ISSN: 0067-2904

A Review on Vision Based Real Time Fingertip Detection Approaches

Ritty Jacob[1]*, N. Sugitha[2]
[1] *Computer Science & Engineering Department, Noorul Islam Centre for Higher Education, Kumaracoil, India*
[2] *Electronics & Engineering Department, Sree Krishna College of Technology, Coimbatore, India*

Received: 11/11/2021 Accepted: 13/7/2022 Published: 30/6/2023

Abstract

Computer vision is an emerging area with a huge number of applications. Identification of fingertip is one of the major parts in those areas. Augmented reality and virtual reality are the most recent technological advancements that use fingertip identification. The interaction between computer and human can be performed easily by this technique. Virtual reality, robotics, smart gaming are the main application domains of this fingertip detection techniques. Gesture recognition is one of the most fascinating fields of fingertip detection. Gestures provide an easy and simple way of communication between computer and human. This review article thoroughly examines different studies done in the field of fingertip identification. A comparison study is also included based on various fingertip detection methods and measures. Based on this study some important observations and difficulties in the fingertip detection fields are identified. This study helps for effectively utilizing the features of fingertip recognition in a wide range of applications from person identification to intelligent home. A correlation chart of various experts is an additional result mentioned in this paper.

Keywords: Fingertip identification, Sensor, Hand gesture, Hand region segmentation, Marker.

1. Introduction

Human Computer Interaction (HCI) is a propelling study field having bunches of chances. HCI frameworks are essentially intended to use the communication among clients and PCs [1]. These communications are conceivable by the assistance of certain components like mouse, Visual Display Unit (VDU), webcam or by using different methods of direct contact way [2]. There are bunches of headways and exploration findings are made in the field of HCI. Some examples are Augmented Reality (AR) and Virtual Reality (VR) [3] [4]. Various HCI application fields are Hand Gesture Recognition (HGR), Object Tracking, and Vision Based Fingertip Tracking [5] [6] [7]. HCI procedures can be categorized into two types: conventional and built-in strategies. Among that, built-in methods are considered as the most adaptable and productive methods for communication. Furthermore, these conventional methods are easier to understand compared with the built-in ones [8].

As the HCI technologies grow, the quantity of vision-based applications is expanded in a colossal manner. Because of these technological boom, yet there exists a numerous difficulties

* Email: ritty@vjcet.org

ought to be tended to it. Fingers serve a significant job in the field of communication, and so the role of fingertip location is also very significant in most of the HCI based applications. The most extricated and comparable solid and basic shapes are fingers as well as fingertips [9]. This comparison can be done on the human hand. Fingertip is a fundamental and significant component of human hand. The fingertip localization is one of the proficient and simple approaches for distinguishing and recognizing the fingers. This recognition plays a significant job in those applications that does not require touch. These factors are the main motivational force behind this research article. The application areas of fingertip detection includes robotics, human gesture based communication framework, automated control, etc. The first and the most significant advance of any location framework are to gather or distinguish the important information identified with that application. For fingertip identification framework additionally, various methods are there to gather significant subtleties. Numerous highlights and strategies were produced for distinguishing and following fingertip from visual data. The main objective of this paper is to analyse the different fingertip identification methods that are popularly used in computer vision area [10].

One of the most necessary phases of almost all applications in HCI frameworks is fingertip tracking. The major step for fingertip tracking is to localize the fingertips. The main attribute of human hand is considered as fingers. So, this procedure is implemented with more attention and consideration because it is a significant undertaking. Because of this highlight, several scopes of uses in the areas of Gesture Recognition systems, Gaming controls, Mouse control, are successfully executed. Fingertip is a major well-known attributes in settling the problems associated with human hand recognition, for example, sign language application and gesture identification systems [11].

The fingertip detection methods can be carried out as a bi-venture measure. The initial significant stage is the hand region separation [12]. After that, fingertip identification is carried out. During the prior periods fingertip identification strategies requires some external gadgets or markers all together recognize hand or fingers from the external backgrounds. These gadgets really behave like auxiliary devices [13]. These auxiliary device based methods were not adequate for large scope of recognition. Moreover, the major drawback with these marker devices is the huge cost. Because of the on-going research works in this field, various techniques developed instead of marker devices. Other image processing techniques or key devices can adequately supplant these marker gadgets [14]. However, the proficiency of the detection methods relies on the background lightening states. Second strong fingertip identification strategy follows sensor utilization. It is carried out by the assistance of information gloves or sensors like camera with optical techniques. In this case, the fingertip recognition is not affected by the background lighting conditions. Nevertheless, this strategy is very expensive and is identified as not much convenient. Now the fingertip discovery process uses some modern cameras, for example Microsoft Kinect. Nevertheless, this gadget is additionally extravagant. Some important objectives of this research article are, [14]

•Identify the practical difficulties in the fingertip detection techniques.

•Analyses the performance of different fingertip detection techniques.

This paper really performs a survey on some fingertip discovery procedures. A brief analysis on few recognition systems is also added. It additionally offers a short investigation and outline of different fingertip detection strategies.

2. Related Works

Fingertip identification is a main phase associated with any Human Computer Interaction systems. There are two phases in this detection operation: segmentation and fingertip detection. The overall fingertip detection process is described in Figure 1.

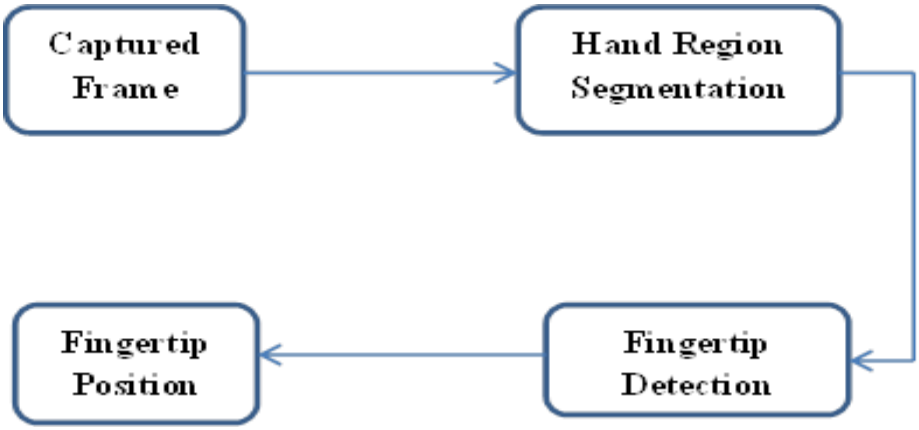

Figure 1: Overall framework of fingertip detection [14]

This framework initiates the operation by capturing the image frames. Afterwards the hand portion is separated out from that captured frame. Then from the segmented hand portion, the fingertip is detected and is localized using localization algorithms. Different techniques like marker based, other auxiliary device based, and some other image processing techniques are currently used for effective fingertip detection and localization. The following sections represent such techniques used for fingertip detection.

2.1 Detection using Markers

Before the technological revolution, fingertip recognition had not followed any high level methods due to the unavailability of technical aspects. The identification process of the finger identification systems of that era mainly used markers. In these systems, markers are used to paint the regions of fingertips. At the next phase, the recorded video of the image is analyzed, and an identification of the relating fingertips can be situated from the captured video. However, the fingertip detection strategy used here is not a popular technique. In this technique, only an analysis is performed on the colors by the markers. This system will not consider any data with respect to the shape or geometry or color of the hand. Because of these reasons, this is an indirect method. So, this system can be considered as an indirect method of fingertip identification. After all, it is a satisfactory technique in view of its ease of execution. However, this strategy creates more inconveniences to the user as the fingers of the user should be painted for distinguishing the fingertips. Because of these reasons, this technique is not a normalized or well-known strategy for fingertip discovery [15].

2.2 Detection using Particular Devices

Data Gloves are replaced in place of extraordinary marking techniques to beat burdens brought about by these techniques [16]. Data glove is a type of wearable supplies, used to gather valuable data for distinguishing precise fingertips. Another special device is information glove. It is recognized like an info gadget. It has some sensors to catch and check the movements of hand region. Then that recognized data is changed in the form of other helpful information that are helpful in applications such as virtual reality and robotics. Hand gloves are utilized

depending upon the type of applications [17]. Texture, shading, monochromatic and virtual gloves are examples of some normally utilized gloves as in Figure 2 [18] [19].

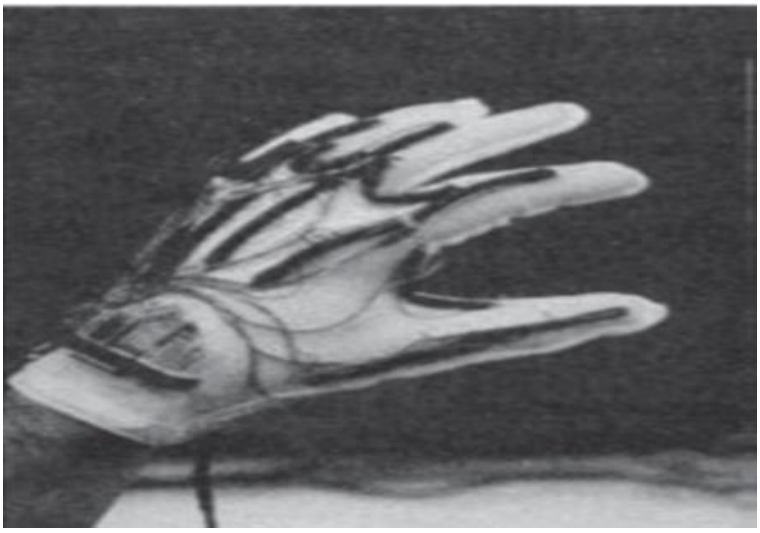

Figure 2: Sample Shading Glove used in fingertip detection [18]

Figure 2 shows a sample wearable shading glove that can be used for fingertip detection. As in figure a series of sensors and electronic wires are attached to these gloves to detect finger motions. This is the actual burden imposed on users by these gloves. So practical usage is difficult. This will degrade the performance of overall fingertip detection process.

2.3 Detection using Latest Technologies

Because of the quick exceptional innovative development, there are advanced methods in computer vision applications too. Fingertip detection technique can utilize it [20]. Here segmentation is performed on the input image to separate the hand area. Segmentation based on skin colour or histogram based segmentation can be used for these separation. These are some of the most recent methods. The segmentation using histogram developed some histogram by referring the entire picture elements on the picture. Next task is the formation of clusters by analyzing these histograms formed from the picture image. Video tracing may easily do by applying this strategy. Figure 3 shows skin color-based segmentation and in that, two categories of pixels like skin or not-skin type will be separated and isolated based on color. From these separated pixels, disposed of those pixels that are not skin type. Since these pixels does not have any importance in the hand identification procedure [21].

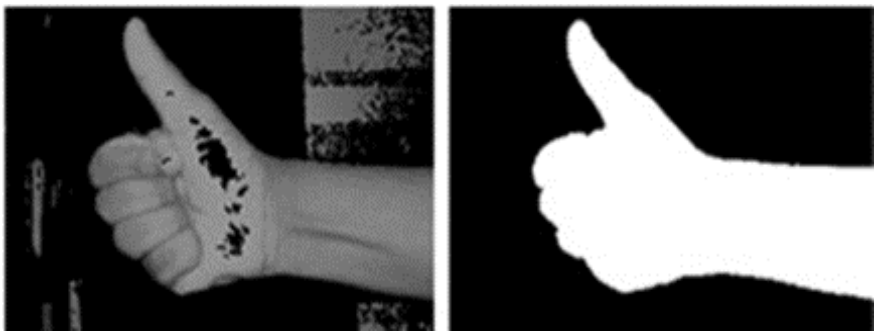

Figure 3: Skin color based segmentation [21]

There are many issues associated with the above methodologies. Output images are clear only when the background conditions are good. This is a primary issue facing these methodologies. Under bad background conditions or full obscurity, these techniques will not function.

2.4 Detection using Sensor Based Cameras

One of the latest sensor camera evolved from Microsoft Incorporation is Kinect [22]. Figure 4 shows a sample Kinect camera. The important image attributes like depth and color are easily extracted using these sensors. Vision based innovations fundamentally rely upon this sensor. It can likewise reproduce high-resolution pictures. These sensors are under the category of non-wearing devices. Therefore, it will naturally avoid the inconveniences caused by the wearable devices. The performance measures like accuracy and resolution are very low in gesture identification applications using Kinect cameras. These gadgets additionally impose some cost related constraints also [23].

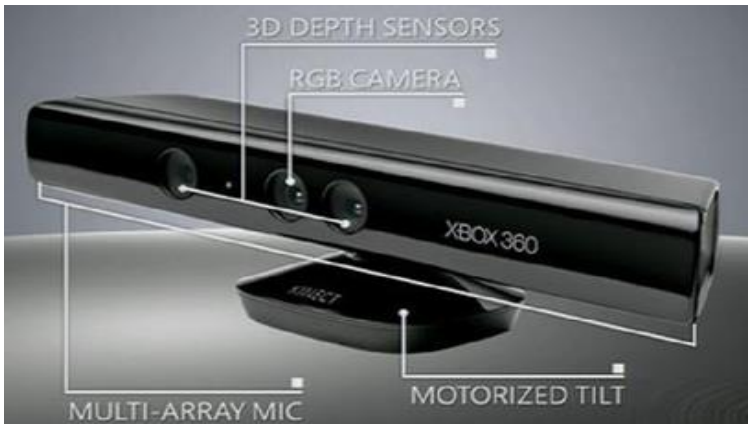

Figure 4: Microsoft's Kinect camera [22]

Another wrist wearing camera sensor is Digits and is shown in Figure 5. Hand communications are very flexible by using it. Robotics, smart homes, game controls are the main areas on which these sensors can be applied. Reusable equipment is used for its fabrication. The hand tracing performed by Digit is in a robust manner [23].

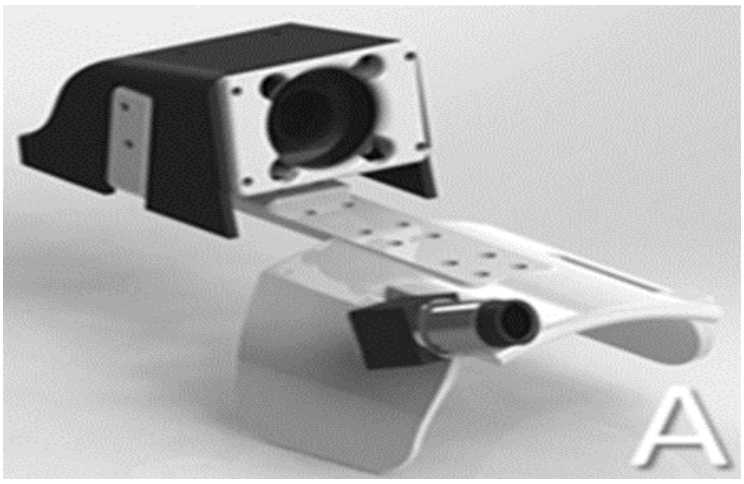

Figure 5: Digit: Sensor equipment [23]

The fingertips can be accurately detected by the emitted light from the Light Emitting Diodes. There is a chance of the noise due to the occurrence of complicated gestures. This leads to serious efficiency issues.

Some other latest techniques use a combined approach of neural networks or Convolutional Neural Network (CNN) and some depth camera sensors like Kinect. Compared with other conventional techniques, it is less complex and quicker. However, the chances of wrong results are high in some complicated input cases [24] [25].

In some other techniques as by Yeo et al, some cheap devices were utilized [26]. One such device is a simple web camera. The pictures taken by these devices will be processed by passing it through some latest image processing schemes. Finally, the fingertips are separated. Even though the accessibility of these gadgets is very effective, the surrounding conditions had a much impact on its output. With technological innovations, some latest three-dimensional capturing gadgets can be utilized in recognition techniques. Examples of such devices are depth movement sensors, cameras using depth information etc. [27].

3. Fingertip Detection Strategies and Renderings for HCI Applications

Most of the vision based HCI frameworks uses fingertip recognition as its major component. A variety of fingertip location techniques are there and are different from individual to individual. There are various methodologies for fingertip recognition. The rest of the sections analyze various strategies.

3.1 Fingertip Detection in HCI Applications

Formally, this writing arranges the overall fingertip identification processes dependent on the devices used for detection also based on the problems related with recognition of gestures. These devices used for detection are wearable devices and non-wearable devices. Examples for some wearable devices are wearable cameras, mechanical gadgets, wearable gloves, and so on [28]. The devices of this kind may impose some inconveniences to client. For the non-wearable devices, not many issues are there compared with the wearable ones. Webcam can be identified as a generally utilized, exceptionally proficient recognition device under not wearable category [29]. The pictures are captured in some productive way at the same time clients does not face many bothers. Classification based on the varieties of gestures is the next categorization. Gestures that incorporate just single indivisible gestures are called Simple gestures [30]. These indivisible gestures are identified as atomic gesture. The movement associated with these gestures, very less. However, this is a significant factor because of complex gestures. These gestures can be formed as a group compared with the atomic gestures. This grouping procedure can be addressed as in Figure 6 as a hierarchical graph. This figure shows the categorization of fingertip detection based on detection devices as well as on complexity of gestures.

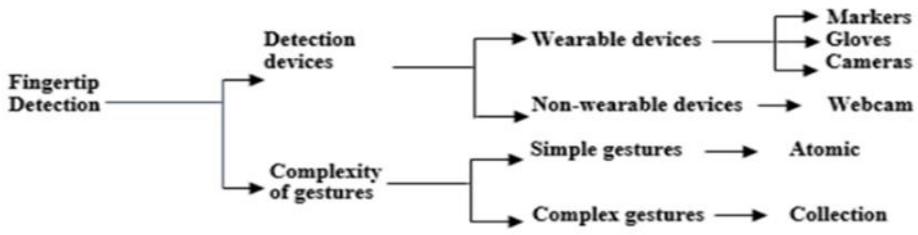

Figure 6: Fingertip detection taxonomies [28] [29] [30, 31]

4. A Comparative Study on Various Fingertip Detection Strategies

In this section a tabular representation of the previously mentioned techniques as in Table 1 are listed. This depends on various parameters like input devices utilized, gestures varieties recognized, cost factors, accuracy, etc.

Table 1: Various fingertip detection technologies and its classification criteria [15] [16] [17] [18] [19] [20] [21][22][23][] [25]

Method	Detection Devices (Wearable or Not)	Gestures (Simple or Complex)	Accuracy	Cost
Liu & Wang [15]	Colored with some marking devices or LED	Simple Gestures	79.4%	Low
Jani et al. [16]	Wearable Hand Gloves	Simple Gestures	76 %	Low
Mazumdar et al. [17]	Wearable Colored Glove	Simple Gestures	71.93%	Low
Ishiyama & Kurabayashi [18]	Wearable fabric Glove	Simple Gestures	99.51%	Low
Placidi et al. [19]	Virtual Glove	Simple Gestures	80.67%	Low
Dani et al. [20]	Non-Wearable Camera	Simple gestures (Including two fingers)	98.35%	High
Zhu et al.[21]	Non Wearable Devices	Simple & complex Gestures	82%	High
Xi et al. [22]	Wearable And Non-Wearable Camera	Simple & Complex Gestures	85%	High
Kim et al. [23]	Wearable Digit sensor	Gestures allows free hand movement	97.3%	Low
Islam et al. [24]	Mobile Camera	Stationary & Dynamic images	83%	High
Qu et al. [25]	Binocular Camera with some image masks	Both gestures with less finger movement	97.73%	High

5. Problem Statements

The following limitations are identified based on the detailed literature review and analysis:

- Physical inconveniences imposed by the wearable devices.
- Background lighting conditions have a greater impact on the quality of output images.
- Accuracy and resolution are low in non-wearable based techniques.
- Implementation cost and complexity are high.

6. Conclusion

This article aims to analyse the latest techniques of fingertip identification to set up a real time HCI framework. Numerous such fields studied and analysed. This is a dynamic field of study with numerous enhancements. Therefore, scientists are always interested to this topic. Latest techniques follow some neural network based approaches or some depth camera based

approaches. However, the cost associated with the gadgets utilized, complication in the identification of hand movements becomes some principle challenges distinguished. Rapid finger motion forces a lot of trouble in fingertip identification system. Another hindrance is the impact of unpredictable surroundings. It has a major role in the entire detection process.

The above aspects have some importance during the entire discovery procedure. It is an investigation survey on the current finger identification procedures with different recognition gadgets. It is concluded with a hierarchy list. An additional taxonomy description is also listed. Exactness, gadgets used for identification, expense, categories of gestures are the important factors studied in this paper.

Conflict of interest

"Conflict of Interest: The authors declare that they have no conflicts of interest."

References

[1] Abdelnour-Nocera and T. Clemmensen, "Theorizing about socio-technical approaches to HCI," in *IFIP Working Conference on Human Work Interaction Design, Springer, Cham*, 2018.

[2] S. Anwar, S. Sinha, S. Vivek and V. Ashank, "Hand gesture recognition: a survey," in *Nanoelectronics, Circuits and Communication Systems, Singapore*, 2019.

[3] Z. Majeed and H. Ali, "A review of augmented reality in educational applications," *International Journal of Advanced Technology and Engineering Exploration*, vol. 7, no. 62, pp. 20-27, 2020.

[4] J. Chen, G. Fragomeni and eds, "Virtual, Augmented and Mixed Reality: Interaction, Navigation, Visualization, Embodiment, and Simulation," in *10th International Conference VAMR, Las Vegas, NV, USA*, 2018.

[5] S. Antoshchuk, M. Kovalenko and J. Sieck, "Gesture recognition-based human–computer interaction interface for multimedia applications," in In *Digitisation of Culture: Namibian and International Perspectives, Springer, Singapore*, 2018.

[6] M. Yasen and S. Jusoh, "A systematic review on hand gesture recognition techniques, challenges and applications," *Peer J Computer Science*, vol. 5, p. e218, 2019.

[7] M. Muller, A. Bibi, S. Giancola, S. Alsubaihi and B. Ghanem, "Trackingnet: A large-scale dataset and benchmark for object tracking in the wild," in *Proceedings of the European Conference on Computer Vision* (ECCV), 2018.

[8] G. Wu and W. Kang, "Vision-based fingertip tracking utilizing curvature points clustering and hash model representation," *IEEE Transactions on Multimedia*, vol. 19, no. 8, pp. 1730-1741, 2017.

[9] X. Ma and J. Peng, "Kinect sensor-based long-distance hand gesture recognition and fingertip detection with depth information," *Journal of Sensors*, 2018.

[10] D. Lopes, F. Relvas, S. Paulo, Y. Rekik, L. Grisoni and J. Jorge, "Feetiche: Feet input for contactless hand gesture interaction," in *17th International Conference on Virtual-Reality Continuum and its Applications in Industry*, 2019.

[11] G. Rao and P. Kishore, "Selfie video based continuous Indian sign language recognition system," *Ain Shams Engineering Journal*, vol. 9, no. 4, pp. 1929-1939, 2018.

[12] G. Wu and W. Kang, "Robust fingertip detection in a complex environment," *IEEE Transactions on Multimedia*, vol. 18, no. 6, pp. 978-987, 2016.

[13] Y. Xu and Y. Dai, "Review of hand gesture recognition study and application," *Contemporary Engineering Sciences*, vol. 10, no. 8, pp. 375-384, 2017.

[14] B. McInroe, C. Chen, K. Goldberg, R. Bajcsy and R. Fearing, "Towards a soft fingertip with integrated sensing and actuation," in *IEEE/RSJ International Conference on Intelligent Robots and Systems* (IROS), 2018.

[15] H. Liu and L. Wang, "Gesture recognition for human-robot collaboration: A review," *International Journal of Industrial Ergonomics*, vol. 68, pp. 355-367, 2018.

[16] A. Jani, N. Kotak and A. Roy, "Sensor based hand gesture recognition system for English alphabets used in sign language of deaf-mute people," *IEEE SENSORS*, pp. 1-4, 2018.

[17] D. Mazumdar, A. Talukdar and K. Sarma, "Gloved and free hand tracking based hand gesture recognition," in *International Conference on Emerging Trends and Applications in Computer Science*, 2013.

[18] H. Ishiyama and S. Kurabayashi, "Monochrome glove: A robust real-time hand gesture recognition method by using a fabric glove with design of structured markers," in *IEEE Virtual Reality* (VR), 2016.

[19] G. Placidi, D. Avola, L. Cinque, M. Polsinelli, E. Theodoridou and J. Tavares, "Data integration by two-sensors in a LEAP-based Virtual Glove for human-system interaction," *Multimedia Tools and Applications*, vol. 80, no. 12, pp. 18263-18277, 2021.

[20] M. Dani, G. Garg, R. Perla and R. Hebbalaguppe, "Mid-air fingertip-based user interaction in mixed reality," in *IEEE International Symposium on Mixed and Augmented Reality Adjunct*, 2018.

[21] X. Zhu, J. Yang and A. Waibel, "Segmenting hands of arbitrary color," in *Fourth IEEE International Conference on Automatic Face and Gesture Recognition*, 2000.

[22] C. Xi, J. Chen, C. Zhao, Q. Pei and L. Liu, "Real-time hand tracking using kinect.," in *2nd International Conference on Digital Signal Processing*, 2018.

[23] D. Kim, O. Hilliges, S. Izadi, A. Butler, J. Chen, I. Oikonomidis and P. Olivier, "Digits: freehand 3D interactions anywhere using a wrist-worn gloveless sensor," in *25th annual ACM symposium on User interface software and technology*, 2012.

[24] M. Islam, S. Siddiqua and J. Afnan, "Real time hand gesture recognition using different algorithms based on American sign language," in *IEEE international conference on imaging, vision & pattern recognition*, 2017.

[25] X. Qu, W. Wang, K. Lu and J. Zhou, "Data augmentation and directional feature maps extraction for in-air handwritten Chinese character recognition based on convolutional neural network," *Pattern recognition letters*, vol. 111, pp. 9-15, 2018.

[26] H. Yeo, B. Lee and H. Lim, "Hand tracking and gesture recognition system for human-computer interaction using low-cost hardware.," *Multimedia Tools and Applications*, vol. 74, no. 8, pp. 2687-2715, 2015.

[27] K. Dhanasree, K. Nisha and R. Jayakrishnan, "Hospital emergency room training using virtual reality and leap motion sensor," in *Second International Conference on Intelligent Computing and Control Systems* (ICICCS), 2018.

[28] S. Sridhar and e. al., "Watchsense: on-or more skin input detecting through a wearable profundity sensor," in *CHI Conference on Human Factors in Computing Systems, ACM*, 2017.

[29] A. Thongtawee, O. Pinsanoh and Y. Kitjaidure, "A novel feature extraction for american sign language recognition using webcam," in *11th Biomedical Engineering International Conference* (BMEiCON), 2018.

[30] F. Caputo, P. Prebianca, A. Carcangiu, L. Spano and A. Giachetti, "Comparing 3D trajectories for simple mid-air gesture recognition," *Computers & Graphics*, vol. 73, pp. 17-25, 2018.

[31] G. Li, H. Wu, G. Jiang, S. Xu and H. Liu, "Dynamic gesture recognition in the internet of things," *IEEE Access*, vol. 7, pp. 23713-23724, 2018.