Wireless and uninstrumented communication by gestures for deaf and mute based on Wi-See technology

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 Abstract: The *fact that technology is advancing as per Moore's law, the attention towards deaf and mute individuals with hi-tech technology is not much. Deaf and mute have to communicate through sign language even for pithy things. And also many people did not understand this language. Now-a-days gesture is becoming an increasingly popular means of interacting with computers. This paper sheds light of an proposed potential idea relying on latest technology named Wi-See which was developed in Washington, US. This technology actually uses our conventional Wi-Fi signals for home automation by gesture recognition. So, depending upon this hi-tech technology, my modified application idea is towards deaf and dumb, especially, one who cannot speak, but knows English language for communication. Since wireless signals do not require line-of-sight and can traverse through walls, proposed idea can be very useful to expressed views by speechless people without requiring instrumentation of the human body with sensing devices. The whole idea is based on Doppler shift in frequency of Wi-Fi signals. Instead of controlling home appliances as by Wi-See, this idea extends its view for speech or words through speakers installed. Each successive pattern of English alphabet generated by Doppler shift by gestures in air, can be recorded and matched with predefined pattern, which when processed, be outputed through speaker as combined letter word ,inspired by English digital dictionary having prediction and correction algorithm.*

Keywords: Wi-Fi, Wi-See, Doppler shift, Gestures, Communication

I. INTRODUCTION

The advancement in application in computer technology is growing at rapid rate. It gave its attention towards hands-free technology requiring least instrumentation and giving tangible experience of interaction. The prior development of the Xbox Kinect[1] is an example of a commercially available input sensor that enables gesture based interaction using depth sensing and computer vision. This is the pioneering step towards making keyboards and mouse obviate in gaming field. It leverages moving hand in air for playing boxing match, shooting with gun by hand motion etc. Moreover, we can control the music volume while showering, or change the song playing on a music system installed in the living room while cooking etc based on this technology. However, cost and burden of installation of equipment like vision-based sensing devices is actually hard to deploy at large scale, for example, in large home or building. Furthermore, Harrison et al. demonstrated the use of bio-acoustic sensors to determine the location of taps on the body [3]. Saponas et al. use electrical recordings of forearm muscles to sense muscle activity and infer finger gestures, which could be extended to other parts of the body [4]. Rekimoto presented a system that used capacitive sensing built into a wristwatch to sense finger gestures [5]. Thus, more traditional approaches have used inertial sensors on the body for tracking whole-body gestures [6].However, these on-body input systems are limited to gestures performed by the parts of the body on which the sensors are placed, and are not particularly effective for recognizing whole-body gestures. Thus, these are limitations which needs to be counter-attack. There is a need to explored ways to move some of the sensing onto the body and reduce the need for environmental sensors. This paper presents potential modified application for society by Wi-See technology[2],a gesture recognition system that requires neither user instrumentation nor an infrastructure of cameras. It can be achieved by leveraging wireless signals   like Wi-Fi in an environment. Taking advantage of these signals, that they do not require line-of-sight and can traverse through walls, this idea can be worked by taking the Doppler shifts and multi-path distortions that occur with these wireless signals from human motion in the environment. The extraction of the minute Doppler shifts are from wide-band OFDM signals, that are typically used in communication technologies including Wi-Fi. Later recognizing the pattern made for mentioning English alphabet at receiver by matching with predefined frequency pattern for alphabets in the system, this information can be feed to speaker for uttering the words from combined letters stored in advanced database. This part is inspired by digital dictionary utterance of words having algorithm of prediction and correction of spelling. And this can be used to express the words through speaker installed in order to communicate by speechless people.

II. RELATED WORK FOR TARGETED PEOPLE

Many researchers and innovators strike very hard in this area of concern for deaf and mute people. Different concepts and approaches are introduced for making the technology easy for personal use. Most of the work is focused on developing different tools inspired from previous one where recognition of sign language if taken into consideration. Rana S. Hassan, Qatar University[8] worked on mobile communication for people with disabilities which is actually a case study on iPhone technology usage for deaf and mute Qatari Adults. The study aims to measure the impact of mobile phones especially the iPhone on deaf community. Moreover, Konstantinos M[9] and this team worked on multimodal tools and interfaces for the intercommunication between visually impaired and deaf and mute people. The main objective of the proposed system is the development of tools, algorithms and interfaces, that will utilize modality replacement so as to allow the communication between blind or visually impaired and deaf-mute users. To achieve this, the system combines the use of a set of different modules, such as gesture recognition, sign language analysis and synthesis, speech analysis and synthesis, haptics, into an innovative multimodal interface available to disabled users. On similar idea, Anbarasi R[10] and team proposed Deaf-mute communication interpreter which too involves glove based Arduino system. The glove comprised of five flex sensors, tactile sensors and accelerometer. For each specific gesture, the flex sensor produces a proportional change in resistance and accelerometer measures the orientation of hand and this whole processing in done by Arduino. Additionally, Shanu Sharma [11] and his students proposed sign language recognition system for deaf and dumb people. They proposed the method and algorithm for an application of recognizing the different signs which is called Indian Sign Language. The images are of the palm side of right and left hand and are loaded at runtime. The method has been developed with respect to single user. Also, the students of Gujarat Technological University, Ahmedabad , Margie A Joshi and her team proposed Electronic support system for physically deaf and dumb[12]. They proposed Gesture Vocalizer which is a multi-microcontroller based system designed to facilitate the communication among the dumb and deaf and their communication with the normal people, in which data glove can detect the movements of a hand and microcontroller based system converts some specified movements into human recognizable data and displays it on screen.

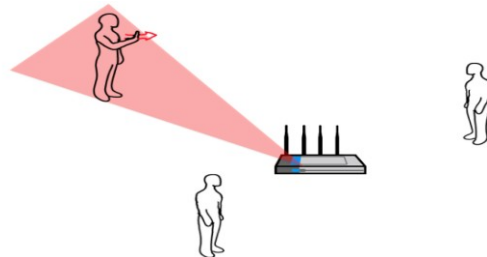## III. OVERVIEW OF WI-SEE AND ITS PROPOSED EXTENDED APPLICATION

Figure 1. Wi-See technology uses multiple antennas to focus on one user to detect the person's gesture
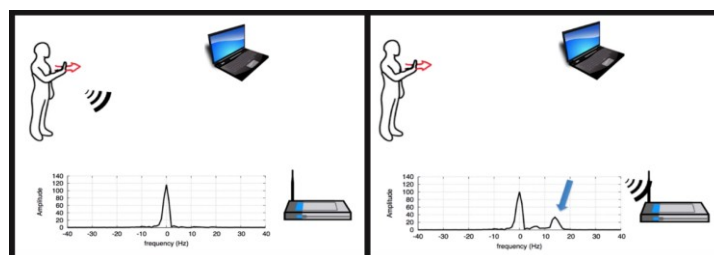

Figure 2. Working of the Wi-See system

Figure 1 and 2,both visualize the concept behind Wi-See technology which involves the key factor of Doppler shift effect developed at University of Washington, US. Later another technology using Wi-Fi as a source of signal named Wi-Vi [13] describes a system that uses single receiver and two transmission antennas which transmit almost identical signals, but out of phase, thus, resulting in interference . This interference causes the signals to cancel each other out. Since any static objects that the signals hit create identical reflections, they are also cancelled out by this effect. Only the reflections that change between the two signals, like moving bodies on the other side of the wall, arrive back at the receiver, allowing the system to track the moving people. But this technology is not area of our interest. The above figures show how there is change in frequency when an object is moved in the air. This detected graph is used to recognize pattern and label our action for specific task.
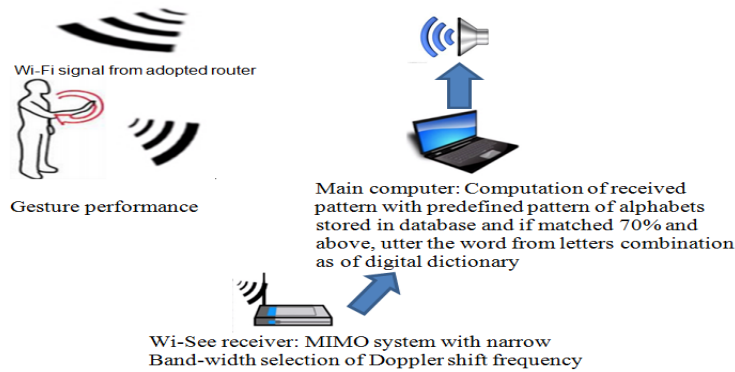
Figure 3. Proposed idea behind this paper

The above Figure 3. gives us the clear idea about extended application of the Wi-See technology. It was quite difficult to recognize Doppler shift pattern information and to extract them. The Wi-See application has identified about 9 different gestures including body movement of which about 94% of accuracy is obtained[7]. So, it is not an easy job to extract all 26 English alphabets from hand gestures in air by Doppler shift of frequency. Since, the shift is very small in the range of 10-150 Hz from 5 GHz Wi-Fi signal, it is difficult to label for all 26 alphabet even though narrow filtering implementation is done. The figures shows that Wi-Fi signal from adopted router having known bandwidth is diverted or reflected by hand motion in the air. The preamble or startup is made for user recognition by repetition of gesture which locks the target user. Then is received by Wi-See receiver which have MIMO system implemented which actually differentiate multiple user by having multiple antennas and also look at the angle and direction of signal received for manipulations. This then can be send to main computer for further processing which includes, pattern recognition and matching with predefined pattern of Doppler shift in database. And thus, can give output based on percentage of match (i.e. if mathcng is about 70% or more)which is then feed to the digital circuitry involving algorithm as that of digital dictionary but, it includes characteristics like spelling correction and prediction of words which is to be uttered.

IV. IMPORTANT FACTORS FOR SYSTEM WORKING

4.1 Capturing information about gestures from signals

The system incorporates the property of Doppler shift [14,15], which is the frequency change of a signal as its source moves relative to the observer. If talking about wireless signals, then a human performing a gesture, results in a pattern of Doppler shifts at the wireless receiver installed. Here point to be noted is that, a user moving her hand away from the receiver results in a negative Doppler shift, while moving the hand towards the receiver results in a positive Doppler shift. And such frequency or amplitude variation having different combination of negative or positive or both Doppler shift can produced different pattern which can be related to alphabets, for example, Moving hand in air by writing H-E-L-L-O can be resulted out when processed. When the person i.e. virtual transmitter moves towards the receiver, the crests and troughs of the reflected signals arrive at the receiver at a faster rate. Similarly, as an object moves away from the receiver, the crests and troughs arrive at a slower rate. More generally, a point object moving at a speed of v at an angle of θ from the receiver, results in a Doppler shift[16] given as,

$$\Delta f \propto \frac{2v\cos(\theta)}{c} f$$

where c is the speed of light in the medium and f is the transmitter's center frequency. However, human hand gestures result in very small Doppler shifts that can be hard to detect from typical wireless transmissions like Wi-Fi, which is about 17Hz[7]. And this problem is solved by transforming the received signal into a narrowband pulse with a bandwidth of a few Hertz. The Wi-See receiver then tracks the frequency of this narrowband pulse to detect the small Doppler shifts resulting from human gestures.

4.2 Classification of gestures

For labeling various letters made by hand motion, the Doppler shift should be clear enough for processing. There are many ways which makes great changes to Doppler shift patterns, of which, the direction of motion with respect to the receiver. For example, a user moving orthogonal to the direction of the receiver results in no Doppler shift, while user moving towards the receiver maximizes the Doppler shift[15]. Since human gestures typically involve multiple point from user moving along different directions, the set of Doppler shifts seen by a receiver can be used to classify different gestures. Higher transmission frequencies result in a higher Doppler shift for the same motion. Thus, a Wi-Fi transmission at 5 GHz results in twice the Doppler shift

as a Wi-Fi transmission at 2.5 GHz. Faster speeds result in larger Doppler shifts, while slower speeds result in smaller Doppler shifts. Thus, this ways one can label different letters of English by varying speed or line of approach, given prior training.

4.3 Registering of user and dealing with multiple path

The system uses the Multiple-Input Multiple-Output (MIMO) concept which is for wireless technology that uses multiple transmitters and receivers to transfer more data at the same time to focus on gestures from a particular user[17]. All wireless products with 802.11n support MIMO, that allows 802.11n to reach much higher speeds. MIMO technology takes advantage of a natural radio-wave phenomenon called multipath. With multipath, transmitted information bounces off - walls, ceilings, and other objects, reaching the receiving antenna multiple times via different angles and at slightly different times. If we consider the wireless reflections from each human as signals from a wireless transmitter, then they can be separated using a MIMO receiver. MIMO makes antennas work smarter by enabling them to combine data streams arriving from different paths and at different times to effectively increase receiver signal capturing power. Furthermore ,in order to register the target for specific action, the target person performs a repetitive gesture, which is used as that person's preamble(start- up). Specifically, the target user pushes his/her hand towards and away from the receiver, and repeats this gesture to form the preamble. This creates a sequence of alternating positive and negative Doppler shifts, i.e., an alternating sequence of +1 and -1 symbols. The Wi-See(system) receiver uses this sequence to correlate and detect the presence of a target human. A system receiver detects this preamble to estimate the MIMO channel that maximizes the energy of the reflections from the user[7]. Once the receiver locks on to this channel, which is like password of someone, the user can perform normal (non-repetitive) gestures of writing alphabets in air rigorously, because to detect each alphabet by distinguishing Doppler shift, and thus can communication , that the receiver classifies using the Doppler shifts.

4.4 OFDM- Modulation involved in this wireless system

Orthogonal Frequency Division Multiplexing is a method of encoding digital data on multiple carrier frequencies[18]. OFDM is the modulation having multicarrier system which is used for most of the modern wireless systems or standards including 802.11 a/g/n and WiMAX. OFDM divides the used RF bandwidth into multiple sub-channels and modulates data in each sub-channel. Figure 1. shows the time-domain OFDM symbol is generated at the transmitter by taking an FFT over a sequence of modulated bits transmitted in each OFDM sub-channel. Specifically, the transmitter takes blocks of N modulated bits (N = 64 in 802.11), and applies an N-point Inverse Fast Fourier Transform (IFFT) given as,

$$\mathbf{x}_k = \sum_{n=1}^{N} \mathbf{X}_n e^{i2\pi kn/N}$$

where Xn is the modulated bit sent in the nth OFDM sub-channel. Each block of x1 to xN forms a time-domain OFDM symbol that the receiver decodes by performing the FFT operation given as,

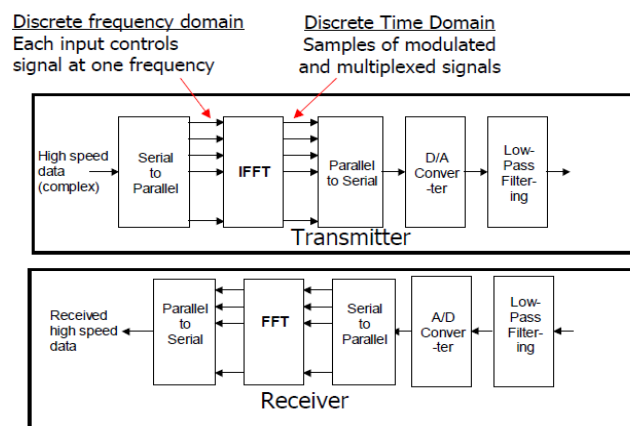$$\mathbf{X}_n = \sum_{k=1}^{N} \mathbf{x}_k e^{-i2\pi kn/N}$$

Figure 4. Baseband ODFM system

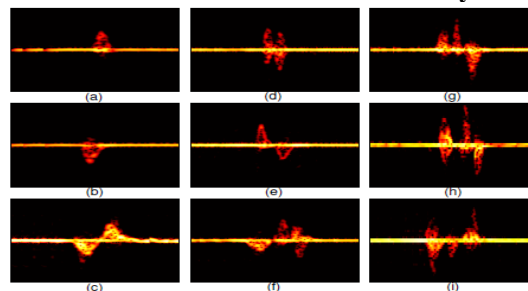## V. Observed Patterns Of Gestures By Wi-See

Figure 5. Frequency-time Doppler patterns of the gestures

Figure 5.[7] show the profiles of gestures performed which are actually combination of positive and negative Doppler Shifts[7]. Figure. 5(a) has just one segment with positive Doppler shift for Push gesture,whereas, Figure. 5(b) has just one negative Doppler shift for Pull gesture .Similarly,Figure .5(c) corresponds to Circle motion gesture,Figure 5.(d) corresponds to Dodge gesture, Figure 5.(e) corresponds to Drag gesture,Figure 5.(f) corresponds to PunchesX2 gesture, Figure 5.(g) corresponds to Strike gesture, Figure 5.(h) corresponds to Kick motion, Figure 5.(i) corresponds to Bowling gesture. Thus, within each segment, the Doppler energy first increases and then decreases (which correspond to acceleration and deceleration of human body parts).Thus, based on such patterns, different patterns for different alphabets can be devised by several experimentation.

VI. Conclusion And Future Scope

There is an attempt to proposed an idea of developing a wireless and uninstrumented aid for deaf and mute people in society by taking the concept of wireless interfacing technology-WiSee. From the main reference[7], it is clear that it is difficult to manipulate the slight variances in Doppler shift. Thus, the proposed idea of labeling such Doppler shift to each hand motion in air for 26 alphabets is quite different which requires intense research in developing Wi-See receiver capable of receiving such small variance in Doppler shift. Then it is possible to implement the idea which can be used for communication by words uttered from speaker installed in buildings or rooms, where deaf and mute people resides. Moreover, this application if developed to full extent can also add symbols for faster communication.

Acknowledgement

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