

Low power glove for hand functioning analysis in children with cerebral palsy

Nada Mahdi Kaittan¹, Sana Sabah Sabry², Ahmed Raheem Abdulnabi¹

¹Business Informatics College, University of Information Technology and Communications

²College of Engineering, University of Information Technology and Communications

ABSTRACT

In this paper, a low-cost glove has been manufactured to monitor and analyse the hand motion for the children who suffer from the cerebral palsy. Cerebral palsy (CP) is a combination of continual disorders affect the movement's evolution due to a non-gradual disturbance in developing fetal or infant cerebrum. An Arduino Nano microcontroller with flex and force sensors are attached to soft cloth glove to form the analysis glove. The data of this study is collected from children who have cerebral palsy, non-cerebral palsy, and children who are treating by physiotherapy and then compared with each other. The results show that the analysis glove helps the physiotherapist to assess the hand functioning problem such as difficulty in hand grip and inability to fully bend the hand figures in general and thumb figure in particular. These remarks can help physiotherapists to define the required program to improve these functions and indications.

Keywords:

Disability, Hand function, Smart glove, Flex sensor, Force sensor, Arduino

Corresponding Author:

Sana Sabah Sabry

University of Information Technology and Communications

Baghdad – Iraq

Email: sana.sabah@uoitc.edu.iq

1. Introduction

Cerebral Palsy (CP) is a clinical diagnosis of a non-progressive growth defect of motion impairment [1]. CP is a common disease that causes physical disability and a lifelong disorder to children that may become worse if it left without treatment [2]. Studies has shown that 2 – 3 per 1000 of newborns all over the world are suffering from CP [3]. The effect of CP on the children was stated in [4], in which CP has impact on three aspects: structures and body functions, activities, and social interaction. In this study, only body movement and activities were considered since the social participation is not affected by hand disability [5]. 50% of the children stated in the data have arm-hand dysfunction [6], [7]. Because hand functioning is the capability of the hand to execute daily activities in a complete manner [5], this will greatly affect the children daily life activities such as self-care, education, self-entertainment [8]. In addition, children who are suffering from CP have a functional limitation in the use of their hands [9]. There are many limitations and problems concerning hand functioning for CP children [10]. Some of these limitations are as follows:

- Excessive thumb adduction and/or flexion
- Limited wrist movement
- Difficulty in hand grasping
- Tone abnormality of upper limb

Examining hand motion is substantial for numerous medical purposes, like rehabilitation and assessing the ability of hand to extension/flexion and pressure force. By acquiring the hands kinematics, the physiotherapists can record and precisely assess the patients' case after hand treatment or hand surgery [11]. A

number of technologies can be helpful in examining hand motion such as Internet of Things [12][13], block chain technology [14], Machine Learning [15] and deep leaning [16].

Based on previous studies, there are two kinds for capturing the hand kinematics: non-contact systems and contact systems [17][18]. The non-contact systems use camera-based devices to record hand motion and process the images using image processing techniques [18][19]. Regardless the ease of use in the non-contact system, where the patient does not need to wear a physical device, the non-contact systems are affected with ambient conditions, like illumination and occlusion [11]. Also, the non-contact systems are not accurate in measuring the extension/flexion angle of the fingers [17]. Moreover, camera-based devices are more expensive and difficult to use in-house when compared with contact-based systems [18]. In brief, contact-based systems are more feasible in medical setup [20][17].

The data capturing gloves are commonly used type of contact-based systems [21]. Therefore, in this article, a low-cost assessment glove is designed to help the therapist in assessing the treatment. The assessment glove consists of a soft cloth glove, an Arduino Nano microcontroller, and flex and force sensors. The main component of the glove is the Arduino microcontroller. An Arduino is a microcontroller known as an open-source hardware and commonly used for prototyping the researchers' projects because of its low price and ability to run different projects [22]. The microcontroller has been attached with flex and force sensors to collect data.

Many researchers have carried out studies to present gloves for rehabilitation and hand movement tracking, but none of them has studied or analysed the hand movement of the children with CP. Therefore, this paper studies, analysis and evaluates the hand functioning of children with CP.

Therefore, this study sheds the light on a new design for hand movement powered wearable glove. This system is low cost, lightweight has shown an ease of use to collect the data, and an efficiency in diagnosing the feasibility of the treatment. The major specialty of this design is that it uses hand movement sensors to measure the ability of movement and strength of fingers for children with cerebral palsy.

Sections of this study are organized as follows: section 2 includes concise review of earlier related study. Section 3 shows the system design in addition to the system measurement. Section 4 discuss the results of the system. While, the final part, section 5, is the conclusion.

2. Related work

A number of researchers have recognized physiotherapy assessment systems in studies related to this subject. Ito et al. 2011 presented a lay out of fine-motion assistance system used as a way to rehabilitate the hand. The system can assist in hand kinematics such as extension/flexion [23]. The previous system is expensive, big in size, and uncomfortable for those who suffer from this illness. To minimize the weight as well as the cost of evaluation devices, data gloves have been promoted applying lightweight materials like optical fibers or resistance sensors. Silva et al. (2011) presented a wearable glove based on fiber optic sensors [23] which led to solving the weight problem. However, the optical fiber equipment is expensive.

Kortier et al (2014), designed a data glove attached with inertial magnetic sensors for assessing hand motion [24]. This system's drawback was that it takes time to stick the sensors on the hand. Moreover, resultant data is inaccurate for most of the tries because of the instability of sensors on the hand.

Choi et al. (2016), employed multiple inertial measurement units in a low-cost data glove [25]. The disadvantage of this system is that the glove is not suitable for small hands and it limits the hand kinematics, which leads to inaccurate data.

Lin et al. (2017), presented a data glove system which provides therapists supported by an effective user-friendly recording and a tool of evaluation to analyze the recovery status of a patient's hand function [26]. The glove provides data for flexion only, but there is no data for the ability to press.

In 2017, Fang et al. presented a wearable glove provided with sensor fusion algorithm to record hand motion [27]. But, the glove was not designed perfectly, and it had a difficulty to wear and mobility because of the glove's wire.

3. System design

An in-house designed system for hand movement measurement is introduced in this study to capture and analyze the hand movement for CP children. In our system, several information can be measured to get insight about the hand problems, such as touch pressure detection, stereo gnosis, proprioception, grip strength.

The system consists of smart glove and receiver node. The system architecture is illustrated in figure (1). The smart glove can be easily wore and it consist of five separated flex sensors, five separated force sensors, microcontroller, and wireless radio frequency transmitter, all powered by a rechargeable Li-ion polymer battery as shown in figure (2a).

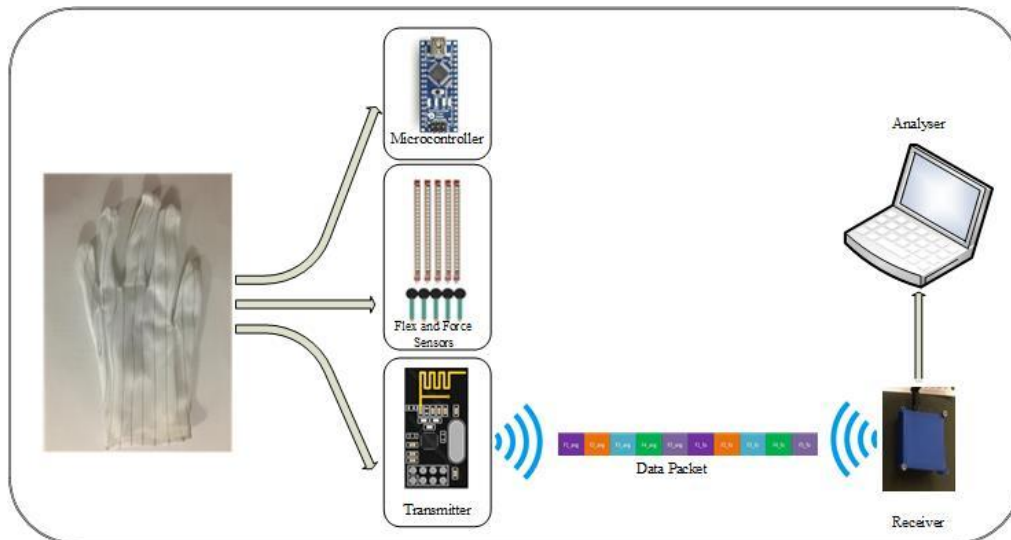


Figure 1. System architecture

In order to reduce the connection complexity among the system components, a special PCB is designed. The flex is used to measure the bend angle of each finger as shown in figure (2-a), while the force sensor utilized is to measure the pressure force for each finger as shown in figure (2-b). The flex sensors placed on the top of the hand, the force sensors placed in the palm side of the hand, while the controller/transmitting circuit placed on the wrist of the hand

An 8-bit at mega328 utilized to collect the measurement of each sensors. NRF24L01 breakout communication unit sends these measurements.

The second part of the system; receiver node, consist of microcontroller and NRF24L01 breakout communication unit covered with 3D printed enclosure as illustrated in figure (2-c). The data exported in a .csv file for further analysis.

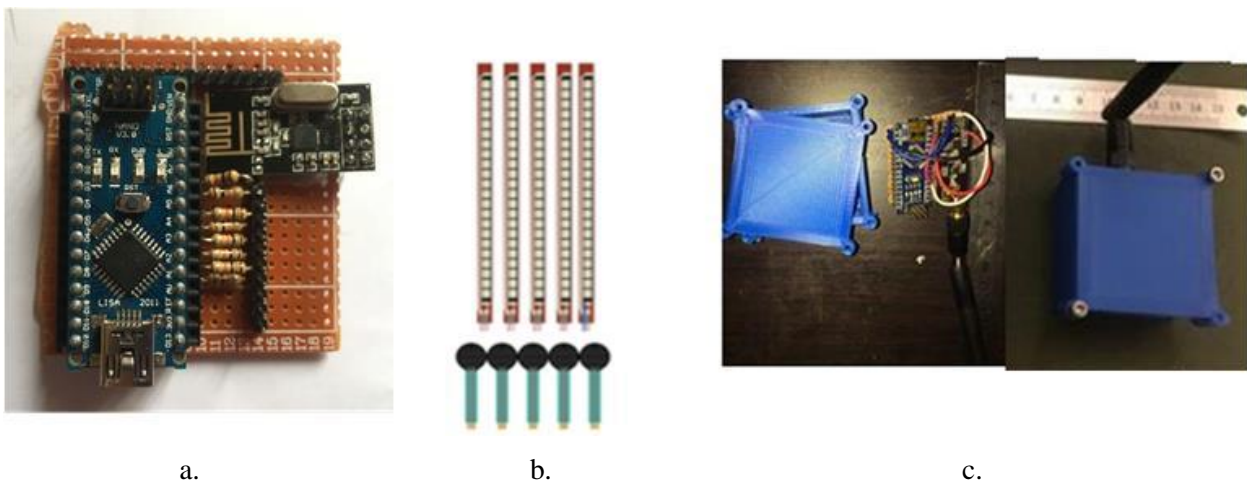


Figure 3. System components

3.1. System measurements

Figure (3), presents the proposed smart glove for testing on cerebral-palsied children to measure touch pressure for each finger, stereo gnosis, proprioception and grip strength.

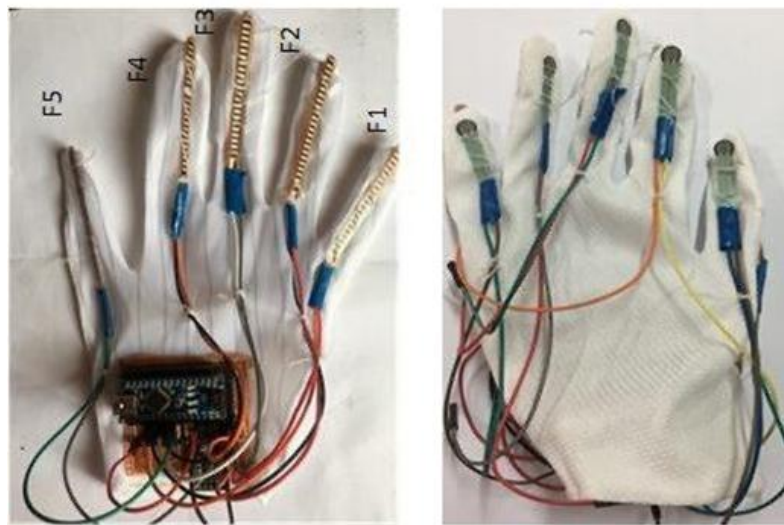


Figure 3. Proposed smart glove

Each participant is instructed to move his/her hand in different directions and bend each finger individually to measure the bending angle for each finger. For accurate hand movement analysis, the measurement calculated from ten sensors is organized in a single packet. Then, the packet will be received by the receiver node and saved to be accessed by therapists. This packet is organized as shown in figure (4).



F1 correspond to Pinky Finger
F2 readings correspond to Ring Finger
F3 readings correspond to Middle Finger,
the F4 correspond to Index Finger
F5 readings correspond to Thumb Finger.
fo represents the force (pressure)
ang represents the bending angle

Figure 4. Packet organization

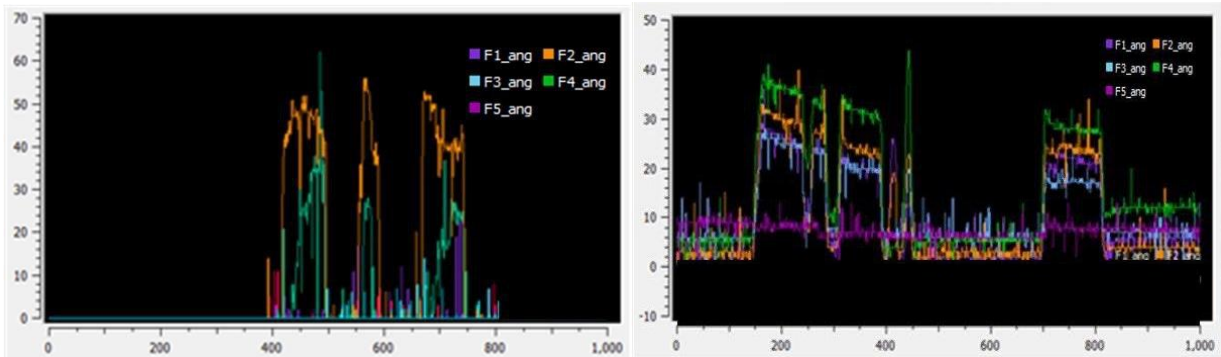
4. Results and discussion

The data glove is tested on both a normal child and CP child. Each category was requested to bend their fingers and grab an object. In the first step, the glove examined in a real-time to find out the device accuracy as shown in figure (5). From this figure, we can notice that the bend angle for a normal person has approximately average of 70 degrees. While, a CP child has roughly average of 30 degrees, except the thumb finger which shows a less average of measurement for about 10 degrees.

The pressure measurements for each finger's tip also examined in a real-time as shown in figure (6). This figure demonstrates the grip ability. Examining the figure, we observe that the grip-ability for a normal child is approximately 500 force-sensitive resistor (FSR), while, a CP child has an approximate average close to 70 FSR with less FSR for the thumb finger. These statistics indicate the inability of CP children to grip their hands, especially in the thumb finger. These facts will help the therapists to do an extra exercise for the thumb fingers.

Next, these measurements saved in a .csv file for clinicians and therapists to define the required physiotherapy program.

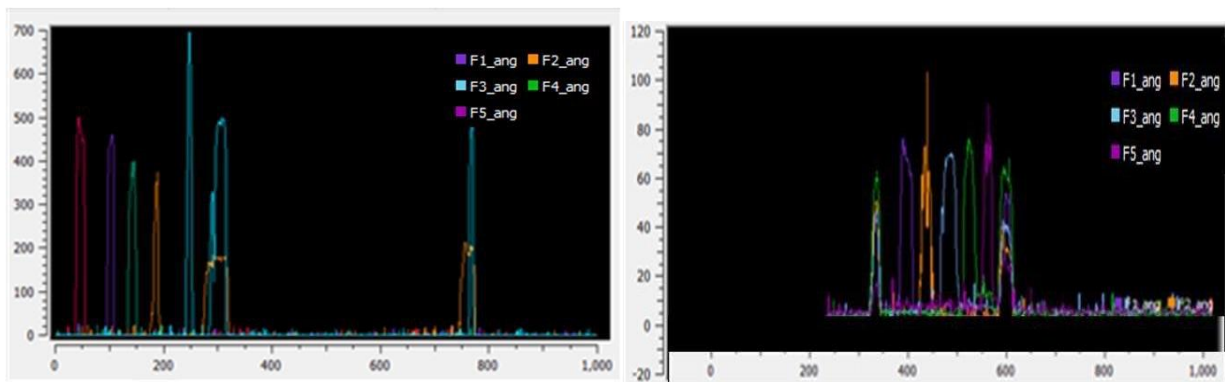
A sample test was done on a normal and CP child. Then, the imported data on .csv file acquired. To explain this, a line chart has been drawn to illustrate the data. Figures (7a) and (7b) demonstrate the line chart of both normal and CP child.



a) Normal child

b) CP Child

Figure 5. A comparison of bending angle between normal and CP child



a. Normal Child

b) CP Child

Figure 6. A comparison of pressure force between normal and CP child

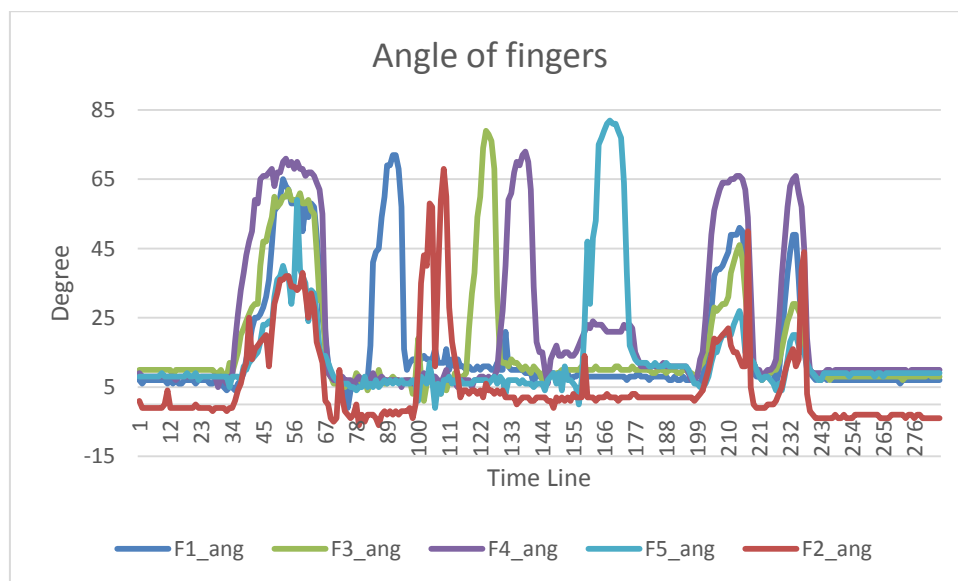


Figure 7a. Fingers' bending angel for normal child

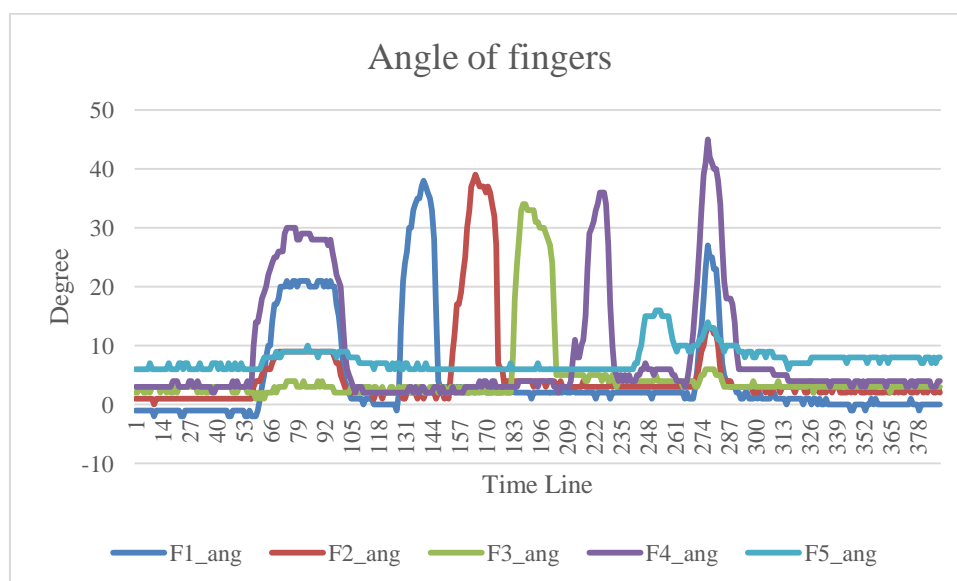


Figure 7b. Fingers' bending angel for CP child

5. Conclusion

In this paper, a new lightweight, low cost, and easy to wear smart glove has been introduced to analyze and assess the hand functioning for CP children such as bending and grip ability. The glove has shown clear results for both flex and force sensors. The assessment process has proven the ability of the smart glove assess the hand functioning for CP children. The results show that the children suffer from difficulty in hand grip and inability to fully bend the hand figure in general and thumb figure in particular. These remarks can help physiotherapists to define the required program to improve these functions. For future work, this data glove can be used to improve hand functioning using virtual game. In addition, an inertial measurement unit can be added to the system for wrist movement measurements.

6. References

- [1] L. T. Emrick and S. M. Dicarlo, "The Expanding Role of Genetics in Cerebral Palsy Cerebral palsy Genetics Exome sequencing," vol. 444, pp. 15–24, 2020.
- [2] N. A. Parikh, A. Hershey, and M. Altaye, "Pediatric Neurology Early Detection of Cerebral Palsy Using Sensorimotor Tract Biomarkers in Very Preterm Infants," *Pediatr. Neurol.*, vol. 98, pp. 53–60, 2019.
- [3] A. Synnes, J. Gillone, A. Majnemer, A. Lodha, and D. Creighton, "Early Human Development Preterm children with suspected cerebral palsy at 19 months corrected age in the Canadian neonatal follow-up network," *Early Hum. Dev.*, vol. 136, no. June, pp. 7–13, 2019.
- [4] "World Health Organization Geneva," *Int. Abil. GenevaWHO(2001)*.
- [5] C. Arnould, Y. Bleyenheuft, and J. Thonnard, "Hand functioning in children with cerebral palsy," vol. 5, no. April, pp. 1–10, 2014.
- [6] C. Arnould, M. Penta, and J. Thonnard, "ORIGINAL REPORT HAND IMPAIRMENTS AND THEIR RELATIONSHIP WITH MANUAL ABILITY IN CHILDREN WITH CEREBRAL PALSY Carlyne Arnould , PhD , Massimo Penta , PhD and Jean-Louis Thonnard , PhD," pp. 708–714, 2007.
- [7] G. O. Pht and D. N. Division, "Hand function in children with hemiplegic cerebral palsy : prospective follow-up and functional outcome in adolescence," no. 1998, pp. 85–91, 2003.
- [8] E. Pagliano, E. Andreucci, R. Bono, C. Semorile, L. Brollo, and E. Fedrizzi, "Evolution of upper limb function in children with congenital hemiplegia," pp. 371–375, 2001.
- [9] C. R. Mpt et al., "Effectiveness of virtual reality in the treatment of hand function in children with cerebral palsy : A systematic review," *J. Hand Ther.*, 2018.
- [10] A. P. Basu, J. Pearse, S. Kelly, V. Wisher, and J. Kisler, "Early intervention to improve hand function in hemiplegic cerebral palsy," vol. 5, no. January, pp. 1–10, 2015.
- [11] C. Engineering, "Brain Controlled Wearable Robotic Glove For Cerebral palsy Patients," 2017.

- [12] S. S. Sabry, N. A. Qarabash, and H. S. Obaid, "The Road to the Internet of Things: a Survey," in 2019 9th Annual Information Technology, Electromechanical Engineering and Microelectronics Conference (IEMECON), 2019, pp. 290–296.
- [13] I. Muhic and M. I. Hodzic, "Internet of Things : Current Technological Review," vol. 2, no. 2, pp. 1–8, 2020.
- [14] S. S. Sabry, N. M. Kaittan, and I. M. Ali, "The road to the blockchain technology : Concept and types," vol. 7, no. 4, pp. 1821–1832, 2019.
- [15] N. Sciences, "Machine learning algorithms for distributed operations in internet of things IoT," vol. 7, no. 4, pp. 1638–1648, 2019.
- [16] A. Azawii, A. Lateef, S. T. F. Al-janabi, and B. Al-khateeb, "Survey on Intrusion Detection Systems based on Deep Learning," vol. 7, no. 3, pp. 1074–1095, 2019.
- [17] Y. Park, J. Lee, and J. Bae, "Development of a Wearable Sensing Glove for Measuring the Motion of Fingers using Linear Potentiometers and Flexible Wires," vol. 3203, no. c, pp. 1–9, 2014.
- [18] C. Yang, V. Stankovic, S. Member, L. Stankovic, S. Member, and A. Kerr, "A Depth Camera Motion Analysis Framework for Tele-rehabilitation : Motion Capture and Person-Centric Kinematics Analysis," vol. 4553, no. c, pp. 1–11, 2016.
- [19] H. Liu and S. Member, "Exploring Human Hand Capabilities into Embedded Multifingered Object Manipulation," pp. 1–10.
- [20] N. Carbonaro, G. D. Mura, F. Lorussi, R. Paradiso, D. De Rossi, and A. Tognetti, "Exploiting Wearable Goniometer Technology for Motion Sensing Gloves," vol. 18, no. 6, pp. 1788–1795, 2014.
- [21] B. Shing, L. I. Jung, P. Ying, C. Shih, Y. Huang, and C. Wei, "A Modular Data Glove System for Finger and Hand Motion Capture Based on Inertial Sensors," *J. Med. Biol. Eng.*, vol. 39, no. 4, pp. 532–540, 2019.
- [22] V. Georgitzikis, O. Akribopoulos, and I. Chatzigiannakis, "Controlling Physical Objects via the Internet using the Arduino Platform over 802 . 15 . 4 Networks," vol. 10, no. 3, pp. 1686–1689, 2012.
- [23] S. Ito, H. Kawasaki, and Y. Ishigure, "A design of fine motion assist equipment for disabled hand in robotic rehabilitation system \$," *J. Franklin Inst.*, vol. 348, no. 1, pp. 79–89, 2011.
- [24] H. G. Kortier, V. I. Sluiter, D. Roetenberg, and P. H. Veltink, "Assessment of hand kinematics using inertial and magnetic sensors Assessment of hand kinematics using inertial and magnetic sensors," 2014.
- [25] Y. Choi, K. Yoo, S. Jin, K. Beomjoo, S. Soo, and K. Kim, "Development of a low-cost wearable sensing glove with multiple inertial sensors and a light and fast orientation estimation algorithm," *J. Supercomput.*, 2016.
- [26] B. Lin, P. Hsiao, S. Yang, C. Su, and I. Lee, "Data Glove System Embedded with Inertial Measurement Units for Hand Function Evaluation in Stroke Patients," vol. 4320, no. c, 2017.
- [27] B. Fang, F. Sun, H. Liu, and D. Guo, "Development of a Wearable Device for Motion Capturing Based on Magnetic and Inertial Measurement Units," vol. 2017, 2017.