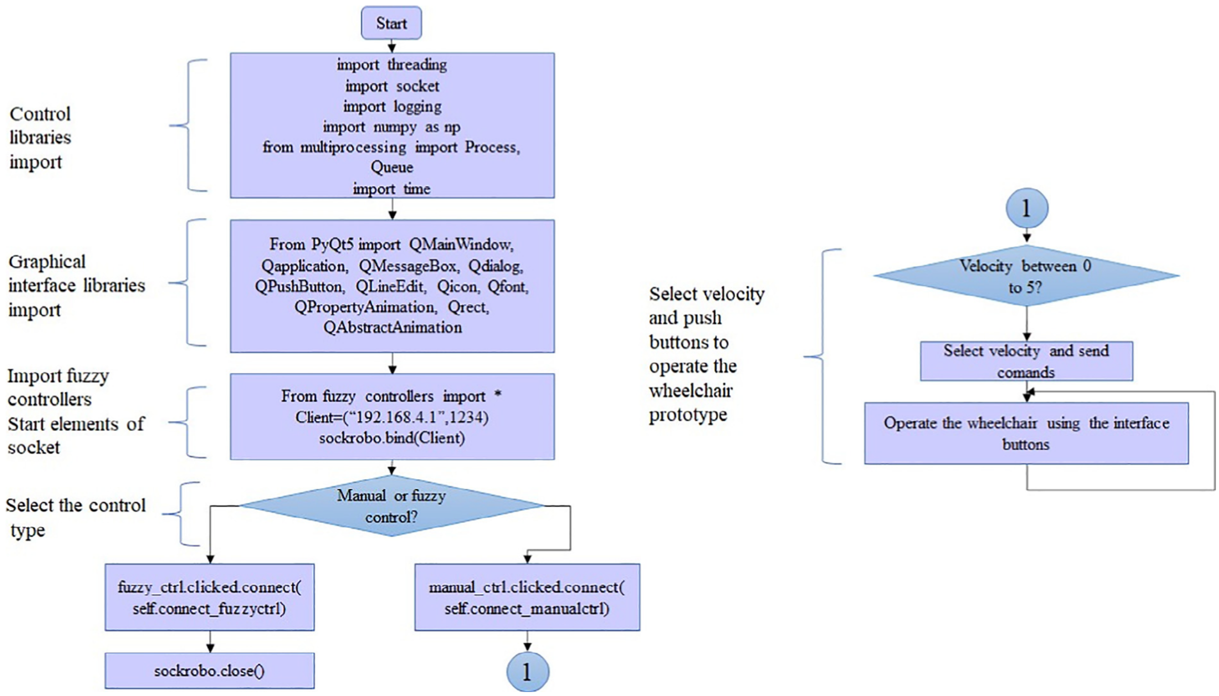

Fig. 13. Block diagram of the GUI algorithm using manual control for operate the wheelchair prototype.

Fuzzy controllers algorithm: The fuzzy controller was made taking into account the Euler angles to establish membership functions with the maximum ranges of head motion. The universe discourse was made and the algorithm uses commands for fuzzy outputs that are sent to the microcontroller to operate the wheelchair prototype. The algorithm is shown in Fig. 14.

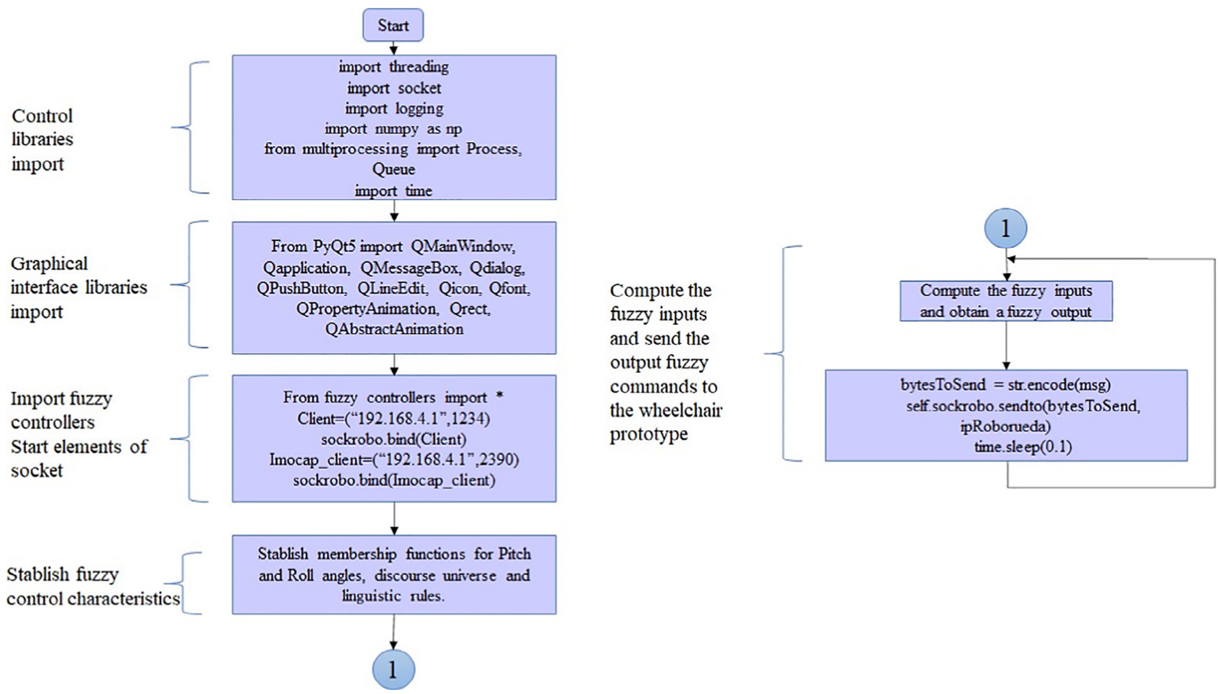

Fig. 14. Block diagram of the fuzzy algorithm using Python™.

Design files summary

The system has files for hardware and software system. The hardware files include the instrumentation, communication and control actions for the wheelchair. The software files include the manual and fuzzy con– troller algorithms and the GUI application. For more details, Callejas-Cuervo et al. [15] shows the design and implementation of the controllers designed and results of the system that are available in https://data.mendeley.com/datasets/ys9s9pgvbg/1.

Bill of materials

The bill of materials is shown in Table2.

Table 2
Materials characteristics and price used for the wheelchair prototype construction.

Component	Description	Quantity	Cost per unit – currency (USD)	Total cost – currency (USD)	Source of material
Microcontroller Teensy®3.2 of PJRC	Controller that com- municates with Iner- tial Measurement Units (IMUs) and another sensors and actuators	1	$31	$31	https://www. pjrc.com/store/teensy32.html
Inertial Mea- surement Unit InvenSense MPU9150	Sensor used for head motion capture	2	$24	$48	https://learn.sparkfun. com/tutorials/ mpu-9150-hookup-guide? ga = 2.37669923. 2076180685. 1631109717–233043870. 1631109717
Inertial sensor MPU6050	Sensor used for mea- suring wheelchair move- ment	1	$2	$2	https://www.sparkfun. com/ products/11028
Ultrasonic Sen- sor HC-SR04	Sensor used for measur- ing distances and detect obstacles	3	$2	$6	https://www.sparkfun. com/ products/15569
WiFi Module ESP8266	Wireless communica- tion module between the prototype and computer	1	$4	$4	https://www.sparkfun. com/ products/17146
Optical Encoder	Sensor used for mea- suring the speed of the prototype	1	$7	$7	https://www.sparkfun. com/ products/12629
Driver L298N DC motors	Controller On/Off to operate the DC motors of the prototype	1	$3	$3	https://www.sparkfun. com/ products/15451
DC Gearmotor	DC motor to drive the prototype	2	$11	$22	https://www.sparkfun. com/ products/15277
Lithium Batter- ies 1000mAh	Energy system	1	$31	$31	https://www.sparkfun. com/ products/11856
Robotic Struc- ture	Physical structure that simulates a wheelchair prototype	1	$113	$113	https://store.makeblock. com/collections/all/products/ diy-coding-robot-kits-mbot- ranger

The materials used for the application can change with the aim to obtain better results such as the distance sensor, improving the measurement error.

Build instructions

The build instructions are divided in step-by-step construction instructions of software and hardware of the system.

- Software.

The software designs were made using Python™ using examples such as https://pythonhosted.org/scikit-fuzzy/auto examples/plot tipping problem newapi.html for the fuzzy controllers. Multiparallelism was the method utilized, specifically the use of threads for real time response of the system, as the reading sensors and fuzzy output control have to occur at the same time. The threads implementation is explained in https://docs. python.org/3/library/threading.html. The GUI was made using a library PyQt5 of Python™ with examples of implementation and basic commands that are shown in https://https:// www.guru99.com/pyqt-tutorial.html. The fuzzy controllers also have developed using a toolbox"LogicFuzzyDesigner" of MATLAB®, and the simulation analysis was made based on the results. The toolbox example is shown in https://www. math-works.com/help/fuzzy/building-systems-with-fuzzy-logic-toolbox-software.html.

- Hardware

The build instructions utilize the schematics mentioned above. The assembly of the system was made in EAGLE, and the PCB was printed through a PCB board and acid to remove the unnecessary parts of copper and exhibit the printed circuit. The resultant board is shown in Fig. 15. The assembly includes the location of the sensors appropriately in the prototype.

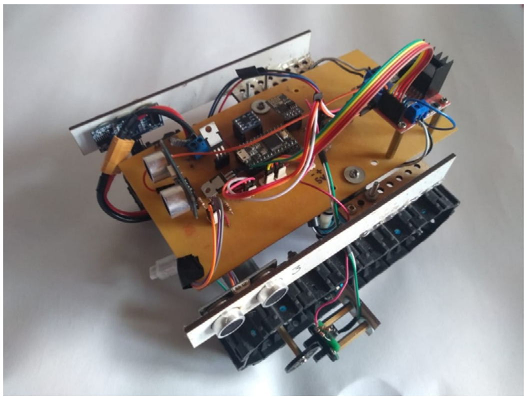

Fig. 15. Block diagram of the GUI algorithm using manual control for operate the wheelchair prototype.

Operation instructions

The building instructions are shown in Fig. 16, where the user turns on the device using a switch button that is located on the prototype. The communication system is activated by means of the algorithm explained above. The user links the prototype with the computer through a WiFi network that generates the prototype. The user connects the computer with this network and run the application that contains the different algorithms for graphical interface, manual and fuzzy controllers as well as time response graphics. The application has a main window where the user selects the type of control. The main window has buttons and the user chooses a velocity if and only if the user wants to drive the wheelchair prototype with a manual control. In the left part of the window, there are buttons for position, speed and orientation controllers. The user can choose the type of control and return to the main window by closing the window that was generated. Fig. 17 shows the main window of the application.

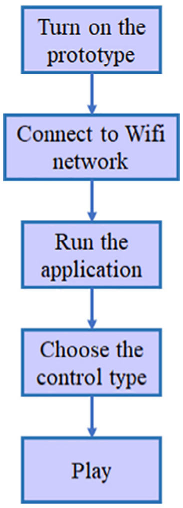

Fig. 16. Block diagram for the application use.

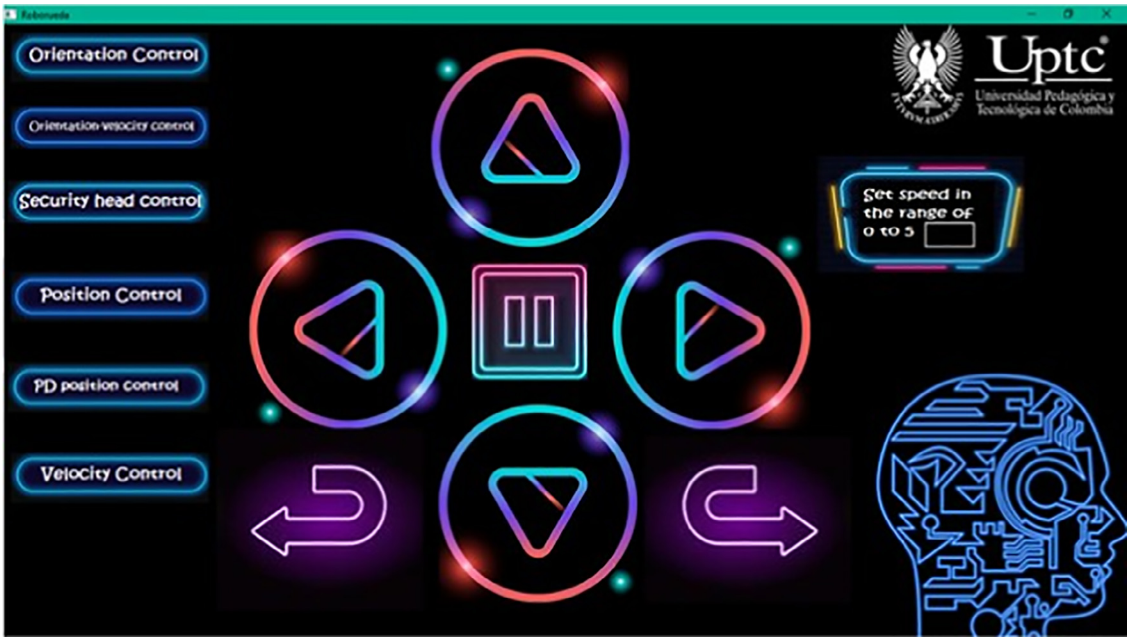

Fig. 17. Main window of the graphical interface.

The user sets the speed range using the keyboard of the computer to establish a number between 0 and 5. Pressing the enter button, the user can select directions through the interface buttons: forward, left, right, backward, back-right, back-left and stop. If the user needs to control the prototype with another type of control, there are six options in the left hand of the GUI.

The new window that is generated when the user selects another type of control different to manual is shown in Fig. 18.

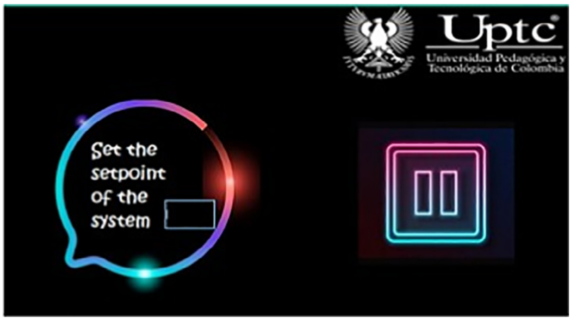

Fig. 18. New window generated when the user selects one controller different to manual control.

Validation and characterization

Experimental tests were conducted with 10 participants including one person with reduced mobility in the lower limbs. The user operated the system using a computer where the GUI was shown. The head motion capture system and the wheelchair prototype explained in this work are shown in Fig. 19 representing the head movement and the prototype location.

The electronic validation was made with the time response of the different controllers implemented. Table3 shows the time response of the orientation controllers and manual controller.

The response time considers one route made by the user in form of Bernoulli lemniscate. The manual control response is slow because the user uses buttons instead of head movements. The mean velocity utilized is the maximum velocity of the prototype, and the freedom degrees of the prototype are limited. The time response of the system with manual control was 37,8 s. A mean orientation control response with constant speed was 36,5 s, and the mean orientation control response with variable speed was 44,2 s, taking into account the results of Table 3 results.

Fig. 19. Use of the system with a person without movement in lower limbs.

Table 3
Response time of the manual and orientation controllers.

Participant	Manual Control	Orientation control response with constant speed	Orientation control response with variable speed
1	40	27	32
2	38	29	34
3	36	24	32
4	45	60	90
5	22	31	38
6	44	34	52
7	22	27	24
8	45	40	42
9	34	35	36
10	52	58	62

The fuzzy logic controllers were made for position, speed and orientation. Qamar et al. [16] developed a fuzzy controller with orientation inputs and the output system variables were speed and steering. The time response of the system is not comparable with this research because the implementation made by Qamar et al. was in an electric powered wheelchair. Onishi et al. [17] controlled a direction and/or speed of the electric powered wheelchair applying fuzzy logic with a head mounted display. The fuzzy variables were the tilt-angle input movements and tilt-angular-velocity movements. The users made a questionnaire about the maneuverability, comfortability and safety of the wheelchair system but do not describe the time response or electrical validations of the development. Future works for this research are the implementation of the system in an electric-powered wheelchair and comparison with other technologies taking into account the response time of the system in specific routes and electronic response of the different controllers. The authors that developed another types of fuzzy controllers such as [11], [12] and [13], for position or speed they did not take into account the fusion of fuzzy controllers with the aim of operate a wheelchair or robot. The objective of this research was the fusion controllers in a proof of concept to control the wheelchair directions.

The literature review described different purposes about wheelchair control using head motion, instrumentation and control techniques, such as Ruzaij et al. [3,4,5] which developed a system using a prototype and a wheelchair. The system uses motors that needs more power to be activated. The authors also used a physical wheelchair with a reaction time of 100 ms. These values cannot be compared with the results of our system because the system developed was tested with a prototype.

Marins et al. [2] used an Arduino Uno for extracting and processing data, as well, MATLAB® for classification data. The use of MATLAB® for this type of control requires a computer and the system cannot be migrated to another unit control. In our case, the system can use any type of unit control.

Gomes et al [7] used similar components for the wheelchair prototype, with the difference of laser sensors which have a better accuracy than ultrasonic sensors. Mahmud et al. [9] used a raspberry pi unit for data processing and an Arduino Nano for hand movements processing. Finally, Kader et al. [10] used another system for communication by means of SMS through GSM modem.

Conclusion

A device that simulates a wheelchair prototype using head movements was built using a graphical interface. The system was made to evaluate seven controllers: manual, position, speed, orientation with constant speed, orientation with variable speed and orientation with obstacle detection. The hardware used for the application has commercial components and the software was described using toolkits and libraries of free use and published in repository's Github or MATLAB® documentation. The reaction response of the system was 100 ms and each controller obtain good responses time through the stablished route for the experiments. Our development used the graphical interface in the computer for monitoring and control the interface taking into account the best visibility and resources for the user. The system can use any type of unit control because it is portable.

Ethics statements

The informed consent of the participants can be obtained writing an e-mail for gis@uptc.edu.co.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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