Good-Eye: A Device for Automatic Prediction and Detection of Elderly Falls in Smart Homes

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Outline of the Talk

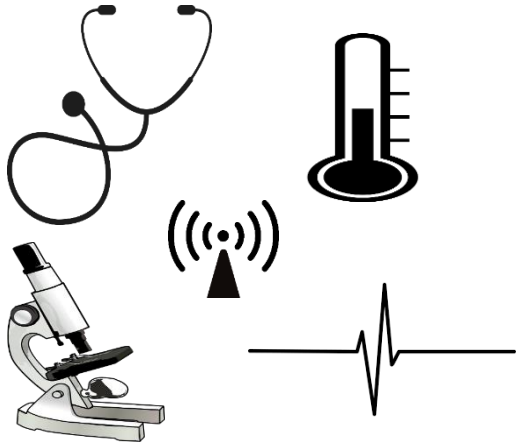
- Introduction
- Motivation
- Existing Solutions - their Issues
- Proposed Solution
- Architecture of Good-Eye
- Proposed Approaches of Good-Eye
- Implementation and Validation of Good-Eye
- Conclusions and Future Research

Introduction

✓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.

Existing Solutions

Wearables	Drawbacks
	Apple watch: uses only accelerometers, doesn't work on low thresholds like double carpet, bathroom, hardwood floors. The user must manually select the option SOS and as a reason it fails if the person is unconscious. Users may remain on the floor with no help for large hours.
	Philips Lifeline: Uses only accelerometers and barometric sensors for pressure changes. After the fall, the system waits for 30 sec and directly connects to help.
	Lively Mobile by greatcall and Sense4Care Angel4: Monitors fluctuations using only accelerometers.
	Bay Alarm Medical and Medical Guardian: Use only accelerometers. Have huge base stations limiting the usage and location access.

Existing Solutions

Research Articles	Drawbacks
Kong, et al. [2017]	This research uses depth camera with tangential position changes. It might not be accurate just to depend on the tangential axes as the positions of the fall vary.
Bhati [2017]	This research uses only physiological sensor data with no usage of camera. This research will not be helpful to have the location access.
Liu, et al. [2014]	Monitors fluctuations using only accelerometers.
Waheed, et al. [2017]	This research proposes a raspberry pi camera solution which has location limitations and has a chance of many false positive chances as the study solely dependent on vision.
Rimminen, et al [2010]	This research proposed fall detection by using floor sensors which limits the movement of the user with an increase in investment.

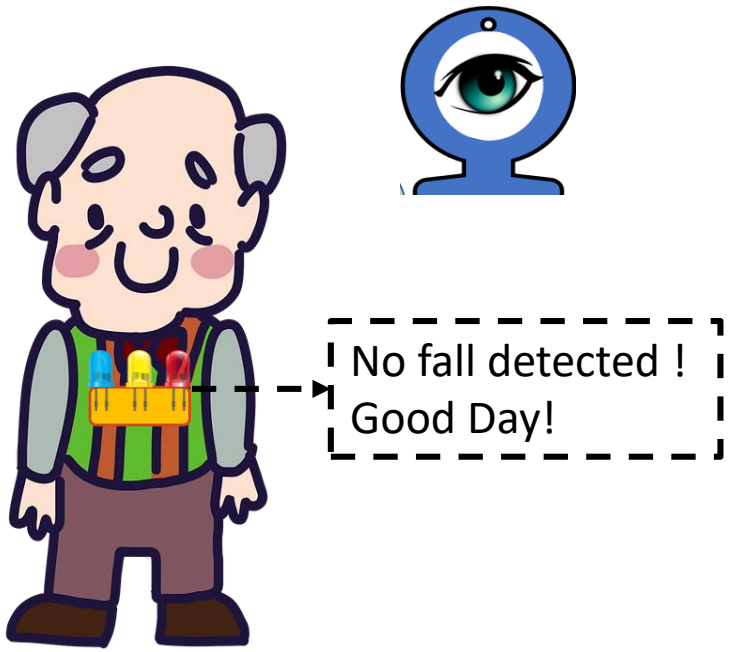
Source: L. Rachakonda, A. Sharma, S. P. Mohanty, and E. Kougianos, "Good-Eye: A Combined Computer-Vision and Physiological-Sensor based Device for Full-Proof Prediction and Detection of Fall of Adults", in *Proceedings of the 2nd IFIP International Internet of Things (IoT) Conference (IFIP-IoT)*, 2019, pp. 273--288.

Issues of Existing Research

- Decisions of fall are only dependent on the changes in accelerometer axes.
- Some applications have user to give response after the fall and that can be time consuming as the user might not be conscious.
- Some applications are limited to a certain location and certain type of surroundings which add up the additional costs.
- The prediction of fall or warning the user that there might be an occurrence of fall is not provided by most of the applications.

Proposed Solution

➢ Conceptual Overview of Good-Eye



- ✓ Provide Constant Care.
- ✓ Provide easy to wear accessories convenient to any age.
- ✓ Provide medical support as per the occurrence of emergency irrespective of the location.

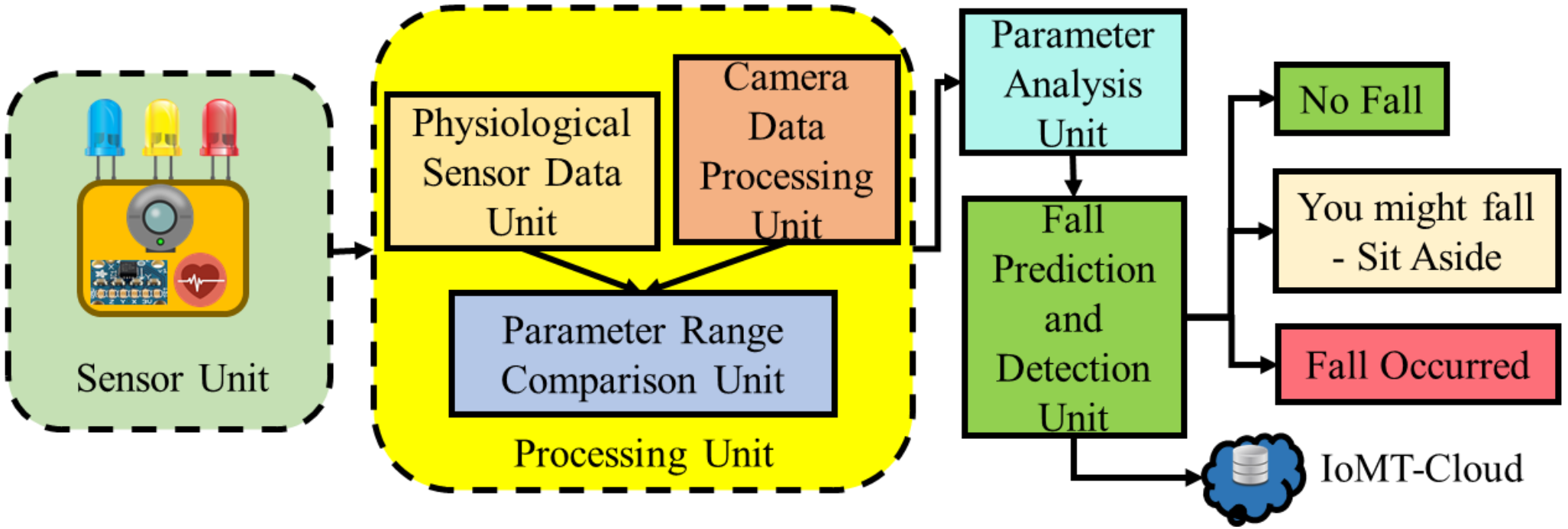
Novel Contributions

- A fall detection mechanism that provides complete analyses of situation using physiological and vision approaches.
- A system that not only detects the fall after the occurrence of event but also predicts the future events and warns the user accordingly.
- A continuously monitoring battery optimized device which gets activated when a change in accelerometer is detected.
- A system that can also be used indoors in order to obtain more accuracy and efficiency.
- An approach where a decision is made and is not waited for the user to respond after the fall.
- An approach that not only determines the fall conditions but also records the surroundings and circumstances for future.
- A fall detection device that is not restricted to a certain place or location.

Issues Addressed in Good-Eye

- Prediction of occurrence of falls are also notified to users as the system continuously monitors the physiological changes.
- Informed detection of fall is made as the decision involves both physiological and vision signal data.
- The decision is not just made depending upon accelerometer but is made along with the variations in heart rate of a person during the fall.
- The user is warned before the occurrence of fall and is asked to sit aside based on the physiological signal data.
- The surroundings and circumstances are recorded in order to accurately analyze the situation of the fall.

Architecture of Good-Eye



Considered Sensor Input Data

- Factors considered in fall predicting approaches are

➢ Change in the axes of the accelerometer

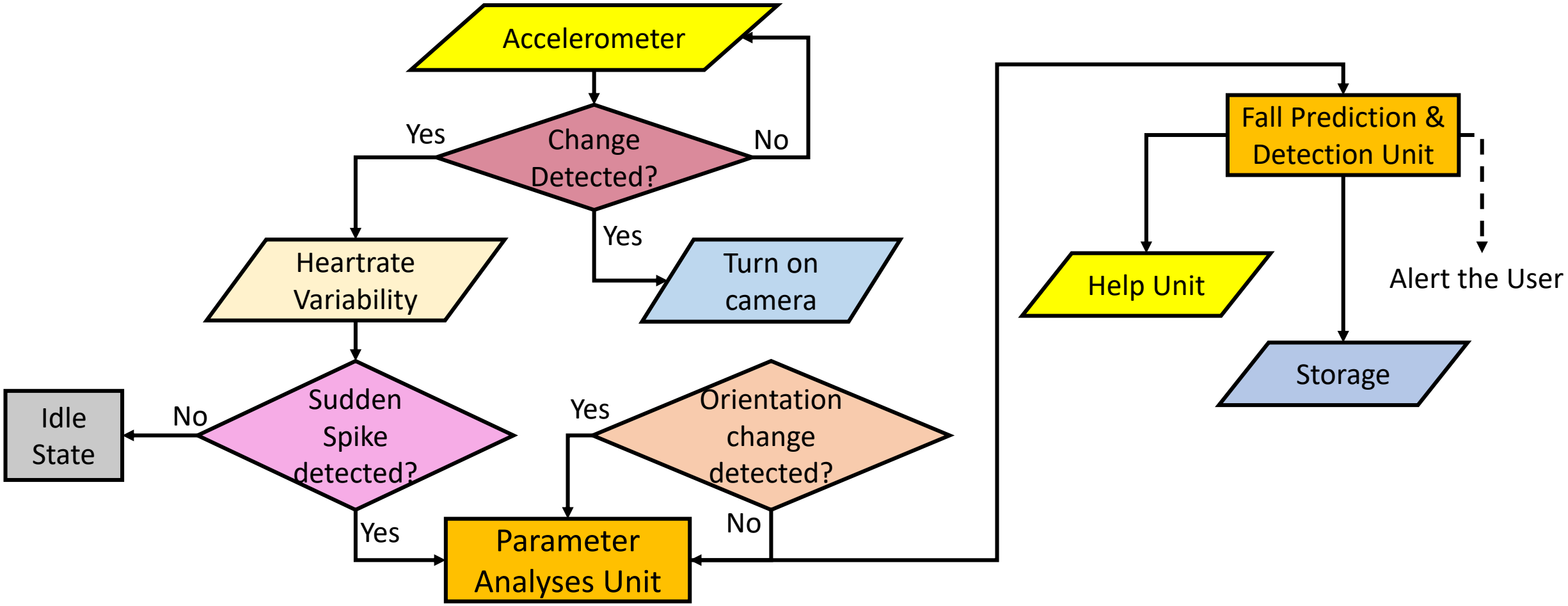
➢ Change in the heartrate of a person compared to the resting heart rate.

➢ Having an on-site camera in the wearable to analyze the intensity of fall and provide certain care as per the intensity.

➢ Having an off-site wall mounted camera in the space of a person, enables continuous person detection and tracking to provide proper feedback.

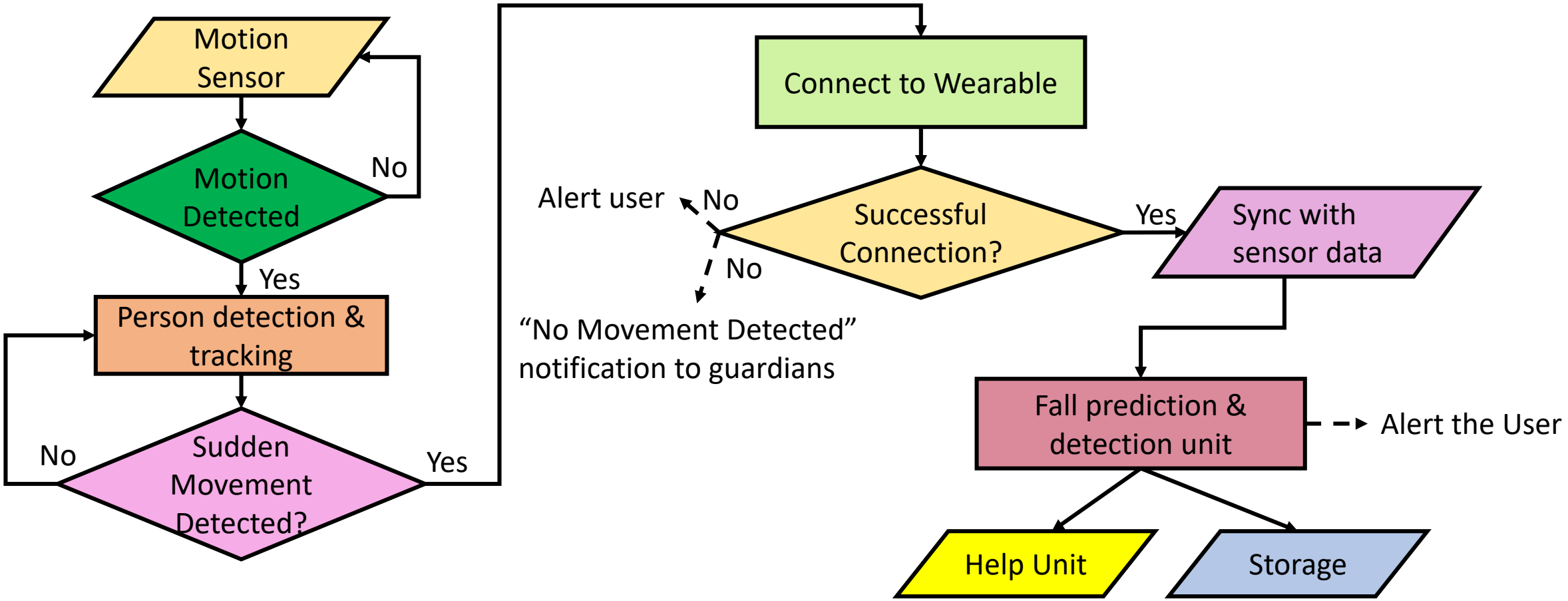
Design Flow of Good-Eye

- Good-Eye System



Design Flow of Good-Eye

- Good-Eye System: On-wall Camera



Parameter Analyses

- The accelerometer would constantly read the x, y, and z values of the g-force exerted upon a human being wearing the device. If the y value of the g-force exceeded +/- 3 g's, the accelerometer would pass the threshold required to detect a fall.
- To implement the heart rate variability into the overall fall detection program, we had the program record a heartbeat every few milliseconds, and if the heart rate suddenly spikes, either upward or downward, the sensor would send a signal to the Arduino stating that the heart rate has spiked.

Parameter Analyses

➢ Vision

- Using a camera that has a resolution of at least 680x480 attached to the device, a program scans a frame of movement at a time and converts each (x,y) position into a position containing three values: (R,G,B), corresponding to the R, G, and B values of each pixel
- The camera then moves to the next frame, doing the same thing
- After R1, R2, G1, G2, B1, B2 are all calculated for two frames, it takes the distance of those three values: d= sqrt((R2-R1)^2+(G2-G1)^2+(B2-B1)^2), aka the distance formula
- It stores all these distance values for every pixel, counting whichever pixels are above a set threshold (say, 70)
- It then checks if this threshold is reached for at least 45% of pixels
- If 45% of the pixels have changed, a fall has occurred

Prediction Vs Detection

✓Prediction

- It is a forecast, a statement about future event. A prediction is often, but not always, based upon experience or knowledge.

✓Detection

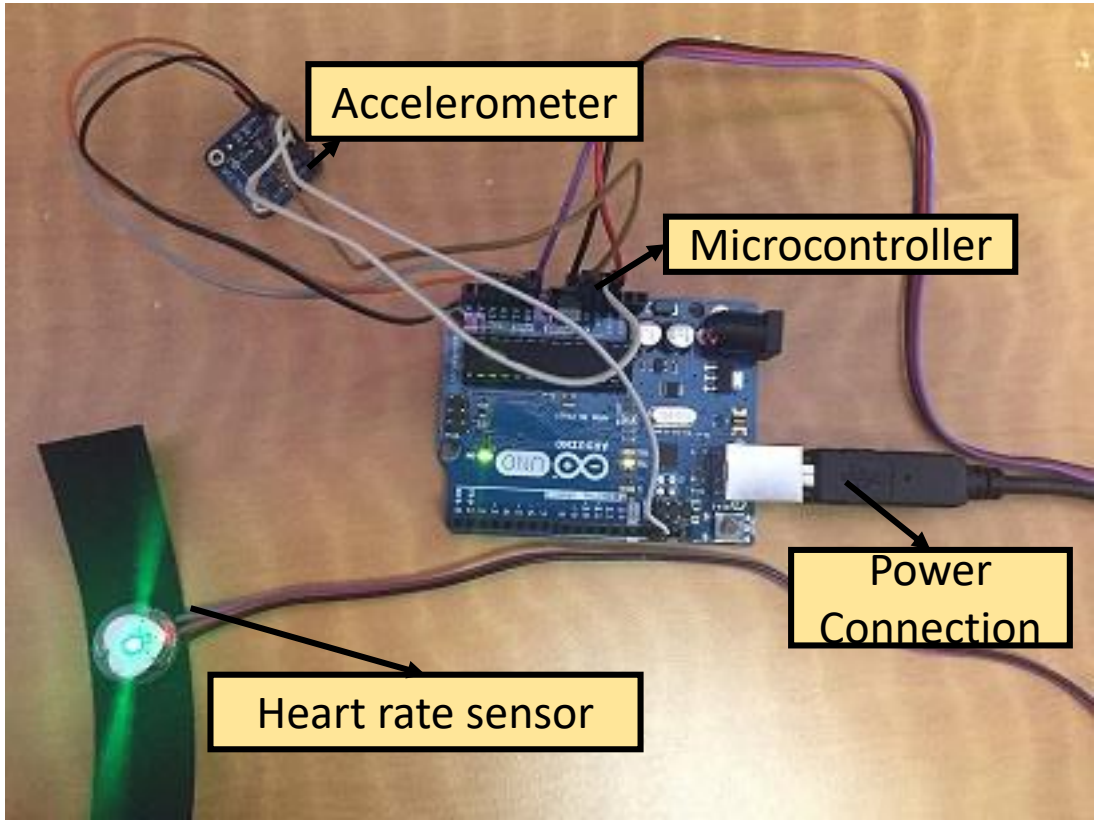
- The action or process of identifying the presence of something concealed. A detection is often based upon the incident.

Fall Prediction & Detection Unit

- Analyses of fall prediction and detection

Accelerometer	HRV	Camera Orientation	Decision
Change in y value to 3 g	Sudden change in heart rate detected; Typically 10bpm	Change in 45% of Pixels	Fall Detected
Change in y value to 3 g	No Sudden change in heart rate detected; Typically 10bpm	Change in 45% of Pixels	No Fall Detected
No Change in y value to 3 g	Sudden change in heart rate detected; Typically 10bpm	Change in 45% of Pixels	Fall Predicted
Change in y value to 3 g	Sudden change in heart rate detected; Typically 10bpm	No Change in 45% of Pixels	Fall Predicted

Implementation : Good-Eye System




```
X accel: -0.03  Y accel: 0.04   Z accel: 0.63                BPM: 78
X accel: -0.03  Y accel: 0.04   Z accel: 0.64
X accel: -0.03  Y accel: 0.03   Z accel: 0.62
X accel: -0.03  Y accel: 0.04   Z accel: 0.63                BPM: 78
X accel: -0.03  Y accel: 0.04   Z accel: 0.64
X accel: -0.03  Y accel: 0.04   Z accel: 0.63
X accel: -0.03  Y accel: 0.04   Z accel: 0.63                BPM: 78
X accel: -0.03  Y accel: 0.04   Z accel: 0.63
X accel: -0.03  Y accel: 0.04   Z accel: 0.63
X accel: -0.03  Y accel: 0.04   Z accel: 0.64                BPM: 78
X accel: -0.03  Y accel: 0.04   Z accel: 0.64
X accel: -0.01  Y accel: 0.04   Z accel: 0.64
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X accel: -0.03  Y accel: 0.03   Z accel: 0.63
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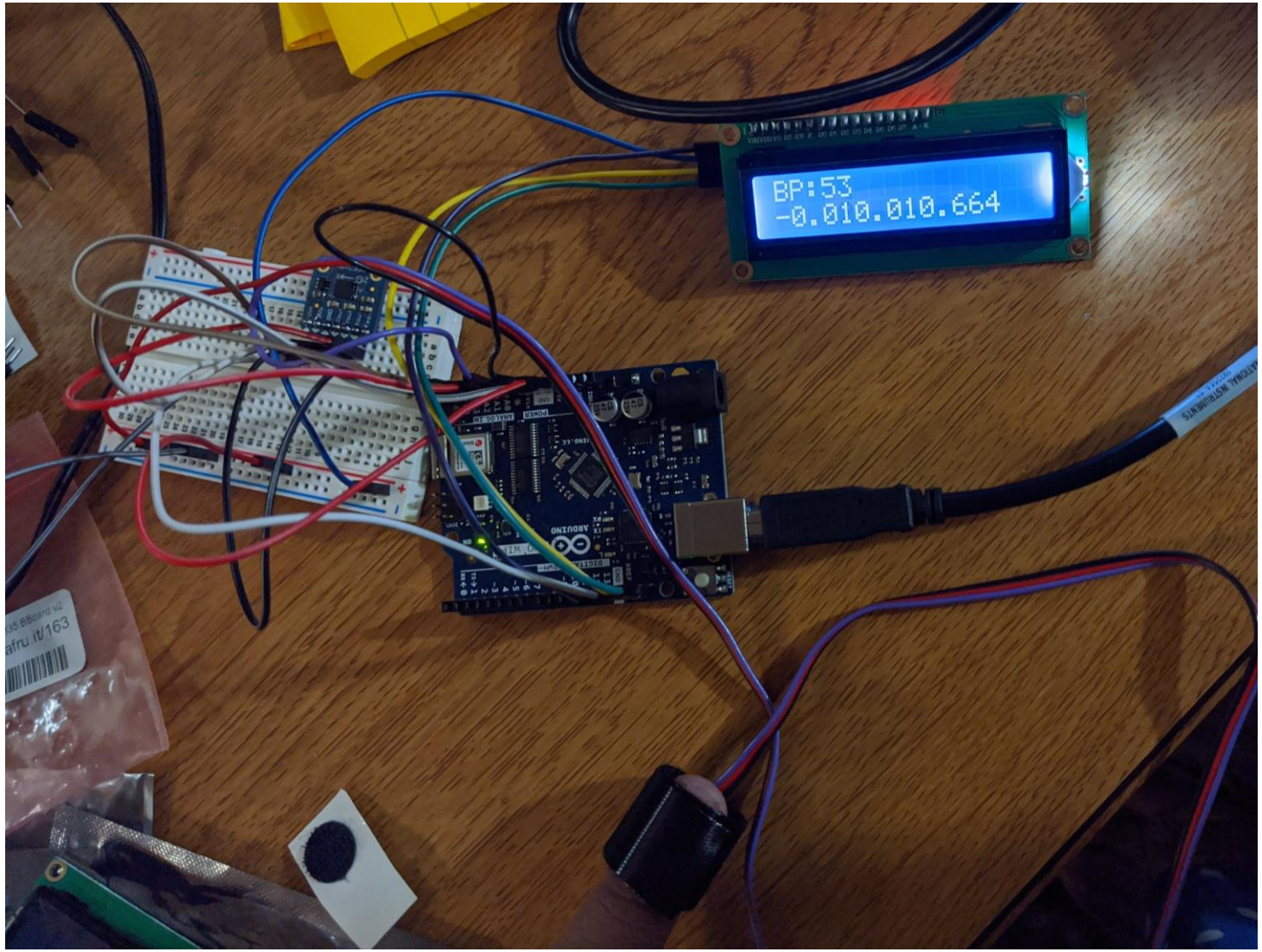
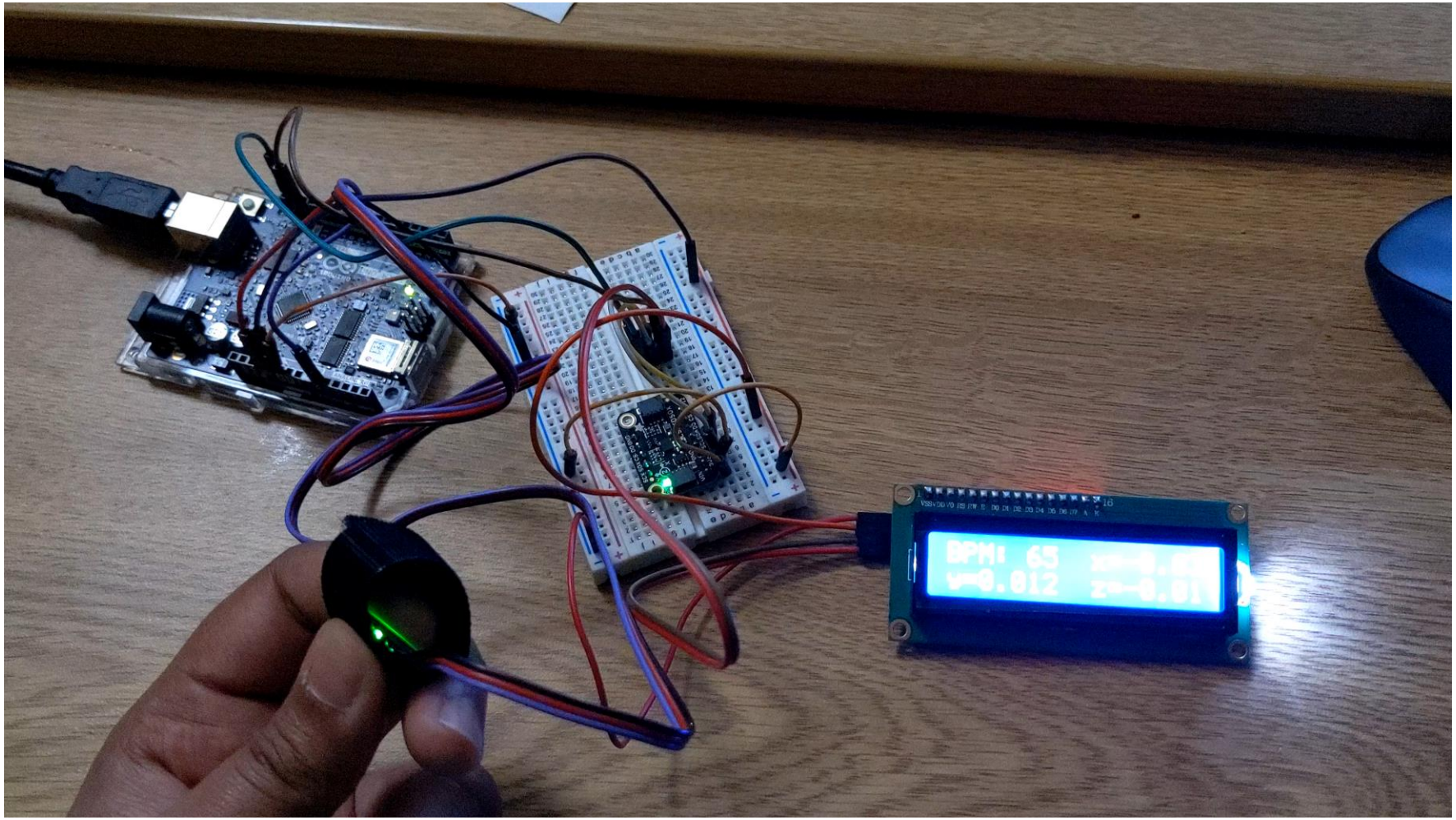
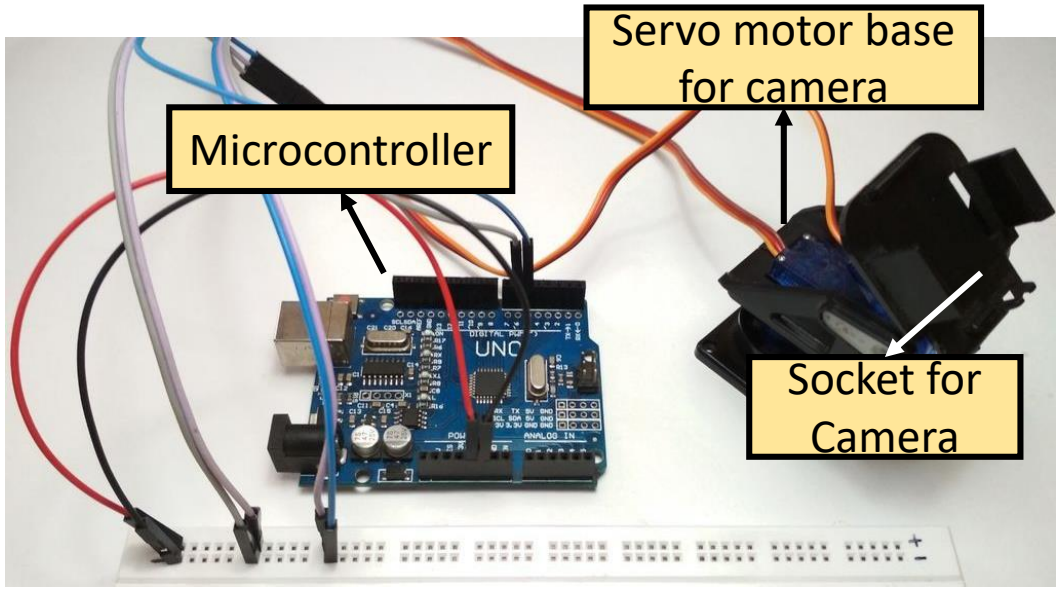

BP:53
-0.010.010.664

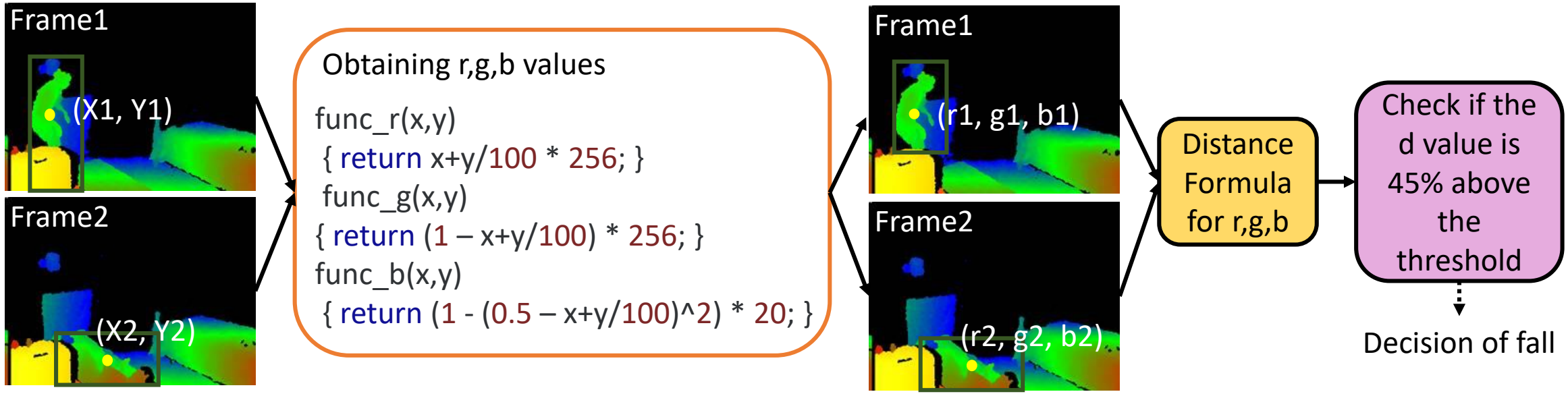

BPM: 65

Implementation: Good-Eye System: On-wall Camera



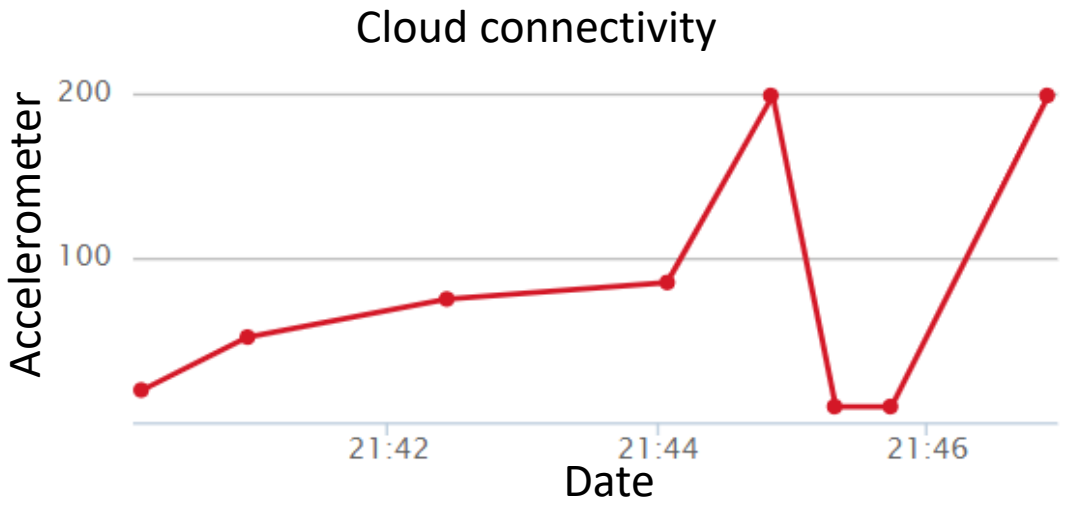

```
Center of Rectangle is : (1082, 181)
output= 'X1082Y181z'
{34 : 322, 626: 914}
X :626
Y: 34
X+W :914
y+h: 322
1083
195
Center of Rectangle is : (1087, 197)
output= 'X1082Y181z'
{34 : 343, 606: 934}
X :606
Y: 34
X+W :934
y+h: 343
1087
199
```

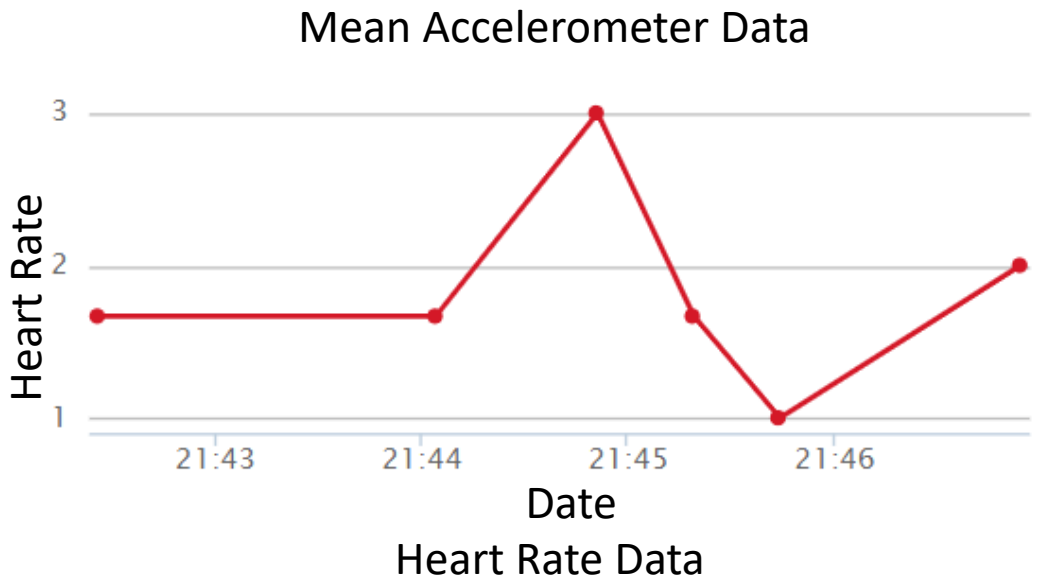
Working- On-wall:



On-wall Working:

Physiological Signal	Change with Fall	Feasibility
Sweat	Inconsistent	Not usable
Heart Rate	Increases	Usable
Blood Pressure	Increases	May be used
Temperature	Inconsistent	Not usable





Conclusions

- The fall detection and prediction is executed in this work with an accuracy of 95%.
- The user is alerted whenever there is a possibility of fall.
- After the fall, instead of waiting for the user to ask for help, the help is provided.
- Constant care and protection are provided.

Future Research

➢ The main research areas that we are focusing are:

- To use more physiological sensors to predict the falls in elderly.
- To develop smart healthcare models which incorporate various activities such as type, amount and time of food consumed, the number of hours slept along with the sleep behaviors and the changes in physiological parameters during sleep to not just predict falls but also to analyze human behaviors.
- To Integrate security and privacy features to our smart healthcare systems using blockchain technology for more credibility.

Thank you!