cStick: A Calm Stick for Fall Prediction, Detection and Control in the IoMT Framework

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Outline of the Talk

- Introduction
- Existing Solutions - their Issues
- Novel Contributions
- Schematic Representation of cStick
- Architectural Flow
- Design Flow
- Implementation and Validation of cStick
- Conclusions and Future Research

Introduction – Why Falls?

- Falls are accidents that come with age.
- Every year, 37.3 million falls are recorded from the elderly, 65 years and above.
- One among four older people falls each year but less than half tell their doctor.
- The probability of having multiple falls increases after having the first fall.
- Every 11 seconds, there is an older person being treated for an incident of fall.
- Statistics indicate that fall incidence rates have increased by 31% from 2007 to 2016 and the rate is expected to grow in the future.

Introduction –Causes of Falls

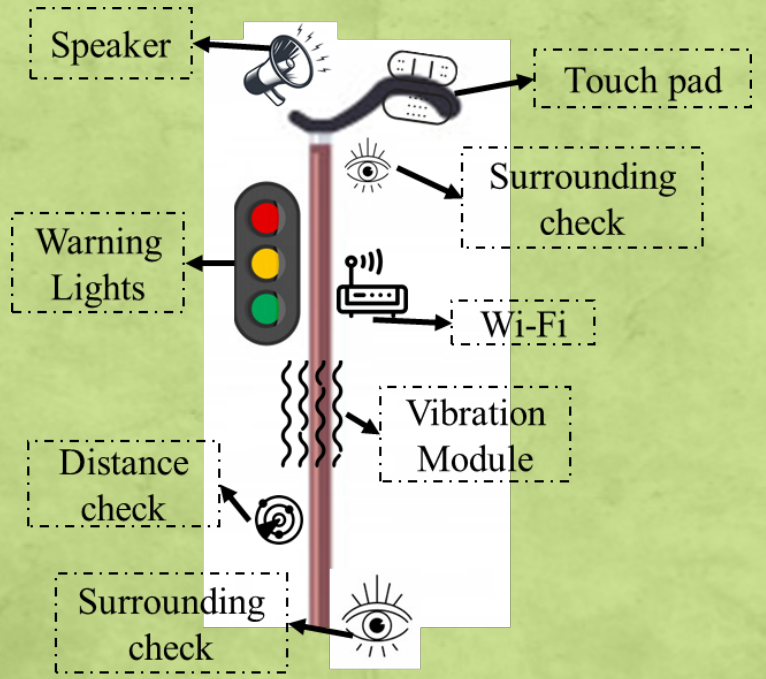
- The occurrences and causes of falls are many.
- 67% of falls do not happen from a height but happen when a person trips or slips.
- Ill-fitting clothes and shoes can also be a reason for the older person to fall.
- Hearing impairments in older adults cause three times the risk of an accidental fall than other older adults.
- Medical conditions, sedatives and antidepressants such as Parkinson's disease, insomnia, sedation, and obesity also contribute to the increased risk of falling in older adults.
- Isolation and physical inactivity due to the pandemic also has an effect on the increased risk of falling in older adults.

Introduction – Impact of Falls

- The impact of falls on the elderly human body is very high.
- Falls can cause broken bones, wrists, arms, ankles and hips.
- In 2014, 29 million older adults received injuries from falls. 95% of the cases involving falls lead to hip fractures.
- In 2013, 50% of the cases involving falls resulted in traumatic brain injuries in older adults.
- In 2016 alone, there were 29,668 deaths in older adults caused due to falls.

Introduction – Proposed System

- cStick, a calm stick to monitor falls in older adults is proposed.
- cStick has been designed in such a way that it can assist both visually and hearing-impaired older adults.



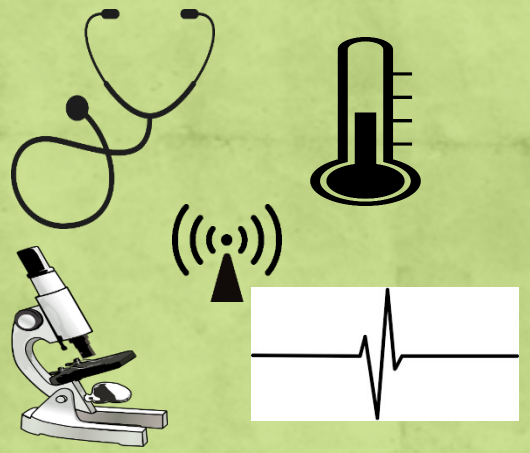
Introduction – Proposed System

- cStick is a state-of-the-art device in the IoMT framework.

✓Internet of Things

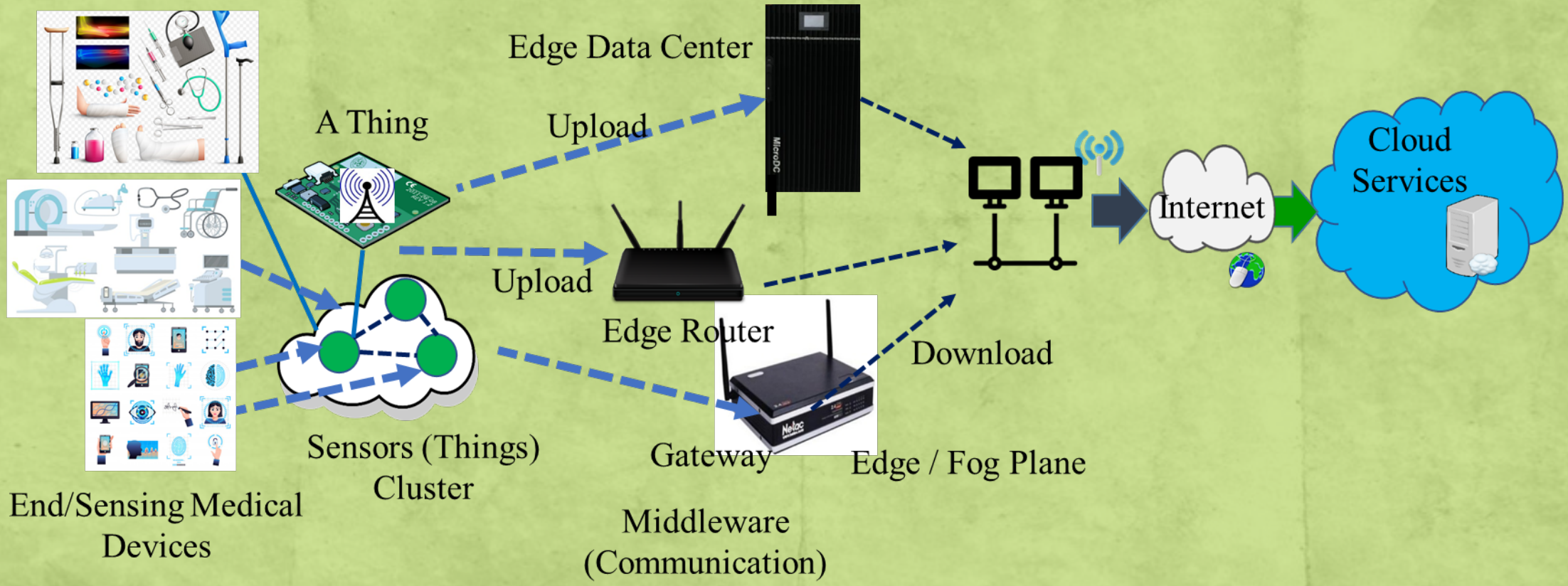
- The Internet of Things is a network of devices where each device in the network is recognizable and connected.

✓Internet of Medical Things

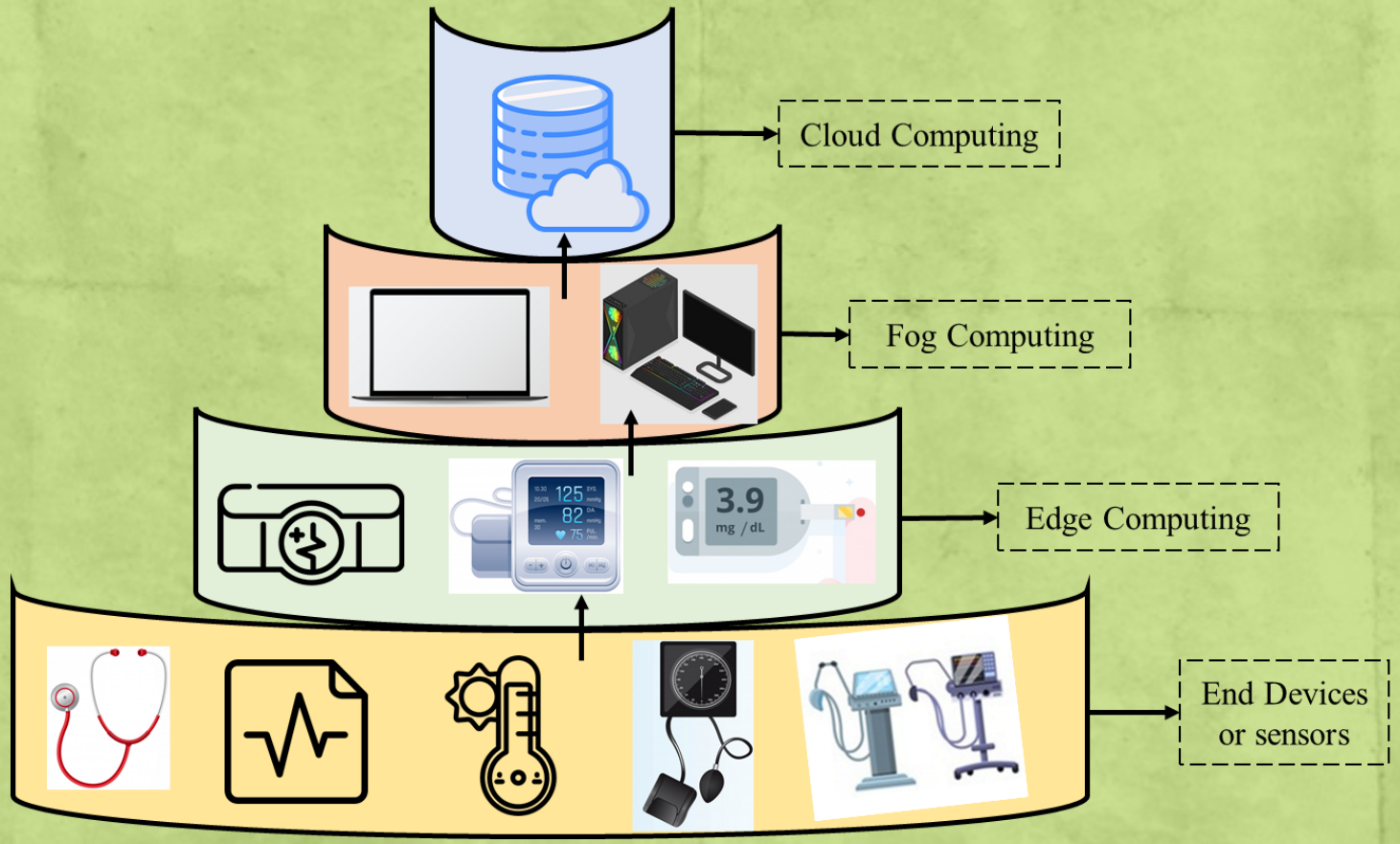


- The Internet of Medical Things is a network of medical devices where each device in the network is recognizable and connected.

Introduction- IoMT – Framework



Introduction – IoMT-Edge Paradigm



Existing Solutions – Their Issues

- There is no unified detection as there are not many physiological signal data that are being considered to make the decision of fall.
- There are no fall prediction mechanisms or strategies included.
- Most of them are location constrained and can only be used at a specific location.
- Users need to manually or verbally request help upon falls, and this can be an issue if the user is unconscious.
- Wearables or the device prototypes proposed may be inconvenient for the users to wear.
- Generation of false positives and negatives can be higher due to which unnecessary alerts can be generated.
- Cost for the installation and maintenance can be higher as most need monthly subscriptions.

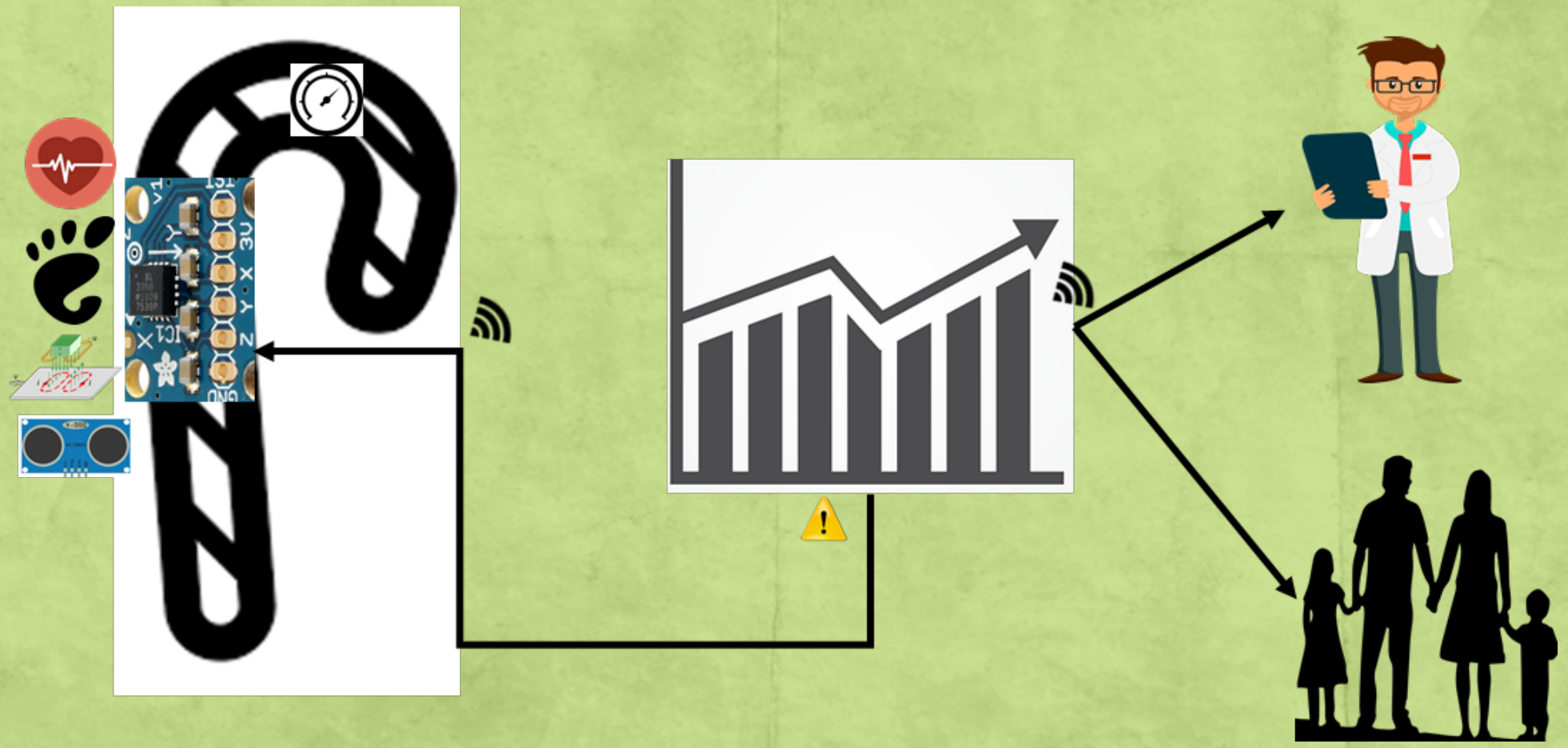
Existing Wearable Products

Wearable	Activity	Physiological Data	Prediction	Detection	Drawback
Owlytics	Walk, trip and slip	Accelerometer	Partially Yes	Yes	• manually request. • one physiological signal to detect falls.
Smart Watch	Physical Activity	Accelerometer	No	Yes	• uses only accelerometers. • user must manually select the option SOS
Vayyar Home	Bathroom activity monitoring	Radars	No	Yes	• Location constraint • manually request

Novel Contributions

- Accounting for multiple physiological signal data to analyze the decision of falls. Continuous data monitoring to predict the occurrences of falls in order to reduce the number of accidents.
- Continuous surrounding monitoring to allow the users to understand the environment in order to reduce tripping and injuries.
- Continuous monitoring of general health signals so as to have to a detailed understanding on the causes of the fall.
- Location tracking of the user to not only provide immediate support but also to notify the user with a warning.
- Ability to have two-way communication with the device, when needed. Assisting visually impaired and hearing-impaired elders by incorporating audio and touch response systems, respectively.
- Having a capability to connect to any wearable or health monitoring device to provide more adaptable elder fall monitoring systems.

Schematic Representation of cStick



Physiological Parameters Considered

- **Grasping Pressure:** cStick monitors the grasping pressure that is applied on the cane. The individual baselines for everyone can be different, so cStick monitors sudden changes in the squeezing force.
- **Dietary Habits:** cStick monitors the blood sugar levels of the older adults. The total occurrences of falls can be linked with low sugar levels (hypoglycemia). When the sugar levels are below 70mg/dL the chances of having falls increases as the older adults may feel weak, tired, anxious, shaky, or suffer strokes and unconsciousness.
- **Posture:** The posture of the human body tells a lot about its orientation. If there is a leaning in any direction, the chances of losing the balance are high. Such scenarios can lead to side and back falls causing injuries to hips or the head.

Physiological Parameters Considered

- **Blood Oxygen Levels:** Older adults have lower saturation levels than younger adults. Oxygen saturation levels about 95% are considered normal for older adults. Lower levels may cause shortness of breath, asthma, excess sweating, low heart rate and sometimes leads to unconsciousness in older adults.
- **Irregular Heart beats per minute:** Cardiac output decreases linearly at a rate of about 1 percent per year in normal subjects past the third decade. The resting supine diastolic blood pressure for younger men was 66+-6 and 62+-8 for older men and higher heart rates can result in shortness of breath, fatigue, stroke and unconsciousness.

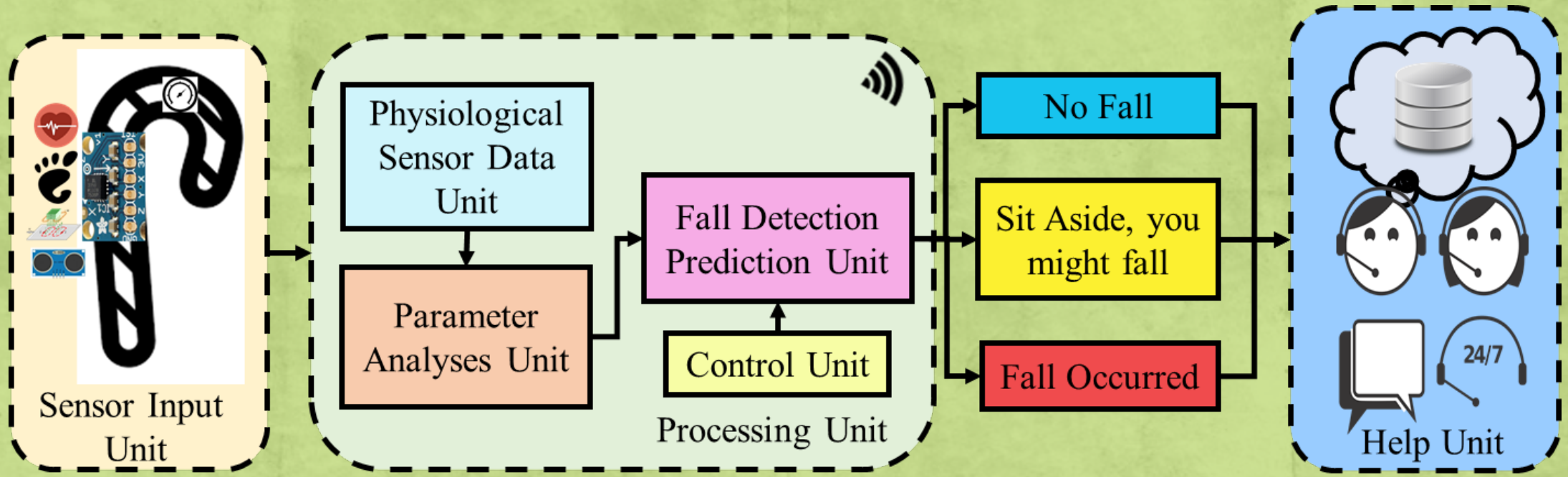
Physiological Parameters Considered

- **Location of the User:** The location of the user plays a very important role as it allows notification of the user to stay alert. Warning the user about a previously occurred fall will make him aware of the surroundings. Location tracking helps to provide required help without the user asking for it.
- **Surroundings of the User:** Surroundings have a larger impact on the human body when a fall occurs. Monitoring the surroundings helps to reduce the impact of falls. Surrounding objects, human beings or any other moving or non-moving things are continuously monitored.

Architectural Flow of cStick

- The architectural flow of the proposed system begins with the data collection from the wearable sensors.
- The data from the stick is compared and analyzed to make the decision of fall or a prediction of a fall.
- This decision is provided to the user using fall response mechanisms which are both compatible for visually or hearing impairment elders.

Architectural Flow of cStick



Parameter Analysis Unit

Distance	Pressure	HRV bpm	Sugar Levels mg/dL	SpO2 Levels	Accelerometer	Decisions
>50cm	Small	60-90	70-80	>90	< +- 3-g for y axis	No fall. Happy walking!
<30cm	Medium	90-105	30-70	80-90	> +- 3-g for y axis	Take a break, you tripped!
<10cm	Large	>105	<30 or >160	<80	> +- 3-g for y axis	Definite fall. Help is on the way!

Fall Prediction and Detection Unit

- The decision of falls is made from the analysis represented in Table.
- Prediction of the fall is defined as a mechanism to let the user know that the user might have an accident and taking a break might be good for him/her.
- Detection is stating that there has been a definite accident of fall and the user needs assistance.

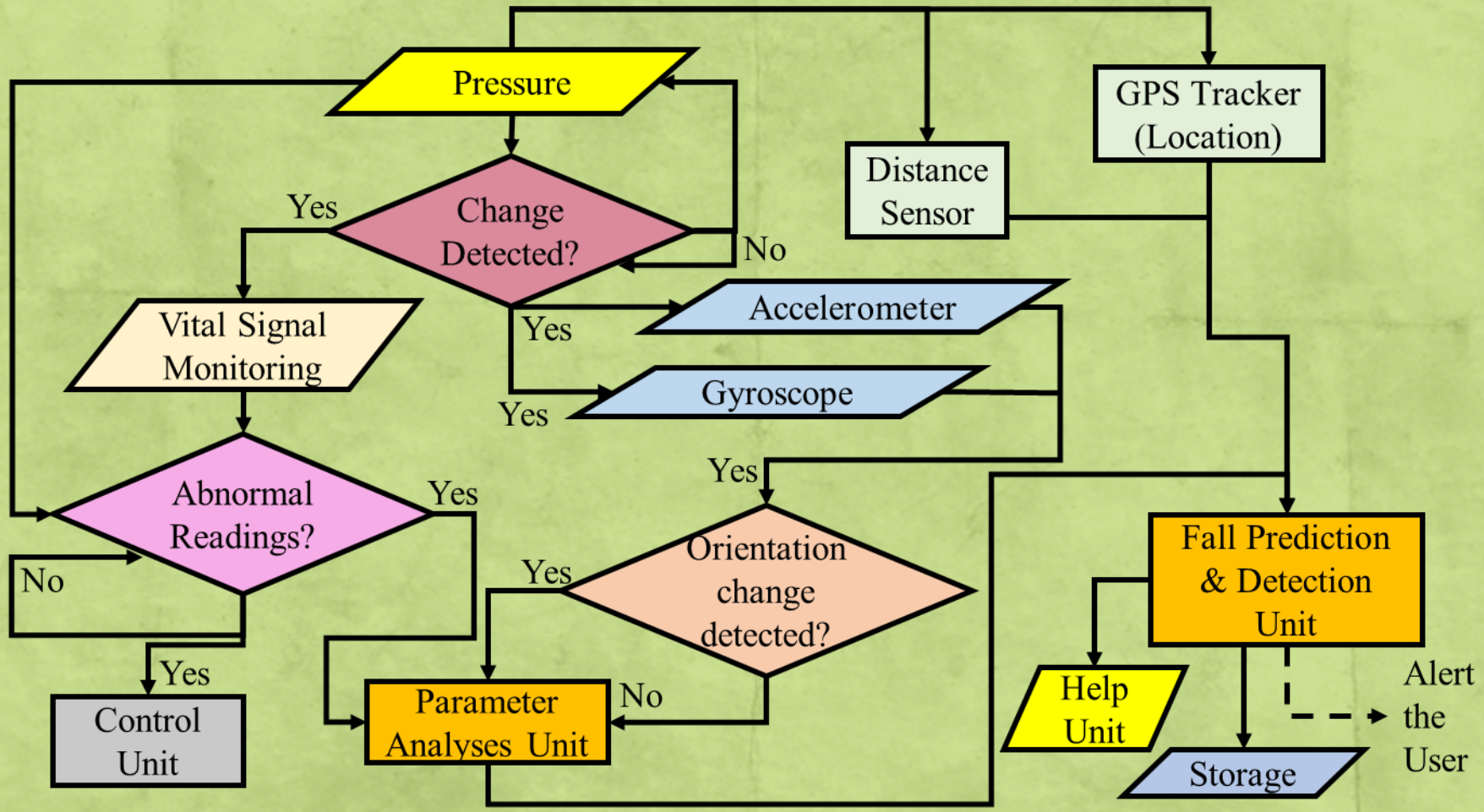
Control Unit

- As there is continuous monitoring of the vital signal data in cStick, any other additional cause an older person may fall is also taken care of.
- This includes monitoring the heart rate, sugar levels and blood oxygen levels.
- If there is anyone of these that are causing the user to lose cognitive ability, strength or even consciousness, cStick will be able to help the user by warning the user to take a break, in other words by predicting the user that there may be an accident.
- In addition, as the location of the user along with the surroundings are also monitored, the chances of having falls or any other accidents can also be reduced.

Design Flow of cStick

- The buzzer, vibrator and microphone attached are activated depending not only on the decision of the fall but also when there is an abnormal reading in the vital signals.
- The location of the user will be updated throughout the time period the user is using the stick.

Design Flow of cStick



Implementation of cStick

Physiological Data Acquisition: A data of 9670 samples from 14 volunteers has been taken.

Machine Learning Model: The well shuffled dataset with 6 features and 3 classes in the label was trained in TensorFlow.

The 6 features here are: Heart rate variability, accelerometer, blood oxygen levels, sugar levels, pressure applied on the stick and distance from the nearest object.

The classes for the label i.e., for the decision are no fall detected, a fall is predicted i.e., the user has tripped or slipped and a fall has detected i.e, a definite fall.

Implementation of cStick

- **Machine Learning Model:** A fully connected neural network or dense model is used.
- A linear stack of layers with 6 nodes in the input layer, two dense layers with 20 neurons each and three nodes in the output layer.
- The rectified linear function is used as an activation function for the hidden layers and the sigmoid function is used for the output layer.
- 200 epochs are provided with batch size of 32 and 0.01 learning rate for the model.

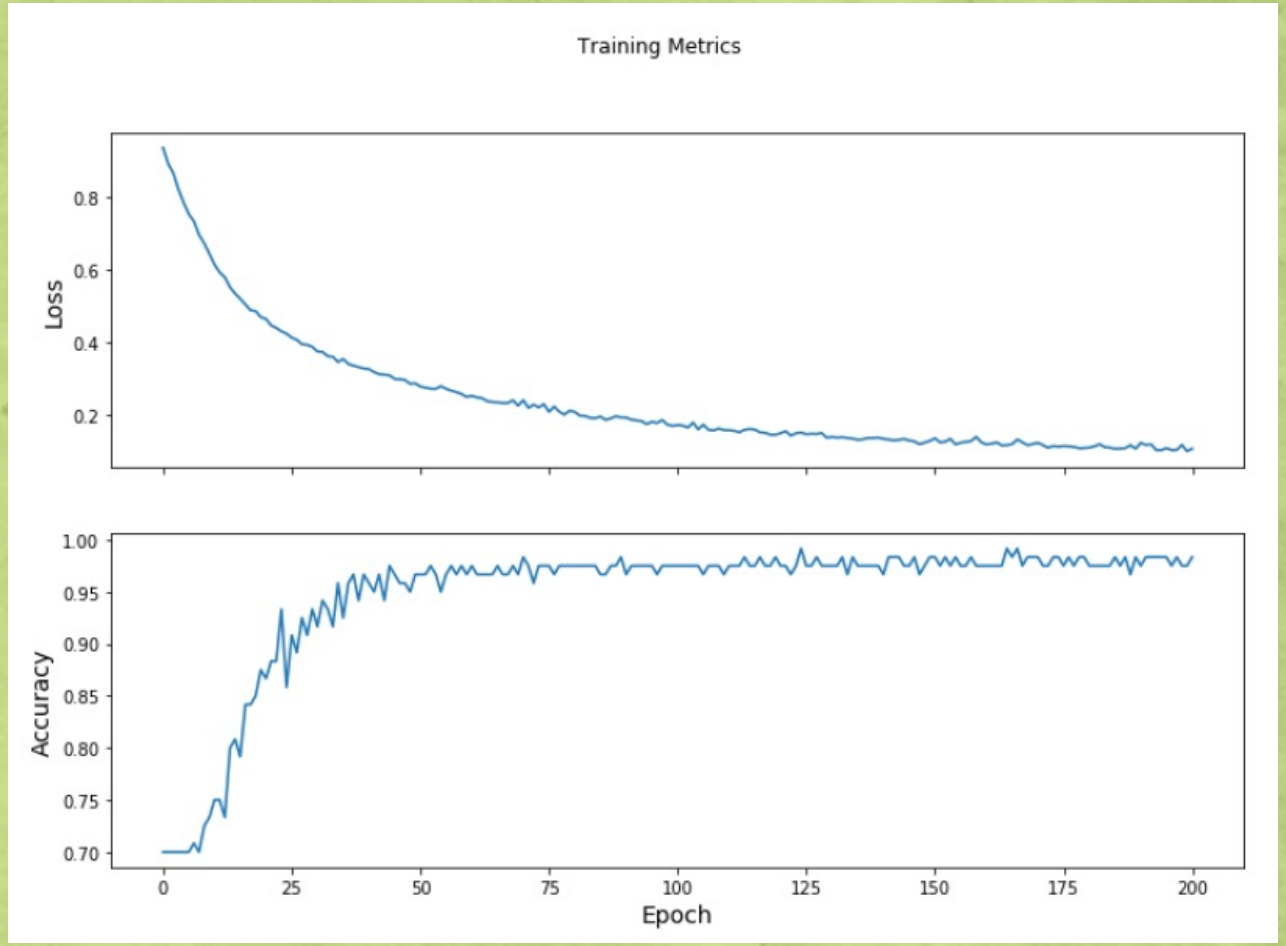
Prediction: [2 2 2 2 2 2 0 2 0 2 2 2 0 0 0 2 2 2 2 2 0 2 2 0 2 2 2 2 2 2 2 2]
Labels: [1 2 1 1 2 0 0 1 0 2 1 1 0 0 0 2 2 0 0 1 0 2 1 0 1 0 1 1 2 1 1 0]

[[1, 1], [2, 2], [0, 0], [1, 1], [1, 1],[1, 1], [0, 0], [2, 2],[1, 1], [2, 2],[2, 2], [0, 0], [2, 2], [1, 1], [1, 1], [0, 0], [1, 1], [0, 0], [0, 0], [2, 2], [0, 0], [1, 1], [2, 2], [1, 2], [1, 1], [1, 1], [0, 0], [1, 1], [2, 2], [1, 1]]

Predictions Before and After Training in cStick.

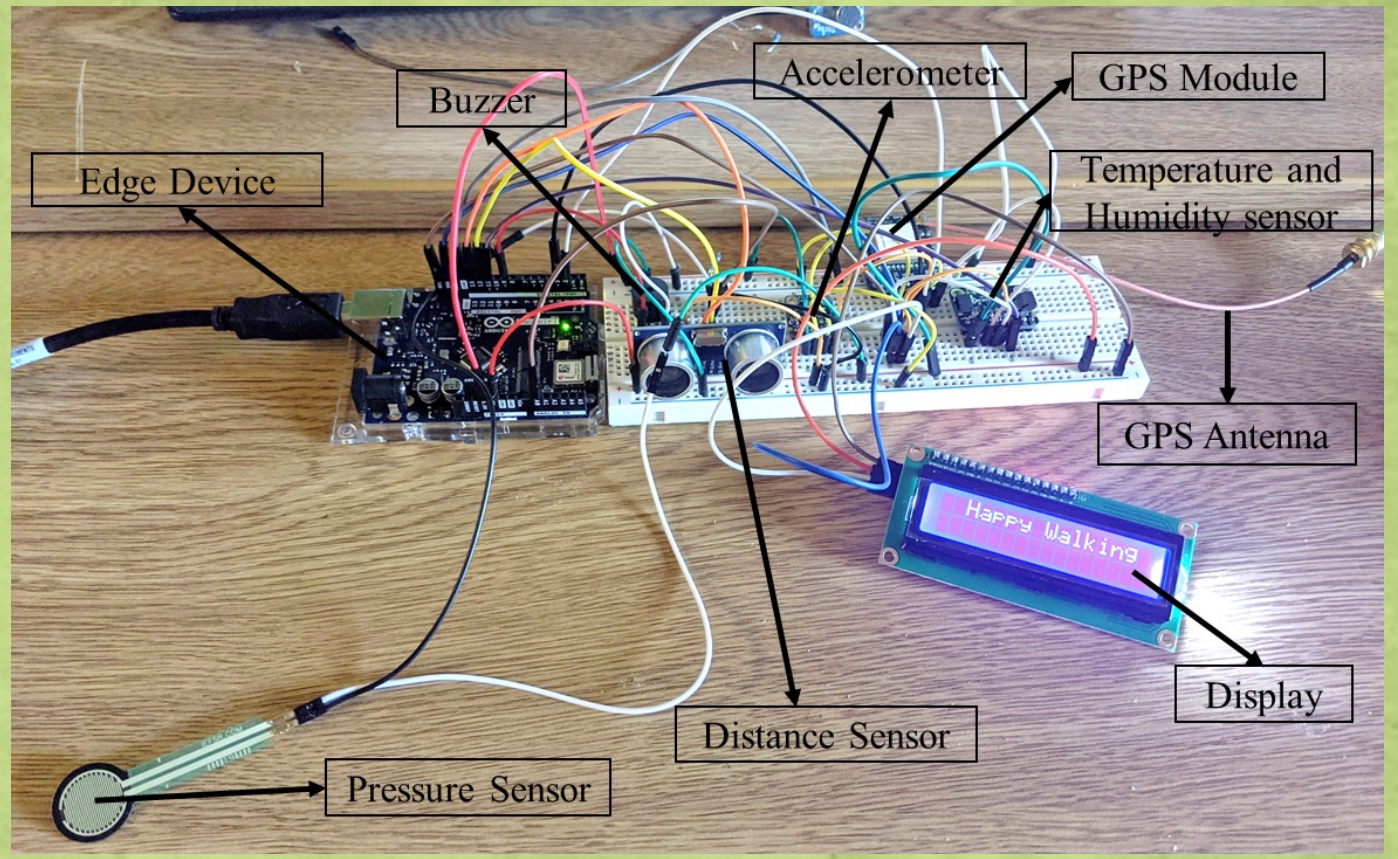
Implementation of cStick

- With loss and accuracy as the metrics and a stochastic gradient descent algorithm as the optimizer, 7736 samples for training and 1934 samples for testing, the model has produced 96.67% accuracy.



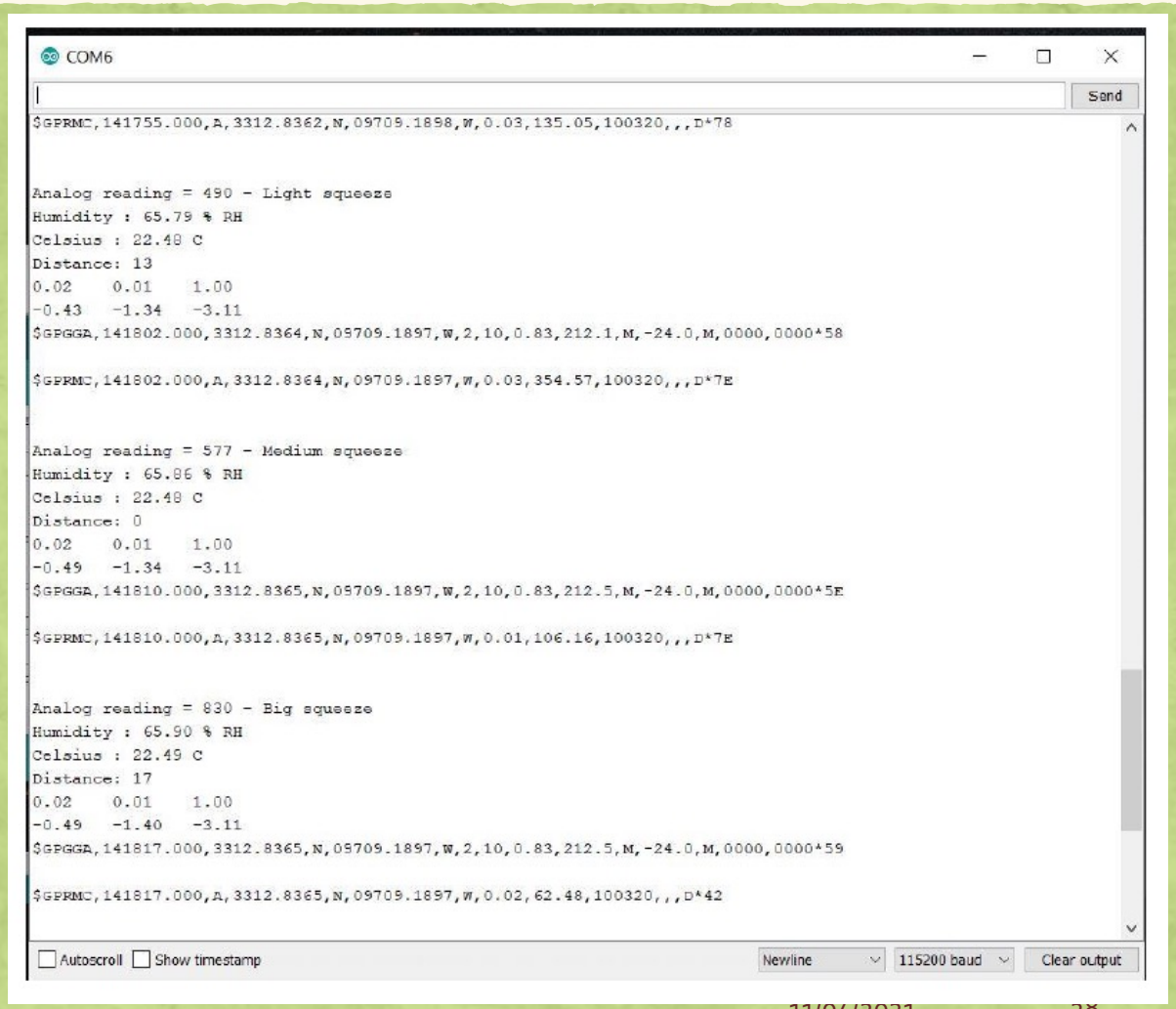
Validation of cStick

- For the IoMT-Edge computing, a controller has been chosen with real time sensor data from various sensors which monitor the required parameters.
- The Edge Computing setup is represented.



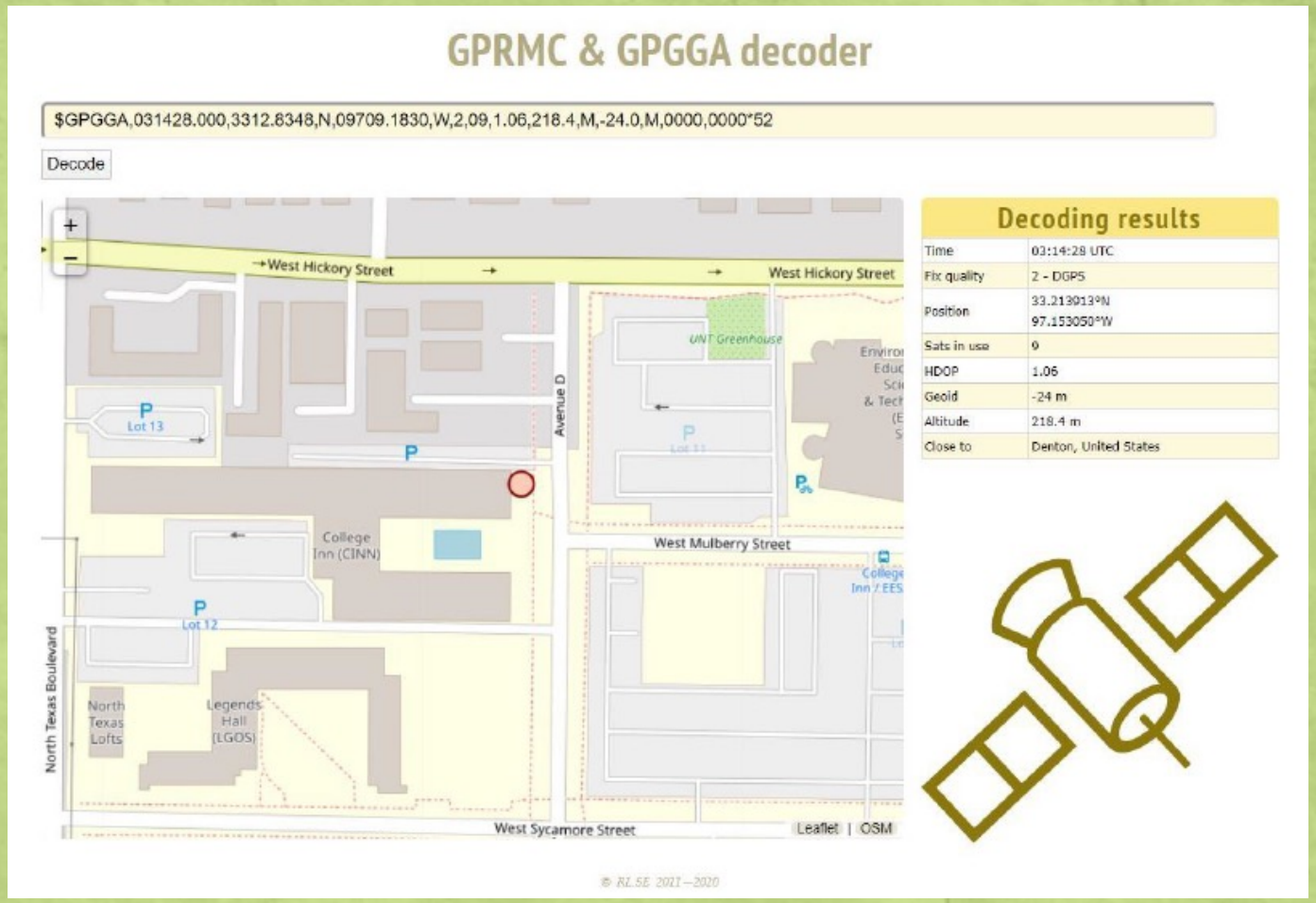
Validation of cStick

- The serial monitor display of the sensors along with the dataset data is shown.



Validation of cStick

- The location of the user is also validated in cStick along with the conceptual validation.



Comparison with State-of-the-Art

Name	Prototype	Activities	Sensors	Prediction	Detection	Accuracy
Han, et.al	No	Walk, sit, fall, lean	Accelerometer, gyroscope	Partially yes	Yes	NA
Pongthanisorn, et al.	No	Sleeping Positions	Piezoelectric and weight	No	Yes	NA
Engel, et al.	No	Walk, trip, stumble, fall	Accelerometer	No	Yes	94%
Razmara, et al	No	Questionnaire	None	No	Yes	90%
cStick	Yes, a calm stick	Walking - Vital signal monitoring	Accelerometer, HRV, Pressure, Sugar levels, SpO2, Gyroscope	Yes	Yes	96.67%

Conclusions

- Elderly care requires utmost attention with the technological developments happening day by day.
- Keeping that in mind, a cStick, also known as calm stick, is proposed with which the users are not only provided with a fall detection monitoring device but also a fall prediction device with an accuracy of approximately 96.67%.
- cStick also monitors the vital signals of the older adults and this allows in the early detection of accidents including falls.
- It has a capability of connecting to any smart or IoMT device to enhance its performance.
- cStick can also be used by visually or hearing-impaired older adults as it has autonomous control mechanisms.

Future Research

- As cStick strives to be an improvement in the existing technology and research for elderly healthcare, in future work more focus will be placed on considering many other vital signals and physiological and psychological parameters.

Questions?

Thank you!