



AN EQUIPPED SENSORIZED GLOVE WITH BENT SENSOR FOR MEASURING FINGER FLEXION

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Abstract–This paper presents the development of medical device that can assist a sensorized glove system using magnetic induction coils as finger movement sensors. This paper focuses on a studying implementing the system for measuring the finger position of one hand movements with the aim of the giving feedback to the rehabilitation system. These sensor are mounted on the glove and suitably configured and connected to the electronic conditioning circuit by using glove we monitor the measurements of patients hand flexion and that information sends and data are stored in acquisition unit from portable device to remote device. An equipped sensorized glove with flex sensor is provide for monitoring the rehabilitation actives of the hand who Have suffered from traumatic brain injuries, articulation traumas robotic system can be aid for rapid patients recovery. Hence the shape of the flex sensor does not change as finger are bending and the quality of the measurement and the lifetime of the sensor will not decrease with time.

Application– the glove have the several types of application such as 1)the recognition of signal language,2)the interaction with virtual reality,3)the recognition of diagnostic measurements of the finger movements and 4)improvement of hand motion.

Index Terms– Exoskeleton, finger flexion measure, low-power system, measurement of body, flex point motion, rehabilitation, resistive sensors, sensorized glove, wearable device, wireless communication.

I. INTRODUCTION

EVERY year, millions of people over the worldwide experience problems because of traumatic brain injuries, degenerative diseases, and articulation traumas. **STROKE** is the leading cause of adult disability, out of 65% four million people in the United States who have survived a stroke living with minor to severe impairments. Impairments such muscle weakness, loss of range of motion, and impaired force generation to create deficits in motor control that affect the stroke survivor's capacity for in depend on the living and economic self-efficiency. Many traditional therapeutic interventions have been used in rehabilitation to promote functional recovery, A stroke, sometimes referred to as

cerebra vascular accident (CVA), cerebra vascular insult (CVI), or colloquially brain attack is the loss of brain function due to a disturbance in the blood supply to the brain. These disturbance is due to either ischemia (lack of blood flow) or haemorrhage. As a result, the affected area of the brain cannot function normally, which may result in an inability to move one or more limbs on one side of the body failure to understand or formulate speech, or a Vision impairment of one side of the visual field. Ischemia is caused by either blockage of a blood vessel via thrombosis or arterial embolism, or by cerebral hypo per fusion. Hemorrhagic stroke is caused by bleeding of blood vessels of the brain, either directly into the brain parenchyma or into the subarachnoid space surrounding brain tissue. Risk factors for stroke include old age, high blood pressure, previous stroke or transient ischemic attack (TIA), diabetes, high cholesterol, tobacco smoking and atria fibrillation High blood pressure is the most important modifiable risk factor. For example, 60 million Americans have disabilities that affect their daily lives [1]. Among the different types of brain trauma, stroke is the major cause of disability in adulthood [2] and the incidence of this trauma is doubling every decade >55 years. In the United States of America, one American out of 100 have had a stroke, in the United Kingdom 700 000 cases occur annually [3], whereas in New Zealand there are 6000 cases of stroke and two-thirds of these are fatal [4]. Rehabilitation aims to restore patient's physical, sensory, and mental abilities is mainly affected by injuries, and disorders, and to support the patient is not medically treated. In addition to the surgery, patients with stroke is a muscular disorders needs rehabilitation to regain mobility [5] in recent evidence has to be demonstrated. that intensive and repetitive practice is effective in the recovery of functional motor skills then the impact of cognitive, musculoskeletal, and perceptive disorders on motor activity increases with age. In 2030,there expected that years will achieve in United States the population will be over 65 will be 20% of the total population; in Europe and Japan it will reach 30% [1]. Under those conditions, the growing demand for rehabilitation many people are suffered from stoke injuries that treatments would increases public spending significantly. time and in the future, would allow the rehabilitation management it

gives the patient the ability to perform the exercises at home, of transport to a hospital. Regarding the specific rehabilitation of the hand flexion then the robotic system needs a sensitized unit, such a glove with suitable sensors. Because of its lightness and portability, the glove allows to measure the position of each finger and it work simultaneously to perform the required movement.

A. Rehabilitation monitoring and coaching technology

Despite attempts at using simple reminders (e.g., timers, pressure monitors, PDA reminders/surveys), user's guides (e.g., handouts, note cards), and consumer booklets developed to promote clinical practice guidelines, users do not seem to follow clinician instructions [4]. The novel operates the use of machine learning and artificial intelligence

B. Virtual Reality and Rehabilitation

Virtual reality (VR) technology [3] is currently being explored in several areas of rehabilitation [42]. VR head-mount displays (HMDs) have been used to present visual cues overlapping the real visual scene during ambulation of patients with Parkinson's disease. This is being investigated as a tool to facilitate a more normal gait pattern. Motor improved following robot-assisted sensor motor activity of that arm. Several commercial companies have developed sophisticated and general-purpose systems. Among the commercial products, of first glove, the Power Glove was developed for home entertainment, with variable resistances and an infrared sensor for the wrist position [6]. An example with multiple sensors is Cyber Glove [7]. The most sophisticated version is a glove equipped by 22 resistive sensors, which measure the flexion extension and the finger and wrist adduction-abduction movements. The glove communicates with a personal computer (PC) either through wireless or USB. The battery power lasts 2/3 h at each charging [8]. This way, the glove can be mainly used for remote handling, the interaction with virtual reality [9], recognition of sign language [10], and computer-aided design and recognition of motor skills. [11] and high cost. In [12], VPL Data Glove consists of optical fiber sensors for detecting the lexicon-extension movements of the fingers and magnetic sensors for detecting the position and orientation of the palm. Communication with the PC is obtained through the serial port. Human Glove (manufactured by Human Ware) consists of 22 Hall Effect sensors, which measure the lexicon-extension and the finger and wrist adduction-abduction movements. Communication takes place according to the Bluetooth standard with a PC. Because of the limits of the commercial products reported above, in particular, regarding the cost and the high complexity, several prototypes have been developed lately. A flux sensor is a transducer that generates an electrical signal proportional to the total heat rate applied to the surface of the sensor. The measured heat rate is divided by the surface area of the sensor

to determine the flux sensor. The bent sensor can have different origins; such as heat flux transducers, heat flux gauges, heat flux plates. Some instruments that actually are single-purpose heat flux sensors like pyranometers for solar radiation measurement in those previous commercial products are very expensive, were as other devices still under development, are low-cost alternatives, but low power consumption issues are not considered. In this paper, to measure the finger flex icon- extension movements, is a simple, low- power, low-cost ,and wireless device is designed, made, and tested proposed sensorized glove permits designed, made, and tested. The proposed sensorized glove is measured.

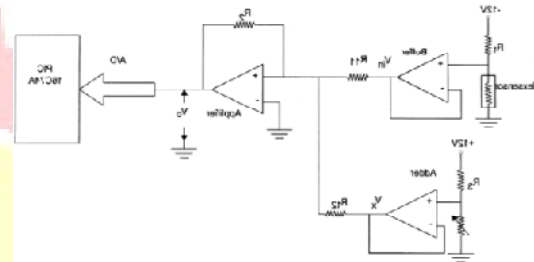


Fig 1. Flex sensor circuit diagram

permits to measure 10 joints of one hand. then the proposed system includes a portable device, consisting in a sensorized glove and its conditioning circuit, which elaborates the data's and sends the data to a remote unit (a PC), recording and displaying the data from the gloves. The design specifications of the portable system are such as: 1) independence from the remote unit; 2) low power consumption; 3) ease and comfort of wearing for people who have reduced hand motion; 4) lightweight; and 5) low cost. that portable system is powered by the battery, the data transmission from the portable device to the remote unit is recorded and then it sends in wireless using a nonstandard protocol to reduce the power consumption. Because patients who wear this device may be suffering from muscle weakness and limited range of motion those device should be light and easy to wear. The low cost makes it suitable for the rehabilitation at home, stability, and repeatability. Fig. 3 shows an image of the sensitized glove with a superimposed scheme of the bones and joints of a human hand and the results are described in both I11 and IV hand and the results are des robotic system needs a sensitized unit, such a glove with suitable sensors. Because of its lightness and portability, the glove allows to measure the position of each finger and it work simultaneously to perform the required movement. general-purpose systems Among the commercial products, of first glove, the Power Glove was developed for home entertainment, with variable resistances and an infrared sensor for the wrist position [6]. An example with multiple sensors is Cyber

Glove[7]. The most sophisticated version is a glove equipped by 22 resistive sensors, which measure the flexion extension and the finger and wrist adduction-abduction movements. The glove communicates with a personal computer (Pc)

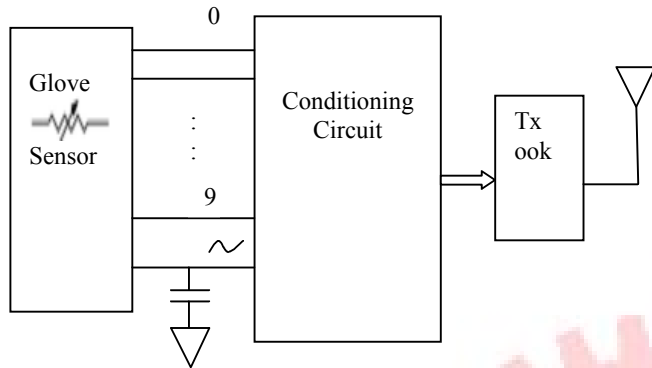


Fig 2 (a). Conditioning circuit(data transmitted)

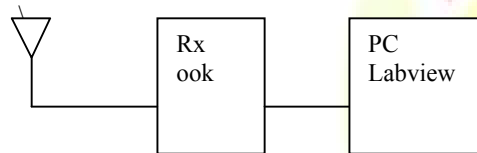


Fig 2 (b) .measured data (remote unit)

II. SYSTEM DESCRIPTION

A block diagram of the system is shown in Fig. 2(a).The system is composed of a portable system and a remote unit. The portable device is the transduction system and consists of a glove comprising 10 resistors (two for each finger) connected to a microcontroller through in front-end of electronics and described under management of the sensor measurement is assigned to the microcontroller that performs several functions: interfacing and conditioning of signals from the sensor block and data transmission. During the operation of the remote unit, made up of a receiver and a PC, converts, records, and displays the received measures of each joint deflection. In Fig. 2(a) the block diagram of the conditioning circuit and transmitting electronics is shown. The resistive value R of each sensor is calculated through the principle of charge and discharge of a capacitor with capacitance C , in series to R , according to the formula $R = \tau / C$, where τ is the time required to charge the capacitor at 63% of the voltage reference of the conditioning circuit is Produced by Flex point Sensor Systems (FLXT),thus the weight is just a few grams. The sensors consists of two layers:1) the sensing element is

consisting of a silver-based material having piezoresistive properties and a flexible substrate composed of polyamide And it protects the sensitive substrate. When the sensor is folded and the piezoresistive material is under goes in a micro strain, which increases its electrical resistance because the conductive particles is moves away from each other and decreasing the conductance of the material and increasing its resistance. The sensors are labelled from 0 to 9.And the capacitor is connected to the comparator of the microcontroller: its output is high or low depending on the level of the signal to Measure with respect to the set threshold. At the beginning of the measurement, the comparator generates an internal rising edge that activates the timer.

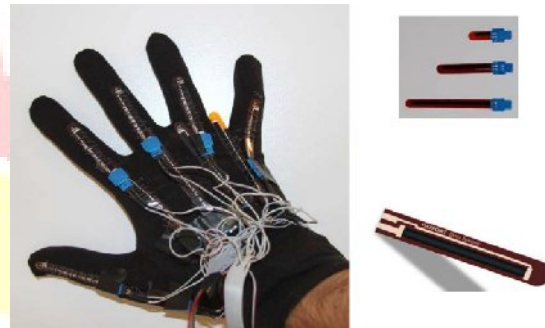


Fig 3 . Sensorized glove with bent sensor

Once the charge of the capacitor reaches the threshold value, the comparator generates a falling edge and stops the timer and the count the value is associated with the specific sensor .after the each measurement, the microcontroller sends the measured data to the transmitter, which uses an ON-OFF key (OOK) modulation. These data are a packet of 21 bits; one bit identifies the start of transmission, four identify the sensor, and 16 bits encode the timer value. In addition, the timers are reset, the capacitor is uncharged and the peripherals are reinitialized. After the another sensor is selected for the measurement and the corresponding pin of the microcontroller is enabled as an output with high value, whereas the pins connected to the other sensors become inputs (this does not affect the measurement). In Fig. 4, an image of the different parts composing the system is shown. which can be connected to a data acquisition card (DAQ).Fig. 4.Shows an image of the sensitized glove with a superimposed scheme of the bones and joints of a human hand. The bent sensors are placed for the measurement a) Proximal inter phalangeal joint (PIP),b) meta carpophalangeal joints (MCP).The sensors are mounted over an elasticized glove made up of 88% polyester and 12% eglantine. This way, the freedom of movement and a stable support for the sensors are guaranteed simultaneously The adopted transducers are thin film sensors, smaller the resistance is greater. Flex point fabricates the sensor in three different lengths: 1–3 in Fig.3.Ten sensors are used, and they

are positioned on the two proximal joints of each finger, as shown in Fig. 3. the sensors are positioned in the glove and hence the finger joints are in the middle of the sensitive area; this way the sensor covers the finger joint area and it follows movement. In addition, each sensor is attached to the glove by stitched elastic; in fact the sensor is sensitive to the pressure at which it is subject During the stretching hand movements, the elastic seems not to exert significant pressure on the sensitive area. For an average size hand the adopted sensor substrate is polyester (because the sensors on the glove are not subjected to abrasive agents) with these dimensions for the MCP joints of the index, middle, ring, and little fingers, the mounted sensors on the mounted sensors are 3-in type and for the other joints, the sensors are 2 in. The choice of each sensor length depends on the hand and joint dimension and by the available commercial dimensions of the sensors Thus for the hand considered of average size the 3-in sensors, being scale. those device has an 8-bit ultralow power longer. The microcontroller is the HC9S08QB8 commercialized by free scale. those device has an 8-bit ultralow power microcontroller. In this case, fig 5. the internal clock is used with a frequency of 32 kHz. The operating supply voltage is between 1.8 and 3.6 V. and operating supply voltage is between 2.1 and 3.6 V with few milliampere of current absorption (maximum 9.6 mA, as reported in its datasheet). its dimensions are $28 \times 13.7 \times 1.57$ cm.

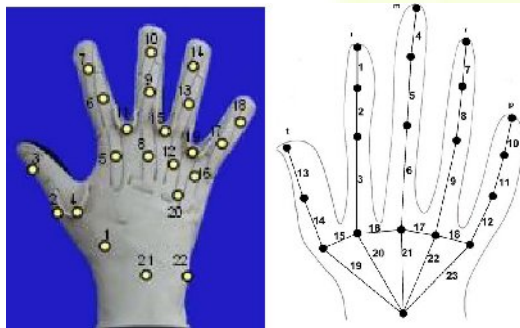


FIG 4. SENSOR POSITIONING

The sensors are connected across I/O pin and an analog-comparator input. When one sensor is supplied, I/O input connected to it becomes high and the other sensor pins are inputs with 10.5 g of weight. It guarantees large autonomy as well An image of the conditioning circuit is shown in Fig. 5. Its dimensions are $3 \times 7.5 \times 2$ cm.

LABVIEW: (short for Laboratory Virtual Instrument Engineering Workbench) is a system-design platform and development environment for a visual programming language from National Instruments. The graphical language is named "G" (not to be confused with G-code). Originally released for

the Apple Macintosh in 1986, LabVIEW is commonly used for data acquisition unit. and industrial automation on a variety of platforms including Microsoft Windows, various versions of UNIX, Linux, and Mac OS X.

A DATAFLOW PROGRAMMING: The programming language used in LabVIEW, also referred to as G, is a dataflow programming language. Execution is determined by the data information

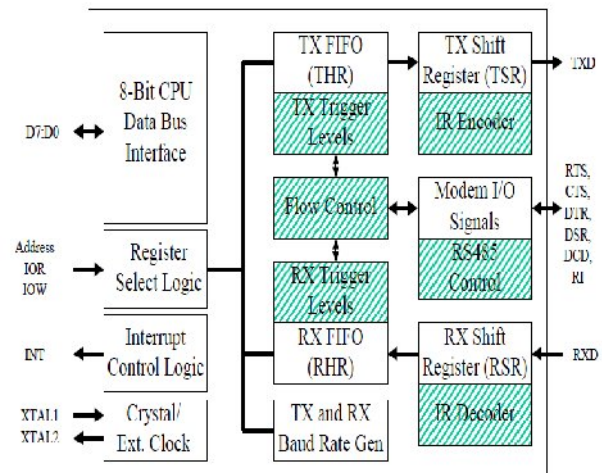


Fig 5. Maxwell diagram

the structure of a graphical block diagram (the LabVIEW-source code) on which the programmer connects different function-nodes by drawing wire and Since this might be the case for multiple nodes simultaneously, G is inherently capable of parallel execution. Multi-processing and multi-threading hardware is automatically exploited by the built-in scheduler, which multiplexes multiple threads over the nodes ready for execution, system weighs only 80. B

GRAPHICAL PROGRAMMI: LabVIEW ties the creation of user interfaces (called front panels) into the development cycle. Each VI has three components has a block diagram, and as front panel and a connector panel. The last is used to represent the VI in the block diagrams of other, calling VI s. The front panel is built using controls and remote unit.

CODE COMPILATION: In terms of performance, LabVIEW includes a compiler that produces native code for the CPU platform. The graphical code is translated into executable machine code by interpreting the syntax and by compilation. The LabVIEW syntax is strictly enforced during the editing process and compiled into the executable machine code when requested to run or upon saving. In the latter case, the executable and the source code are merged into a single file. The executable runs with the help of the LabVIEW time engine, which contains some precompiled code to perform common tasks that are defined by the G language

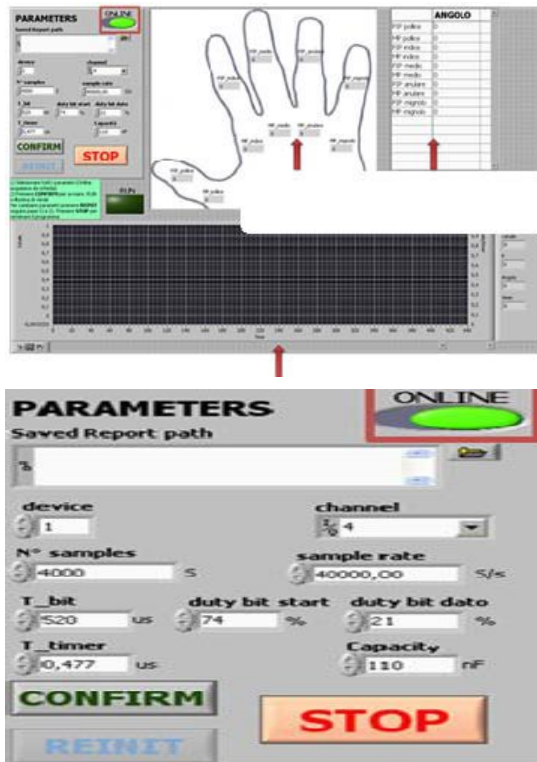


FIG 6. ANGULAR POSITION OF THE FINER POINT

III EXPERIMENTAL SYSTEM

In this section, the experimental system (Fig. 7) used to calibrate the sensors and test the conditioning circuit is shown. The sensitized glove is worn by a person and the conditioning circuit and is connected to the glove and fed with using the battery. The multimeter used for measuring the power supply and the resistance of the sensors is the model of Hewlett-Packard HP34401. The used oscilloscope is TDS 1001B with a bandwidth of 40 MHz and a frequency acquisition of maximum 500 MS/s. The receiver is connected to a DAQ card (6024E) and a LabVIEW program is developed. The function of the PC is to convert the received signal from the transmitter into angular information associated with the correct channel and displays it on the screen. During the calibration phase, it is important to record the resistance measure of the sensors, obtained by the transduction. The optical system adopted is commercialized by Optic-Track that is composed by three cameras (V100:R2) with a resolution of 640×480 video graphics array and a sub millimetre accuracy. All those cameras are connected with an USB to a PC. An example for the measure of the position of a single joint with the optical system is shown in Fig. 8 three

optical markers are placed: 1) on the PIP; 2) on the McLane 3) on the metacarpal bone. Then the two segments formed the three points are monitored and the rotation of one segment with respect to the other is calculated and system.

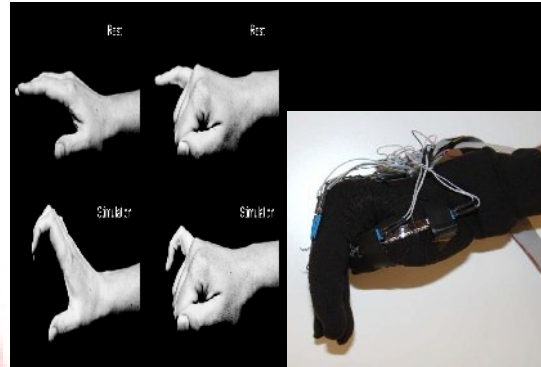


FIG 7. IMPROVEMENTS OF HAND FLEXION

IV EXPERIMENTAL RESULTS

In this section, the experimental results are presented. One of the challenges of this paper is to have a long working time obtained by reducing power consumption. To measure supply voltage range and power consumption, the battery is replaced with a variable voltage generator and the current consumption. The minimum voltage supply under that the system does not work is 1.9 V, whereas the maximum current request is 3.6 am. Experimentally, keeping active the device powered by the battery, the working time exceeds a week. Three reference resistors (100 k_Ω, 150 k_Ω and 200 k_Ω), used to emulate the sensors, are used to validate the conditioning and transmitting electronics. In Fig. 9, a measure example is reported: the green line (Sens3) is the supply voltage of a resistor (in this case that with 200 k_Ω of resistance), the black line (EN) is the enable signal of transmission, the blue (TX) is the transmission data output to the transmitter, whereas the different resistors were measured with the multimeter HP34401. The resistors were connected to the conditioning circuit and the resistance measures were continuously five times. The results are and compared with the measured values then the system commits a percentage error <0.7% relative to each reference. Bending tests of the fingers, consisting of the bending of every single joint of 0°–90°, were executed wearing the sensorized glove and using the optical system reported in the experimental system paragraph. In these tests the experimental and the Data shown in Fig. 8 regards the sensor on MCP joint of index; the behavior is similar for the other sensors., because only three Markers are necessary. The bend data acquired by the optical system and by the sensitized glove system were collected those test was repeated two



times. Fitting the measures with polynomial approximation the calibration curve is sensorized and that measured data are sends Approximated with two polynomial curves of the second order, One of the angles $>30^\circ$ and one for angles under 30° , as shown in. The obtained polynomial coefficients (a , b , and c) for the 0° – 30° curve are +7.9, -45.3, and 17 833, and for the 30° – 90° are -8.2, +1628, and 18 156, respectively.

The same procedure is repeated for the other joints and the coefficients are different due to the bending tests of the fingers were performed for four consecutive times To evaluate the performance and the experimental results

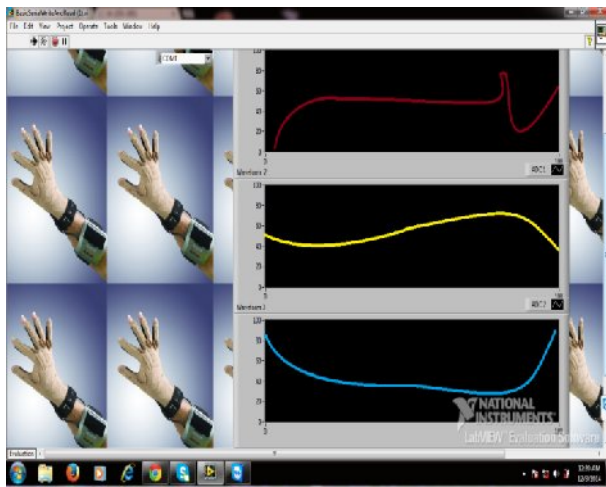


FIG 8. MONITORING THE HAND FLEXION

are obtained with the sensorized glove are reported. The average values are shown with dots, whereas the dashes represent the limits of the confidence interval of 95.4%. The graph shows the best fit line as well. Therefore, the measurements for the characterization and calibration of the system composed of the sensorized glove and the conditioning electronics have a good agreement with what was previously designed.

V. CONCLUSION

In this paper, a new device to measure the position of the hand finger flexion is proposed. With respect to patients condition this system is used to monitoring the improvements of patients hand movements and this is reduces the power consumption. The battery lifetime covers over a week. Furthermore, the proposed glove is lighter than commercial devices in fact, it weighs only 80 g. The use of flex resistive sensors and of the OOK modulation for the transmission, instead of Bluetooth standards, we used wireless communication, Makes the device simple, light, portable low power, and low cost. The

experimental results acquired with the sensorized glove show a good correspondence with the values obtained with anoptical system used as a reference. For new users, the system must be calibrated, as for all the types of sensorized Gloves. In the future, the focus will be paid on the experimental validation arranging we can use single glove for different and flexion in different tests on different subjects.

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