A Review of Hand Gesture Recognition

Dhanashri Patil[1], Prof. S. M. kulkarni[2]
[1, 2] Department of Electronics and telecommunication
[1] GSMCOE, Balewadi, Pune
[2] P.V.P.I.T., Bavdhan, Pune

Abstract- *In the field of image processing hand gesture recognition system having great attention in the recent few years for general life applications. Hand gesture recognition is a growing field of research among various human to machine interactions. This research area is full of innovative approaches. Hand gesture recognition has the potential to be a natural tool supporting interaction between human and the computer. In this paper a review of recent hand gesture recognition systems is presented. This has motivated many researchers in analysis and interpretation of hand gestures as a very active research area. We reviewed literature on interpretation of hand gestures regarding its role in Human Computer Interaction (HCI) and similar works of researchers are emphasized. The aim of this review is to introduce the field of gesture recognition as mechanism for interaction with machines.*

Keywords- Gesture recognition, Hand Gesture, Human Computer Interaction (HCI), Hand Gesture recognition, image processing.

I. INTRODUCTION

Development of information technology needs new type of human to machine interaction that is easy to use. User's generally use hand gestures for expression of their feelings and thoughts. Hand gesture recognition system is used to create interaction between human and computer[29]. Recognized gestures can also be used for controlling a robotor conveying meaningful information.

Human computer interaction also known Man-Machine Interaction (MMI) [2].It is based on the relation between the human and the computer or machine.HCI system is designed with the consideration of it's functionality and usability [2].System functionality defined as the set of functions or services that the system offers to the users, while system usability defined as the level and scope that the system can operate and perform specific user purposes efficiently [2]. The system that matains a suitable balanced between functionality and usability known as influential performance and powerful system.

Gestures used as a communication medium. Gestures used for communicating between human and machines as well as between people using sign language. There are two types of gestures performed by human static and dynamic gestures[4][5].Static gestures are easy to understand, while dynamic gestures are more complex. For real time application dynamic gestures are more suitable. A dynamic gesture is indicates to change over a period of time whereas a static gesture is observed at the moment. A waving hand means goodbye is an example of dynamic gesture and the stop sign is an example of static gesture. To understand a full message, it is necessary to interpret all the static and dynamic gestures over a period of time. This complex process is called gesture recognition[32].The aim of gesture recognition research is to create a system which can analyse specific human gestures and use them to convey information or use for device control. A gesture may be defined as a physical movement of the hands, arms, face, and body. Gesture recognition consists not only the tracking of human movement, but also the interpretation of that movement as meaningful commands.

Some recent explained gesture recognition system applications and its growing importance in our life[8] especially for Human computer Interaction HCI, Robot control, games, human to machie interaction, electronic device contro[7][9]l. This work indicates the advancement of the gesture recognition systems, with the discussion of different stages required to build a complete system.

II. APPLICATION AREAS OF THE HAND GESTURE RECOGNITION

Hand gestures recognition system has been used for various applications in different domains, like[5][7]Human Computer Interaction (HCI), Man Machine Interaction (MMI), sign language translation, virtual environments, smart surveillance, robot control, medical systems etc. Some applications of hand gesture recognition system are listed below [5][6].

A. Sign Language Recognition:

Sign language is an important communication medium of communicative gestures. Sign languages are being used by deaf and dumb persons for communication since sign languages are highly structural. At the same time, they can also be a good way to help the disabled to interact with computers. Sign language for the deaf (e.g. American Sign

Language) is an example than this received significant attention in the gesture literature[32].The sign language is used for describing and details of a certain topic during the conversation; it has received special attention [5]. Various systems have been proposed to identify gestures using different types of sign languages [6]. For example recognized American Sign Language ASL is using boundary histogram, MLP neural network and dynamic programming matching [25] recognized Japanese sign language JSL using Recurrent Neural Network, 42 alphabet and 10 words [22]. Recognized Arabic Sign language ArSL using two different types of Neural Network, Partially and Fully Recurrent neural Network

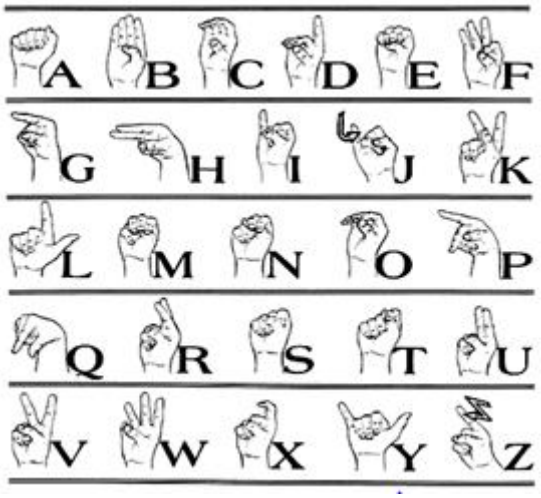

Fig 2.1 American Sign Language

B. Virtual Environments (VEs):

Virtual environments VEs is most popular application of gesture recognition system [7][26]. It is provided 3D pointing gesture recognition for natural human computer Interaction HCI in a real-time from binocular views. The proposed system is accurate and independent of user characteristics and environmental changes [26].Virtual reality interactions use gestures to enable realistic manipulations of virtual objects using ones hands, for 3D display interactions or 2D displays that simulate 3D interactions[30][31].

C. Robotics and Tele presence:

Tele presence and Tele robotic applications are typically situated within the area of space exploration and military-based research projects [29]. In some cases there is need of manual operations such as system failure or emergency hostile conditions. Always it is impossible for human operators to be physically present near the machines [34]. Tele presence is that area of technical intelligence which aims to provide physical operation support that handles the operator arm to the robotic arm to carry out the necessary task. The prospects of tele-presence includes space, undersea mission, medicine manufacturing and in maintenance of nuclear power reactors [35].Here hand gesture recognition is used to control the movement of the robot [4].Hand gesture recognition system uses the numbering to count the five fingers for controlling a robot using hand pose signs [13]. The orders are given to the robot to perform a specific task ,where each sign has a specific meaning and represents different function for example, “one” means “move forward”, “five” means “stop”, and so on.

D. 3D Modeling:

Hand shapes determination are necessary to create, built and view 3D shape of the hand [7].Some systems built the 2D and 3D objects using hand gestures. CAD (computer aided design) is used to interpret 3-dimentional gestures Manipulating 3D inputs with a mouse is a time consuming task as the task involves a complicated process of decomposing a six degree freedom task into at least three sequential two degree tasks[33].A 3space sensor is embedded in a flat palette, representing the plane in which the objects rest .The CAD model is moved synchronously with the users’ gesture movements and objects can thus be rotated and translated in order to view them from all sides as they are being created and altered[33].

E. Graphic Editor Control:

Graphic editor control system needs the hand gesture to be captured and located as a preprocessing [5]. It is used 12 dynamic gestures for drawing and editing graphic system. Various shapes for drawing are; triangle, rectangular, circle, arc, horizontal and vertical line, and commands for editing graphic system are; copy, delete, move, swap, undo, and close[17].

F. Television Control:

Hand postures and gestures are also used for controlling the Television device [7]. TV activities are controlled by a set of hand gestures like turning the TV on and off, increasing and decreasing the volume, muting the sound, and changing the channel using open and close hand [27].

G. Games:

We can also use hand gesture to control the movement of objects in a computer game. Camera is used to capture hand movements. When we used hand gestures for playing it becomes more interesting [29].

III. LITERATURE REVIEW

Recognizing gestures is a complex task which involves many aspects such as motion modeling, motion analysis, pattern recognition and machine learning various researcher are working on that Christopher Lee and YangshengXu [36] developed a glove-based gesture recognition system that was able to recognize 14 of the letters from the hand alphabet, learn new gestures and able to update the model of each gesture in the system in online mode, with a rate of 10Hz. Over the years advanced glove devices have been designed such as the Sayre Glove, Dexterous Hand Master and Power Glove [37]. The most successful commercially available glove is by far the VPL Data Glove as shown in figure 3.1

It was developed by Zimmerman [38] during the 1970's. It is based upon patented optical fiber sensors along the back of the fingers. Star-ner and Pentland [33] developed a glove-environment system capable of recognizing 40 signs from the American Sign Language (ASL) with a rate of 5Hz

Fig 3.1 VPL data glove [38]

Hasan [14] applied multivariate Gaussian distribution to recognize hand gestures using non geometric features. The input hand image is segmented using two different methods [15]; skin color based segmentation by applying HSV color model and clustering based thresholding techniques [15]. Some operations are performed to capture the shape of the hand to extract hand feature; the modified Direction Analysis Algorithm are adopted to find a relationship between statistical parameters (variance and covariance) [14] from the data, and used to compute object(hand) slope and trend [14] by finding the direction of the hand gesture [14],

Hyeon-Kyu Lee and Jin H. Kim [39] presented work on real-time hand-gesture recognition using HMM (Hidden Markov Model). Kjeldsen and Kendersi [40] devised a technique for doing skin-tone segmentation in HSV space, based on the premise that skin tone in images occupies a connected volume in HSV space. They further developed a system which used a back-propagation neural network to recognize gestures from the segmented hand images.

Kulkarni[28] recognize static posture of American Sign Language using neural networks algorithm. The input image are converted into HSV color model, resized into 80x64 and some image preprocessing operations are applied to segment the hand [28]from a uniform background[28], features are extracted using histogram technique and Hough algorithm. Feed forward Neural Networks with three layers are used for gesture classification. 8 samples are used for each 26characters in sign language, for each gesture, 5 samples are used for training and 3samples for testing, the system achieved 92.78% recognition rate using MATLAB language[28]

Etsuko Ueda and Yoshio Matsumoto [40] presented a novel technique a hand-pose estimation that can be used for vision-based human interfaces, in this method, the hand regions are extracted from multiple images obtained by a multiview point camera system, and constructing the "voxel Model." Hand pose is estimated. Chan Wah Ng, Surendra Ranganath[41] presented a hand gesture recognition system, they used image furrier descriptor as their prime feature and classified with the help of RBF network. Their system's overall performance was 90.9%.

Hasan [3] applied scaled normalization for gesture recognition based on brightness factor matching. The input image with is segmented using thresholding technique where the background is black. Any segmented image is normalized (trimmed), and the center mass [3] of the image are determined, so that the coordinates are shifted to match the centroid of the hand object at the origin of the X and Y axis [3]. Since this method depends on the center mass of the object, the generated images have different sizes [3] for this reason a scaled normalization operation are applied to overcome this problem which maintain image dimensions and the time as well [3], where each block of the four blocks are scaling with a factor that is different from other block's factors. Two methods are used for extraction the features; firstly by using the edge images, and secondly by using normalized features where only the brightness values of pixels are calculated and other black pixels are neglected to reduce the length of the feature vector [3]. The database consists of 6 different gestures, 10 samples per gesture are used, 5 samples for training and 5 samples for testing. The recognition rate for the normalized feature problem achieved better performance than the normal feature method, 95% recognition rate for the former method and 84% for the latter one [3].

Wysoski et al. [6] presented rotation invariant postures using boundary histogram. Camera used for acquire the input image, filter for skin color detection has been used followed by clustering process to find the boundary for each group in the clustered image using ordinary contour tracking algorithm. The image was divided into grids and the boundaries have been normalized. The boundary was represented as chord's size chain which has been used as histograms, by dividing the image into number of regions N in a radial form, according to specific angle. For classification process Neural Networks MLP and Dynamic Programming DP matching were used. Many experiments have implemented on different features format in addition to use different chord's size histogram, chord's size FFT. 26 static postures from American Sign Language used in the experiments. Homogeneous background was applied in the work.

Stergiopoulou [11] suggested a new Self-Growing and Self-Organized Neural Gas (SGONG) network for hand gesture recognition. For hand region detection a color segmentation technique based on skin color filter was used, an approximation of hand shape morphology has been detected using (SGONG) network; three features were extracted using finger identification process which determines the number of the raised fingers and characteristics of hand shape, and Gaussian distribution model used for recognition.

IV. HAND GESTURE RECOGNITION

Hand gesture recognition is mainly divided into four steps that are image acquisition, image preprocessing, feature extraction and classification. Block diagram of hand gesture recognition is shown below

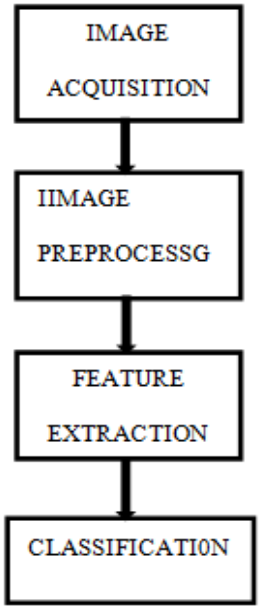

Fig. 4.1 Block diagram of hand gesture recognition

4.1 Image Acquisition-

Image acquisition is the first step in any vision system, only after this process you can go forward with the image processing. In this system it is done by using Webcam. The system uses the camera present in the pc for continuous image capturing and a simultaneous display on the screen. Image is then showed in the GUI.

4.2 Image Preprocessing-

Here the color RGB image is converted to gray scale image using matlab inbuilt command When converting an RGB image to grayscale, we have to take the RGB values for each pixel and make as output a single value reflecting the brightness of that pixel.. Segmentation process is the process for recognizing hand gestures. It is the process of dividing the input image (in this case hand gesture image) into regions separated by boundaries[10]. The segmentation process depends on the type of gesture, if it is dynamic gesture then the hand gesture need to be located and tracked [10], if it is static gesture (posture) the input image have to be segmented only. The hand should be located firstly, generally a bounding box is used to specify the depending on the skin color [11] and secondly, the hand have to be tracked, for tracking the hand there are two main approaches; either the video is divided into frames and each frame have to be processed alone, in this case the hand frame is treated as a posture and segmented [10], or using some tracking information such as shape, skin color using some tools such as Kalman filter[11]. The common helpful cue used for segmenting the hand is the skin color [10], since it is easy and invariant to scale, translation, and rotation changes. Different tools and methods used skin and non-skin pixels to model the hand. These methods are parametric and non-parametric techniques, Gaussian Model (GM) and Gaussian Mixture Model (GMM) are parametric techniques, and histogram based techniques are non-parametric. However it is affected with illumination condition changes abs different races [4]. Some researches overcome this problem using data glove and colored markers which provide exact information about the orientation andposition of palm and fingers [10]. The segmentation considered as an open issue problem itself [7]. The color space used in a specific application plays an essential role in the success of Segmentation process, however color spaces are sensitive to lighting changes, for this reason, researches tend to use chrominance components only and neglect the luminance components such as r-g, and HS color spaces. However there are some factors that obstacle the segmentation process which is [10]; complex background, illumination changes, low video quality.[4][12] applied HSV color model which concentrates on the pigments of the pixel, B[11] used YCbCr color space.

[13] Used normalized r-g color space. Some preprocessing operations are applied such as subtraction, edge detection, and normalization to enhance the segmented handimage [6][12].

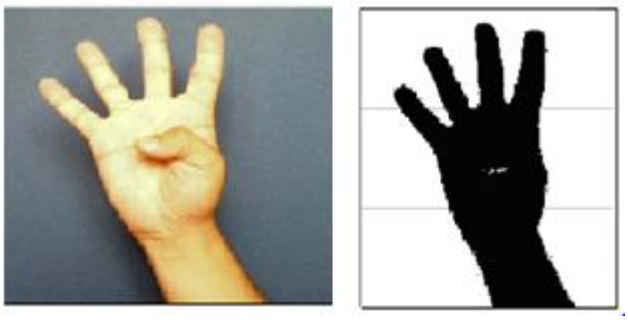

Figure 4.2 Segmentation method

4.3 Features Extraction

After segmentation process features extraction is done and the latter play an important role in a successful recognition process [4]. Features vector of the segmented image can be extracted in different ways according to particular application. Various methods have been applied for representing the features can be extracted. Some methods used the shape of the hand such as hand contour and silhouette [4] while others utilized fingertips position, palm center, etc.[4] created 13 parameters as a feature vector, the first parameters represents the ratio aspect of the bounding box of the hand and the rest 12 parameters are mean values of brightness pixels in the image. [11] used Self-Growing and Self-Organized Neural Gas (SGONG) neural algorithm to capture the shape of the hand, then three features are obtained; Palm region, Palm center, and Hand slope[13].Calculated the Center Of Gravity (COG) of the segmented hand and the distance from the COG to the farthest point in the fingers, and extracted one binary signal (1D) to estimate the number of fingers in the hand region.[12] divided the segmented image into different blocks size and each block represents the brightness measurements in the image. Many experiments were applied to decide the right blocks size that can achieve good recognition rate [13][14][15] used Gaussian pdf to extract geometric central moment as local and global features.

4.4 Gestures Classification

After feature extraction and analysis of the input hand image, gesture classification method is used to recognize the gesture. Recognition process affected with the proper selection of features parameters and suitable classification algorithm [5]. For example edge detection or contour operators [7] cannot be used for gesture recognition since many hand postures are generated and could produce misclassification [7]. Euclidean distance metric used to classify the gestures [16][3][14]. Statistical tools used for gesture classification, HMM tool has shown its ability to recognize dynamic gestures [B20][B13]besides, Finite State Machine (FSM) [18], Learning Vector Quantization [19], and Principal Component Analysis (PCA) [20]. Neural network has been widely applied in the field of extracted the hand shape [11], and for hand gesture recognition [21][22][23]. Other soft computing tools are effective in this field as well, such as Fuzzy Means clustering (FCM) [4], and Genetic Algorithms GAs [24].

V. CONCLUSION

In this paper various methods and techniques of hand gesture recognition are discussed, these methods include neural network, fuzzy c-means clustering, HMM feature extraction and also its representation. Neural networks are used as a classifier. For dynamic gestures HMM is used it is also efficient for robot control. For capture the shape of hand, hand segmentation and feature extraction some methods and algorithms are required. The selection of specific algorithm for recognition depends on the application needed. In this work application areas for the gestures system are discussed. Explanation of recent recognition systems are given in detailed.

REFERENCES

[1] Rafiqul Zaman Khan and Noor Adnan Ibraheem B, “Hand Gesture Recognition: A Literature Review”, International Journal of Artificial Intelligence & Applications (IJAIA), Vol.3, No.4, July 2012.

[2] Fakhreddine Karray, Milad Alemzadeh, Jamil Abou Saleh, Mo Nours Arab,“Human-Computer Interaction: Overview on State of the Art”, International Journal on Smart Sensing and Intelligent Systems, Vol. 1(1),2008.

[3] Mokhtar M. Hasan, Pramoud K. Misra, “Brightness Factor Matching For Gesture Recognition System Using Scaled Normalization”, International Journal of Computer Science &Information Technology (IJCSIT), Vol. 3(2),2011.

[4] Xingyan Li., “Gesture Recognition Based on Fuzzy C-Means Clustering Algorithm”, Department of Computer Science, the University of Tennessee Knoxville,2003.

[5] S.Mitra, and T. Acharya, “Gesture Recognition: A Survey” IEEE Transactions on systems, Man and Cybernetics, Part C: Applications and reviews, vol. 37 (3), pp. 311- 324,2007.

[6] Simei G. Wysoski, Marcus V. Lamar, Susumu Kuroyanagi, Akira Iwata, "A Rotation Invariant Approach On Static-Gesture Recognition Using Boundary Histograms And Neural Networks," IEEE Proceedings of the 9th International Conference on Neural Information Processing, Singapura,2002.

[7] Joseph J. LaViola Jr.,"A Survey of Hand Posture and Gesture Recognition Techniques and Technology", Master Thesis, Science and Technology Center for Computer Graphics and Scientific Visualization, USA,1999.

[8] Rafiqul Z. Khan, Noor A. Ibraheem, "Survey on Gesture Recognition for Hand Image Postures", International Journal of Computer And Information Science, Vol. 5(3),2012

[9] Thomas B. Moeslund and Erik Granum,"A Survey of Computer Vision-Based Human Motion Capture," Elsevier, Computer Vision and Image Understanding, Vol. 81, pp. 231–268,2001.

[10] N. Ibraheem, M. Hasan, R. Khan, P. Mishra, "comparative study of skin color based segmentation techniques", Aligarh Muslim University, A.M.U., Aligarh, India,2012.

[11] E. Stergiopoulou, N. Papamarkos, "Hand gesture recognition using a neural network shape fitting technique", Elsevier Engineering Applications of Artificial Intelligence, vol. 22(8), pp. 1141–1158,2009.

[12] M. M. Hasan,P. K. Mishra, "HSV Brightness Factor Matching for Gesture RecognitionSystem", International Journal of Image Processing (IJIP), Vol. 4(5)2011.

[13] Malima, A., Özgür, E., Çetin, M,"A Fast Algorithm for Vision-Based Hand Gesture Recognition For Robot Control", IEEE 14th conference on Signal Processing and Communications Applications, pp. 1-4,2006.

[14] Mokhar M. Hasan, Pramod K. Mishra,"Features Fitting using Multivariate Gaussian Distribution for Hand Gesture Recognition", International Journal of Computer Science & Emerging Technologies IJCSET, Vol. 3(2) 2012.

[15] Mokhar M. Hasan, Pramod K. Mishra, "Robust Gesture Recognition Using Gaussian Distribution for Features Fitting', International Journal of Machine Learning and Computing, Vol. 2(3)2012.

[16] W. T. Freeman and Michal R., "Orientation Histograms for Hand Gesture Recognition", IEEE International Workshop on Automatic Face and Gesture Recognition,1995.

[17] Min B., Yoon, H., Soh, J.,Yangc, Y., & Ejima, T.,"Hand Gesture Recognition Using Hidden Markov Models". IEEE International Conference on computational cybernetics and simulation. Vol.5,1997.

[18] Verma, R., Dev A., "Vision based hand gesture recognition using finite state machines and fuzzy logic". IEEE International Conference on Ultra-Modern Telecommunications & Workshops (ICUMT '09),pp. 1-6, 2009.

[19] Luigi Lamberti, Francesco Camastra, "Real-Time Hand Gesture Recognition Using a Color Glove", Springer Proceedings of the 16th international conference on Image analysis and processing: Part I ICIAP,2011.

[20] Minghai Y., Xinyu Q., Qinlong G., Taotao R., Zhongwang L.,"Online PCA with Adaptive Subspace Method for Real-Time Hand Gesture Learning and Recognition", journal World Scientific and Engineering Academy and Societ WSEAN, Vol. 9(6),2011.

[21] N. A.Ibraheem., R. Z. Khan, "Vision Based Gesture Recognition Using Neural Networks Approaches: A Review", International Journal of Human Computer Interaction (IJHCI), Malaysia,Vol. 3(1),2012.

[22] ManarMaraqa, Raed Abu-Zaiter, "Recognition of Arabic Sign Language (ArSL) Using Recurrent Neural Networks", IEEE First International Conference on the Applications of Digital Information and Web Technologies, (ICADIWT), pp. 478-48, 2008.

[23] Tin Hninn H. Maung, "Real-Time Hand Tracking and Gesture Recognition System Using Neural Networks," World Academy of Science, Engineering and Technology 50, pp. 466- 470,2009.

[24] Cheng-Chang L. and Chung-Lin H., "The Model-Based Dynamic Hand Posture IdentificationUsing Genetic Algorithm", Springer, Machine Vision and Applications Vol. 11,1999.

[25] Kouichi M., Hitomi T., "Gesture Recognition using Recurrent Neural Networks" ACMconference on Human factors in computing systems: Reaching through technology (CHI '91), pp.237-242, 1999.

[26] Guan, Y., Zheng, M., "Real-time 3D pointing gesture recognition for natural HCI",IEEEProceedings of the 7th World Congress on Intelligent Control and Automation WCICA 2008.

[27] Freeman, W. T., Weissman, C. D., "Television Control by Hand Gestures", IEEEInternational Workshop on Automatic Face and Gesture Recognition, 1995.

[28] V. S.Kulkarni, S.D.Lokhande,"Appearance Based Recognition of American Sign LanguageUsing Gesture Segmentation", International Journal on Computer Science and Engineering (IJCSE),Vol. 2(3), pp. 560-565,2010.

[29] G. R. S. Murthy & R. S. Jadon, "A Review of Vision Based Hand Gestures Recognition", International Journal of Information Technology and Knowledge ManagementVolume 2, No. 2, pp. 405-410, July-December 2009.

[30] Sharma, R., Huang, T. S., Pavovic, V. I., Zhao, Y., Lo, Z., Chu, S., Schulten, K., Dalke, A., Phillips, J., Zeller, M. & Humphrey, W. "Speech/Gesture Interface to a Visual Computing Environment for Molecular Biologists". In: Proc. of ICPR'96 II (1996), 964-968.

[31] Gandy, M., Starner, T., Auxier, J. &Ashbrook, D. "The Gesture Pendant: A Self Illuminating, Wearable, Infrared Computer Vision System for Home Automation Control and Medical Monitoring". Proc. of IEEE Int. Symposium on Wearable Computers (2000), 87-94.

[32] Sanjay Meena, "A Study on Hand Gesture Recognition Technique", Department of Electronics and Communication Engineering National Institute Of Technology, RourkelaOrissa 769 008, INDIA,2011.

[33] Thad Starner and Alex Pentland, "Real-time American sign language recognition from video using hidden markovmodels",Technical Report No. 375, M.I.T Media Laboratory Perceptual Computing Section, 1995.

[34] Jennifer Schlenzig, Edward Hunter, and Ramesh Jain, "Recursive spatio-temporal analysis: Understanding Gestures", Technical report, Visual Computing Laboratory, University of San Diego, California, 1995.

[35] ArunKatkere, Edward Hunter, Don Kuramura, Jennifer Schlenzig, Saied Moezzi, and Ramesh Jain, "Robogest: Telepresence using hand gestures",Technical report, University of California, San Diego, Visual Computing Laboratory, Technical Report No. VCL-94-104, December 1994.

[36] Christopher Lee and YangshengXu, "Online, interactive learning of gestures for human robot interfaces" Carnegie Mellon University, The Robotics Institute, Pittsburgh, Pennsylvania, USA, 1996

[37] RichardWatson, "Gesture recognition techniques", Technical report, Trinity College, Department of Computer Science, Dublin, July, Technical Report No. TCD-CS-93-11, 1993

[38] Thomas G. Zimmerman , Jaron Lanier , Chuck Blanchard , Steve Bryson , Young Harvill, "A hand gesture interface device", SIGCHI/GI Proceedings, conference on Human factors in computing systems and graphics interface, p.189-192, April 05- 09, , Toronto, Ontario, Canada, 1987

[39] Rick Kjeldsen and John Kender,"Finding skin in colour images", In Proc. IEEE Int. Conf. on autom. Face and Gesture Recognition, pages 3 12-3 17, 1996

[40] Etsuko Ueda, Yoshio Matsumoto, Masakazu Imai, Tsukasa Ogasawara. "Hand Pose Estimation for Vision-based Human Interface", IEEE Transactions on Industrial Electronics, Vol. 50, No. 4, pp. 676–684,2003.

[41] Chan Wah Ng, SurendraRanganath, "Real-time gesture recognition system and application", Image Vision Comput, 20(13-14): 993-100 ,2002.