

AN IOT-BASED WEARABLE FALL DETECTION SYSTEM AND ALERTING SYSTEM

¹K.NAGA MALLESWARI, ²K.SAIKUMAR, ³CH.DURGARAO, ⁴SK.AKBAR, ⁵RAJESH KATRAGADDA

^{1,2,3,4}Students of ECE, Chalapathi Institute of Engineering and Technology, Lam, Guntur.

⁵Professor of ECE, Chalapathi Institute of Engineering and Technology, Lam, Guntur.

ABSTRACT:

Seamless monitoring is one of the major challenges for human community because of increasing the strength of sixty years old people and occurrence of many accidents in falls-risk related works like construction, manufacture and others. Wearable IoT devices are useful for continuous health monitoring, analyzing the behaviours, and fall detection. Falls are one of the foremost causes for injuries and death in our life. Present work proposes the human movement monitoring by using the pressure sensor for avoiding human falls and also the health report prepared from historical data's uploaded in cloud by support-vector machine (SVM) algorithm. The proposed wearable IoT device for seamless monitoring system is proving 99% accuracy, less complex and compatible to use over other IoT wearable devices.

KEYWORDS: wearable IoT devices, fall detection, SVM algorithm, machine learning.

1. INTRODUCTION

Fall is the most important reason for the increase in the injury rate and mortality rate in the elderly and hazardous work related community. Moreover, there is a significant risk to the nation and world through the financial costs related with accidents and injuries. In this situation, monitoring individuals over the wearable devices for possible falls during job-related events, unbalance elder or any health issue fall. Many fall detection systems were established as the time passed. The systems which were developed are classified as: Wearable sensors-based and Surveillance-based fall detection systems. Infrared sensors, vibration detection sensors, cameras, depth cameras, range-Doppler radar, fiber optic sensors, smart tiles, acoustic sensors etc. have been used in Surveillance-based fall-detection systems. These devices are generally positioned in a pre-built area to monitor the elderly moments. The radar and cameras are fixed in particular place in room. Due to their fixed characteristics, these are able to monitor specific predetermined zones only. Monitoring the people, the surveillance based systems are comfortable but particularly systems based on camera do not cover the customer's secrecy, and consequently prohibited in areas like washrooms, toilets etc. On the other hand, wearable sensor-based systems employ several sensors such as pressure sensor, pulse sensor, gyroscope and tri-axial accelerometer etc. Ascribed to developments in micro electromechanical systems, numerous sensors like pressure sensor, gyroscopes and accelerometers have developed very condense and effortlessly combined into embedded systems. Several Fall detection algorithms based on smartphones have been projected in current years. The most used algorithms in fall detection include Machine-Learning

algorithms such as Random Forest, Decision Trees, Support Vector Machine (SVM), KNearestNeighbors (K-NN).

2. RELATED WORK

Fangzheng Wang, et al (2019) proposed a multi-sensor fusion gait recognition system to accurately control the exoskeleton movement. The system receives plantar pressure and human foot acceleration alerts. In the experiment, the device obtained pressure signals from both feet, left calf and right calf, waist, left thigh, right thigh, motion data from five test subjects, and examined level walking gaits, going down the stairs, going up the stairs, going down the slope, going up the hill and standing. It contrasted the gait recognition accuracy of neural network back propagation (BP), radial base function (RBF), support vector machine (SVM) neural network. Various sliding window sizes of SVM algorithm were analyzed.

Komal Singh et al (2020) provides a review of device which are wearable, vision based systems and context-aware fall detection systems. People often forget to carry the wearable devices with them in case of wearable device-based method. If the system is button operated, the people often not able to press the button after fall or forget to press the button before fall to generate an alarm. At the other side, children often use this button just to create inconvenience for their parents. Vision is used in context-aware approaches. It analyses the information produced by pressure and vibration during a fall that is susceptible to environmental noise. It uses surveillance cameras that have been mounted in the environment anywhere, such as hospitals, houses, shelter homes, to collect data with rich information which can be used to perform many functions. Also, working with photos and videos has become simple and smart with the advent of Deep Learning. Anita Ramachandran et al (2020) Applied different machine-learning algorithms to a public fall detection dataset. A combination of vital sign and IMU sensors that are designed to be incorporated into a wrist-band also describes the data generated. Such wrist bands will be worn in care homes for elderly adults, where the edge device is intended to be installed.

Anuradha Singh et al, (2020) The fall detection system is categorized into image, acoustic, PIR, radar, floor pressure, smartphone-based, near field imaging, ultrasonic based on the suggestions of sensor technologies. Sensor technology for different applications was summarized for selecting the suitable technology by the researchers and the manufacturers. Harish Chander et al, (2020) summarized the challenges of the current WSS design, development and testing an ankle and foot wearable device with a soft-robotic-stretch(SRS) sensor for human fall detection. The SRS sensor based series of Parts from I to V articles in “Closing the Wearable Gap” investigate were analyzed. Insoo Kim et al (2019) proposed fall detection system to detects fall accidents in farming events by using insole-integrated sensor devices. The system responds to the emergency service. It comprises a force sensitive resistor pressure sensor and a three-axial accelerometer. Threshold values were fixed using data took by the sensors to differentiate the emergency situations and fall. When a fall or emergency is detected, the accident- associated message automatically sent to a authorized person or nursing center. Lan Wang et al (2020) proposed multi-class fall recognition system. Multi-source CNN Ensemble (MCNNE) structure is used for obtaining the feature from multiple sensed data. Data from N number of sensors are pre-processed and configured as a training data set individually, and output features map from N number of sensors are combined to engender an complete feature map.

Zhixin Liu, et al (2020) proposed scheme has two major advantages. Firstly, the proposed system uses temperature analysis and basic personnel positioning to identify unusual fall points. Analyzing the suspicious points not only detects the fall state in authentic time, but additionally minimizes the analysis of impertinent data. Secondly, the layered data processing and the improved methods in the extraction phase of the feature enhance the accuracy. Random forest classifier machine learning algorithm is used to achieve better generalization capacity and more precise classification. Huda Ali Hashim, et al (2020) Depending on sensed data which one generated by the two accelerometer were placed on the patient's body, the data event algorithm (DEA) based low-power wearable fall-detection system (WFDS) using ZigBee was suggested for PD patients. Direction-drop event (DFE) algorithm helpful to identify the fall path of the PD was precisely determined. XugangXi et al (2020) Based on plantar pressure and surface electromyography (sEMG) signals, categorized the daily activities and fall statistics was investigated. Fisher class separability index, adequate features were selected for extracting the obtained plantar pressure and sEMG signals. In order to minimize dimensions, a feature-level fusion process, the genetic weighting algorithm, was suggested.

David Sarabia-Jácome et al, (2020) Present an advanced, highly efficient intelligent framework for the timely detection of falls using Deep Learning techniques installed on resource-controlled devices (fog nodes), based on a fog-cloud computing architecture. To enable the management of DL models and remote deployment in LSTM,GRU and fog, a intelligent IoT-Gateway were installed using virtualization to maximize the inference time, resources and assess their efficiency. Sheikh Nooruddin et al (2020) investigated fall identification system using a tri-axial accelerometer, GPS, GSM, Wi-Fi , buzzer, smartphones and Raspberry Pi, Arduino, Node MCU as an processor. The framework is mainly based on the architecture of client-server. A linear classifier model is used by pre-trained multi-threaded server hosts. The devices attach to the server threads and continuously communicate the movement information to the server from the accelerometer. The server forecasts whether or not a fall has happened and responds. Response messages are kept by the processors. The server sends an emergency signal containing the proximity of the concerned client and various related statistics to the authority if a fall is observed. Through using SMS holding device location, sounds the buzzer as a failsafe and contacts emergency services and intermediaries. Instant clinical assistance can therefore be obtained by the monitored person.

The rest of the paper is structured as follows: Section 2 gives a description of the entire fall detection system. The experimental results of the suggested system are given in Section 3. Finally, a closing comment such as constraints and steadiness of the system are given in Section 4.

3. PROPOSED SOLUTION

The fall prediction and prevention system architecture which was proposed is showed in Figure. 1. It has four blocks: The data collection unit contains different sensors like pulse sensor, temperature sensor, pressure sensors and all, Multi-threaded server for execute the pre-trained model with historical data and existing date to generate the reports, Control unit for taking choice from cloud data and sensor data, Service unit has Airgap for stopping from injuries, Wi-Fi module for sending SMS to authored individual and emergency services. An Wi-Fi module, accelerometer module, GSM module, GPS module are communicate modules. These modules are used in all cutting-edge smartphones. For these purposes, single-board computers such as single-board microcontrollers and Raspberry Pi such as NodeMcu and Arduino are used and can also interact easily with and use these modules accordingly. The Raspberry Pi has a Wi-Fi on-board module. NodeMcu is based on a Wi-Fi module named ESP8266. To interface the analogue sensors with the Raspberry Pi, an extra ADC module is needed.

The gadget is kept in the pant pocket on the left or right of the person. The processor collects the movement data of the user. The data is sent to the server for each movement. The server analyses the data and sends back the product of the classification to the respective unit. For our design, we are using pulse sensor, insole pressure sensor along with accelerometer inbuilt in smartphone for data collection unit to sense the human data, Bolt IoT controller and Arduino UNO used in controller unit to take decision either hit the fall prevention by sending the trigger signal to airgap unit and send SMS to authorized person by Twilio or not from the sensing data and cloud data which one generated by SVM (support vector machine) Machine learning algorithm.

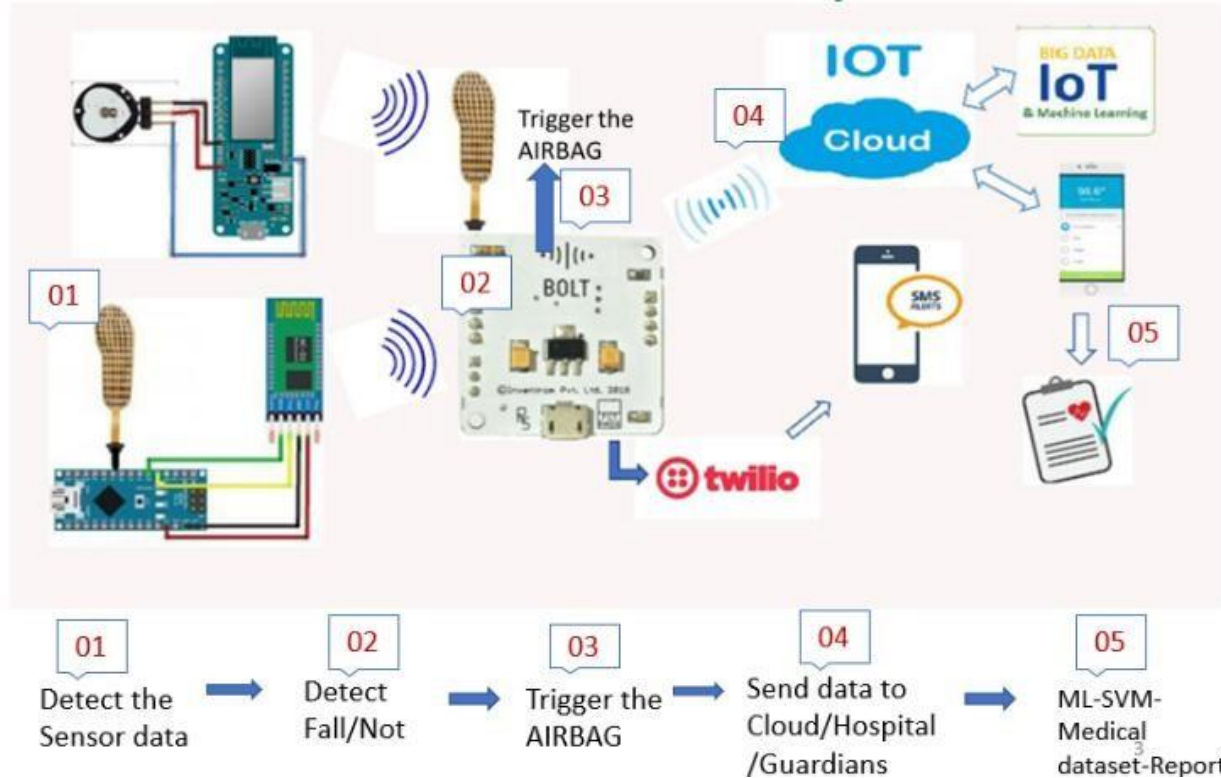


Figure 1. Overview system model of Proposed system

Bolt IoT module:

Bolt is an IoT network that lets companies and manufacturers connect to the internet with their devices. To connect your sensors to the Internet, the Bolt comes with a Wi-Fi / GSM chip. To receive, store and visualise the data, we can configure this system via the Bolt cloud. It has 32 bit RISC MCU, inbuilt ESP8266 and auto cloud connectivity.

Film Foot Pressure Sensor:

High Accuracy Film Foot Pressure Sensor, Induction Flexible Sensing Mat for Gait Analysis has the bottom and top layers are bonded by double-sided adhesive, and the sensing areas of the upper and lower layers are isolated. The bottom layer is a flexible film and a conductive layer conforming thereto, and the top layer is a flexible film and a pressure-sensitive material compounded thereon. The foot pressure sensor is composed of a polyester film with excellent comprehensive mechanical properties, a highly conductive material and a nano-scale sensing material. Fast response, durable and long service life. When the sensing area is pressurized, the wires separated from the bottom layer are turned on, and

the output resistance of the sensing area changes with the pressure. It operate in 100g triggering Force, 0.5K-50KΩ Resistance Use Range, 0.1KG-10KG Pressure Range and <1ms response Time. Film Foot Pressure Sensors arrangement and observation are shown in Figure 3. Two Film Foot Pressure Sensor are using to detect the human activities like stand, walk, run, stair, sit or fall with respect of both pressure sensor values are stable, continuously change, Changing leg1 and 2, both pressure value is zero respectively.

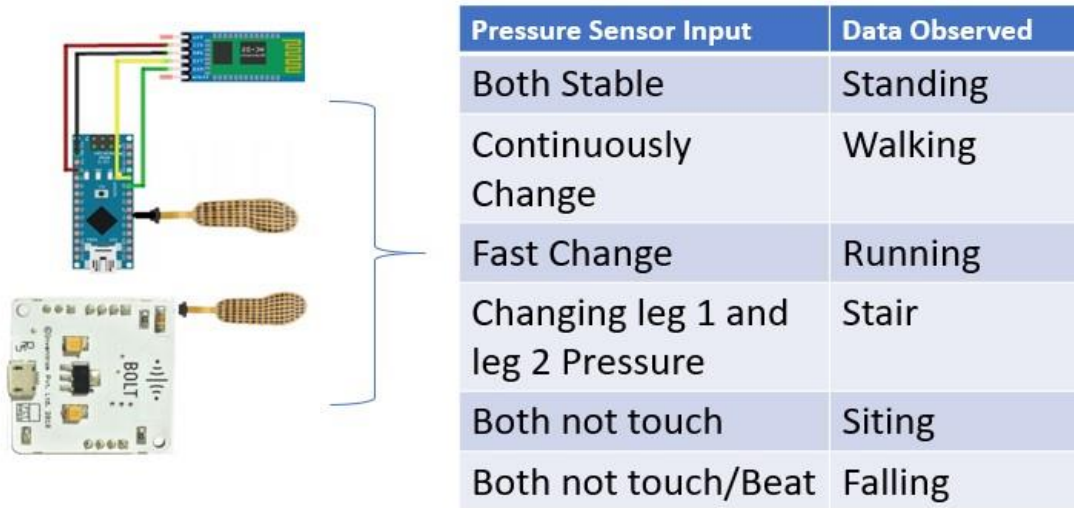


Figure 2. Film Foot Pressure Sensors arrangement and observation

4. **METHODOLOGY-convolutional neural network**

In proposed system, When power ON, Bolt IoT module sense the pulse rate(P1), temperature(T1), sound signal(S1) if any, pressure value of both leg(L_{P1},L_{P2}), value of accelerometer(A1) from smart phone and send to Bolt Cloud.

All P1,T1,S1, L_{P1},L_{P2} and A1 values were stored in Bolt cloud as a time frame signal pattern and classify the frame as siting, standing ,walking ,running, Stair Up, Stair down and Fall.

SVM algorithm predict the either siting, standing, walking ,running, Stair Up, Stair down and Fall with help of current data frame, historical data and trained data set.

Based on server signal which one generated by SVM algorithm and sensor signals, Bolt IoT module generate the trigger signal to Airbag unit and send the alert signal to authorized mobile number in advance if fall predicted.

After a minutes, proposed system check whether Airbag and sensors values are normal or Not. If normal process goes to step one and repeated.

If detected null value from foot pressure sensors and accelerometer sensor then make a call to family doctor and ambulance service.

5. **DATA COLLECTION AND PREPARATION**

A.Experimental Setup

One Bolt IoT module, two Arduino inbuilt with WiFi module, two smart phones inbuilt with accelerometer module, two film foot pressure sensors, one pulse sensor, one temperature sensor, sound sensor were used to design a Wearable IoT Devices for Fall avoidance by Human Movement Monitoring system. For providing connection, JIO M2 Wireless Router was also used. For generating warning noises, an active buzzer was chosen as it does not need timing circuits or external oscillators, not like a passive buzzer. Integromat and Twilio also used to send the SMS alert to the authorized phone numbers.

Bolt IoT has ESP8266 module for connectivity, 32-bit RISC CPU ,80Mhz clock frequency,64 KB instruction RAM, 4MB Flash memory, 96 KB of data RAM,1pin 10 bit ADC, PWM capable pins and auto connected Bolt Cloud setup also. Arduino Uno ATmega328P+ WiFi R3 ESP8266 4MB board also used in our proposed system along with pulse sensor, temperature sensor and sound sensor for gathering biological value in our body.Two smartphones: a Oppo A9 128GB and Xiaomi Redmi Note 9 Pro 4GB RAM, 64GB Storage were substantially tested for the proposed system as client devices. These Smartphones has Octacore processor, onboard Wi-Fi and supports 802.11 a/b/g/n onboard accelerometer. Python code used for collecting and analyzing the sensed data in client and implementing SVM algorithm in server for taking Advance decision to trigger the airbag.

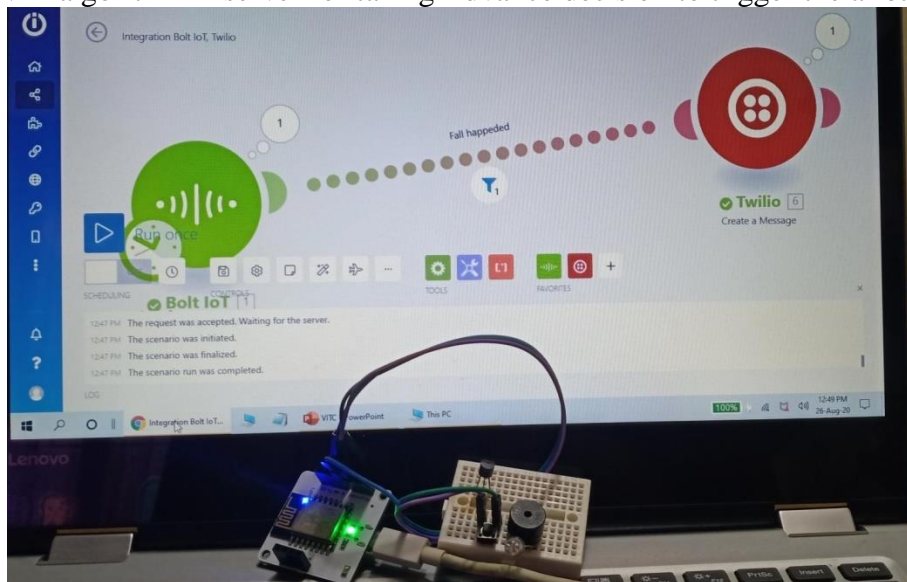


Figure 3. Proposed model Hardware and Software setup.

B.Results analysis

The sensitivity and specificity are two statistical measures to quantify the performance of SVM classifiers. The other term used to measure a classifier model's overall performance is accuracy. Sensitivity is the proportion of actual positives that the classifier has properly defined as positive. Specificity is the percentage of real negatives that the classifier has correctly well-defined as negatives. The part of relevant occurrences among the retrieved occurrences is defined as accuracy or positive predictive value. Relevance measurement is described by both Precision and Recall. Precision can be seen as an accuracy or quality measure, whereas remembrance is a completeness or quantity measure. In numerical investigation of binary classifiers, F1 score is the estimate of a test's precision. It considers both the importance of the test's precision and recall to assess the ranking. The F1 score is the harmonic indicator of accuracy and recall. The maximum F1 rating is 1 and the minimum rating is 0. A

confusion matrix is created to estimate the performance of the trained model by True Positives (TP) are the fall data that the classifier has correctly classified as "fall." True Negatives (TN) are non-fall data that the classifier has properly categorized as non-fall. False Positives (FP) are non-fall data wrongly classified by the classifier as falling, while False Negatives (FN) are fall data incorrectly classified by the classifier as non-falling. A low False Positive and Fall Negative rate should have a stable machine-learning model. Accuracy is the amount of correct positive outcomes separated by the number of all positive outcomes returned by the classifier, and accuracy is the number of correct positive outcomes separated by the number of all appropriate samples (all samples that should have been marked as positive).

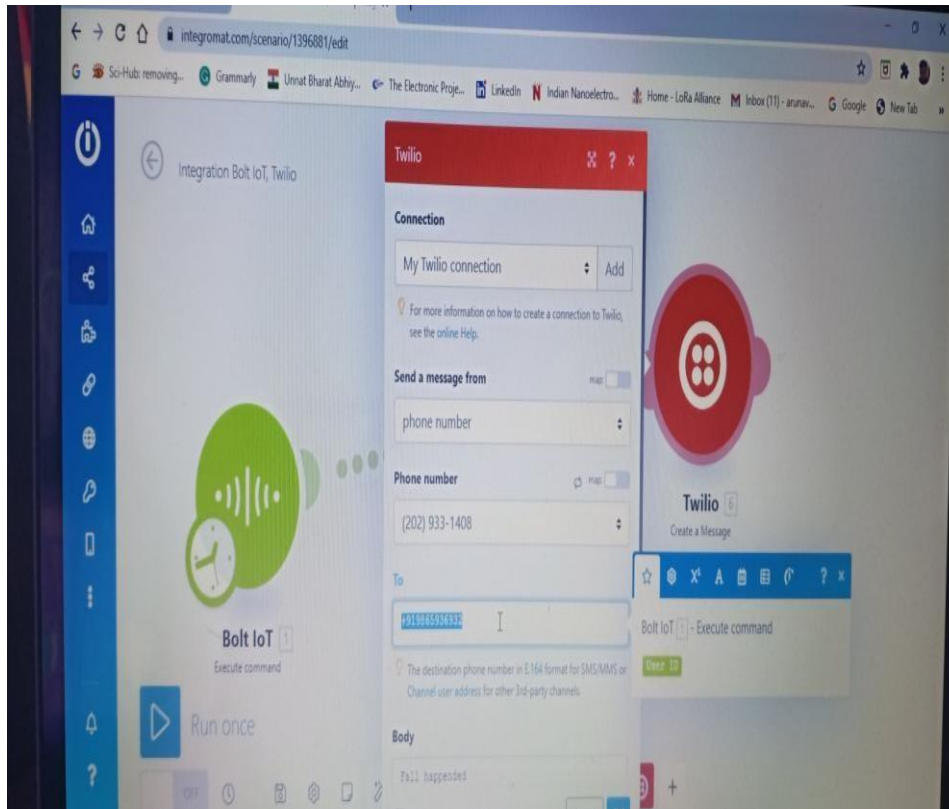


Figure 4. Software Setup for send alert from Twilio

C.Rolls of the server and clients: In client's case, a cycle means that a total time required to transmit a message containing data, receive a server response, and describe the response note. The First loop, roughly 720ms, required a considerable amount of time. This Second cycle and all other successive cycles required a constant total time to complete, around 180ms. This amount depends on different variables, such as network form, speed of connection, weather condition, etc. In view of a server, a cycle is characterized as the total time taken for a server thread to receive a client's parse the message, data message predict the data, and return the data to the client concerned. The Bolt IoT customers can operate effectively for 80~87 consecutive hours with the use of larger volume power series such as 20000mAh power series. It should also be noted that the active buzzer was still active when measuring the power consumption of the Bolt IoT. In real-life situations, however, the buzzer only actives when it senses a fall event.

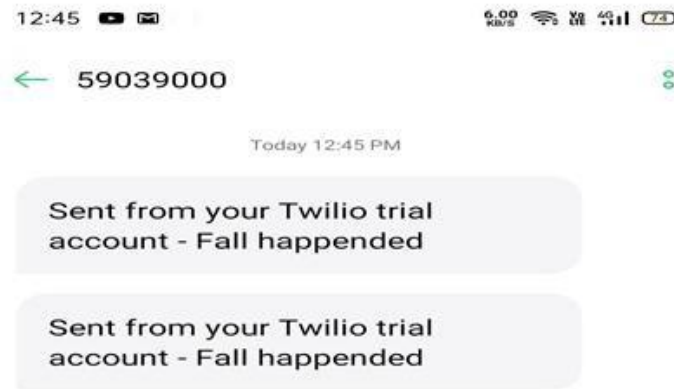


Figure 5. Sample output-sent Alert SMS from BOLT IoT to authorized phone number.

5. CONCLUSION

This paper proposes an Wearable IoT Devices Using pressure Sensors for Fall avoidance by Human Movement Monitoring system with simple hardware module such as Bolt IoT, smartphones, Arduino, triaxial accelerometer, Wi-Fi, GSM, buzzer and GPS. The Client-server based architecture, SVM classifier model based pre-trained multi-threaded server hosts are framework. The devices connect to the server's threads and send moving object data to the server continuously from the accelerometer. The server evaluations whether or not there have been a fall and reacts accordingly. The response message is received by the server. The server sends an alert notification containing the location of the client and other related records to the intermediary if a fall is observed. The system generates buzzer sound, emergency services via SMS. Thus, the controlled person may get instant medical aid. In large-scale settings where real-time monitoring of several individuals is needed, such as hospitals or treatment spots etc., this system can be implemented. 99.7% precision, 99.6% percent specificity and 96.3% sensitivity achieved using SVM linear classifier model. As the response time is very short, approximately 180ms, the developed system is very rapid. This ensures that the server and client's controller knows whether a fall happened or not within about 180ms of sending the sensed data to the server.

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