Chapter 2
Historical Development of Hand Gesture Recognition

The history of hand gesture recognition for computer control started with the invention of glove-based control interfaces. Researchers realized that gestures inspired by sign language can be used to offer simple commands for a computer interface. This gradually evolved with the development of much accurate accelerometers, infrared cameras and even fibreoptic bend-sensors (optical goniometers). Some of those developments in glove based systems eventually offered the ability to realize computer vision based recognition without any sensors attached to the glove. These are the coloured gloves or gloves that offer unique colours for finger tracking ability that would be discussed here on computer vision based gesture recognition. Over past 25 years, this evolution has resulted in many successful products that offer total wireless connection with least resistance to the wearer and will be discussed in Chap. 7. This chapter discusses the chronological order of some fundamental approaches that significantly contributed to the expansion of the knowledge of hand gesture recognition.

2.1 History of Data Glove

This book is never going to be complete without the historical development of hand gesture recognition based on computer vision without giving the due recognition for the evolution of hand gesture system based on data glove. Data glove in essence is a wired interface with certain tactile or other sensory units that were attached to the fingers or joints of the glove, worn by the user. The tactile switches, optical goniometer or resistance sensors which measure the bending of different joints offered crude measurements as to determine a hand was open or closed and some finger joints were straight or bent. These results were mapped to unique gestures and were interpreted by a computer. The advantage of such a simple device was that there was no requirement for any kind of pre-processing. With very limited processing power on computer back in 1990s, these systems showed great promise despite the limited manoeuvrability due to tethers that connected the glove to the computer. Figure 2.1

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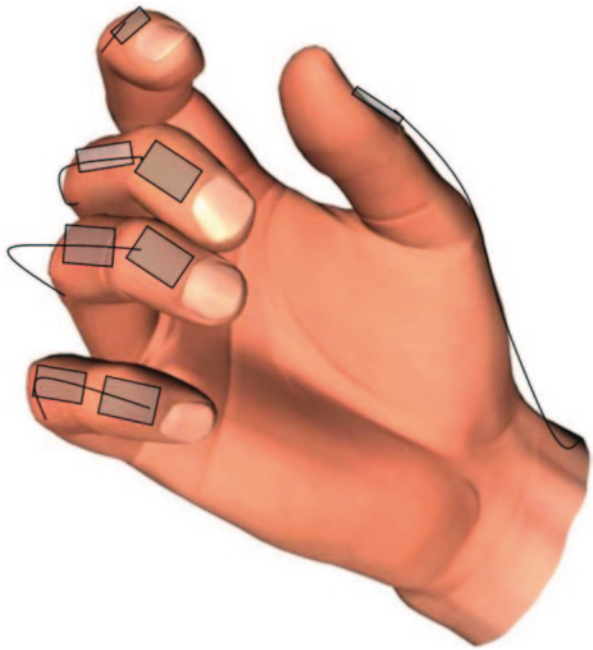

Fig. 2.1 Artistic impression of a sensor glove that places sensors on finger joints

shows an artistic impression of a data-glove or a sensor glove that strategically places variety of sensors to monitor the flexing of fingers to form different gestures.

Today, there exists gloves that are wireless and easy to wear unlike the ones we had 20 years ago. The following sections of this chapter will discuss the history of some of these devices and their performance scores in interpreting hand gestures.

By looking at the evolution of data gloves, there were two distinct categories emerged over the years.

1. Active data glove—consisted of few or variety of sensors on the glove to measure flexing of joints or acceleration and had a communication path to the host device using wired or wireless technology. These gloves are known to restrain the user of artistic ability.
2. Passive data glove—consisted only of markers or colours for finger detection by an external device such as a camera. The glove did not have any sensors onboard.

The first glove prototypes to emerge included the Sayre Glove, the Massachusetts Institute of Technology (MIT)-LED glove and the Digital Entry Data Glove [1]. The Sayre Glove which was developed in 1977 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. Bending fingers resulted in decreasing the amount of light passed between the LED and the photodiode. The system thus detected the amount of finger bending using the voltage measured by a photodiode [2].

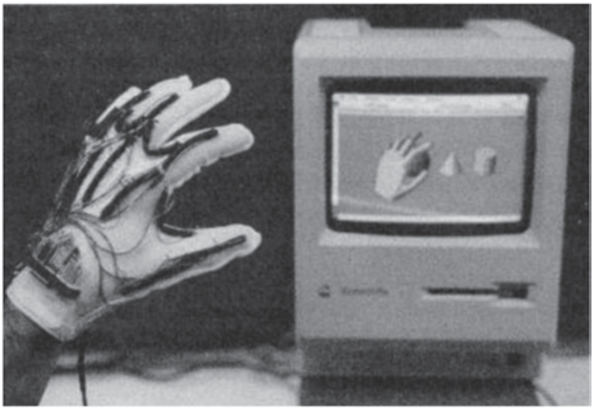

Fig. 2.2 The Z^{TM}Glove developed by Zimmerman [2]

The first glove to use multiple sensors was offered by the 'Digital Entry Data Glove' which was developed by Gary Grimes in 1983. It used different sensors mounted on a cloth. It consisted of touch or proximity sensors for determining whether the user's thumb was touching another part of the hand or fingers and four "knuckle-bend sensors" for measuring flexion of the joints in the thumb, index, and little finger. It also had two tilt sensors for measuring the tilt of the hand in the horizontal plane and two inertial sensors for measuring the twisting of the forearm and the flexing of the wrist [1]. This glove was intended for creating "alphanumeric characters" from hand positions. Hand gestures were recognized using hard-wired circuitry, which mapped 80 unique combinations of sensor readings to a subset of the 96 printable ASCII characters.

These gloves had limited accuracy and were tethered to computers using cumbersome wiring. They were meant for very specific applications and as proof of concept. They never received any attention beyond experimental tools and were never commercialized.

During 1980s, the sensor technology developed rapidly due partly to cold war fears and the natural expansion of industry in many European countries. These sensor technology paved way for rapid developments in computer technology and peripherals. Many leading research teams around the world started new computer peripherals with a market orientation using then recently developed new technical knowledge. The first commercially available Data Glove appeared in 1987 [1]. This was an improved version of the first DataGlove developed by Zimmerman in 1982 which is shown in Fig. 2.2 [3]. The technology was similar to the one used in Sayre Glove in 1977. However, the 1987 version carried fibre optics instead of light tubes and was equipped with 5–15 sensors increasing its ability to distinguish different gestures. The multiple sensors available on the DataGlove made it popular among researchers of different fields and number of similar devices was developed. Data Glove inspired development of Power Glove [4–6], which was commercialized by Mattel Intellivision as a control device for the Nintendo video game console in 1989. The Power Glove used resistive ink to measure the flexion of the finger joints

Fig. 2.3 MIT Acceleglove with its multiple sensors. [8]

[1]. There were other development such as Super Glove [4] developed Nissho Electronics in 1995 consisted of 10–16 sensors and used resistive ink printed on boards sewn on the glove cloth. An updated version of the Power Glove, the P5 Glove, was commercialized by Essential Reality, LLC, in 2002 [7].

2.2 What's Out There Today?

The following section details the state of the data glove today. A number of these are now commercially available for different types of human computer interaction (HCI). These data gloves are mainly aimed at researchers to develop sophisticated systems to make the HCI a reality.

2.2.1 MIT Data Glove

From its developments in early 1980s, MIT Data Glove has evolved dramatically offering different capabilities with different models. Currently developed under MIT spinoff company AnthroTronix, acceleGlove as shown in Fig. 2.3, is a user programmable glove that records hand and finger movements in 3D. The other models available from them include 5DT's Data Glove for virtual reality that cost between $ 1000–$ 5000. The company initially developed Data Gloves for US Defence for controlling robots. Their acceleGlove is also used in video games, sports training, or physical rehabilitation.

As shown in Fig. 2.3, an accelerometer rests just below each fingertip and on the back of the hand. The accelerometers can detect the three dimensional orientation of the fingers and palm with respect to the gravity when a gesture or any movement

Fig. 2.4 CyberGlove III for motion capture

is made. The accuracy of these measurements is within a few degrees which allow programs to distinguish slight changes in hand position. The glove has openings for finger tips which would allow the user to type or write while wearing the glove.

2.2.2 CyberGlove III

The CyberGlove III (MoCap Glove) developed by CyberGlove Systems is a device that aims to record gestures accurately for motion capturing for movie making and graphic animation industry as shown in Fig. 2.4. The streamlined industrial designs that they developed allows for rigorous physical mobility in hand motion capturing for motion movies and graphic animation industry today [9]. The device also consists of Wi-Fi for data communication with a transmission range of 30 m. The unit contains 22 sensors and can operate for 2–3 h with the rechargeable battery onboard. The SD memory card offers motion recording option for motion capture animation purposes but the device is not aimed at computer or any other peripheral control.

2.2.3 CyberGlove II

CyberGlove has been developed to deliver many data inputs due to different flexing of joints motion from other areas of the hand. The 18-sensor data glove features two bend sensors on each finger, four abduction sensors, and sensors measuring thumb crossover, palm arch, wrist flexion, and wrist abduction. Different version of this glove that contains 22-sensors has three flexion sensors per finger, four abduction sensors, a palm-arch sensor, and sensors to measure wrist flexion and abduction. Each sensor is extremely thin and flexible making the sensors almost undetectable in the lightweight elastic glove. As shown in Fig. 2.5, one version of the glove offers open finger tips that would allow a user to type, write and grasp objects easily. The CyberGlove motion capture system has been used in many applications including digital prototype evaluation, virtual reality biomechanics, and animation.

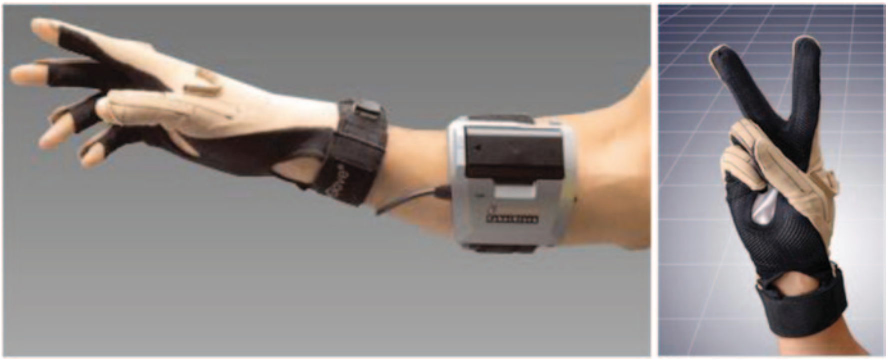

Fig. 2.5 CyberGlove II [10]

Fig. 2.6 5DT Motion Capture Glove and Sensor Glove Ultra. (Courtesy of [10]). (*left*) Current version, (*right*) early version

2.2.4 Fifth Dimension Sensor Glove Ultra

The 5DT Data Glove Ultra is another glove based gesture recognition device with very high precision flexor resolution. With its arrays of sensors, it provides 10-bit flexor resolution which is aimed at highly natural motion capture for movie industry [11]. The Sensor Glove Ultra is known to produce high data quality with low cross-correlation between different sensor metrics for realtime animations using Bluetooth data transfer. Figure 2.6 shows early and current version of Sensor Glove by Fifth Dimension (5D).

2.2.5 X-IST Data Glove

X-IST Data Glove from Inition [12], provides a motion capture solution with finger tip touch sensors that can be used for music related application. Since the unit is

Fig. 2.7 X-IST Data Glove. [12]

Fig. 2.8 P5 Glove—a cheaper alternative. [13]

wired to an usb interface, the user is not completely at rest. Each finger joint flex is measured along with the tilt of the hand. A cable connects user to the computer peripheral as shown in Fig. 2.7.

2.2.6 P5 Glove

P5 Glove has been developed by MindFlux as a way to provide cheaper alternative to many expensive wired gloves available in the market that can be used for gaming [13]. The P5, as shown in Fig. 2.8, incorporates a bend sensor and remote tracking technologies, which provides users intuitive interaction with 3D and virtual

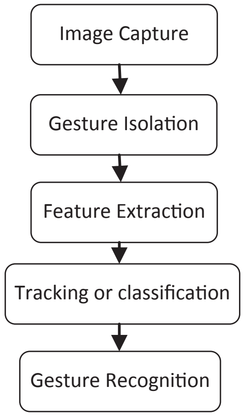

Fig. 2.9 Typical computer vision based gesture recognition approach

environments, such as games, websites and educational software. This is one of the very few technologies currently reaching the user as a means for controlling machines using peripherals other than, mouse, joystick or keyboard.

Today these gloves are no longer limited for use in computer human interactions as was illustrated above. Some of them are indeed for interacting with a computer for gaming and other natural like communication. Yet others are for 3D movie animation and some are for healthcare applications such as monitoring of vital signs to physiotherapy on injured or healing hands and fingers.

2.3 Vision Based Hand Gesture Recognition

Using cameras to recognize hand gestures started very early along with the development of the first wearable data gloves. There were many hurdles at that time in interpreting camera based gestures. Coupled with very low computing power available only on main frame computers, cameras offered very poor resolution along with color inconsistency. The theoretical developments that lead to identifying skin segmentation were in its infancy and were not widely recognized for its good performance that we see today. Despite these hurdles, the first computer vision gesture recognition system was reported in 1980s. Figure 2.9 shows a flow diagram of a typical gesture recognition strategy.

2.3.1 Hand Gesture Recognition Using Colored Gloves

The MIT-LED glove was developed at the MIT Media Laboratory in the early 1980s as part of a camera-based LED system to track body and limb position for real-time computer graphics animation [14]. A camera sitting in front of the user could capture number of LEDs as they were studded on the glove. This resulted in

Fig. 2.10 Gesture tracking using coloured finger tips of the glove. (Courtesy of Davies et al. [15])

different illumination patterns for different gestures that could be interpreted by a computer. However, the performance was poor due to occlusions and the variations of any gesture performed by different users.

One of the first instances of gesture recognition using a glove with finger tip markers was reported by Davies et al. [15]. They used colored markers on fingertips as shown in Fig. 2.10, and a gray scale camera to track the finger tip movement and their relative organization to determine seven hand gestures. They managed to realize their system on image sampling speed of only 4 Hz on a SPARC-1 computer without any specialized hardware. Given the state of image capturing and computer processing power available in 1994, the system demonstrated the capability of computer vision approach as a viable contender against wired glove techniques for gesture recognition.

In 1996 Iwai et al. [16] proposed a colored glove technique in which 10 finger regions were identified. They used multiple colors to designate different parts of the finger and sections of the palm in order to avoid the occlusion problem many computer vision approaches suffered. In the occlusion problem, certain parts of the hand or fingers are covered by occlusion and the camera is unable to interpret the gesture accurately. When different color regions denoted different sections of the hand (fingers, palm), the system could rely on the color and the boundary to make informed decisions. They used a decision tree method to automatically recognize limited number of gestures.

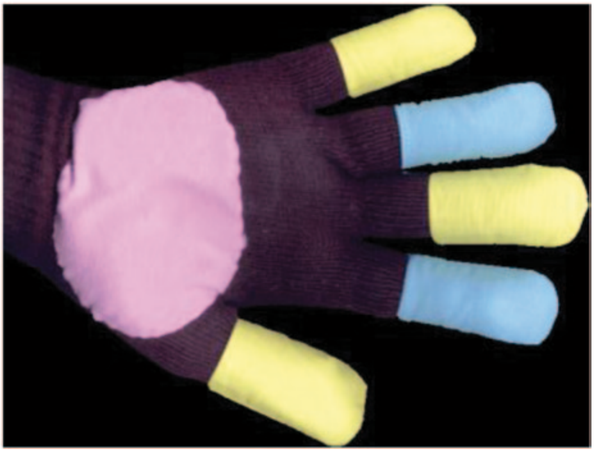

Fig. 2.11 A simple colored glove developed by Lamberti et al. [17]

Fig. 2.12 A colored glove system for virtual reality applications. (Courtesy of [18])

In recent years, more and more research was concentrated on vision based hand gesture recognition. Compared to non-vision based recognition (data glove or electro-magnetic waves etc.), vision based recognition are more natural and comfortable [17], as it does not constrain the flexibility of hand movements. Based on the data glove and electromagnetic waves, a coloured glove has been developed Lamberti et al. [17] which is easy to wear without constraining the user. As shown if Fig. 2.11, the colored glove contains separate color to track the palm and fingers are marked with alternating colors. The aim of this approach has been to develop a very low cost approach against the dataglove with much more flexibility and very low computation requirements so that disabled users can make use of the technology in a classroom environment.

Articulated hand-tracking systems have been widely used in virtual reality but are rarely deployed in consumer applications due to their price and complexity. MIT researchers, R. Wang and J. Popovic recently developed a simple and inexpensive for 3D articulated user-input using the hands [18]. Their approach, as shown in Fig. 2.12, uses a single camera to track a hand, wearing an ordinary cloth glove that is imprinted with a custom pattern. The pattern is designed to simplify the pose estimation problem, allowing them to employ a nearest-neighbor approach to track hands in an interactive manner.

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