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A SURVEY OF SENSORIZED GLOVE FOR REHABILITATION PURPOSE

P D NANDNIKAR[1], M S NAGMODE[2], M N ANNADATE[3]
[1]E&TC, Savitribai Phule Pune University, Kothrud, Pune, INDIA
[2,3]E&TC, MITCOE, Kothrud, Pune, INDIA
[1]*priti.nandnikar@gmail.com*, [2]*manoj.nagmode@mitcoe.edu.in*, [3]*mrunal.annadate@mitcoe.edu.in*

ABSTRACT

In our everyday life our connection to the world is through our hands. We perform most of the task with them. In many engineering applications which are ranging from the analysis of gestures to the biomedical sciences the hand movement data attainment is used. For acquiring hand movement data the Glove-based systems represent one of the most important efforts. For over three decades, they are attracting the interest of researchers from progressively miscellaneous arenas. As researchers have taken interest in hand movement data attainment there is a scientific and technological progress in the development of medical devices. The diseased person (trauma, stroke like diseases) that means the person who requires hand exercise, robotic systems can be an aid for rapid patient recovery. This paper emphasise on the study of a system for quantifying the finger position of hand with the aim of giving cosiness to do the exercise and to the rehabilitation treatment. These systems involve a glove where sensors are riding suitably arranged and connected to an electronic conditioning circuit. The information regarding the position is then sent to a remote system that is computer using the wireless communication. In this paper we will surveys such glove systems and their applications. It provides an evolution of the glove technology.

Keywords: *Hand motion, rehabilitation, sensorized glove, glove technologies, Piezo-resistive.*

[1] INTRODUCTION

In our everyday life we use hands for interacting with and handling our environment in a huge number of tasks. So to develop technologies for studying interaction and manipulation some research effort has been devoted. The progress of the most popular devices for hand movement attainment, glove-based systems, started about 30 years ago and continues to involve a growing number of researchers. So this hand movement data attainment is used in many engineering applications as shown in below Fig.1.

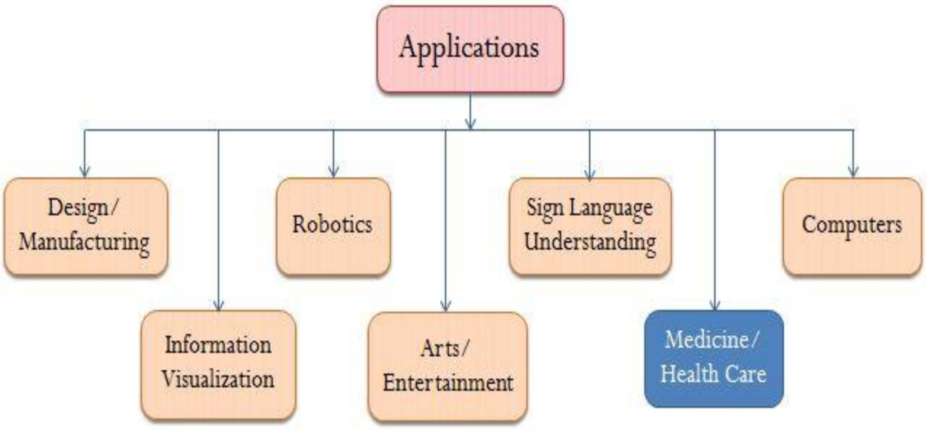

Fig.1. Applications of glove-based system.

From survey we can see that every year, millions of people worldwide experience problems because of traumatic brain injuries, degenerative diseases, and articulation traumas. Stroke, among the different types of brain trauma, is the major cause of disability in adulthood and the rate of this trauma is expanding every decade, so there is a growing need of rehabilitation treatment. The purpose of rehabilitation is to restore patients' physical, sensory and mental abilities affected by injuries, diseases and disorders, and to support the patient to recompense the deficit that is not medically treatable. In addition to surgery, patients with stroke and muscular disorders need rehabilitation to regain mobility.
Recent substantiation has revealed that intensive and repetitive practice is effective in the recovery of functional motor skills. The influence of cognitive, musculoskeletal, and perceptive disorders on motor activity upsurges with age. Under these conditions, the increasing request for rehabilitation treatments would raise public spending significantly. The acceptance of robotic systems would lessen the healing time and, in the future,

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would let the tele-rehabilitation management, giving the patient the facility to perform the exercises at home, thus dropping costs and worries of transport to a hospital. Regarding the specific rehabilitation of the hand, the robotic system needs a sensorized unit, like a glove with suitable sensors. Because of its lightness and movability, a sensorized glove permits to measure the position of each finger, but simultaneously, to perform the required movement.
For describing hand motions can use the hand joints and the degrees of freedom (DoFs). The distal interphalangeal (DIP) and proximal interphalangeal (PIP) joints of each finger have 1 DoF each (flexion/extension). The metacarpophalangeal (MCP) joints have 2 DoFs (flexion/extension and abduction/adduction). The third DoF of the trapeziometacarpal (TMCP) joint allows the thumb to rotate longitudinally. A glove equipped with one sensor per DoF may appear to be the most obvious design choice. A number of gloves with different designs have been proposed over the years and it will become clearer in the following section 3.

2. APPLICATION AREAS OF GLOVE

As told above there are seven areas of application for sensorized glove-based system. These areas are divided into two parts, which describe classical and recent applications. The first part of application areas describes applications in design and manufacturing, information visualization, robotics, art and entertainment, and sign language understanding. Since early research on glove systems these applications were explored. Here we will focus on the work from the mid-1990s onwards and for this earlier work refer [1]. The second part of these application areas describes applications in medicine and health care and in portable and wearable computers. From last few decades researcher started looking at glove systems and started to develop new technology. These seven applications are explained below one by one.

2.1 Classical Applications

2.1.1 Design and Manufacturing.

In this, glove-based systems are used to interact with computer-generated environments (typically virtual reality). The user, who can be located either on site or remotely over the internet, can visualize environments or artifacts that are being designed before their actual construction or manufacturing using a computer screen or a head mounted display eliminating the need for expensive mockups [2]. Keyboards and mice are traditional interfaces and compared to them the glove-based systems permit a more natural interaction with the environment; for example, via gestures the user can grasp virtual objects or issue commands. Typical commands contain the flying gesture or pinching gesture. Flying gesture means pointing with the index finger changes the users' viewpoint through the virtual world as if they were flying through that space [3]. Pinching gesture means pinching between the fingers and thumb selects an option from a menu [4].

2.1.2 Information Visualization.

To create visual representations to aid in the understanding of data computer graphics is often used. Glove-based systems can possibly improve the genuineness of the users' interaction with the data that means potentially augmenting the success of traditional data visualization techniques [5]. In the late 1980s NASA showed the feasibility of this concept with the virtual wind tunnel. In this users could visualize a simulated airflow around an aircraft. To grab onto one or more streamlines of the fluid flow they have used a Data Glove. Using this Data Glove they could move streamlines of fluid flow and observe the changes in the flow, which were calculated and visualized by supercomputers in real time [6].

2.1.3 Robotics.

To make robot programming more natural and easier a Glove-based system is used particularly when method is based on teleoperation or automatic programming. This is predominantly true for multi-DoF systems that need the control of a large number of joints, which is problematic to achieve with standard control techniques. In automatic programming the robot learns its behavior spontaneously. To explain this studies an example of observing a demonstration performed by a human [7].

2.1.4 Art and Entertainment.

There is an attraction between glove-based systems and the entertainment industry. In entertainment industry gloves have been used for video games and animation of computer-generated characters [8] along with movie productions [9]. In musical performance a glove devices have also been used typically to control acoustic parameters [10]. In this framework gloves allow simultaneous control of many DoFs and also give the musician the freedom to move expressively, transmitting that expression to music.

2.1.5 Sign Language Understanding.

Many projects used glove-based systems for automatic understanding of gestural languages used by the deaf community after the innovative project of Grimes with the Digital Entry Data Glove [1]. But the systems developed in these projects contrasted in characteristics such as i) number of classifiable signs, which could range from a few dozen to several thousand ii) types of signs, which could be either static or dynamic iii) percentage of signs correctly classified. In these all systems the modest systems were limited to understanding

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of finger spelling or manual alphabets that means a series of hand and finger static configurations that indicate letters. Takahashi and Kishino [11] and Murakami and Taguchi [12] have used a Data Glove for recognition of the Japanese alphabets. Mehdi and Khan used a Data Glove [13] for recognition of the American alphabet, whereas Hernandez-Rebollar used an AcceleGlove [14]. The extra complex systems directed at understanding sign languages which is a series of dynamic hand and finger configurations which show words and grammatical structures.

2.2 Recent Applications

2.2.1 Medicine and Health Care.

Early research was narrowed to automatic sign language recognition and now current research is exploring the appropriateness of these systems for a bigger range of applications such as Motor Rehabilitation [15], Analysis of Motor Performance [16], [17], Ergonomics [18], Medical Education and Training [19] etc.

2.2.2 Wearable and Portable Computers.

The most recent developments in glove-based systems applications are the introduction of gloves as controllers for consumer electronics, as text entry and pointing devices for portable and wearable computers. For more portable peripherals computer makers first chased the idea of making traditional peripherals smaller; but such solutions had a major limitation: peripherals cannot be diminished beyond a certain limit, as they need to be big enough to be seen and easily operated upon with our hands. Therefore a new method based on substituting traditional peripherals with wearable ones was then pursued. So glove-based systems appeared like the flawless solution: postures could be seized and turned into keystrokes or commands, in that way eliminating the need for a physical traditional keyboard. From last few decades some projects attempted to use Data Glove-like devices [20]. Now many looked at chord gloves that are gloves that detect data patterns corresponding to hand configurations. Rosenberg and Slater [21] designed the Chording Glove which was equipped with five sensors located at the tips of each finger that detected when a finger was pressed against something. In this paper we will see different glove technologies for medical and health care application area. These different glove technologies are described in below section 3.

3. GLOVE TECHNOLOGIES

Several commercial companies have developed sophisticated and general-purpose systems. Some of them are summarized in this paper. The first glove, Sayre Glove was developed in 1977 by Thomas de Fanti and Daniel Sandin. They have used flexible tubes with a light source at one end and a photocell at the other, which were mounted along each finger of the glove [1]. After this the MIT-LED glove was developed at the MIT Media Laboratory in the early 1980s which is shown in below Fig.2. It was as part of a camera-based LED system to track body and limb position for real-time computer graphics animation and for this used LEDs studded on a cloth [1].

Fig.2. MIT LED glove [33].

Gary Grimes designed the Digital Entry Data Glove and patented it in 1983. The glove is shown in Fig.3. It used different sensors mounted on a cloth like touch or proximity sensors, knuckle-bend sensors, tilt sensors, inertial sensors [22]. The purpose of this glove was creating an alphanumeric character that means it generates information regarding alpha-numeric data and control characters by moving hand to form various positions in sequence. For different character or other data each such position is unique that can be transmitted by the glove to a data receiving device.

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Fig.3. Grimes digital Data entry glove [33].

Thomas Zimmerman and others developed a DataGlove in 1987; it is shown in Fig.4. This was a large improvement over the camera-based hand-monitoring techniques since it did not rely on line-of-sight observation. It consists of a light weight Lycra glove which was fitted with specially treated optical fibres along the backs of the fingers [23].

Fig.4. Zimmerman VPL data glove [33].

In 1989 Mattel Toy Company manufactured a low-cost control device, the Power Glove, for the Nintendo video games and became well known among video games players. It is shown in Fig.5. They have used resistive ink printed on flexible plastic bends which follows the movements of each finger to measure the overall flexion of the thumb, index, middle, and ring finger [24].

Fig.5. Nintendo power glove [33].

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The Super Glove [25] was developed by Nissho Electronics in 1995. It consists of 10 to 16 sensors. Also used resistive ink printed on boards sewn on the glove cloth. The P5 Glove, an updated version of the Power Glove, was commercialized by Essential Reality, LLC, in 2002 [26]; it is shown in Fig. 6. This glove is a 3D input device which captures the finger-bending and relative hand-position which enables the interaction with 3D environments. It becomes the interface to game console or a PC since the Essential Reality P5 glove fits perfectly over the hand. This senses all its movements in three dimensions.

Fig.6. The P5 Glove [34].

The data gloves then improved using the force sensors. Which are widely used in many applications such as virtual reality applications, robotics, telecheric applications, and biomechanics. This new data glove will have all information of finger position as well as the force the fingers apply on an object. The force sensor was made of a steel plate substrate where the commercial strain gauges are attached [27]. James Kramer at the Virtual Exploration Laboratory at Stanford University developed a Cyber Glove in 1992 which shown in below Fig. 7. It was developed to translate American Sign Language into spoken English [28]. It consists of 18 or 22 Piezo-resistive sensors. In this, a small electronics box converts the analog signals into a digital stream and that can be read by a computers standard serial port. For this glove calibration is needed to make glove measurements insensitive to differences in users' hands, finger length, and thickness, and it is accomplished through the VirtualHand calibration software. This software also includes several packages for manipulation of computer-aided designs (CADs) and character animation [29]. A wireless version of the CyberGlove, known as CyberGlove II, was also commercialized in 2005.

Fig.7. CyberGlove [33].

The Piezo-resistive effect means a change in the electrical resistivity of a semiconductor or metal when mechanical strain is applied [30]. The Piezo-resistive sensors change resistance when pressure is applied. This sensor is made up of semiconductor material like Silicon with Boron as trace impurity [31]. Whenever this sensor is bended it will give an output in the form of resistance. The output resistance depend upon the radius of

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curvature of sensors. When sensor is flat it gives a 25KOhms resistance and when sensor is bended it gives a resistance in the range of 45K to 125 KOhms. The calibration of the sensors on the CyberGlove can also be done using ANNs. There are three main reasons for choosing ANNs for the calibration of the CyberGlove. First reason is that, ANNs have been successfully applied for the calibrations of many systems in many different engineering fields. Second, there are some direct and consistent relationships between the correspondent-sensors and the human-hands segment size and third is once the final NNs are found for each sensor, the generation of calibration data for any new subject is simple and fast [32]. The first glove-based systems were designed in the 1970s, and later then a number of different glove-based designs have been proposed. The below Table 1 give a list of glove-based systems that has been appeared in the marketplace or in the literature over the past three decades.

Table 1. List of Glove-Based System.

Device	**Technology**	**Sensors**	**Applications**
MIT LED Glove (MIT)	LED	N/A	Entertainment
Data Glove (MIT, VPL Inc.)	Fiber Optic	5-15 Flex	Sign language understanding, Medical and Rehabilitation
Power Glove (Mattel Intellivision)	Piezo-resistive	4 Flex	Sign language understanding, Entertainment
P5 Glove (Essential Reality Inc.)	Piezo-resistive	5 Flex	Entertainment, Virtual Reality
Cyber Glove (Stanford University)	Piezo-resistive	18, 22 Flex	Entertainment, Medical and Rehabilitation, 3D Modeling
Pinch Glove (University of Central Florida)	Electrical contacts	7	Virtual Reality
Human Glove (Humanware Srl)	Hall-effect sensors	20, 22 Flex	Analysis of motor performance
3D Imaging Data Glove (University of Newcastle)	3D electro-magnetic sensors	11	Medical and Rehabilitation
Fingernail Glove (MIT)	Electro-optical	6 LED/ 8 Photodiodes per sensor	Robot control and tele-operation
Didji Glove (MIT)	Capacitive sensors	10 Flex	Entertainment
Strin Glove	Magnetic	24 Flex	Sign language understanding

4. CONCLUSIONS

This paper made clear that the breadth of research in glove devices has expanded and grown over the past three decades. Since this area of research remains very active it is evident that technological advances in computing, sensor devices, materials and processing/classification techniques will make the next generation of glove devices cheaper, more powerful and versatile.

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