

# A Futuristic Approach for Stroke Rehabilitation Using Smart Gloves

T Aghil <sup>1</sup>, S Rahul <sup>1</sup>, S Buwan Kumar <sup>1</sup>, Yati Vijay <sup>1</sup>, S Tharun Kumar <sup>1</sup>,  
Sidhharth B <sup>1</sup>

<sup>1</sup> Department of Electronics and Computer Engineering, Vellore Institute of  
Technology, Chennai, Tamil Nādu, India

\*Email: [aghilthamizh@gmail.com](mailto:aghilthamizh@gmail.com)

**Keywords:** UI, ESP32, Rehab, Physiotherapist.

**Abstract.** Stroke is a serious, common, and assured as a global health issue across the globe. Stroke is one of most common cause of death and is a leading cause of impairment in adults. Despite all impressive progression and development in the treatment of stroke, without effective modes of care most stroke patients care will continue to rely on physiotherapy involvement. The purpose of this paper is to explain about a new and better device which helps patients affected by stroke who are not able to move their hands. To rehabilitate stroke survivors, the proposed prototype is designed such that it is a portable smart glove which helps users to regain their muscle memory by continuously contracting and releasing their muscles without the involvement of physiotherapist. This device/glove also consists of sensors that collect and send data to UI using ESP32. This UI is available for the doctors to see the statistics of glove usage and monitors the patient's conditions. The Glove uses a soft robotics approach to replicate the human hand. The Glove initially aims to contract and release all the muscles in the hand in regular intervals of time. This muscle movement aims to build lost muscle memory.

## 1. Introduction

This paper's objective is to create a therapeutic glove that helps stroke survivors to undergo rehabilitation from their home. This results in a higher rate of recovery compared to other traditional methods and reduces the rehabilitation expenses. It can be said that one of the gravest and assured as a global health issue across the globe. Also, post stroke the survivors have to undergo rehabilitation to completely recover. It has also been proven that rehabilitation can be supported in well integrated multidisciplinary stroke-units. When it comes to motor recovery of the arm, some of the potentially beneficial options include robotics and constraint-induced movement therapy [1].

Transfer function may also be improved by repetitive-task training. Undergoing occupational therapy will result in considerable improvement in the activities of daily living. Various trials of rehabilitation practices and of new therapies like repetitive trans-cranial magnetic stimulation, stem-cell therapy, robotic-therapies etc., are developed in the near future [2]. Stroke-recovery is miscellaneous. By the extent of subsequent recovery and the size and position of the first stroke attack the long-term effect of stroke can be determined. Recovery is a complex procedure that likely happens through a collection of impulsive processes, including compensation, substitution, and restitution. After several cohort studies it has come to light that, in the first few days after stroke improvement of functions in the body and action is foreseeable [3,4].

The main goal of the stroke rehab gloves is to enhance and relearn the skills which have degraded due to stroke. Stroke rehabilitation helps to regain the muscle memory and improve the quality of life. Each person has different degree to recover during the process because there are many complications in the severity of stroke. Also, researchers have found people becoming better when one undergoes the process of rehabilitation comparing to people who didn't [5].

Other objectives of this paper are to create a more economic means for stroke survivors to undergo rehabilitation, to prevent travelling and additional expenses, produce better results compared to traditional methods in terms of rate of recovery and to reduce the time taken to recover. The

objective of this project is to create a compact, portable and a low-cost rehabilitation glove, thus ensuring a higher rate of recovery compared to traditional methods. This eliminates the need to visit a physiotherapist for every rehabilitation session, which in turn reduces the travelling expenses and have a comfortable rehabilitation experience from their home. It is also a smart glove that automatically reads the temperature and blood pressure of the user. This data will be available for users in the Blynk app user-portal and for the doctors in the web UI created by the team.

The literature review is done by researching about topics pertaining to stroke rehabilitation. The below research materials are compiled from various sources such as International Journal of Engineering and Technology, International Conference, and stroke research material.

**Table 1.1** shows the ideas and works of various people on stroke rehabilitation gloves.

Sl. No.	Name of article	Inference
1.	Design and Development Approach of Smart Glove for Post Stroke Rehabilitation [4].	In this paper, the operation of Smart Glove function very well as been programmed in Arduino. The device already perform operation based on the sensitivity level programmed in Arduino microcontroller. Key difference from this paper is that the proposed gloves is portable and much cheaper than this paper's glove and it is much simpler compared to the paper's glove.
2.	Smart hand gloves for disabled people [16].	In this paper, the authors have introduced the Smart Hand Gloves for Disabled people. It will provide reliable, efficient, easy to use, and low-weight solutions for users as you compare other proposed papers. This will commit to creating purpose in the lives of people with disabilities. The paper focuses on minimizing the problem. One the problem exists to make it wireless.
3.	Smart Glove: An Assistive Device to Enhance Recovery of Hand Function [11].	In this paper, smart Glove was successfully fabricated, and the total cost of fabrication was \$68.24 making it potentially affordable for clinics and patients. Proper communication was established between the data acquisition, data conversion, data processing and display modules. Resistive sensors mounted on the Smart glove were able to detect finger and wrist extensions performed by both control subjects and stroke patients while performing therapy. The sensitivities for detecting wrist and finger extensions could be adjusted independently depending on the amounts of spasticity manifested in the wrist and fingers. Additional Velcro straps were stitched on the glove to provide a snug fit to the users.

## 2. Design

### 2.1. Approach

Smart Glove is a portable device to rehabilitate stroke survivors which helps users to regain their muscle memory by continuously contracting and releasing their muscles. In order to regain muscle memory and for the functionality of arms, it challenges the patient through to and forth movement of fingers [6]. The Smart Glove ensures that patients do their exercises timely and give users instant feedback to evaluate their performance with only the slightest effort needed for success [7].

It is a positioning device for those with gentle stiffness of muscle or hand weakness. The extender helps to decrease the tone of muscle by encouraging the fingers into an extended open hand

position with adjustable pressure straps. For a safe grasp while holding an object, the finger strapping can likewise be turned around to support [8].

## 2.2. Features

- Silicone-covered finger surfaces improve traction during grasping.
- During exercises & functional hand movements, a non-slip liner minimizes the movement.
- The cotton material provides ventilation and antibiotic properties which allow for comfortable long wear.
- The exposed palm is designed in order to increase breathability & to make it easier to put on & take off.
- Hand-washable.

## 2.3. Prototype

First Prototype— Cotton gloves with plastic tubes and fiber wires. (The plastic tubes and wires were not durable). Cotton gloves were used so that the entire glove's weight is below 150 grams. In order to create a motion of contraction and expansion fiber strings are used and a DC motor. The strings are attached to the DC motor. To spin the motor in both clockwise and anti-clockwise direction a mini-Arduino board was used. Plastic channels were attached to each finger of the glove to act as a channel for the strings and prevent tangling. This prototype was not suitable for prolonged use as the cotton gloves wore out due to its excessive motion.



**Figure 1.** The above image depicts the first prototype which is made using cotton gloves with plastic tubes and fiber wires to act as channels.

Second Prototype – Industrial gloves with metal tubes. (The gloves did not have adhesive properties and so it did not hold the tubes after gluing it. In this prototype cotton gloves were replaced with industrial gloves. This prototype did not have adhesive properties to hold the hold the motor and string's channel on to its surface.



**Figure 2.** The above image portrays the second prototype which consist of gloves made of durable material suitable for industrial conditions.

Third Prototype – Cotton gloves with metal tubes and metal wires. (This glove gave better results than the previous ones. But, in the long run it wears out. In this prototype plastic tubes and fiber strings were replaced with metal channel and strings.



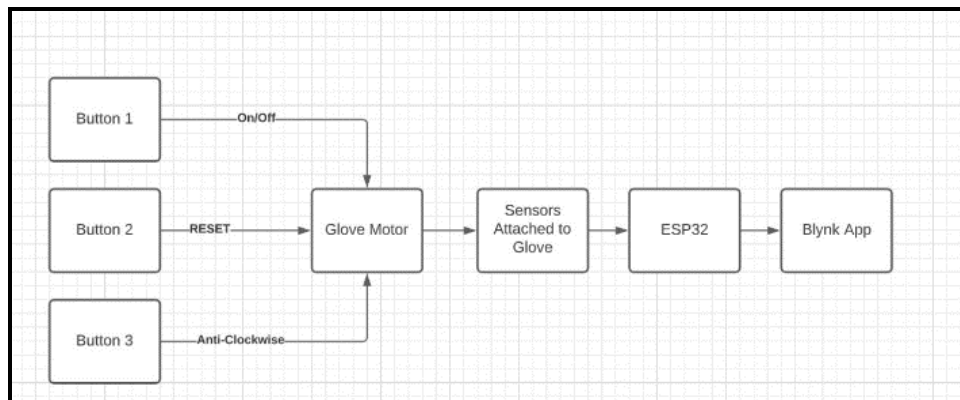
**Figure 3.** The above image depicts the third prototype which is a improvised version of the former ones with gloves made of cotton with metal tubes and wires to act as channels.

Fourth and Final Prototype – 3D Printing using TPU. In this prototype the metal channels were replaced with a 3D-printed exoskeleton. This change was done to the 3<sup>rd</sup> prototype to increase the glove's lifetime.



**Figure 4.** The image describes the final prototype of the rehab glove made using 3D printed TPU glove structure for increased durability and ergonomic design.

#### 2.4. Block Diagram



**Figure. 5.** This image depicts the block diagram for the device.

There is a switch to control the moment of the glove in which three buttons are impacted. Button 1 is for on and off Button 2 is for reset operation and button 3 is for anti-clockwise operation. Basically, if any case glove stopped in inappropriate position, then this button can be used to reorient the glove position. Then there is a motor for to and forth moment of the glove for fingers which will be useful to regain the muscles strength. Then there are some sensors attached to the glove used to record frequency of usage, time duration, temperature or pressure and this data will simultaneously reflect to the blynk app using esp832. This data is used by the doctor to give feedbacks and to check on their patients. With blynk app individual can also control the moment of the glove same as the buttons on switch [9].

### 2.5. Standards

802.11g is a Wi-Fi standard for transmitting data over a wireless network which is developed by the IEEE. It supports up to 54 Mbps data transfer rates and operates on a bandwidth of 2.4 GHz. 802.11g is in reverse viable with 802.11b device; however, in case there is any 802.11b-based device on the network, the whole network should run at 11 Mbps. Nonetheless, you can arrange your 802.11g remote switch to just acknowledge 802.11g device, which will guarantee your network runs at its maximum velocity.

For wireless LAN, 802.11 is in 3rd modulation. 31.4 Mbit per second is the greatest net-throughput workable for packets of 1500(bytes) and a 54 Mbit per second remote rate. Practically speaking, passages might not have an optimal execution and may accordingly not even have the option to accomplish 31.4 Mbit per second throughput with 1500(byte) packets. 1500(bytes) is as far as possible for packets on the Internet and along these lines an appropriate size to benchmark against. More modest packets give much lower hypothetical quantity, down to 3 Mbit per second utilizing 54 Mbit per second rate and 64byte packets. Additionally, the accessible amount is divided among all positions sending, along with the AP so together upstream and downstream traffic is restricted to a common absolute of 31.4 Mbit per second utilizing 1500(byte) packets and 54 Mbit per second rate.

802.11g device is completely in reverse viable with 802.11b equipment. Subtleties of making g and b function admirably organized. In an 802.11g device, in any case, the existence of an inheritance 802.11b member will fundamentally diminish the speed of the in general 802.11g networks. Some 802.11g switches utilize a back-viable means for 802.11b client that is 54g LRS.

## 3. Hardware Specification

**ESP32 MCU** - ESP32 is adept for industrial environments, and it can operate in the range of  $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ . It is a series of dual core, low cost, and low power SOC (system on a chip) which combines Wi-Fi and Bluetooth technologies. ESP32 can adapt to external environments, and it is highly versatile. ESP32 has ultra-low power consumption by combining different types of proprietary software [10]. It also consists of features like various power modes, dynamic power scaling and clock gating.

**Motor Driver (L293D)** - Motor Drivers act as an interface between the Arduino and motors. L293D is a dual H bridge motor driver and a single H bridge it is capable of driving a motor bi-directional. It is a 16-pin motor driver which can control a pair of motors in any direction. L293D can provide bi-directional currents of 600 mA from 4.5 V to 36 V. It is designed to provide loads for solenoids, DC motors, bipolar motors, as well as other high- current and voltage loads in supply applications. L293D is suitable for operating at  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ . L293D is a low-cost IC which is capable of providing continuous bi-direction direct current to the motor. Output of the motor driver is a complete pole drive circuit, with a transistor sink and a pseudo-source [11].

**DC Motor** - A Direct Current (DC) motor is a motor that converts direct current into mechanical energy. Motors turn electricity into motion by the application of electromagnetic induction. The motor



features a permanent stationary magnet and a turning coil of wire which is capable of rotating thereby providing motion.

**Push Button** - Push Button is an elementary controller which is capable of controlling a certain aspect of a machine by closing the electrical circuit. These are generally metal or thermoplastic switches that are used to provide easy access to the user. When it is in ON mode, the spring inside the electrical circuit makes contact with two wires, resulting in the circuit to be complete allowing electricity to flow. When it is in OFF mode, the spring refrains from touching the wires, so the contact is interrupted and circuit is incomplete hence, current won't flow. A Normally Closed (NC) push button, as the name implies the circuit is closed generally i.e., current flows through the circuit. When the switch is pressed, the circuit becomes open i.e., current stops flowing through the circuit [12]. A Normally Open (NO) push button, as the name implies the circuit is open generally i.e., no current flows through the circuit. When the switch is pressed, the circuit becomes closed i.e., current starts flowing through the circuit.

#### 4. Software Specification

**Arduino IDE** - The Arduino Integrated Development Environment (IDE) is a software which can be used for writing code and uploading to a working environment. This software is compatible with any Arduino board, and it is a cross-platform application for Windows, macOS and Linux. The biggest advantage that Arduino IDE has over its other counterparts is the fact it's all-in-one software. It can work as an on-site application and also function as an editor and consists of various board module options, and integrated Arduino libraries which make the software user friendly and easy to adapt [13]. It also makes it easy for novice coders to write code and upload to Arduino compatible boards with a simple process. It can also be done with the help of third-party cores, other vendor development boards.

**Blynk App** - Blynk is a cross-platform application for iOS and Android platform to execute Arduino, Raspberry Pi, and similar ones via the Internet. It is a digital dashboard capable of building a graphic interface for a project by simply selecting and dropping widgets. The application is user friendly and easy to adapt for users switching for other platforms. It takes minimum time to set up everything in the project and start working and seeing results. Blynk application is not limited to some specific board or shield, one can choose any supporting hardware to get started and helps the users to get accustomed to the very concept of Internet of Things (IOT) [14,15].

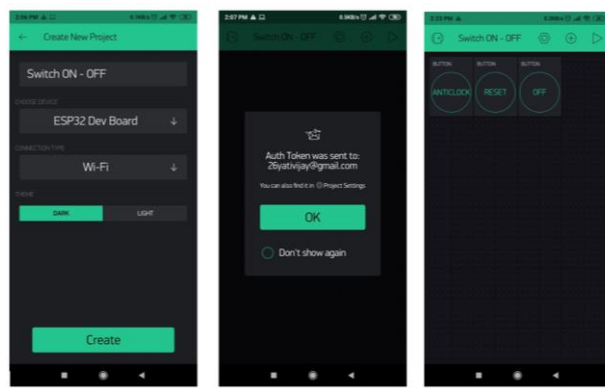
#### 5. Implementation and Analysis

Our design implements a soft robotics approach to replicate human muscle. The 3d printed Exoskeletal structure helps in guiding the movement of the finger when contracted and released. The 3d Printed material is made with TPU with a 100% infill which results in stiff and flexible areas. The portion where there is a joint in hand has a flexible TPU and the rigid portion of the hand has a more rigid TPU structure. This helps us by accurately defining the flexible parts and the rigid parts hence giving a more refined movement. The 3d printed exoskeleton is lined with metal strings which help in contracting and releasing the exoskeleton. The string is actuated by a motor which rolls the string and hence giving us the rolling motion. The strings are lined with metal tubes to prevent the strings from tangling. There is an interactive app which helps us in starting the actuation, resetting the position, and resetting the controller.

##### 5.1. System Implementation



**Figure. 6.** The image portrays the final glove prototype which is made using 3D printed TPU glove material to act as the skeletal structure after several testing runs and analysis.



**Figure. 7.** The image shows the process of controlling the glove from blynk app.

Figure 6 shows the final prototype has a 3D printed exoskeleton with metal channels to guide the movement of metal strings. An app was developed to control the movement of the gloves which helps in rotating the motor clockwise, counterclockwise, start, stop and resetting the glove. The app and the ESP32 connect wirelessly and help in remotely operating the glove.

## 6. Results and Inferences

The gloves are working seamlessly. Once the gloves are turned on, the esp32 board automatically establishes a secure connection to blynk app portal and the data taken from the gloves is continuously updated and stored in it.



**Figure. 8.** The image depicts how the user can connect to blynk app to control the gloves via app.

Figure. 8. shows the establishment of connection between esp32 and blynk app portal. Only after the connection is established will can send and view the data in blynk app portal.

```
Done uploading
Writing at 0x00000000... (96 %)
Writing at 0x00070000... (100 %)
Wrote 663376 bytes (394791 compressed) at 0x00010000 in 6.5 seconds (effective 818.0 Kbit/s)...
Hash of data verified.
Compressed 3072 bytes to 144...

Writing at 0x00000000... (100 %)
Wrote 3072 bytes (144 compressed) at 0x00000000 in 0.0 seconds (effective 877.7 Kbit/s)...
Hash of data verified.

Leaving...
Hard resetting via RTS pin...
```

**Figure. 9** The image shows the process of sending data to blynk app from the user device to execute commands.

The above figure depicts transmission and reception of data from esp32 to blynk app.



**Figure. 10.** The image shows the fully completed and working stroke rehab gloves after a particular period of usage. This gives an insight into the durability and reliability of the rehab gloves.

The above figure depicts the entire glove setup (i.e., esp32, motor driver, gloves, 3D printed exoskeleton).

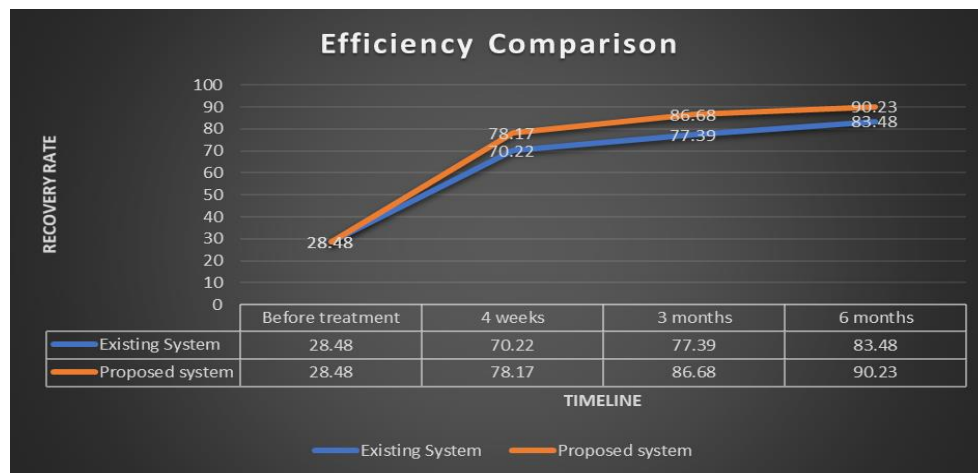
## 7. Conclusion and Future work

### 7.1. Conclusion

The stroke rehab gloves were built and implemented. The system is targeted at stroke survivors and physically disabled people. The developed prototype can be used by anyone irrespective of their hand size. The gloves increase the rate of recovery and the time taken to recover too is minimized. The preliminary test results are promising.

Comparison of recovery rate between the existing system which is currently used in hospitals and the proposed system that is discussed in this paper is depicted in figure 11. The data for the existing system was gathered from a paper titled “Six-month functional recovery of stroke patients: a multi-time-point study” [17].





**Figure. 11.** Efficiency Comparison between the existing system vs proposed system is visualised in the above graph and table formats.

From the obtained results the proposed system has 8.085% more recovery efficiency compared to the existing system. The existing system is not portable and affordable whereas, the proposed system is very compact, inexpensive, easy to carry around. Furthermore, during pandemic situation, the proposed system eliminates the need to visit the doctor. Hence, it is safer and a better alternative for the existing systems.

## 8.2. Future work

Analysis on the data collected from the glove usage can be performed. Based on the analytics it is possible to predict the exact period it will take for the patient to completely recover. Other materials can also be given a try to make the exoskeleton more durable. Implementation of GSM server can be adopted to operate in a wide range. Design and integration of an online web control panel can also be integrated.

## 8. References

- [1] Vladimir Vujovic and Mirjana Maksimovic 2015 Raspberry Pi as a Sensor Web node for home automation *Computers and Electrical Engineering* **44** 153-171
- [2] P. Jaworski, T. Edwards, J. Moore and K. Burnham 2011 Cloud computing concept for intelligent transportation systems Proc. *14th Int. IEEE Conf. Intelligent Transportation Systems Washington DC USA* vol 44 pp 391–936
- [3] Arshdeep Bhaga and Vijay Madiseti Internet of Things 1/e, *Orient Black Swan* 2017
- [4] Design and Development Approach of Smart Glove for Post Stroke Rehabilitation Nurhazlinda Fariha Mohd Nawi<sup>1</sup>, Audrey Huong Kah Ching<sup>1</sup>, Nabilah Ibrahim<sup>1</sup>, Wan Nur Hafsha Wan Kairuddin<sup>1</sup>, Nur Anida Jumadi<sup>1</sup>, Raja Mohd Aizat Raja Izaham<sup>2</sup>, Gan Hong-Seng<sup>3</sup>, Wan Mahani Hafizah Wan Mahmud<sup>1</sup> \* *International Journal of Engineering & Technology* 2018
- [5] Dhawal L. Patel<sup>1</sup>, Harshal S. Tapase<sup>2</sup>, Praful A. Landge<sup>3</sup>, Parmeshwar P. More<sup>4</sup> Prof. A. P. Bagade<sup>5</sup> 2018 *International Research Journal of Engineering and Technology (IRJET)*

- [6] Abdul Malik. M. Ali, Zulkhairi MD.Yusof, Kushairy A.K, F. Zaharah H and Azman Ismail 2015 *International Conference on BioSignal Analysis, Processing and Systems (ICBAPS)*
- [7] Ms. Pallavi Verma M.E. Scholar, Mrs. Shimi S.L. Assistant Professor, EE Dr. S. Chatterji Professor and Head 2014 *EE International Journal of Engineering Research & Technology (IJERT)*ISSN: 2278-0181www.ijert.orgIJERTV3IS110222(This work is licensed under a Creative Commons Attribution 4.0 International License.) Vol. 3 Issue 11
- [8] Mihkel Hiob 2016 Interactive glove for mobility training and rehabilitation after stroke Certec, Division of Rehabilitation Engineering Research Department of Design Sciences Faculty of Engineering LTH • Lund University • 2016 *International Journal of Engineering & Technology*
- [9] M Sivak<sup>1</sup>, D Murray, L Dick, C Mavroidis, M K Holden<sup>1</sup> 2012 Development of a low-cost VR based smart glove for rehabilitation *CDVRAT 2012 Conference*
- [10] Nur Syazani Binti Suin 2019 Glove finger Rehabilitation *International Journal of Engineering & Technology*
- [11] Smart Glove: An Assistive Device to Enhance Recovery of Hand Function During Motor Rehabilitation *Stroke Research and Treatment*, vol. 2020, Article ID 9259017, 7 pages, 2020
- [12] Seth Kwame Agyenkwa, Cosmos Yarfi, Adjoa Nkrumah Banson, Woyram Abba Kofi-Bediako, Ulric Sena Abonie, Seth Kwadjo Angmorterh and Eric Kwasi Ofori Assessing the Use of Standardized Outcome Measures for Stroke Rehabilitation among Physiotherapists in Ghana 2020 *Stroke Research and Treatment* vol. 2020 Article ID 9259017,7 pages
- [13] Alassane Dravé, Julie Marie Adeline Kyelem, Saïdou Ouedraogo, Christian Napon, and Jean Kaboré Frequency and Mortality Risk Factors of Acute Ischemic Stroke in Emergency Department in Burkina Faso 2020 *Stroke Research and Treatment* vol. 2020, Article ID 9745206, 7 pages
- [14] Francesco Aggogeri<sup>1</sup>, Tadeusz Mikolajczyk<sup>2</sup> and James O' Kane<sup>3</sup> Robotics for rehabilitation of hand movement in stroke survivors 2019 *Advance in Mechanical Engineering*
- [15] Pablo Maceira-Elvira<sup>1,2</sup>, Traian Popa<sup>1,2</sup>, Anne-Christine Schmid<sup>1,2</sup> and Friedhelm C. Hummel<sup>1,2,3\*</sup> Wearable technology in stroke rehabilitation: towards improved diagnosis and treatment of upper-limb motor impairment
- [16] Dhawal L. Patel<sup>1</sup>, Harshal S. Tapase<sup>2</sup>, Praful A. Landge<sup>3</sup>, Parmeshwar P. More<sup>4</sup>Prof. A. P. Bagade<sup>5</sup> 2018 Smart Hand Gloves for Disabled People *International Research Journal of Engineering and Technology (IRJET)*
- [17] Lee KB, Lim SH, Kim KH, et al. 2015 Six-month functional recovery of stroke patients: a multi-time-point study. *Int J Rehabil Res*; **38**:173–80.