LIGHT INTERFACE OF 3D HAND MOTIONAL GESTURE RECOGNITION IN HUMAN COMPUTER INTERACTION

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Abstract - Hand gestures play a significant role in Human-Computer Interaction(HCI) where traditional interaction method like Keyboard, Mouse or Joystick induce stress and fatigue to the user when interacting with computing environments. Technique like smart wearable glove, able to capture gestures more accurately compare to image-based recognition but it disturbs the user's way of living. In this proposed light-based technique, simple motions of a hand like up, down, left, right, combine fingers motion like zoom in, zoom out, left rotation, right rotation, forward & Backward will be interfere with light-medium. The reflections of light from hand motional actions capture to process as interaction into computing environment. The technique, interact user's hand motion with Infrared(IR) light medium. And through an array of Photodetectors(IR), the reflected light intensity measure to extract various distances from the array to hand and fingers. The sensor array directly coupled with the processing device, which convert light various intensities into voltages. Through programming and Machine Learning techniques, the proposed method able to identify the gestural aspect of the hand. The technique able to overcome the problems like background conditions, proper exposure towards the camera, start/stop aspect of the gesture and noise in image based HCI techniques. By continuous processing of IR reflections, the method able to identify various hand 3D motional gestures with easily compare to direct and indirect based interaction techniques. The technique easily able to customize for different users' requirements and different environment to support human Computer Interaction. Further, this method supports simultaneous multiple user 3D interaction with the computing environment.

Keywords - Hand Gestures, Light-medium, Interaction, IR, customize.

I. INTRODUCTION

Gesture recognition is the informal way of interacting with computing devices through hand movements and postures (Rajeshri R Itkarkar, Anilkumar V. Nandi, 2016). The identifiable differences in hand motions and relative variations in fingers provide a set of variables as input to the computing devices. The approaches of Vision, Colour and sensor embedded gloves are being used in the field of recognition of gestures in HCI. Vision-based recognition techniques are sensitive to background and lighting conditions and the other glove based techniques, the user has to wear the electronic or colour glove (Hong Cheng,Lu Yang, Zicheng Liu, 2015) all the time to make an interaction, which disturbs the normal ability of work. In 2D vision based recognition techniques, complex mathematics involved in the aspects of segmentation, feature extraction, and recognition process. As an improvement to the 2D vision based recognition of gestures, 3D depth based techniques able to identify depth information of the gesture of sequence, and provides 3D position and orientation (Rajeshri R Itkarkar, Anilkumar V. Nandi, 2016) information of the gesture to the computing environment. Current techniques like Kinect, Leap Motion, and Time of Flight (TOF) sensors able to capture and identify gestures accurately with compare to 2D vision-based techniques.

In the field of robotics, IR based techniques used to measure distances from an object or identification of obstacle along the path when the robot is moving (Yuebin Yang, Guodong Feng, Shaoxian Wang, Xuemei Guo, Guoli Wang, 2013), Also another application of IR is to detect human presence by detection body temperature using Passive Infrared (PIR) sensors. In the distance based sensing and ranging, Light Detection and Ranging sensor (LiDAR) provides the highest accuracy in distance measurement. By using the principle of TOF information in the transmitted and receive signals of light. The LiDAR sensors are heavily used in Smart vehicles and autonomous robots for collision and obstacle - free navigation.

Considering the weaknesses in vision-based, glove based and depth based recognition techniques, and the considering principles of LiDAR, TOF, and Light, the novel proposed method use the falling light intensity measurement on to a photodetector array to identify gestures. Hand motional gestures like up, down, left, right, combine fingers motion like zoom in, zoom out, left rotation, right rotation, forward & Backward motions able to extract after processing of the light fallen on to the photodetector array (Yilong Li, 2016). The proposed method, further support to identify complex gestural behaviour in the light -medium through Machine learning.

II. METHODOLOGY/EXPERIMENTAL DESIGN

Research Methodology based on the study reflection of light at the various region of the hand when gestures in the medium of light. The various gestures from the hands, legs or head able to produce reflections on to single or multiple directions, which in turn able to capture using single or multiple light source & detector arrangement. The reflected light contains the information of different intensity values of the hand and fingers. After processing of reflected light, processer enables to identify the intended gesture (Piero Zappi, Elisabetta Farella, Luca Benini, 2008). The light wavelengths in the electromagnetic spectrum fall into three categories as infrared, visible and ultraviolet. IR wavelengths are not visible to the human naked eye, hence IR the best medium without the strain of fatigue to the eyes. Further IR radiation does not disturb the surrounding environment and there is no interference from other visible light wavelengths.

The behavior of these three bands is similar in nature, for easy visualization of the incident light on the hand, the experimental design made with Light Emitting Diode(LED) and Light Dependent Resistors(LDR). The Light interface and Photodetector array supports to study of the hand(s) simple motions such as up, down, left, right, combine fingers motion like zoom in, zoom out, left rotation, right rotation, waving actions, forward & Backward as probable manipulative gestures into the computing environment. The motions interaction in the light medium captured as reflections on to the photodetector array to process and identify the gesture.

A. Radiance

The proper unit for measuring the delivery of light in space is radiance, which is defined as:

"The amount of energy traveling at some point in a specified direction, per unit time, per unit area perpendicular to the direction of travel, per unit solid angle".

The radiance at the patch is $L(x1,\theta,\varphi)$, then the energy transmitted by the patch into a tiny region of solid angle $d\omega$ around the direction θ,φ in time dt is

$$L(x1,\theta,\varphi)(\cos\theta1\,dA1)(d\omega)(dt)$$

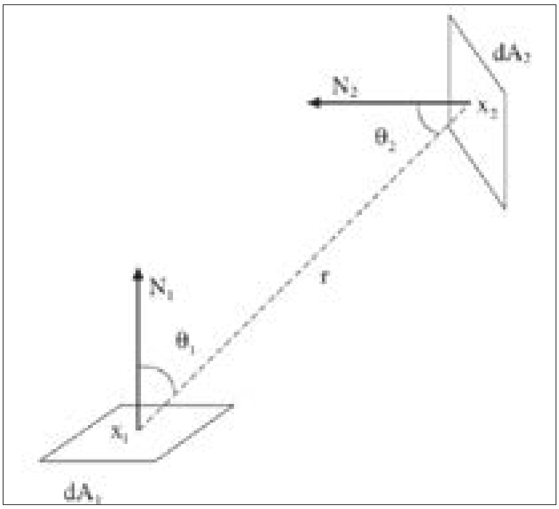

Figure 1: Transmitted light energy from path dA1 to dA2

Figure 1 shows the two patches are located at $x1$, $x2$ with the area of $dA1$ & $dA2$. The radiance leaving $x1$ in the direction of $x2$ is $L(x1,x1 \rightarrow x2)$ and the radiance arriving at $x2$ from the direction of $x1$ is $L(x2,x1 \rightarrow x2)$. In time dt, the energy leaving $x1$ towards $x2$ is

$$E1\rightarrow2 = L(x1,x1 \rightarrow x2)\cos\theta1\,d\omega2(1)dA1\,dt$$

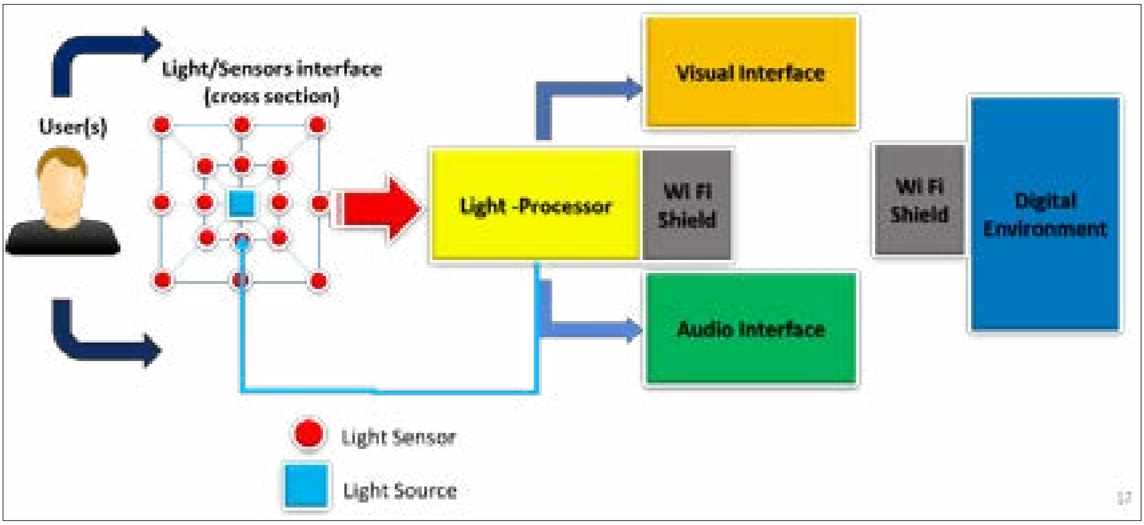

Figure 2: Research Design

where $d\omega 2(1)$ is the solid angle subtended by patch 2 at patch 1 ($d\omega 2(1) = \cos\theta 2dA2/r2$)

$$E1\rightarrow 2 = L(x1,x1 \rightarrow x2)\cos\theta 1 d\omega 2(1)dA1dt$$
$$= L(x1,x1 \rightarrow x2)\cos\theta 1 \cos\theta 2dA2dA1dt/r2$$

B. The Bidirectional Reflectance Distribution Function(BRDF)

To identify the relationship between incoming illumination and outgoing reflected light. The most general model of local reflection is the Bidirectional Reflectance Distribution Function(BRDF). The BRDF defined as the ratio of the radiance in the outgoing direction to the incident irradiance

$$\rho bd(\theta o,\varphi o,\theta i,\varphi i) = Lo(x,\theta o,\varphi o)/\mathrm{Li}(x,\theta i,\varphi i)\cos\theta i d\omega$$

The radiance leaving a surface due to irradiance in a specific direction is given as:

$$Lo(x,\theta o,\varphi o) = \rho bd(\theta o,\varphi o,\theta i,\varphi i)Li(x,\theta i,\varphi i)\cos\theta i d\omega$$

If the transmitting light source (Li) model as a point source using a LED, the reflected light from the gestural hand able capture through an array of photodetectors such as $Lo1$, $Lo2$, $Lo3$,…… Lon. The photodetector array measures different dynamic intensities of reflected light from the palm and fingers. By processing this dynamic information, the system able to identify the gestural aspect of the hand.

Experimental design & study phased out as a light transmitter & Photodetector, processing, visualizing and networking phase. For visualization of the light, a Red colour square LED selected as the light source, which was capable of an emitting radiance power of 10W.

Sixteen number of LDR photodetectors were arranged as shown in Figure 3 to capture the reflection from the hand. The motions like up, down, left, right, combine fingers motion like zoom in, zoom out, left rotation, right rotation, forward & Backward were able to reflect light differently towards the photodetector array. For identification of major directions as Up, Down, Left & Right, the minimum number of four sensors were sufficient (Fig. 3 V2, V4, V6 & V8). Corner placed photodetectors (Fig. 3 V1, V3, V5 & V7) were able to identify the directions in-between Up, Down, Left & Right, and the outer rectangular array of photodetectors support to confirm the selected basic motions of the hand.

Each photodetector connected to the light processor (ArduinoMega 2560 Rev 3) through a 100k variable resistor, which enables to control the intensity level of fallen light on to a photodetector. Based on the light intensity level, processor reading value could be adjusted from 0 to 1023 levels. The sensing array input clarity can be improved by integration of the number of sensor transmitter units and processing using Machine Learning techniques to support more diverse interaction.

The visual interface gives direct feedback to the user's interaction as the action to act upon in HCI environment. In experiment design for verification of interactions, the author has used the sensor to LED, 1:1 mapping technique to identify the affected photosensor. In which each photosensor node mapped to output LEDs to indicate when reflected energy fall on to it.

Experimental design integrated with an audio interface to support vision impaired users to interact with the computing environment through basic hand motions. Vision impaired users' interaction assigned with different tones to identify the hand motion gestural aspect with the HCI environment. Further, through Wi-Fi interface system provides connectivity with the computing environment and support with mobility for the user.

III. RESULTS AND DISCUSSION

For the study of light reflections, interface designed with 16 number of Photodetectors. 8 x 02 photodetectors arranged in squares as shown in figure 2. The measured intensity of reflection light from the hand (right or left) as shown in table 1. In the experimental design, hand motion distance varied from 20cm to 100cm with 20 cm steps to identify the gestural aspect. Each similar motion interaction from the same distance introduced an error, which varied up to ±40 from the measured intensity. Error tolerance compensated through programming to the identification of the gestures.

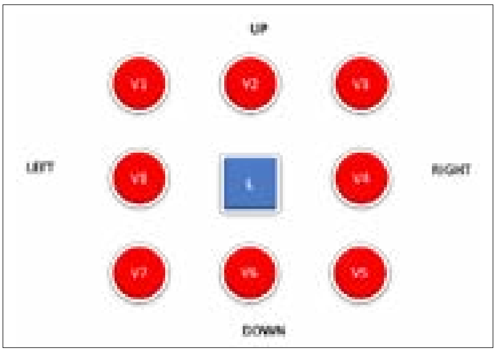

Figure 3: Photosensor Array
Table 1: Individual sample data collected from 20 cm to 100 cm

Table 1 shows the measured intensity data for a user's hand

IV. CONCLUSION

In this work, introduced an efficient method for human -computer interaction through the light based medium. The Interaction technique was able to address the drawback of vision-based interaction and was able to use the principles of light- based depth recognition to support interaction with basic hand motions. Novice to professional users' simply can interact with computing environment using simple motion aspect of the hands, legs or head. By different configuration of Light Transmitters, Photosensor arrays and Machine Learning the method could be developed to support multiuser interaction with more & finer variations of gestures for identification into the system. Further, the light-based interaction able to support differently able people to interacting with computing aspect through the available motion of hands, legs or head.

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Table 1: Individual sample data collected from 20 cm to 100 cm

User	Distance	Right Hand	Direction of The Hand Motion				Photo Sensor Value							
		Right	Left	Right	Up	Down	V1	V2	V3	V4	V5	V6	V7	V8
1	100 cm		yes				360						380	400
				yes					400	460	410			
					yes		460	500	473					
						yes					402	480	444	
	80 cm		yes				580						555	625
				yes					580	600	612			
					yes		625	680	645					
						yes					633	666	650	
	60 cm		yes				700						695	730
				yes					745	780	715			
					yes		725	740	735					
						yes					712	745	710	
	40 cm		yes				725						740	760
				yes					739	780	745			
					yes		745	760	749					
						yes					710	770	746	
	20 cm		yes				824						800	850
				yes					869	890	873			
					yes		856	875	843					
						yes					848	880	865	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

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