International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-2, December 2019

Real Time Vision Based Fingertip Detection Strategies

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Abstract: ***The Fingertip Detection acts a specific role in most of the vision based applications. The latest technologies like virtual reality and augmented reality actually follows this fingertip detection concept as its foundation. It is also helpful for Human Computer Interaction (HCI). So fingertip detection and tracking can be applied from games to robot control, from augmented reality to smart homes. The most important interesting field of fingertip detection is the gesture recognition related applications. In the context of interaction with the machines, gestures are the most simplest and efficient means of communication. This paper analyses the various works done in the areas of fingertip detection. A review on various real time fingertip methods is explained with different techniques and tools. Some challenges and research directions are also highlighted. Many researchers uses fingertip detection in HCI systems those have many applications in user identification, smart home etc. A comparison of results by different researchers is also included.***

Keywords: Fingertip detection, Fingertip tracking, Hand gesture recognition, Human computer interaction.

I. INTRODUCTION

Human Computer Interaction (HCI) [1] is an advancing research area with lots of opportunities. HCI systems are basically meant to leverage the interaction [2] between users and computers. These interactions are possible with the help of some intermediaries like mouse, screen, camera or some other means like direct contact manner. With the development of Augmented Reality (AR) [3] and Virtual Reality (VR) [4], lots of advancements and research directions are created in the field of HCI. A wide variety of application fields like Hand Gesture Recognition (HGR) [5] [6], Object Tracking [7] , and Vision Based Fingertip Tracking [8] are related to these HCI systems.HCI techniques can be generally classified into two types: traditional and intuitive techniques. Among that, intuitive techniques are considered as the most flexible and efficient means of communication. And are more user friendly compared with the traditional techniques. With the advancements in HCI, there is a tremendous increase in the number of computer vision applications. With these technological advancements, there are still many challenges should be addressed.

Revised Manuscript Received on December 30, 2019.
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Fingers have most important role in communication and so fingertip detection has a major role in vision based HCI applications [9]. Fingers and fingertips are the most reliable & simple shapes can be extracted and can be compared with the human hand. Fingertip is an essential and important feature of human hand. One of an efficient and easiest way to identify and detect human fingers is to locate the fingertips. For touch less applications [10] fingertip detection has a major role. It has applications in gesture recognition, human sign language system, and robotic control and so on. The first and most important step of any detection system is to collect or detect the necessary data related to that application. For fingertip detection system also, different techniques are there in order to collect relevant details. Many features and methods were developed for detecting and tracking fingertip from visual information. Throughout this paper various fingertip detection techniques are analyzed.

Fingertip tracking is an unavoidable stage of vision based HCI systems. For fingertip tracking first of all we have to locate the fingertip points. Fingers are considered as the most important feature of human hand [8]. So the finger extraction process [11] is considered as an important task also requires more care and attention. By extracting that feature, wide range of applications like mouse control, TV-Video games control, Hand gesture recognition systems can be effectively implemented. Fingertip is considered as one of the most popular characteristics in solving the issues involved in human hands such as sign language recognition and gesture recognition.

All fingertip detection techniques can be implemented as a two step process [12]. First and most important stage is the segmentation of the hand region [13]. Followed by segmentation, fingertip detection can be implemented. In earlier days fingertip detection techniques actually needs some special devices or markers in order distinguish hand or fingers from the surroundings [14]. These devices actually serve as some auxiliary devices [15]. The techniques adopted these devices were good enough for a short range of detection. The main short comings of these devices were the high cost of these auxiliary devices. As many researchers are working on these fingertip detection techniques, a lot of advanced techniques were emerged to replace these special markers. By applying some fundamental tools or techniques of image processing [16], can effectively replace these auxiliary marker devices. But the performance of these techniques will depend upon the lighting conditions of the surroundings. Another robust fingertip detection method is by the use of some types of sensors. This can be implemented with the help of some data gloves or optical sensors like camera. The main advantage here is that the background lighting conditions will not disturb this type of fingertip detection.

But this method is also very expensive and inconvenient. Recently there are advanced cameras like Microsoft Kinect were available for fingertip detection. But this device is also very expensive.

This paper actually provides a review on available fingertip detection techniques. A discussion of some detection methodologies is also included. It also gives a brief analysis and summarization of various vision based fingertip detection methods.

II. FINGERTIP DETECTION TAXNOMIES AND REPRESENTATIONS

Fingertip detection is an important role in almost all vision based human computer interaction systems. Various fingertip detection strategies have been proposed in the literature that is varying among person to person. Theoretically the above literature classifies the fingertip detection based upon the detection devices [17] used and the complexity of gestures identified. The detection devices can be wearable or non-wearable. The wearable devices [18] [19] uses some mechanical devices, hand gloves, camera etc. This may create some inconveniences to the user. There are no such problems related with these non-wearable devices. A widely used, highly efficient non wearable detection device is webcam [20]. It can capture the images in an efficient and effective manner without impose any inconveniences to the user. Another important classification strategy is the types or the detected. Simple gestures [22] are gestures that include only one atomic gesture [23]. In those simple gestures, not much movement is there. Whereas in the case of complex gestures [24], movement should be an important factor. Complex gestures include a collection of gestures in place of a single atomic gesture. This classification strategy can be represented as in Fig.1 in the form of a taxonomy chart.

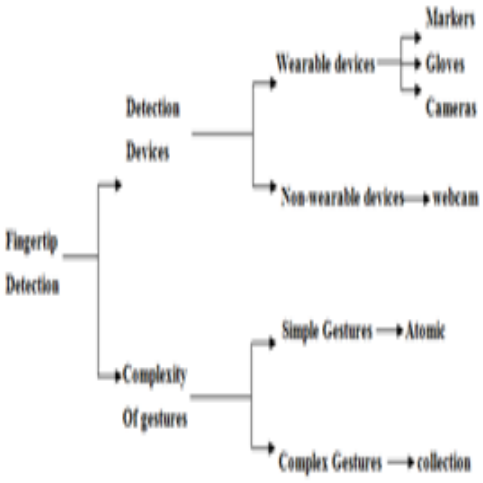

Fig. 1. Fingertip detection taxonomies.

III. FINGERTIP DETECTION METHODOLOGIES

As mentioned in the previous sections, fingertip detection is identified as the most important stage of any HCI related applications, hand tracking for the easy interaction between human and computer. The overall fingertip detection process can be implemented in two stages. First stage is the hand region segmentation and then followed by the fingertip detection [12].

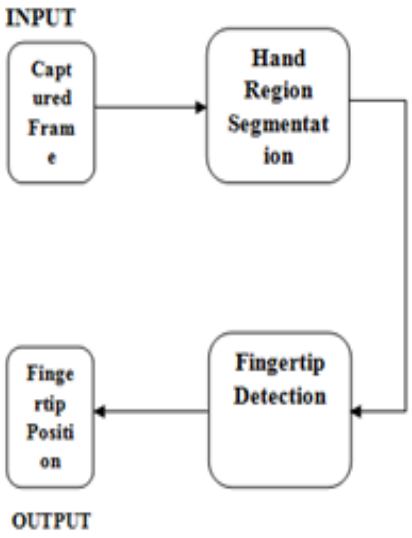

Fig. 2. Fingertip detection process.

There are different approaches for fingertip detection. The following section illustrates the different techniques available for the fingertip detection.

A. Detection Based on Markers

In earlier days fingertip detection had not followed any advanced techniques because of the lack of technological advancements. In those days, the detection strategy followed some markers or paints. The fingertips of the hand will be painted or marked using some markers or colours [25]. Then these paints can be easily identified and the corresponding fingertips can be located from the video of the captured frame. Later this method was identified as a non-standard method for detecting the fingertips. Here only the paints or marked fingertips in the captured video frames are analysed. Information regarding the colour or geometry of the hand is not considered here. So this detection strategy can be considered as an indirect way of detecting fingertips. This will be considered as an acceptable method because of its low cost of implementation. But actually it is considered as an inconvenient method since the user needs to paint or mark his or her fingers in order to detect the fingertips [26]. So this is not considered as a standardized or popular method of fingertip detection.

B. Detection Based on Special Devices

In order to overcome inconveniences caused by the special marking technologies, some auxiliary devices like Data Gloves [27] were developed. These gloves are special wearable equipments, and can collect useful information of hand in order to detect accurate fingertips. Data glove is a wearable device, and can be identified as an input device that contains sensors for capturing & monitoring hand movements. The captured information can be transformed into some useful input data for virtual reality and robotics like applications.

Different types of hand gloves [28] were used depending upon the applications. The commonly used gloves are colour gloves, monochromatic gloves [29], fabric gloves [29], virtual gloves [30] and so on.

Fig. 3. Example for a Hand Glove for fingertip detection

C. Detection Based on Image Processing Techniques

As the technological growth is very fast, the latest techniques were evolved in the image processing applications also. Some of these techniques can be effectively utilized in the fingertip detection strategy [31]. From the captured image frames, hand region should be segmented. For this segmentation latest techniques like histogram or skin colour based segmentations [32] can be adopted. In the histogram based approach, histogram is constructed based on all of the image pixels. And by referring these histograms, clusters can be located in the image. These methods can be effectively utilized for video tracking. In Skin colour based segmentation skin and non-skin pixels are identified and separated. And these non-skin pixels are not used for hand detection process, so can be discarded.

Fig. 4. Skin Colour Based Segmentation

The main problem with these approaches is that, the clarity of the output (here the fingertip) depends on the lighting conditions on the background. It cannot work well in poor lighting or complete darkness.

D. *Detection Based on Camera Sensors*

Kinect [33] is a sensor developed by Microsoft Corporation. It can provide colour and depth images [34]. Computer vision technologies mainly depend on this sensor. It can also produce images with high resolutions. The discomfort of wearing data gloves can be avoided using these sensors. In hand gesture recognition related applications, Kinect sensors shows low resolution and inaccuracy [35]. It also expensive compared with the wearable devices.

Fig. 5. Kinect Sensor

Digits is a small camera based sensor [36] that can be worn on wrist. It enables free hand interactions. Its potential applications include Home TV control, gaming, and robot control and so on. It was built using a reproducible hardware. It can perform robust hand tracking.

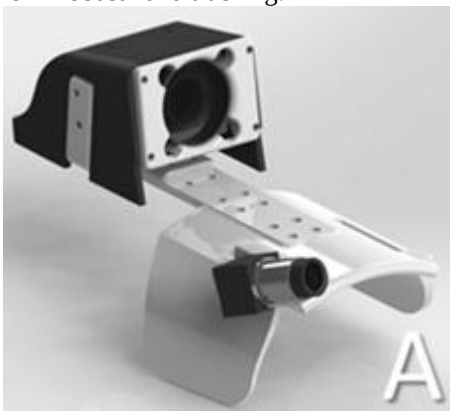

Fig. 5. Digit Wrist-worn Sensor

Light fall from the LEDs helps to identify the fingertips correctly. Occlusions produced as a result of some complex hand gestures may leads to some serious performance problems.

In another approach based on Kinect depth sensors, depth information from the camera is used along with the Convolutional Neural Networks (CNNs) [37] [38] for fingertip detection. It is simpler and faster compared with the ordinary methods. But there is a possibility of erroneous results in complex geustures and multiple fingertip detection. Yeo et al [39] used a low cost USB webcams for capturing images and these images can be processed by applying different image processing techniques. From these processed images fingertips can be extracted. These devices are easily available but the main problem with these USB devices is the influence of the background. As the technology advances, new 3-D acquisition devices like depth cameras, deep motion sensors [40] are also used for better detection strategies.

IV. ANALYSIS OF FINGERTIP DETECTION METHODOLOGIES

Previous sections described about fingertip detection and various detection methods. In the coming section asummary of the above mentioned methods are performed in a tabular form manner. This is based on different considerations like input devices used, gesture types detected, cost factors, accuracy and so on. A table as shown in Table 1 is formulated based on these considerations.

.Table- I: A Summary of Fingertip Detection Methods

Method	Detection Devices (Wearable or Not)	Gestures (Simple or Complex)	Accuracy	Cost
Siam et al.[25]	Painted with Special markers or LED	Simple Gestures	79.4%	Low
Greenberg et al. [27]	Wearable Hand Gloves	Simple Gestures	76 %	Low
Mazumdar et.al. [28]	Wearable Coloured Glove	Simple Gestures	71.93%	Low
Ishiyama et.al. [29]	Wearable fabric Glove	Simple Gestures	99.51%	Low
Placidi et.al. [30]	Virtual Glove	Simple Gestures	80.67%	Low

Kim et al. [36]	Wearable Digit sensor	Gestures allows free hand movement	97.3%	Low
Oka et.al. [31]	Non Wearable Camera	Simple gestures (Including two fingers)	98.35%	High
Zhu et al.[32]	Non Wearable Devices	Simple & complex Gestures	82%	High
Li et al. [33]	Wearbale And Non Wearabale Camera	Simple & Complex Gestures	85%	High
Ren et al. [34]	Kinect Sensor Camera	Gestures with complex background	93.2%	High
Nguyen et al. [37]	RGB depth Camera	Stationary & Dynamic images	83%	High
Chen et al. [38]	Binocular Mask images from Camera	Simple &Complex gestures with less finger movement	97.73%	High

V. CONCLUSION

The most important goal of fingertip detection is to develop a dynamic advanced Human Computer Interaction platform. Now vision based techniques are more preferred.Fingertip detection is one of the most advancing and challenging field in the computer vision technology. Many vision based applications adopt various fingertip detection methods. In HCI Application like Human Gesture Recognition (HGR) Systems, TV remote control, Gaming Control, the foundation process is the fingertip detection process. Researchers currently focus on this field. Many improvements are going on in this active research area.The main difficulties identified in these fields are the complexity of gestures to be identified and the cost of the detection devices used. Movement of fingers imposes much difficulty in fingertip detection strategy. Another barrier is the influence of a complex background. This will also hinder the fingertip detection process. So for a better fingertip detection strategy, all these factors should be considered.

In this review paper an analysis of some existing fingertip detection techniques are performed with emphasis on detection devices. Classification taxonomy is identified based on that. A classification chart is also included in the last section. That comparative study is performed by considering the detection devices, types of gestures, cost and accuracy.

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