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Monitoring Body Motions Related To Huntington Disease by Exploiting the 5G Paradigm

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Abstract- The modern wireless technology exploiting the full potential of 5G IoT is the future for healthcare sector. In the healthcare sector, the 5G technology will maximize the performance and will reduce the chances of damage to the patient by providing careful and advance activity monitoring scenarios. We have proposed the idea of monitoring different body posture in Huntington disease by exploiting the low cost wireless devices operating at 4.8 GHz frequency. The system captures the wireless channel information for three body motions and classification of these motions was performed by using support vector machine. The SVM used 10 time-domain features for the classification process by using three main kernel functions, such as, Linear, Polynomial and Radial basis function. The system minimizes all the external noise by using the microwave absorbing materials. This increases the performance and feasibility of sensing body motions.

Keywords—Wireless channel information, support vector machine, wireless sensing, internet of things, Huntington disease.

I. INTRODUCTION

In modern wireless communication, IoT (Internet of things) is the emerging technology and enhances the performance of modern wireless sensing. The sensing capabilities of wireless devices increases with the help of IoT. The 5G technology and its integration with the IoT will intensify the machine to human interaction with modern sensing systems. In healthcare sector, there is huge demand of remote sensing and the modern IoT technology makes this viable by transferring or interchanging healthcare data over a long distance [1].

The eHealth sector is highly efficient with in the IoT paradigm and 5G technology will transfer the healthcare data through reliable wireless channel with maximum spectral efficiency. In the 5G paradigm, the healthcare sector will progress exponentially by exploiting higher spectral efficiency and better sensing scenarios. [2] Remote sensing for healthcare sector demands reliable data transfer and sensing capabilities, both covered with 5G technology by supporting huge number of healthcare applications with maximum data bandwidth and safe remote sensing.

Wireless sensing using RF technology within 5G C-Band paradigm is enhancing the living standards of human beings

by providing the safe and reliable remote healthcare monitoring scenarios for patients with different diseases. In many hospital environments, many patients need to be monitored timely to avoid any uncertainty [1]. The 5G C-Band technology is the key to these problems and provides best possible human activity monitoring scenarios. The disease like Huntington is one of the neurodegenerative disease. It mainly affects the body movement and damages the neurological system with the passage of time. Patient needs monitoring to avoid critical accidents and monitor the patient's condition over time. Huntington disease is an inherited disease and was enlightened by Huntington in the era of 1872. One of the most common form of HD [3] is adult-onset. People in their thirties and forties are highly affected by this stage and the most common symptoms includes, depression, uncontrolled body movement, unable to think, unable to speak etc. If we deeply dig into HD, chorea [3] [4] is one of the dangerous form of this disease, where patient feels jerky movement and body twitching. In the absence of careful monitoring, chances of damage increases, as this disease is a progressive disease. There must be a system, which carefully monitors the chorea stage of HD [5], the jerky movements.

In this paper, we have proposed the unique system, which exploit very simple and low cost commodity wireless devices operating at 4.8 GHz frequency to monitor various human activities. Each body motion imprints unique wireless channel information (WCI). The WCI then used to differentiate the human activities. We have used machine-learning algorithm (SVM) to classify different body motions in Huntington disease. In HD, body motion related to fits must be monitored to provide necessary medical assistance to patient on time. Our system shows maximum feasibility to capture all the motions with in HD.

II. RELATED WORK

In healthcare sector, there are many wearable systems to monitor the body postures but none of the technique monitor the jerky motions in HD wirelessly. Patrica Sampson et al [6] showed the concept of Functional Electrical simulation by

using the concept of passive robotic. In this, patient's upper limb is monitored using virtual reality tasks and improvement was made with some modification in the system. Subhash chand Agrawal et al [7] presented the idea of monitoring the human activity using video surveillance system, although this system showed some promising results compromises the patient's privacy. Tran Duc Tan et al [8] presented the idea of using accelerometer sensor integrating with GSM module. In general, our system showed some promising results for monitoring the human activities. The proposed system is cost effective and works in low power mode.

III. PROPOSED SYSTEM DESIGN

The proposed approach exploits the low cost commodity wireless devices operating at 4.8 GHZ frequency to capture the WCI for different body motions [9]. The RF signal generator is at the transmitter side behaves as the AP and pings at 20 packets per seconds. The Omni-directional antenna connected with the Dell desktop behaves as receiver. The network interface card (NIC) is mounted inside the desktop to capture the WCI for all body motions. The NIC captures 30 subcarriers [10] information for each body motions.

In the wireless communication the multipath greatly affect the transmission and degrades the system performance, due to the multipath, the reflection and fading disturbs the real data transmission and hence the sensing system captures the noise as well [11]. To overcome these scenarios we have used microwave-absorbing materials. The system with microwave absorbing platform (MAP) reduces the noise such as, reflection, refraction and multipath fading. Figure 1 shows the activity-monitoring scenario of our system.

Figure 1: System Activity Monitoring Scenario

The overall system capture the information of 30 subcarriers in the form of WCI. The transmitter and receiver were placed one meter above the ground and four meters below the ceiling. The distance between the transmitter and receiver was adjusted around four meters. The person moves between the transmitter and receiver, disturbs the wireless signals and showed unique WCI, captured by NIC at the receiver side. The received data presented in the form of matrix of H of dimension 30×1 . This matrix H shows unique Channel frequency responses for every motion and represented as follow,

$$H_m = [h^1(m), h^2(m), h^3(m), \dots, h^{30}(m)] \quad (1)$$

The above equation shows the CFR of all the subcarriers, where m represents the total number of received packets. In this system, we capture the WCI three body motions, walking, falling and fits. The WCI for three motions is shown in Figure 2.

Figure 2: Raw CFR for different body motions.

IV. RESULT AND DISCUSSION

This section explains the obtained results from the proposed wireless sensing system [15]-[23]. The operating frequency of the proposed system is 4.8 GHz [12]. The system captures the WCI of different body motions in HD disease. We have performed the measurements on six different subjects. The system design is shown in Figure 1.

The system works, as AP pings at 20 packets / seconds and the receiver receive the WCI of different body motions in the form of matrix H (channel matrix) of 30×1 [13][14]. The system captures the CFR of 30 subcarriers and the obtained CFR gives the information regarding frequencies and number of antennas used in the sensing process. After measuring the wireless data, SVM then perform the classification and classify each motion correctly to its corresponding class.

SVM used hyperplane to separate two classes with better classification. This classifier lies in the category of supervised machine learning and showed better performance by using best possible features. Matlab built in function, *svmtrain*, did the training of SVM by using *one-versus-rest* approach. Three kernel functions used in the classification process are shown in the Table 1.

Table 1: Kernel Function

Type	Kernel Function $S(x, x_i), i=1,2,3,\dots,P$
Linear	$x^t x_i + C$
Quadratic	$(x^t x_i + C)^d$
Radial-basis function (RBF)	$e^{-\frac{\ X - X_i\ ^2}{2\sigma^2}}$

Furthermore, the CFR of different body motions show unique changes and hence can easily be differentiated. Figure 3 shows the CFR for three body motions.

Figure 3: CFR for three body motions with different subcarriers

The above Figure 3 show unique frequency response for three body motions. Every body motions shows the CFR for different subcarriers. Each mentioned subcarrier (walking #9, running #21, fits #7) gives the best result for sensing each human activity. We have tested all 30 subcarriers for each body motion but the mentioned subcarriers showed best possible results. The system showed feasibility of using all subcarriers [23][24]. Figure 3 shows the total number of packets received, 600 packets represents each mentioned class. Total 400 packets used for the training of the classifier and 200 for testing purpose. The Table 2 represents the confusion matrix for testing using RBF Kernel.

Table 2: Confusion matrix

Class (H1, H2, H3)	Confusion matrix for SVM		
	Walking	Running	Fits
Walking	197	0	2
Running	1	198	1
Fits	2	2	197

Table 2 represents the confusion matrix for SVM. Total 10 time-domain features are used in the classification process [16][17]. The RBF and polynomial kernel functions showed better performance as compared with the linear kernel function. The accuracy of the classifier is directly proportional to the number of features used; hence, accuracy increases by increasing the number of features. Each body motion then classified to its particular class represented by H1, H2, and H3 [18]. The SVM performance was measured by calculating the six performance matrices such as accuracy, precision, recall, specificity, Kappa and F-measure. These performance matrices are shown in the Table 3.

The overall result from the classification using RBF kernel [19] clearly differentiate the three human activities related to HD. The accuracies for walking, running and fits are above 90 % and the fits motion shows maximum accuracy of 100 %. The recall values for three classes lies between 95 to 99 % and hence represents the maximum classification result [20][21]. The values of specificity and F-measure lies between 96 to 99 %. The obtained kappa value for SVM classifier with RBF kernel is 0.96. If the kappa value is 1, it shows maximum classification and the SVM in our case showed best classification result. We have performed the experiment on 6 different subjects [25][26][27].

The experiment was performed for multiple times on six different subjects and average of the experimented values were observed. Every subject showed unique WCI for different motion [22]-[28]. The subject stayed in the particular motion for 30 seconds each.

Table 3: Classification results for SVM using RBF Kernel

Class	Accuracy	Recall	Precision	Specificity	F-Measure	Kappa
Walking	97.5	97.4	97	99	96.4	0.96
Running	98	98	98	97	98	
Fits	99.25	98	97	98	99	

The above result is obtained using 10 time-domain features using RBF kernel function. The time domain features showed reliable performance in our case. Table 4 represents the mentioned time domain features used by SVM for the classification of different human activities.

Table 4: 10 time-domain features

Root mean square (Y_{RMS}) = $\sqrt{\frac{1}{P} \sum_{i=1}^P x_i^2}$	Crest Factor (Y_{CF}) = $\frac{\max(x_i)}{Y_{rms}}$
Marginal factor (Y_{MF}) = $\frac{\max(x_i)}{Y_{SRA}}$	Skewness value (Y_{SV}) = $\frac{1}{P} \sum_{i=1}^P \left(\frac{x_i - \mu_x}{\sigma} \right)^3$
Square root of amplitude (Y_{SRA}) = $\left[\frac{1}{P} \sum_{i=1}^P \sqrt{ x_i } \right]^2$	Impact factor (Y_{IF}) = $\frac{\max(x_i)}{\frac{1}{P} \sum_{i=1}^P x_i }$
Mean value (Y_{MV}) = $\frac{1}{N} \sum_{i=1}^P x_i$	Peak to peak value (Y_{PPV}) = $\max(x_i) - \min(x_i)$
Kurtosis value (Y_{KV}) = $\frac{1}{P} \sum_{i=1}^P \left(\frac{x_i - \mu_x}{\sigma} \right)^4$	Standard deviation (Y_{STD}) = $\sqrt{\frac{1}{P} \sum_{i=1}^P (x_i - \mu_x)^2}$

V. CONCLUSION

The proposed system increases the performance of monitoring human activities in healthcare sector. This system monitor different body movements related to Huntington disease by using wireless sensing technology operating at 4.8 GHz frequency. The amplitude information for each body motions shows unique WCI and SVM is used to classify these body motions. Our system shows maximum classification results with 96 to 99% of accuracy.

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