# Good-Eye: A Combined Computer-Vision and Physiological-Sensor based Edge Device for Full-Proof Prediction and Detection of Fall of Adults

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# Outline of the Talk

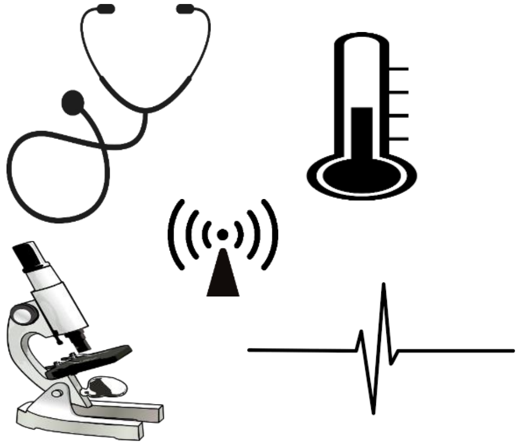
- Introduction
- Motivation
- Existing Solutions - their Issues
- Proposed Solution
- Novel Contributions
- Broad Perspective of Good-Eye
- Proposed Approaches of Good-Eye
- Implementation and Validation of Good-Eye
- Conclusions and Future Research

# Introduction

## ✓Internet of Things

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

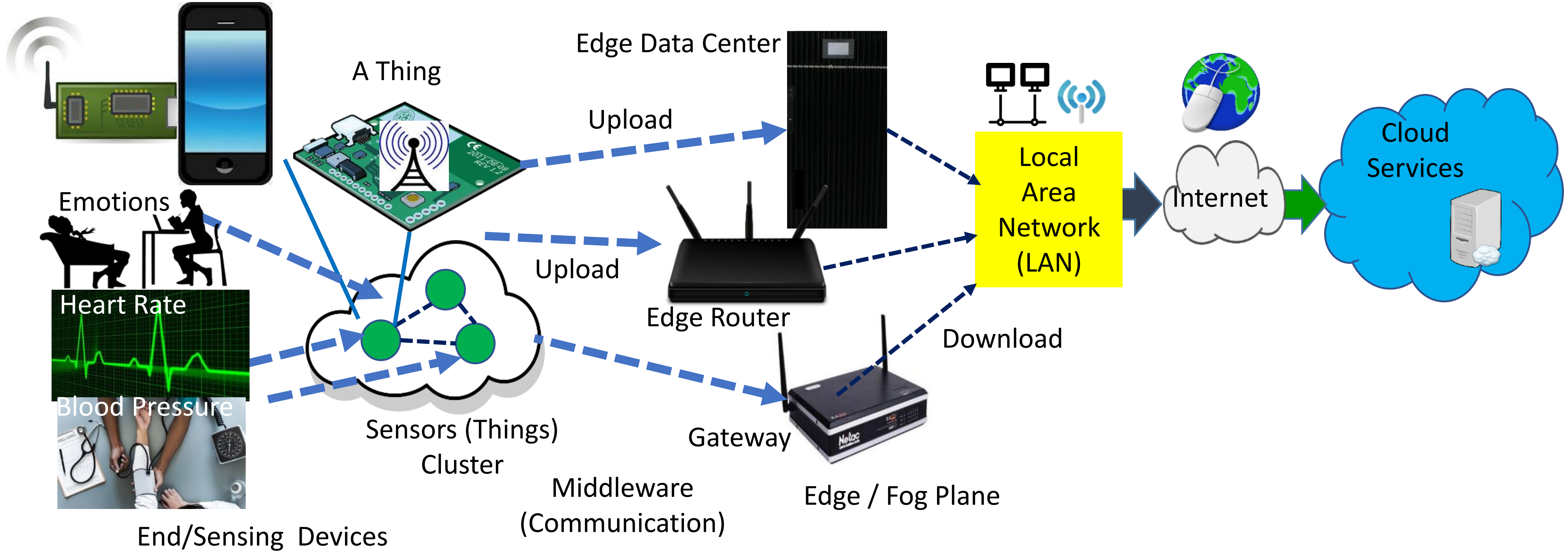
## ✓Internet of Medical Things



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

# Introduction

## ✓What is Edge?



# Motivation

- 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.

# 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.X, et.al | 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. N | This research uses only physiological sensor data with no usage of camera. This research will not be helpful to have the location access. |
| Jian Liu, et. al | Monitors fluctuations using only accelerometers. |
| Waheed, et.al | 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 | This research proposed fall detection by using floor sensors which limits the movement of the user with an increase in investment. |

# Issues of Existing Research

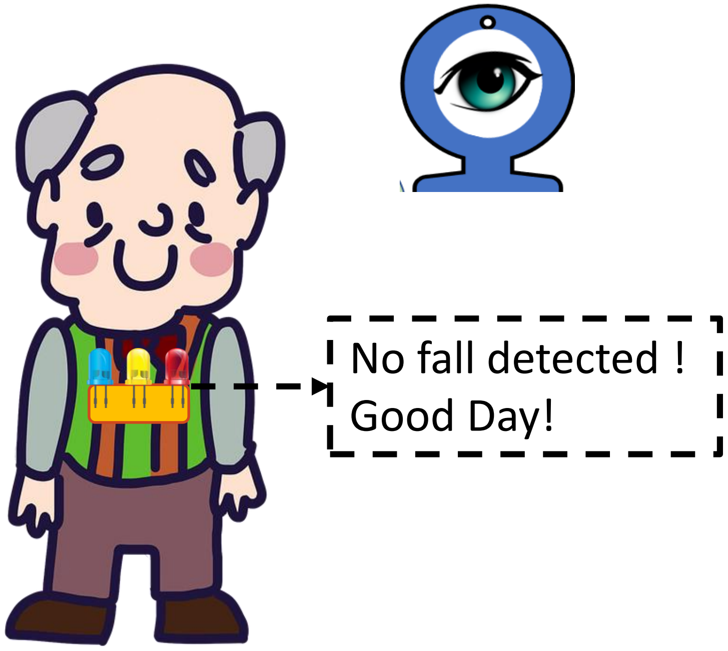
- Decisions of fall are only dependent on the changes in accelerometer axes.
- Some applications have user to give response after the fall and that can be time consuming as the user might not be conscious.
- Some applications are limited to a certain location and certain type of surroundings which add 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.

# Addressed Research Question

- How to have a non-invasive, optimized, IoT enabled system which detects and predicts the falls in elderly based on the physiological and vision signal data, analyses the data at the user end (at IoT-Edge) and stores the data at the cloud end (at IoT-Cloud)?

# Proposed Solution

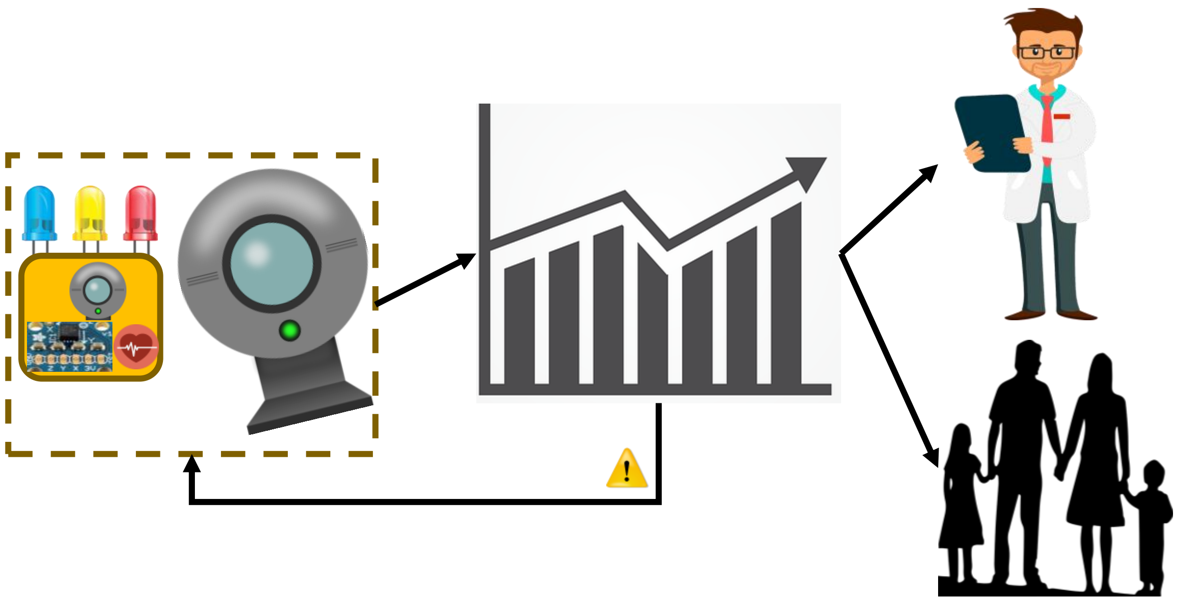
➢ Conceptual Overview of Good-Eye




- ✓ 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.

# Proposed Solution

➢Schematic Representation of Good-Eye



The data from the wearable and non-wearable devices is taken and is analyzed in the microcontroller. The fall prediction that is made in the microcontroller is sent to the doctor and guardian.
The notification on the level of prediction and detection is represented using the LED lights on the wearable.

# Novel Contributions

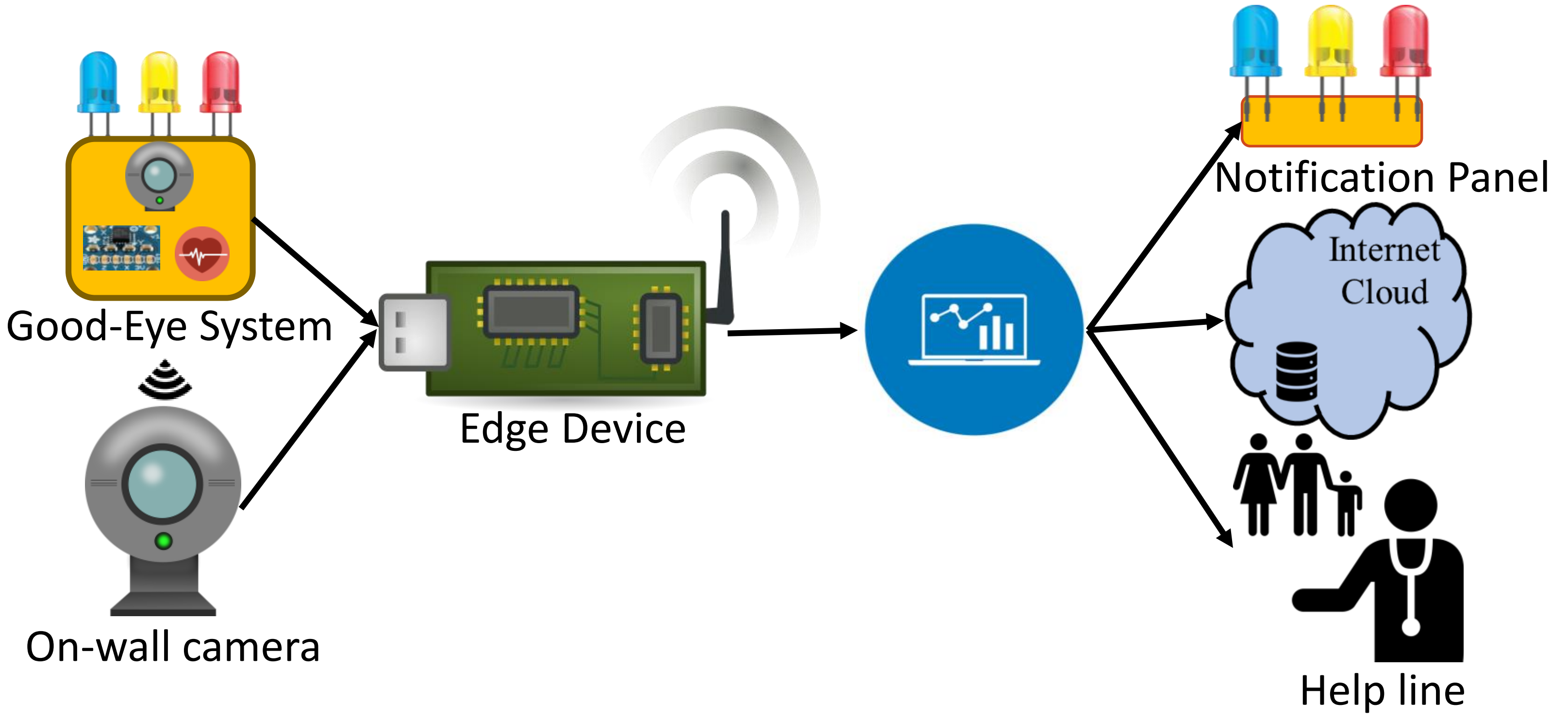
- A fall detection mechanism that provides complete analyses of situation using physiological and vision approaches.
- A system that not only detects the fall after the occurrence of event but also predicts the future events and warns the user accordingly.
- A continuously monitoring battery optimized 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

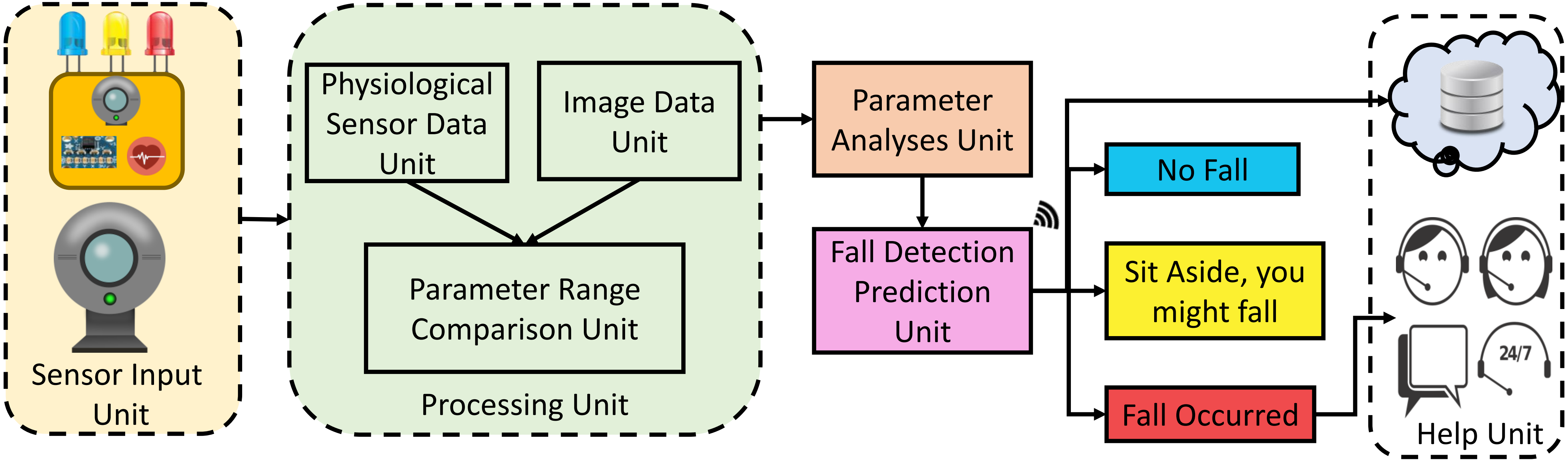
- Prediction of occurrence of falls are also notified to users as the system continuously monitors the physiological changes.
- Informed detection of fall is made as the decision involves both physiological and vision signal data.
- The decision is not just made depending upon accelerometer but is made 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.

# Broad Perspective of Good-Eye

- ➢Broad Conceptual View of Good-Eye



# Architecture of Good-Eye

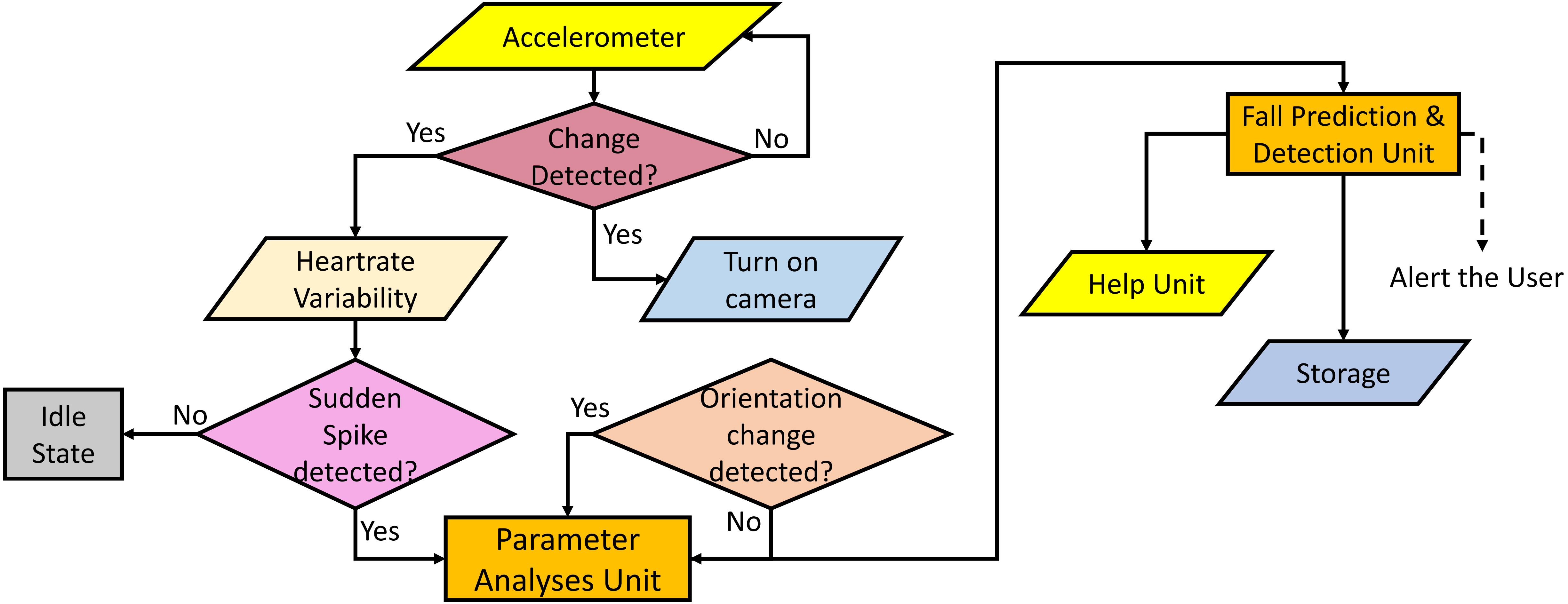


# Considered Sensor Input Data

- 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.

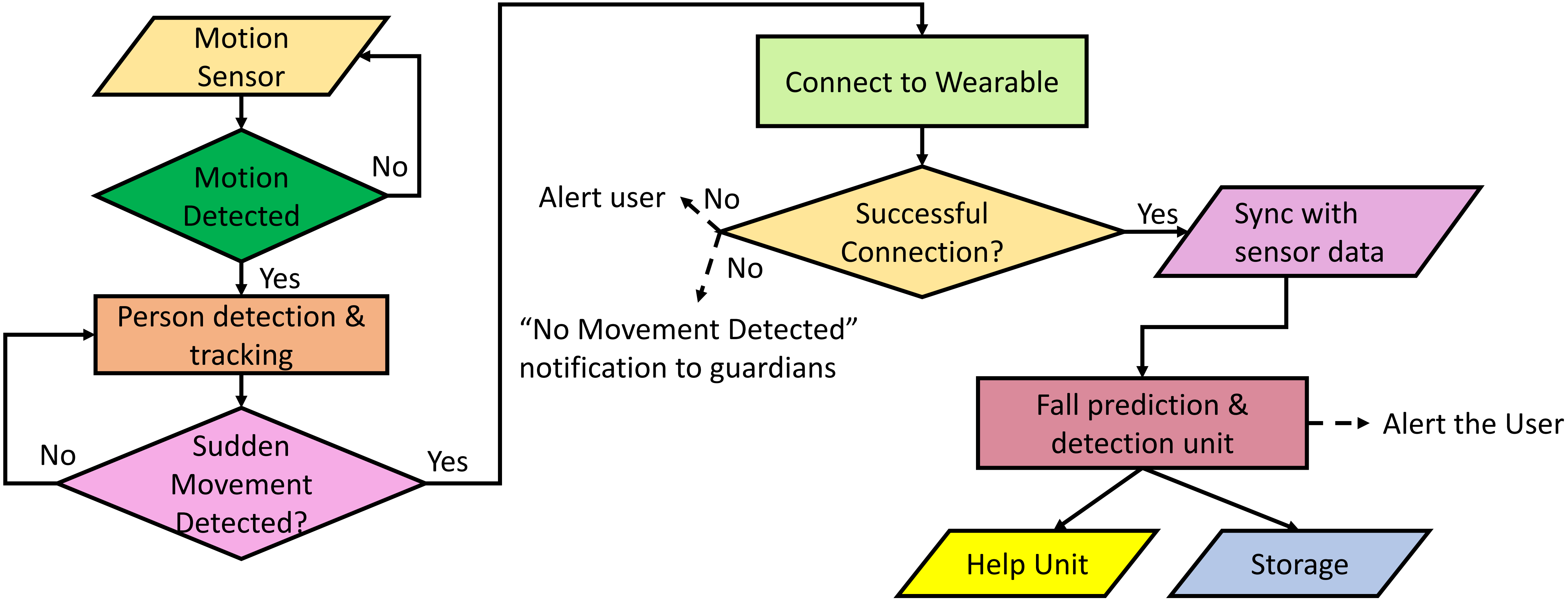
# Design Flow of Good-Eye

- 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, 40)
- 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

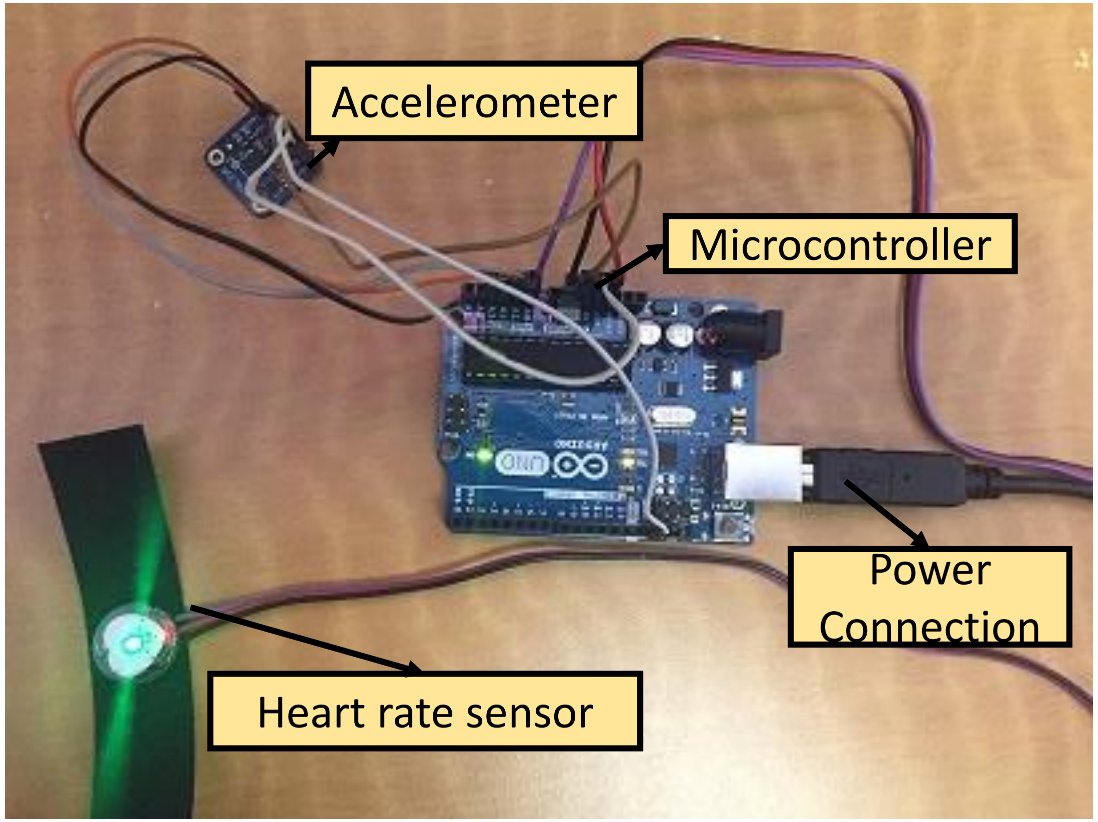
• The action or process of identifying the presence of something concealed. A detection is often based upon the incident.

# Fall Prediction & Detection Unit

- Analyses of fall prediction and detection

| Change in y value to +/- 3 g | Heart Rate (Baseline Information) | Sudden change in heart rate | Change in 45% of pixels | Prediction | Detection |
|---|---|---|---|---|---|
| Less than threshold | Age 60 and up: 75 to 136 bpm | < 60 or more than > 136- danger Typically +/- 10bpm | Change | Not a fall | None Required |
| Greater than Threshold | | | No change | Sit aside you might fall | None Required |
| Greater than Threshold | | | Change | Definite fall | Fall Detected |

# Implementation : Good-Eye System




| | | | |
|---|---|---|---|
| X accel: -0.03 | Y accel: 0.04 | Z accel: 0.63 | BPM: 78 |
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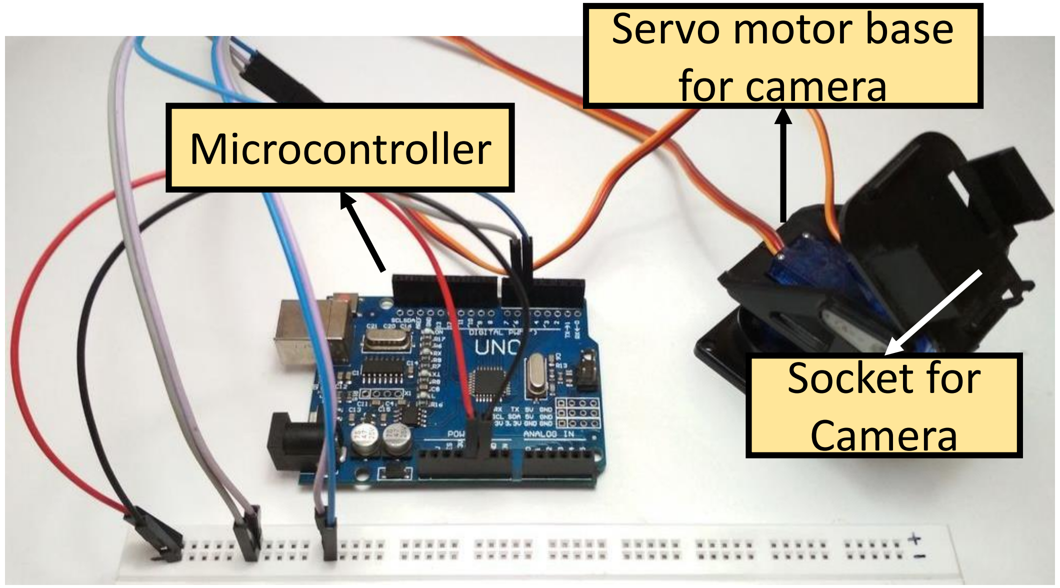
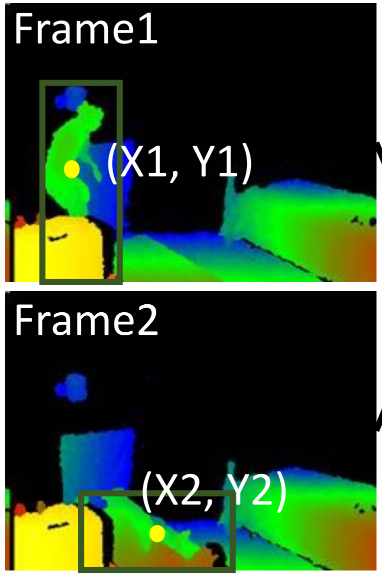
| X accel: -0.01 | Y accel: 0.04 | Z accel: 0.64 | |
| X accel: -0.03 | Y accel: 0.04 | Z accel: 0.63 | BPM: 79 |
| X accel: -0.03 | Y accel: 0.03 | Z accel: 0.63 | |

# Implementation: Good-Eye System: On-wall Camera



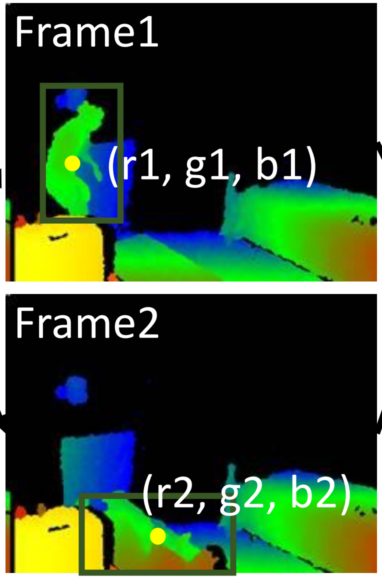

```
Center of Rectangle is : (1082, 181)
output= 'X1082Y181z'
{34 : 322, 626: 914}
X :626
Y: 34
X+W :914
y+h: 322
1083
195
Center of Rectangle is : (1087, 197)
output= 'X1082Y181z'
{34 : 343, 606: 934}
X :606
Y: 34
X+W :934
y+h: 343
1087
199
```

# Validation: Good-Eye Model




Obtaining r,g,b values

```
func_r(x,y)
 { return x+y/100 * 256; }
 func_g(x,y)
{ return (1 – x+y/100) * 256; }
func_b(x,y)
 { return (1 - (0.5 – x+y/100)^2) * 20; }
```

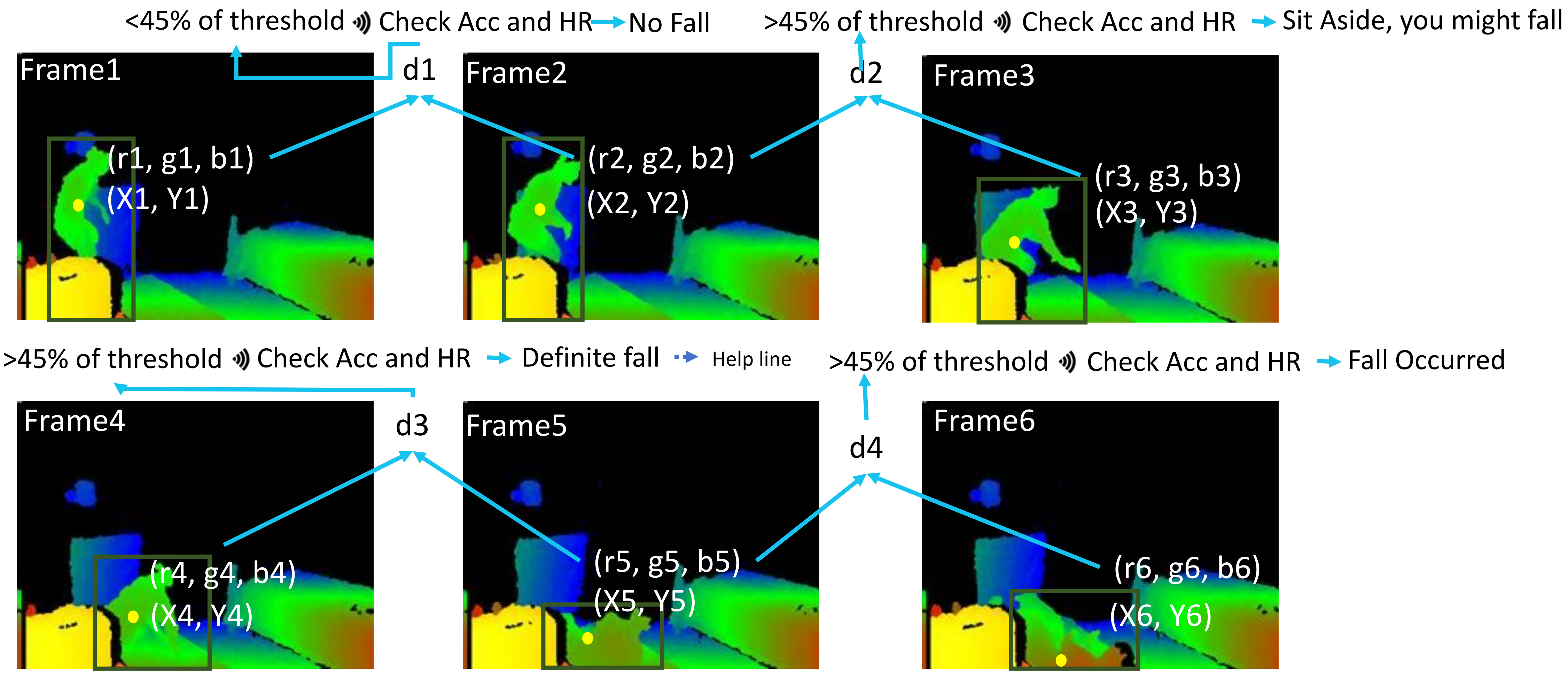



Distance Formula for r,g,b

Check if the d value is 45% above the threshold

Decision of fall

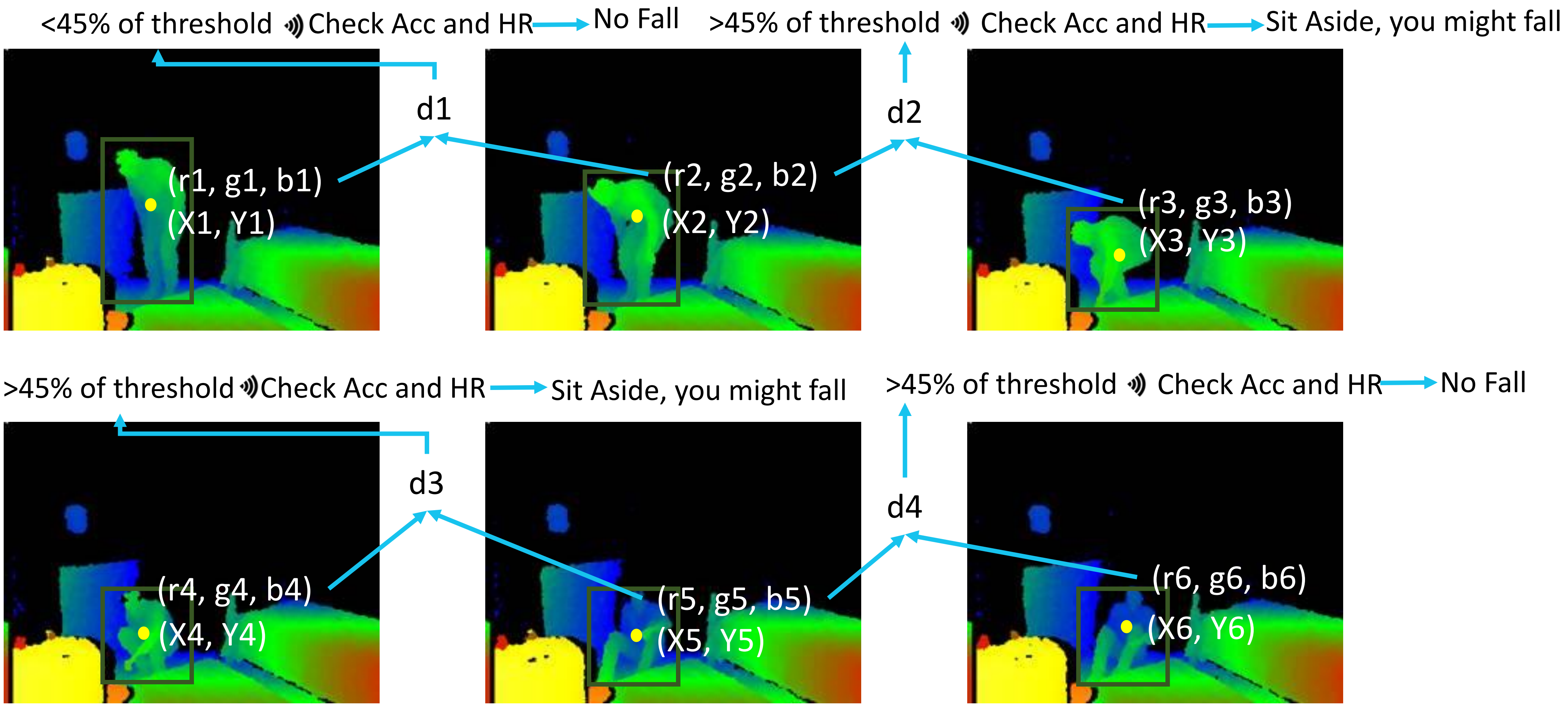
# Validation




Event of fall [1].


[1] Z. Zhang and V. Athitsos, "Fall Detection," Website, fall Detection Dataset. [Online]. Available: http://vlm1.uta.edu/zhangzhong/falldetection/

# Validation




Person sitting down [1]

[1] Z. Zhang and V. Athitsos, “Fall Detection,” Website, fall Detection Dataset. [Online]. Available: http://vlm1.uta.edu/zhangzhong/falldetection/

# Validation

➢ Metrics Involved:

- True positive (TP): Fall correctly identified as Fall
- False positive (FP): Not a fall incorrectly identified as fall
- True negative (TN): Not a fall correctly identified as not a fall
- False negative (FN): Fall incorrectly identified as not a fall

- Sensitivity or Recall or True Positive Rate (TPR) = (TP)/ (TP+FN)
- Precision = (TP)/(TP+FP)

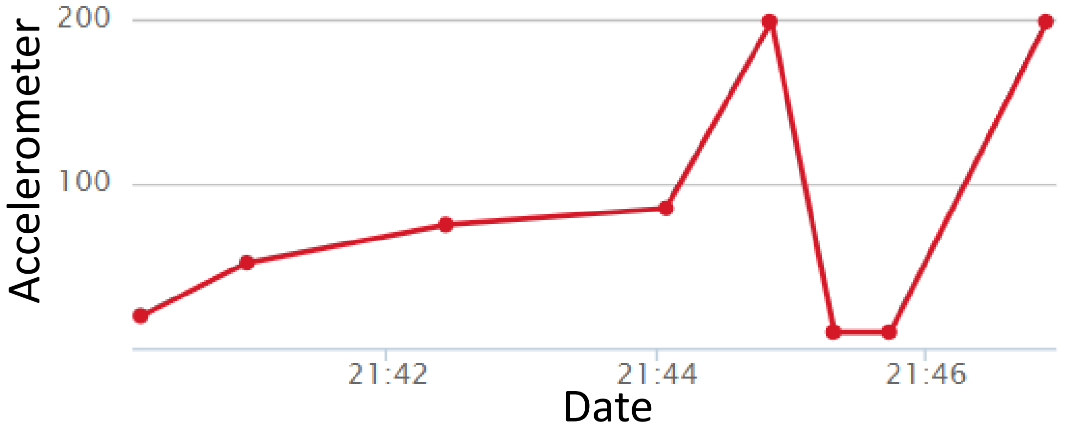
- **Accuracy** = (TP+TN)/(TP+TN+FP+FN) and
- Confidence Interval = $(z^*( (A * (1-A)) ) / n)^{1/2}$ )

where z is the critical value, A is accuracy, n is sample size

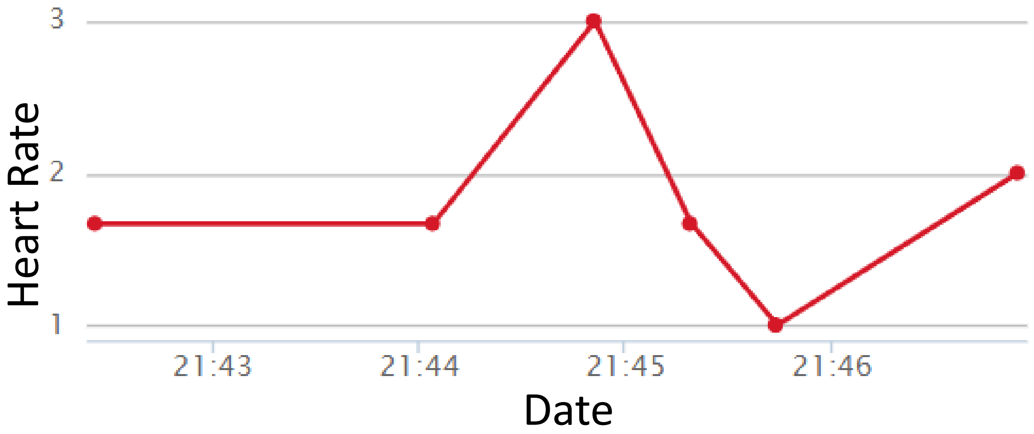
# Validation of Good-Eye

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

Cloud connectivity




Mean Accelerometer Data




Heart Rate Data

# 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

- Using more physiological sensors such as blood pressure, amount and time of food consumed, the sleep behaviors in order to predict and analyze falls will be our future work.

- Integrating security and privacy features to our smart healthcare systems using blockchain technology will be future research as well.

# Questions?

# Thank you!