# Human Computer Interaction for Vision Based Hand Gesture Recognition : A Survey

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Abstract—The ultimate aim is to bring Human Computer Interaction to a regime where interactions with computers will be as natural as an interaction between humans, and to this end, incorporating gestures in HCI is an important research area. Gestures have long been considered as an interaction technique that can potentially deliver more natural, creative and intuitive methods for communicating with our computers.This paper provides a summary of previous surveys done in this area and focuses on the different application domain which employs hand gestures for efficient interaction. The use of hand gestures as a natural interface serves as a motivating force for research in gesture taxonomies, its representations and recognition techniques.Also provides an analysis of existing literature related to gesture recognition systems for human computer interaction by categorizing it based on different parameters.The main goal of this survey is to provide researchers in the field with a summary of progress achieved to date and to help identify areas where further research is needed.

Keywords-Human-Computer Interaction ;Gesture recognition; human computer interaction; representations; recognition; natural interfaces.

## I. INTRODUCTION

Since the first introduction of computer into the modern era, it has penetrated into all corners of our personal and social lives as a key element revolutionizing our way of living. Surfing the web, typing a letter, playing a video game or storing and retrieving personal or official data are just a few examples of the use of computers or computer-based devices. Due to increase in mass production and constant decrease in price of personal computers, they will even influence our everyday life more in near future. Nevertheless, in order to efficiently utilize the new phenomenon, myriad number of studies has been carried out on computer applications and their requirement of more and more interactions. For this reason, Human-Computer Interaction (HCI), among others, has been considered to be a lively field of research in the last few years [1],[2]

Gesture recognition and gesture-based interaction are becoming an increasingly attractive research subject in HCI. [3] in this work reported that hand has been widely used in comparison to other body parts for gesturing as it is a natural form of medium for communication between human to human hence can best suited for human computer interaction also as shown in table I,II,III.The interest in this area has led to a large body of research which has been digested in a number of surveys directly or indirectly related to gesture recognition. Table I shows some of the important surveys and articles presented in the area of gesture recognition. The following comprehensive analysis of the surveys and articles published earlier related to hand gesture recognition could be used for the design, development and implementation of evolved, robust efficient and accurate gesture recognition systems for human computer interaction. The key issues addressed in the research articles could in many ways help the researchers in identifying the arid regions of the said area and tapping these arid regions towards advances in more user friendly human computer interaction systems.

## II. ENABLING TECHNOLOGIES FOR GESTURE RECOGNITION

Gesture recognition the term collectively refers to the whole process of tracking human gestures to their representation and conversion to semantically meaningful commands. Research in gesture recognition aims to design and development of such systems than can identify explicit human gestures as input and process these gesture representations for device control through mapping of commands as output. Creation and implementation of such efficient and accurate gesture recognition systems are aided through two major types of enabling technologies for human computer interaction namely contact based and vision based devices. Contact based devices employed for gesture recognition systems are based on physical interaction of user with the interfacing device i.e. the user needs to be accustomed with the usage of these devices, hence not adaptable to the nave users. These devices are usually based on technologies like data glove, accelerometers, multi-touch screen etc which uses several detectors. Also there are devices that use only one detector as the accelerometer of the Nitendoc Wii- Remote. This class of contact based devices for gesture recognition can be further classified as mechanical, haptics, ultrasonic,

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Table I: ANALYSIS OF SOME COMPREHENSIVE SURVEYS AND ARTICLES

| ((Moeslund et al.: 01) -[7] | |
|---|---|
| Scope of Analysis | * Covers a large domain of over 130 papers discussing initialization, tracking, pose estimation and recognition of a motion capture system and discusses types of information being processed. * Primarily focused with gesture recognition. * System functionality is broken down into 4 core processes namely: initialization, tracking, pose estimation, recognition. * The significance of this survey is that it provides a comprehensive overview of publications on motion capture for over two decades and the role machine vision plays in terms of full body motion capture discussing the state-of-the-art and how it can be taken forward. |
| Key issues addressed | * Performance characteristics related to system functionality and modern advancements in each of these fields are comprehensively discussed and evaluated. It is interesting to note that while some features (consider robustness, accuracy and speed) are required in a specific domain it may not be a requirement in others. * Problems predominant throughout the domain such as the lack of training data, the large amount of time required for gesture capture, lack of invariance and robustness are explored and possible solutions such as the employment of a approach similar to speech recognition, abstracting the motion layer have been investigated. * While these have proven to be successful to a certain extent it is notable that almost all approaches are greatly limited due to the lack of modularization. |
| (Derpanis : 04) -[8] | |
| Scope of Analysis | * The paper reviews the vision based hand gestures for human computer interaction. *Various aspects of vision based gesture recognition problems are discussed related to: the feature set, the classification method and the underlying representation of gesture set. |
| Key issues addressed | * Research in the areas of feature extraction, classification methods and gesture representation are needed to be performed in order to acquire the ultimate goal of humans interfacing with human machines on their natural terms.*The problem hampering most approaches is that they rely on several underlying assumptions that may be suitable in a controlled lab setting but do not generalize to arbitrary settings. |

Table II: ANALYSIS OF SOME COMPREHENSIVE SURVEYS AND ARTICLES

| (((Mitra et al.: 07)- [4] | |
|---|---|
| Scope of Analysis | *A comprehensive survey on gesture recognition techniques particularly focusing on hand and facial movements.*Covers the use of Hidden Markov Models, particle filtering and condensation, finite-state machines, optical flow, skin color and connectionist models in great detail.*The application of gesture recognition are manifold, ranging from sign language through medical rehabilitation to virtual reality |
| Key issues addressed | * The need for different recognition algorithms depending on the size of the dataset and the gesture performed is identified and various combinations can be drawn out in this regard.*(Eg-A hybridization of HMM and FSM has been proposed in order to recognize a complex gesture consisting of a large range of smaller gestures, the use of a Neural network for a large dataset etc.)*From the research it is notable that any developed system should be both flexible and expandable in order to maximize efficiency, accuracy and understandability of a developed system. |
| ((Chaudhary et al.: 11) -[9] | |
| Scope of Analysis | * This paper discusses the role of intelligent approaches including soft computing based methods like artificial neural network,fuzzy logic, genetic algorithms etc in designing the hand gesture recognition.*The methods in the preprocessing of image for segmentation and hand image construction also taken into study. |
| Key issues addressed | * Appearance based methods is mostly used for detection of fingertip in hand.*Soft computing provides a way to define things which are not certain but with an approximation makes use of learning models and training data. It is effective in getting results where the exact positions of hand or fingers are not possible. |

inertial and magnetic [12]. CyberGlove II and CyberGrasp [13]. Mechanically primed devices are set of equipments to be used by the end user for human computer interaction like IGS-190 a body suite that captures body gestures, CyberGlove II and CyberGrasp a wireless instrumented glove used for hand gesture recognition [13]. These devices need to be paralleled with some other devices for gesture recognition like IGS-190 has to be used in association with eighteen inertial devices for motion detection. Cybergloves and magnetic trackers are also used for trajectory modeling for hand gesture recognition. Haptics primed devices are very commonly used in our daily life based on sense of touch with hardware for human computer interface i.e. multi touch screen devices like Apple iPhone, tablet PC and other devices with multi touch gestural interactions using HMM [14]. Ultra-sonic based motion trackers are composed sonic emitters that emit ultrasound, sonic discs that reflect ultrasound and multiple sensors that time the return pulse. The position and orientation of gestures are computed based on propagation, reflection, speed of time and triangulation respectively [12]. Low resolution and lack of precision are pertained to this set of devices but their applicability to environments having lack of illumination and presence of magnetic obstacles or noise make them usually favored. Inertial primed devices work on the basis of variations of earths magnetic field for detecting motion. Schlomer et

Table III: ANALYSIS OF SOME COMPREHENSIVE SURVEYS AND ARTICLES

| | |
|---|---|
| (Wachs et al.: 11)- [10] | |
| Scope of Analysis | *A comprehensive article on vision based hand gesture application.*Focuses on different aspects of gesture based interface using hands.*Provides an overview on the different challenges present in vision based gesture recognition systems.*The paper discusses different applications which can be controlled using hand gestures. |
| Key issues addressed | * No single method for automatic hand gesture recognition is suitable for every application; each gesture-recognition algorithm depends on user cultural background, application domain and environment.*Aside from technical obstacles like reliability, speed, and low cost implementation hand gesture interaction must also address intuitiveness and gesture spotting.*Two handed dynamic hand gesture interaction is promising area for future research. |
| ((Corera et al.: 11) -[11] | |
| Scope of Analysis | * A survey on tools and techniques used for capturing hand gesture movements. Analysis has been done on different vision based and sensor based hand gesture recognition techniques. * Further discusses on logical issues and design consideration for gesture recognition system. |
| Key issues addressed | * Compares the merits and demerits of vision and sensors based techniques. * It suggests that the way forward is through modularization, scalability and essentially decentralizing the entire approach from gesture capture to recognition. |

al. [15]. proposed gesture recognition using Wii-controller employing HMM independent of the target system. Bourke et al. [16]. proposed recognition systems to detect the normal gestures which are used in our daily activities using accelerometer. Noury et al. [17]. proposed system for multimodal intuitive media browsing in which the user can learn personalized gestures. Variations of artificial magnetic field for motion detection are measured using magnetic primed devices. These devices are not preferred due to health hazards related to artificial electromagnetism. Restrained by the dependence on experienced users the contact based devices do not provide much acceptability, hence vision based devices have been employed for capturing the inputs for gesture recognition in human computer interaction. This set of devices relies on captured video sequence by one or several cameras for interpreting and analyzing the motion [4]. The cameras include infrared cameras that give brittle view of gestures and can be used for night vision. Traditional monocular cameras are cheapest with variations like fish eye cameras for wide angle vision and time of flight camera s for depth information. Stereo vision based cameras deliver 3D world information employing embedded triangulation process. To identify more precisely the detailed particulars in a captured scene PTZ cameras are used. Vision based also uses hand markers for detection of human hand motion and gestures. The hand markers can be further classified as reflective markers which are passive in nature and shines as strobes hit it whereas LED light are active in nature and flashes in sequence. In these systems each camera delivers marker position from its view with a 2D frame which lightens with either strobe lights or normal lights. A preprocessing step is further executed for interpreting the views and positions into a 3D space. The main challenge of vision-based gesture recognition is to cope with the large variety of gestures. Recognizing gestures involve handling a considerable number of degrees of freedom (DoF), huge variability of the 2D appearance depending on the camera view point (even for the same gesture), different silhouette scales (i.e. spatial resolution) and many resolutions for the temporal dimension (i.e. variability of the gesture speed). Moreover, it need also to balance the accuracy-performance-usefulness trade-off according to the type of application, the cost of the solution and several criterias such as real-time performance, robustness, scalability and user-independence. In real-time process the system must be able to analyze the image at the frame rate of the input video to give the user instant feedback of the recognized gesture. Robustness plays an important role in recognizing different hand gestures successfully under different lighting conditions and cluttered backgrounds. The system should also be robust against in-plane and out-of-plane image rotations. Scalability helps in handling a large gesture vocabulary which can be included with a small number of primitives. This makes the composition of different gesture commands easily controlled by the user. User-independence creates the environment where the system can be handled by different users rather than specific user and should further recognize gestures performed by humans of different sizes and colors. The above mentioned enabling technology for gesture recognition has their advantages and disadvantages. As the contact based can be uncomfortable for user since they require physical contact with the user, still having a verge over the accuracy of recognition and less complexity of implementation goes in favor of these devices. Vision based devices though is user friendly but suffer from configuration complexity and occlusion problems. Some of the major merits and demerits of both enabling technologies has been summarized in table IV.

The main disadvantage of contact based devices is the health hazards which are caused by its devices like mechanical senor material which raises symptoms of allergy, magnetic devices which raises risk of cancer etc. Whereas vision based devices have initial challenge of complex configuration and implementations but are more user friendly and hence more privileged for usage in long run. Reckoning the above facts about the two streams of enabling technologies this paper focuses on vision based enabling technologies for hand gesture recognition in its further sections. The

Table IV: COMPARISON BETWEEN CONTACT-DEVICES AND VISION-DEVICES

| Criterion | Contact-devices | Vision-devices |
|---|---|---|
| User cooperation | Yes | No |
| User intrusive | Yes | No |
| Precise | Yes/No | No/Yes |
| Flexible to configure | Yes | No |
| Flexible to use | No | Yes |
| Occlusion problem | No(Yes) | Yes |
| Health issues | Yes(No) | No |

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## III. VISION BASED GESTURE TAXONOMIES AND REPRESENTATIONS

Gesture acts a medium of communication for non vocal communication in conjunction with or without verbal communication is intended to express meaningful commands. These gestures may be articulated with any of the body parts or with combination of one or many of them. Gestures being major constituent of human communication may serve as an important means for human computer interaction too. Though the significance and meaning associated with different gestures differ very much with cultures having less or invariable or universal meaning for single gesture. Hence the semantic interpretation of gestures depends strictly on given culture. Theoretically the literature classifies gestures into two types static and dynamic gestures. Static gestures are defined as orientation and position of hand in the space during an amount of time without any movement and if a movement is there in the aforementioned time duration it is called dynamic gesture. Dynamic gestures include gestures involving body parts like waving of hand as shown in figure 4 while static gestures include single formation without movement like jamming the thumb and forefinger to form the ok symbol is a static pose which represents static gesture. According to research [18]. 35 of human communication consists of verbal communication and 65 is non verbal gesture based communication. Gesture [19]. can be categorized into five types i.e. emblems, affect displays, regulators, adaptors and illustrators. Emblematic gestures also referred as emblem or quotable gestures are direct translation of short verbal communication like waving hand for good bye or nodding for assurance. The quotable gestures are specifically culture specific. Gestures conveying emotion or intensions are called affect displays. The affect displays are generally universal less dependent on culture. Gestures controlling interaction are called regulators. Gestures like headshaking, quickly moving ones leg that enables the release of body tension are called adaptors. Adaptors are generally habit of communicators that are not used intentionally during a communication. Illustrator gestures emphasize the key point in speech to depict the communications pronouncing statements. Being emphasized by the communicators pronouncing statements these gestures are inherently dependent on communicators thought process and speech. These gesticulations could further be categorized into five sub category namely beats, deictic gestures, iconic gestures, metaphoric gestures and cohesive gestures [20]. Beats are short and quick, rhythmics and after repetitive gestures. Concrete pointing to real location object or person and abstract pointing to abstract location or period of time are called deictic gestures. Hand movements depicting figural representation or actions for example moving hand upward with wiggling gingers to depict tree climbing are called iconic gestures. Abstractions are depicted by metaphoric gestures. Thematically related but temporally separated gestures are called cohesive gestures. The temporal separation of these thematically related gestures is due to interruption of current communicator by any other communicator. Vision based Gesture Representations: To abstract and model the human body parts motion several gesture representations and models have been proposed and implemented by the researchers. The two major categories of gesture representation are 3D model based methods and appearance based methods.

## IV. VISION BASED GESTURE RECOGNITION TECHNIQUES

Some of the common techniques used for static and dynamic gesture recognition are as follows: K-means [21]: This classification finds statistically similar groups in multi-spectral space. The algorithm starts by randomly locating k clusters in spectral space. Each pixel in the input image group is then assigned to the nearest cluster centre and the cluster centre locations are moved to the average of their class values. This process is then repeated until a stopping condition is met. The stopping condition may either be a maximum number of iterations (specified by the user) or a tolerance threshold which designates the smallest possible distance to move cluster centres before stopping the iterative process. K-nearest neighbor [22] : It is a method for classifying objects based on closest training

examples in the feature space. k-NN is a type of instance-based learning, or lazy learning where the function is only approximated locally and all computations are deferred until classification. An object is classified by a majority vote of its neighbors, with the object being assigned to the class most common amongst its k nearest neighbors. k is a positive integer, typically small. If k = 1, then the object is simply as signed to the class of its nearest neighbor. In binary (two class) classification problems, it is helpful to choose k to be an odd number as this avoids tied votes. The same method can be used for regression, by simply assigning the property value for the object to be the average of the values of its k nearest neighbors. It can be useful to weight the contributions of the neighbors, so that the nearer neighbors contribute more to the average than the more distant ones. The neighbors are taken from a set of objects for which the correct classification (or, in the case of regression, the value of the property) is known. This can be thought of as the training set for the algorithm, though no explicit training step is required. In order to identify neighbors, the objects are represented by position vectors in a multidimensional feature space. It is usual to use the Euclidean distance, though other distance measures, such as the Manhattan distance could in principle be used instead. The k-nearest neighbor algorithm is sensitive to the local structure of the data. Mean shift clustering [21]: The mean shift algorithm is a nonparametric clustering technique which does not require prior knowledge of the number of clusters, and does not constrain the shape of the clusters. The main idea behind mean shift is to treat the points in the d-dimensional feature space as an empirical probability density function where dense regions in the feature space correspond to the local maxima or modes of the underlying distribution. For each data point in the feature space, one performs a gradient ascent procedure on the local estimated density until convergence. The stationary points of this procedure represent the modes of the distribution. SVM [24]: Support vector machine (SVM) is a non-linear classifier which is often reported as producing superior classification results compared to other methods. The idea behind the method is to non-linearly map the input data to some high dimensional space, where the data can be linearly separated, thus providing great classification (or regression) performance. One of the bottlenecks of the SVM is the large number of support vectors used from the training set to perform classi fication (regression) tasks. HMM [25]: A joint statistical model for an ordered sequence of variables. It is the result of stochastically perturbing the variables in a Markov chain (the original variables are thus ”hidden”). The Markov chain has discrete variables which select the ”state” of the HMM at each step. The perturbed values can be continuous and are the ”outputs” of the HMM. A Hidden Markov Model is equivalently a coupled mixture model where the joint distribution over states is a Markov chain. DTW [26]: Dynamic Time Warping (DTW) has long been used to nd the optimal alignment of two signals. The DTW algorithm calculates the distance between each possible pair of points out of two signals in terms of their associated featur e values. It uses these distances to calculate a cumulative distance matrix and nds the least expensive path through this matrix. This path represents the ideal warp - the synchronization of the two signals which causes the feature distance between their synchronized points to be minimized. TDNN [27]: Time delay neural networks are special artificial neural networks which focus on working with continuous data making the architecture adaptable to online networks hence advantageous to real time applications. Theoretically, time delay neural networks are also considered as an ex-tension of multi-layer perceptron. TDNN is based on time delays which gives individual neurons the ability to store the history of their input signals. Therefore the network can adapt to sequence of patterns. Due to the concept of time delay, each neuron has access not only to present input at time t but also to the inputs at time t 1, t2 .tn. Therefore each neuron can detect relationship between the current and former input values which might be a typical pattern in the input signal. Also, the network is able to approximate functions that are derived from time sampled history of input signal. Learning of typical TDNN can be accomplished by standard back propagation as well as its variants. FSM [28]: A finite state machine is one that has a limited or finite number of possible states (an infinite state machine can be conceived but is not practical). A finite state machine can be used both as a development tool for approaching and solving problems and as a formal way of describing the solution for later developers and system maintainers. There are a number of ways to show state machines, from simple tables through graphically animated illustrations.

## V. Conclusion

Over the last decade numerous methods for gesture tax-onomies and representations have been evaluated for the core technologies proposed in the gesture recognition systems. However the evaluations are not dependent on the standard methods i n some organized format but have been done on the basis of more usage in the gesture recognition systems. Hence the analysis of the detailed survey presented in the paper states the fact that the appearance based gesture representations are more preferr ed than the 3D based gesture representations in the hand gesture recognition systems. Though there are vast amount of information and research publications available in both the techniques but due to complexity of implementation the 3D model based representations are less preferred. The state of art for appli-cations of the gesture recognition systems present desktop applications to be the most implemented application for gesture recognition systems. Future research in the field of gesture recognition systems provide an opportunity for the researchers to come up with efficient systems overcoming

the disadvantages associated with the core technologies in the current state of art for enabling technologies gesture representations and gesture recognit ion systems as a whole. The industrial applications also require specific advances in the man to machine and machine to machine interactions.

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