DESIGN AND DEVELOPMENT OF CONTINUOUS HEART RATE VARIABILITY MONITOR

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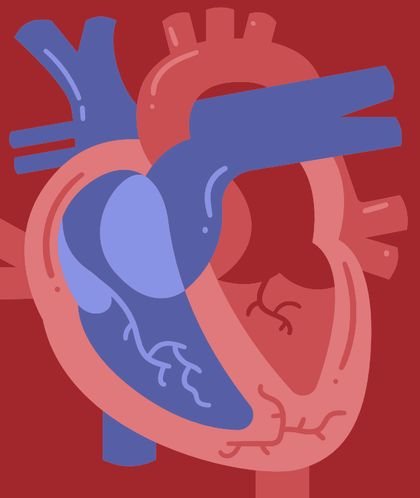


Guided by Sujay Deb Sir

WHAT IS HRV

Heart Rate

It measures how many times heart beats in a single minute.

Heart Rate Variability

(HRV) is a measure of the difference between consecutive beats of heart. It measures the steadiness of the heartbeats,like how much the beat between each of the heartbeats varies.

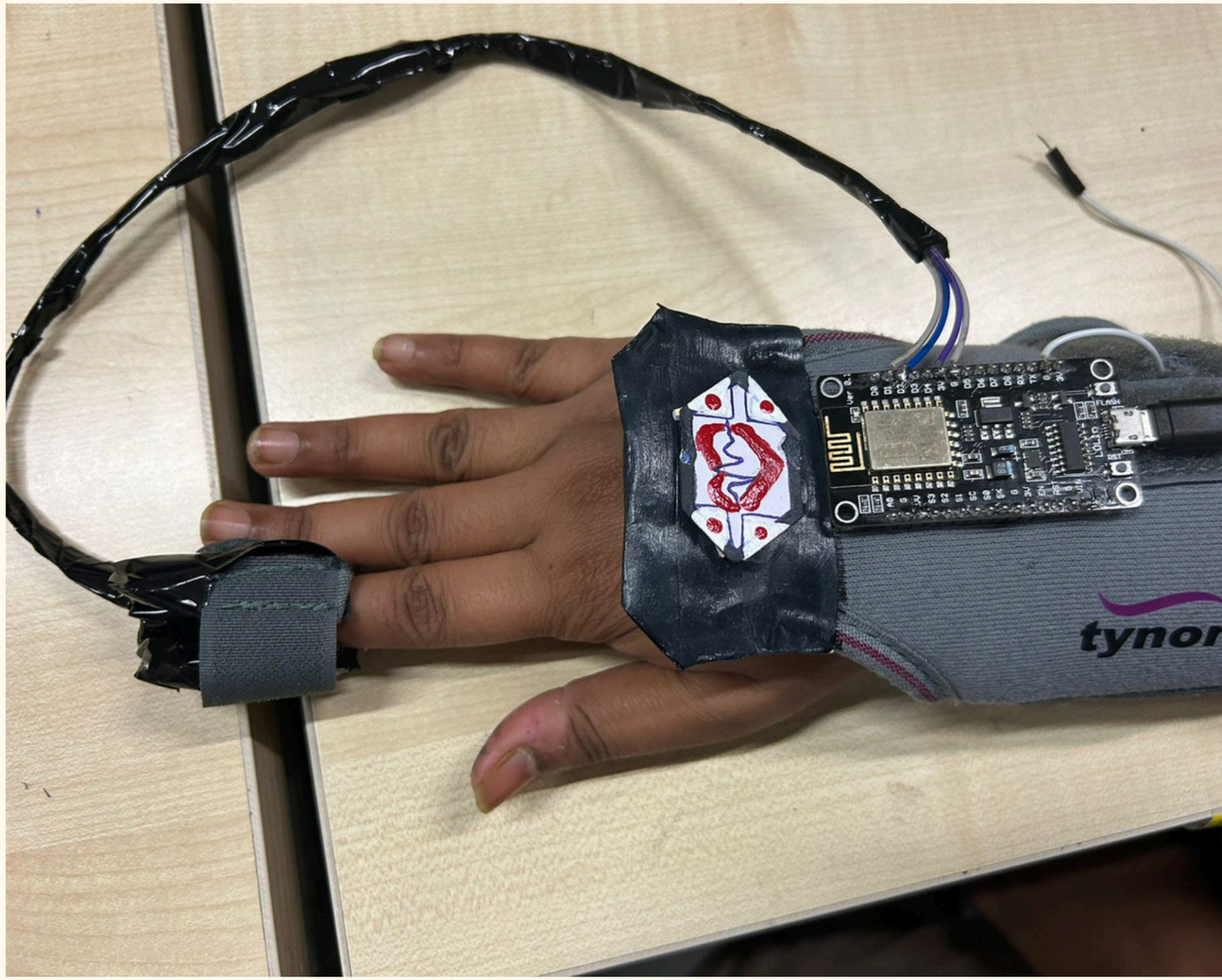
HRV is controlled by **Automatic nervous system** (**ANS**)

Factors Impacting HRV

Stress, Sleep, Activities, mood, etc.

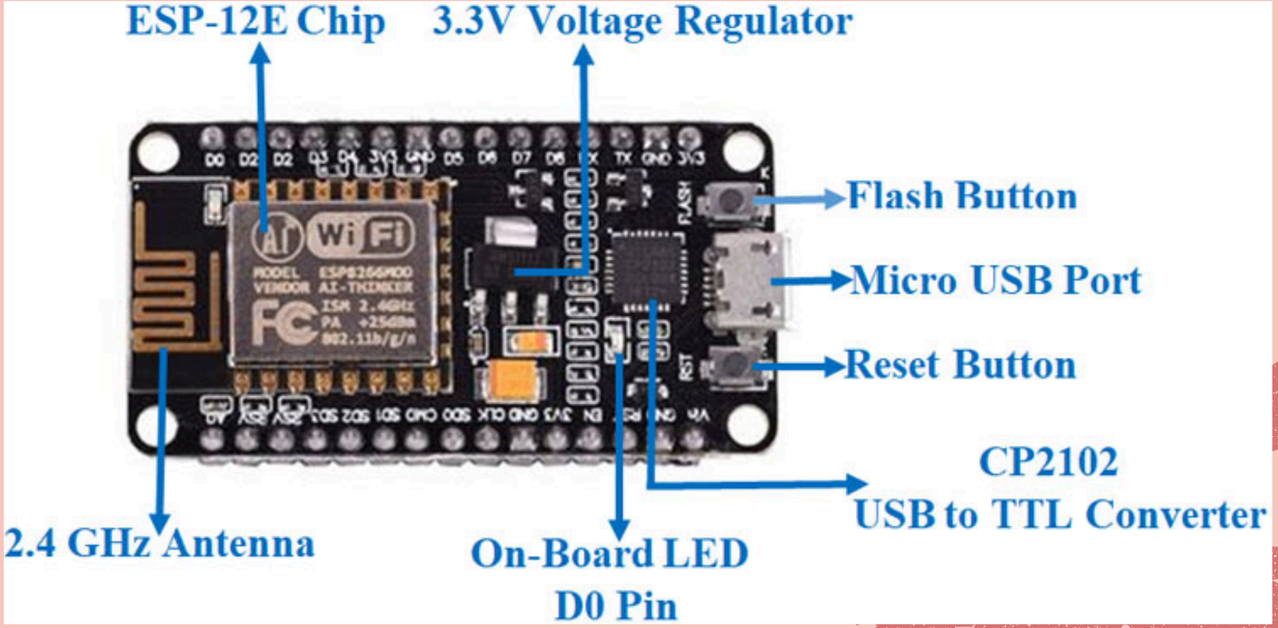
VARISCAN

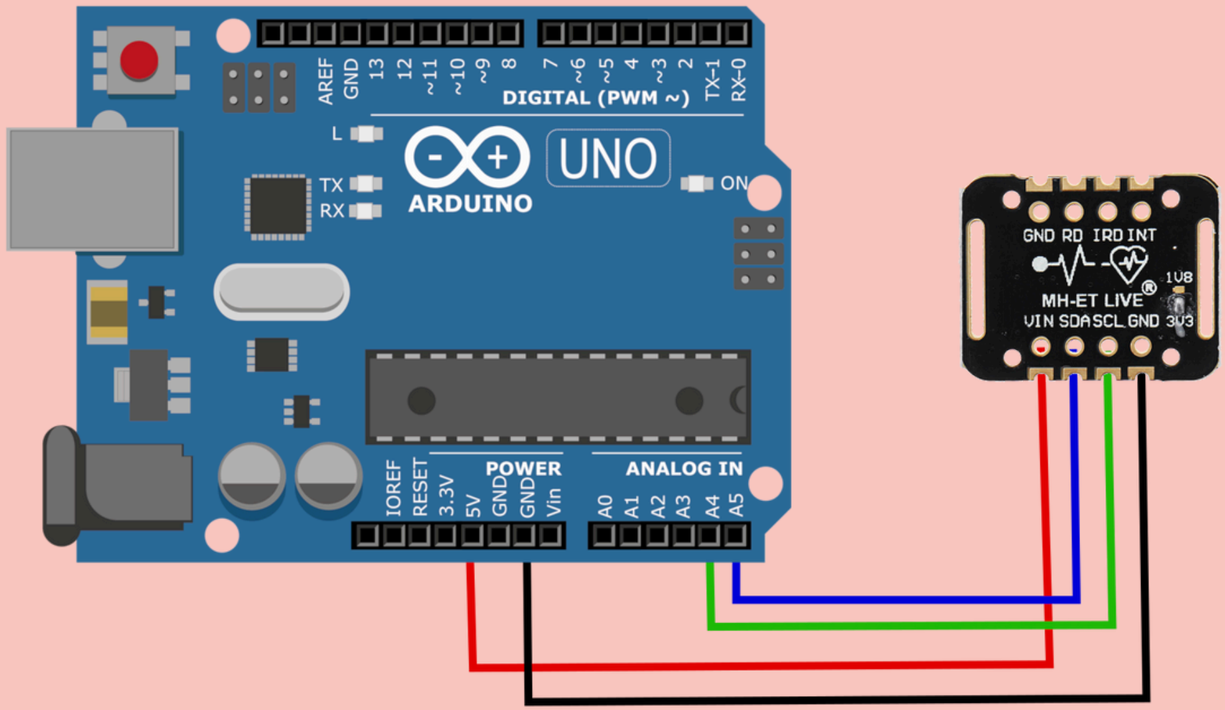
VariScan is a continuous heart rate variability (HRV) monitor, meticulously engineered to provide users with accurate insights into their cardiovascular health.



HARDWARE SELECTION AND INTEGRATION:

1. **NodeMCU ESP8266:** Provides WiFi connectivity for data transmission to a computer or cloud server.
2. **MAX30102 sensor:** Measures heart rate by detecting changes in blood volume in the fingertip, enabling continuous monitoring.
3. **9V Rechargeable battery**




AREF
GND
13
12
~11
~10
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8
7
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4
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2
TX-1
RX-0
DIGITAL (PWM ~)
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UNO
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RESET
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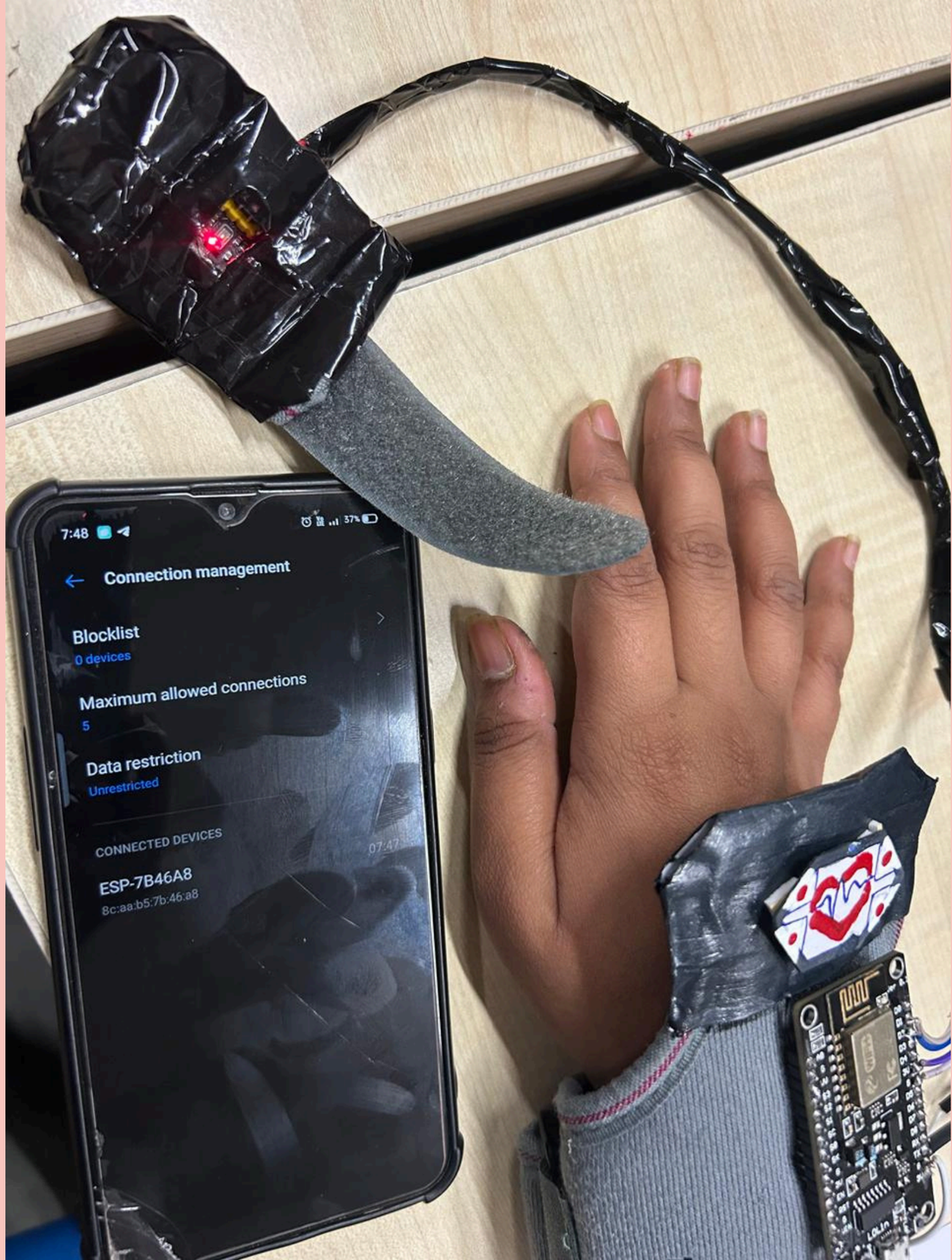
VIN SDA SCL GND 3V3


7:48
Connection management
Blocklist
0 devices
Maximum allowed connections
5
Data restriction
Unrestricted
CONNECTED DEVICES
ESP-7B46A8
8c:aa:b5:7b:46:a8

DATA COLLECTION

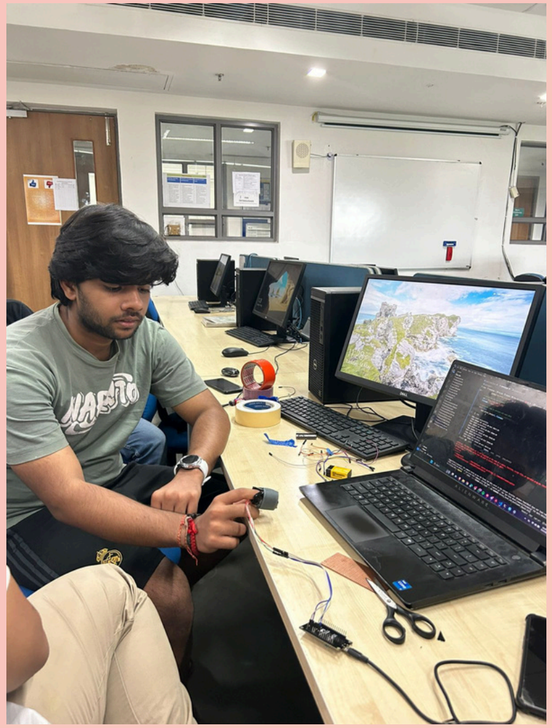
Data was collected for 5 minutes for each participant

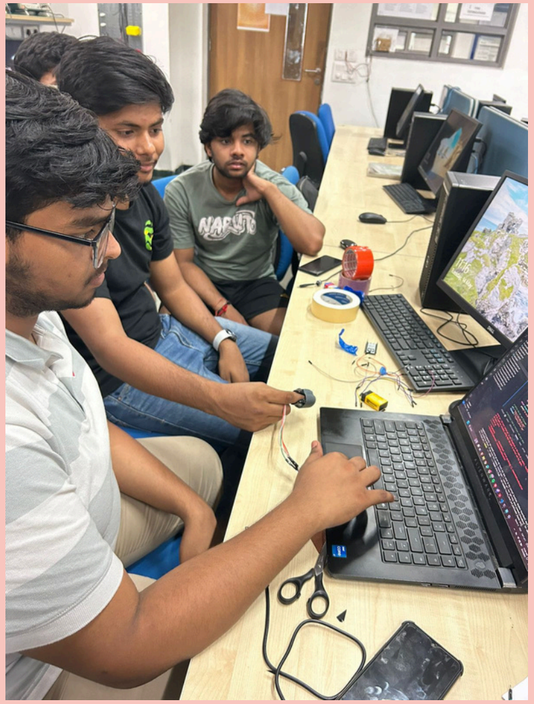
1 MAX30102 Sensor Data:

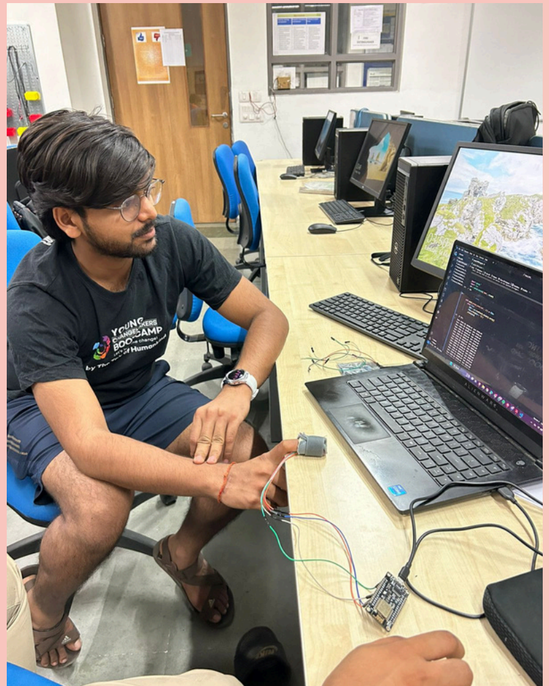
- We collect data from the MAX30102 sensor, capturing both infrared (IR) and red light intensity readings, along with corresponding timestamps.
- The collected data is transmitted via WiFi to a server and saved in a text file format for further analysis.
- The format of the data includes timestamps, IR intensity, and red light intensity values.

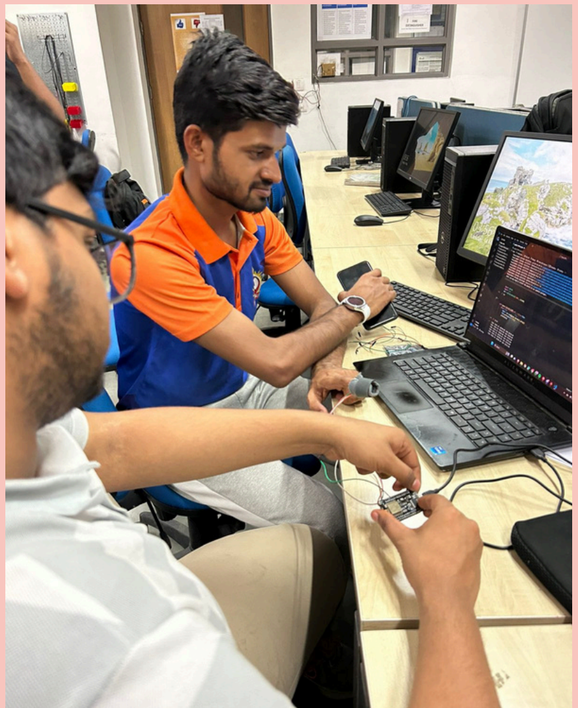
2 Samsung Watch 4 data

- In addition to the MAX30102 sensor data, we gather average beats per minute (BPM) using a Samsung Watch 4.
- This supplementary information enhances our understanding of heart rate variability and overall health status.









DATA COLLECTION

aaman1_test_Server.txt

```
Time: 22815 IR: 98752.00 Red: 63697.00
Time: 22915 IR: 99039.00 Red: 63755.00
Time: 22995 IR: 99235.00 Red: 63809.00
Time: 23095 IR: 99456.00 Red: 63842.00
Time: 23195 IR: 99665.00 Red: 63874.00
Time: 23295 IR: 99847.00 Red: 63879.00
Time: 23396 IR: 98060.00 Red: 63435.00
Time: 23496 IR: 98378.00 Red: 63542.00
Time: 23596 IR: 98677.00 Red: 63613.00
Time: 23716 IR: 98961.00 Red: 63674.00
Time: 23817 IR: 99184.00 Red: 63717.00
Time: 23916 IR: 99492.00 Red: 63778.00
Time: 24016 IR: 99842.00 Red: 63847.00
Time: 24097 IR: 100007.00 Red: 63895.00
Time: 24177 IR: 100012.00 Red: 63784.00
Time: 24257 IR: 98150.00 Red: 63427.00
Time: 24357 IR: 98285.00 Red: 63417.00
Time: 24457 IR: 98085.00 Red: 63311.00
Time: 24557 IR: 97742.00 Red: 63241.00
Time: 24638 IR: 97731.00 Red: 63226.00
Time: 24738 IR: 97594.00 Red: 63154.00
Time: 24837 IR: 97500.00 Red: 63120.00
Time: 24918 IR: 97692.00 Red: 63198.00
Time: 25018 IR: 97996.00 Red: 63236.00
Time: 25118 IR: 98246.00 Red: 63284.00
```

```
Time: 247417 IR: 95302.00 Red: 69156.00
Time: 247518 IR: 95445.00 Red: 69112.00
Time: 247618 IR: 94287.00 Red: 68932.00
Time: 247737 IR: 94963.00 Red: 69115.00
Time: 247837 IR: 95338.00 Red: 69184.00
Time: 247937 IR: 95587.00 Red: 69287.00
Time: 248057 IR: 95956.00 Red: 69429.00
Time: 248156 IR: 96202.00 Red: 69544.00
Time: 248257 IR: 95444.00 Red: 69266.00
Time: 248376 IR: 95791.00 Red: 69439.00
Time: 248476 IR: 96061.00 Red: 69512.00
Time: 248576 IR: 96164.00 Red: 69563.00
Time: 248716 IR: 96439.00 Red: 69633.00
Time: 248855 IR: 96584.00 Red: 69611.00
Time: 248955 IR: 95414.00 Red: 69310.00
Time: 249075 IR: 95828.00 Red: 69450.00
Time: 249175 IR: 96157.00 Red: 69533.00
Time: 249275 IR: 96242.00 Red: 69589.00
Time: 249375 IR: 96492.00 Red: 69665.00
Time: 249494 IR: 96691.00 Red: 69705.00
Time: 249594 IR: 95928.00 Red: 69384.00
Time: 249694 IR: 95769.00 Red: 69437.00
Time: 249773 IR: 95979.00 Red: 69472.00
Time: 249854 IR: 96263.00 Red: 69528.00
Time: 249974 IR: 96476.00 Red: 69560.00
Time: 250073 IR: 96697.00 Red: 69609.00
Time: 250193 IR: 96815.00 Red: 69608.00
Time: 250313 IR: 96149.00 Red: 69299.00
```

DATA PREPROCESSING & VISUALIZATION

1 Data Format Conversion

- We preprocess the collected data and convert it into a standardized format for analysis.
- The data is represented in the format of timestamp, infrared (IR) intensity, and red light intensity.

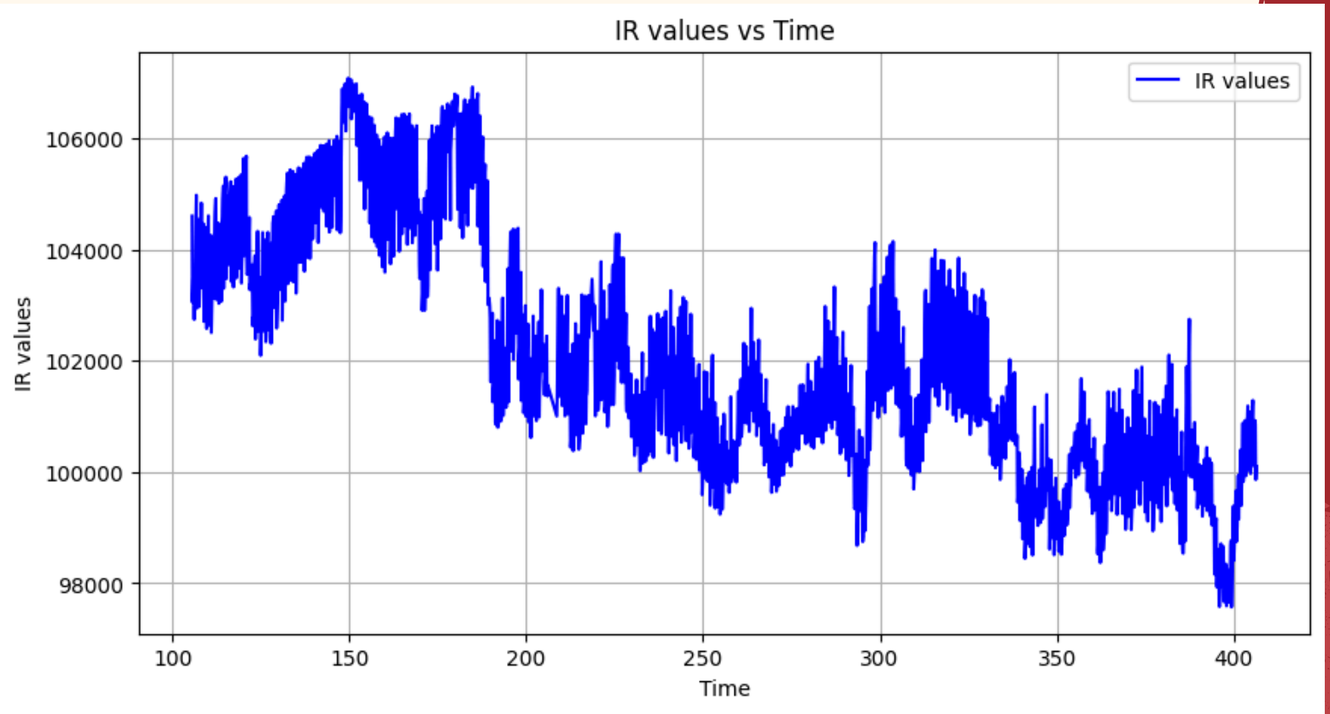
Time	IR	Red
103593	1935.0	2194.0
103692	1877.0	2185.0
103812	1891.0	2199.0
103893	1934.0	2218.0
103993	2400.0	2258.0
104093	6887.0	3464.0
104193	12665.0	9436.0
104293	45748.0	40143.0
104373	55689.0	45796.0
104474	88484.0	62851.0
104573	92431.0	63503.0
104674	93282.0	63626.0
104773	93548.0	63669.0
104873	93943.0	63854.0
104974	94669.0	64080.0
105075	96214.0	64514.0
105174	95452.0	63830.0
105254	91904.0	63025.0
105354	90122.0	62675.0
105455	91388.0	63213.0

DATA PREPROCESSING & VISUALIZATION

2

Graph Generation:

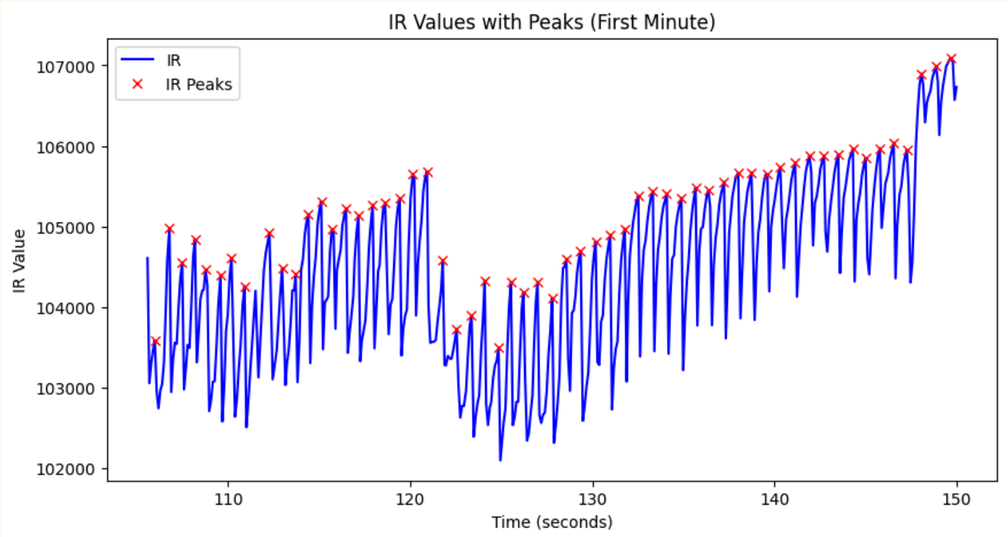
- We generate graphs representing IR intensity vs. time and red light intensity vs. time.
- These graphs provide visual insights into the variations of IR and red light intensities over time.

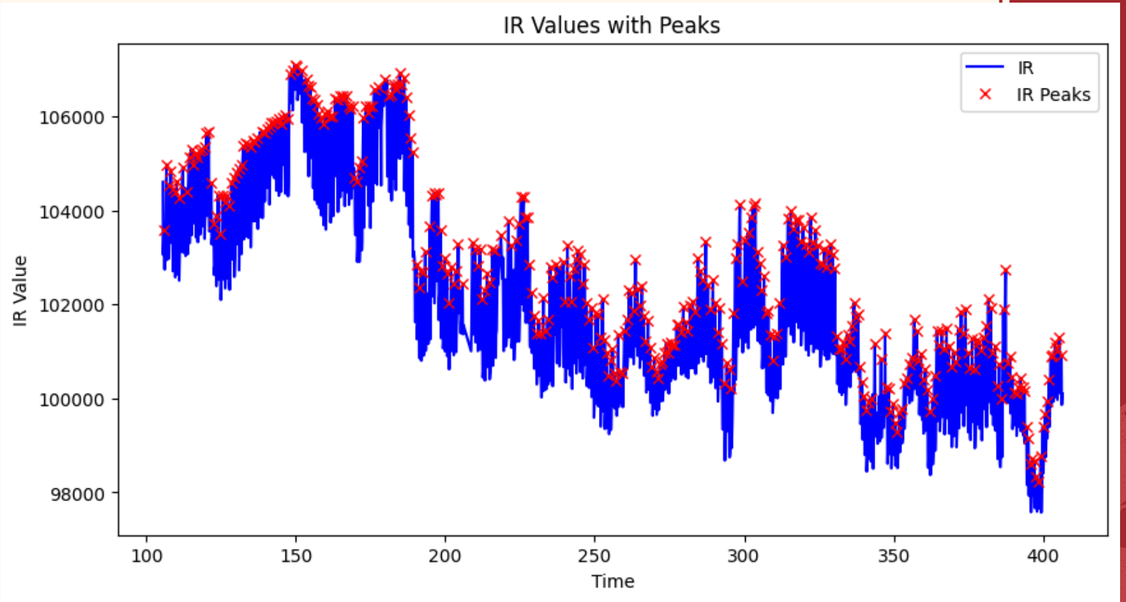


DATA PREPROCESSING & VISUALIZATION

2 Peak Detection

- Using the generated graphs, we identify peaks corresponding to significant changes or spikes in intensity.
- The difference between consecutive peak timestamps represents the RR interval, providing valuable information about heart rate variability over time.





LITERATURE REVIEW

1 Heart Rate Variability: An Old Metric with New Meaning in the Era of using mHealth Technologies for Health and Exercise Training Guidance. Part One: Physiology and Methods

- This paper discussed about time domain and frequency domain for measuring HRV followed by different sensors and types of devices used like Photoplethysmography (PPG), Pulse Oximeterand ECG.Later it discussed how Autonomic Nervous System controls HRV.

2 Heart rate variability: A review

- The paper discussed the interplay between the sympathetic and parasympathetic nervous systems.It also highlighted that Heart rate (HR) is a nonstationary signal, its variation may contain indicators of current disease, or warnings about impending cardiac diseases.
-
- This paper has discussed the various applications of HRV and different linear, frequency domain, wavelet domain, nonlinear techniques used for the analysis of the HRV.

HRV CALCULATION

1 RR Interval

- R-R interval is the timing between heartbeats, so HRV is measuring the variability of R-R intervals.

2 RMSSD of RR Intervals

RMSSD is calculated by taking the square root of the mean of the squares of the successive differences between adjacent RR intervals. Mathematically, it is expressed as:

$$\text{RMSSD} = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N-1}(RR_{i+1} - RR_i)^2}$$

- RR_iRRi is the i-th RR interval,
- NN is the total number of RR intervals.

HRV CALCULATION

1 ln(RMSSD)

- The range of RMSSD is highly varying, so we then calculated ln(RMSSD). This ranges between (0 to 6.5), where higher values represent high HRV and healthy heart activity.

2 Interpretation of ln(RMSSD)

- Parasympathetic Activity
- Stress and Recovery
- Health and Fitness
- Autonomic Balance

Name	Gender	Age	Height(inches)	Weight(kg)	BPM(watch)	Calculated BPM	RMSSD	ln(RMSSD)
Test1	M	21	74	69	76	81	86.48115624	4.459926543
Test2	M	21	71	80	92-94	85	106.7013257	4.670033583
Test3	M	22	69	100	90	89	453.4723998	6.116934407
Test4	F	22	61	63	88	84	59.02995608	4.078045045
Test5	M	21	65	65	82,83	82	102.74	4.63
Test6	M	34	67	77	67,70	ERROR	ERROR	ERROR
Test7	M	22	67	53	87,89	84	73.867	4.3
Test8	M	20	68	75	80,61,55,72	70	146	4.9
Test9	M	19	64	70	88,96	88.4	189.81	5.24
Test10	M	19	69	66	79,78,87	73	188.76	5.24
Test11	M	19	68	50	55,64	63	318.33	5.76

REFERENCE TABLE

Age Range	Gender	rMSSD	ln(rMSSD)	Elite HRV	HRV4Training	Bioforce	ithlete
18-25	Male	86.5	4.5	68.7	86.5	89.2	89.2
	Female	68.7	4.2	65.1	68.7	84.6	84.6
25-35	Male	66.0	4.2	64.5	66.0	83.8	83.8
	Female	55.7	4.0	61.8	55.7	80.4	80.4
35-45	Male	50.4	3.9	60.3	50.4	78.4	78.4
	Female	45.6	3.8	58.7	45.6	76.4	76.4
45-55	Male	39.6	3.7	56.7	39.6	73.6	73.6
	Female	41.7	3.7	57.4	41.7	74.6	74.6
55-65	Male	32.1	3.5	53.3	32.1	69.4	69.4
	Female	32.5	3.5	53.5	32.5	69.6	69.6
65-75	Male	30.6	3.4	52.7	30.6	68.4	68.4
	Female	24.8	3.2	49.4	24.8	64.2	64.2
75+	Male	33.1	3.5	53.9	33.1	70.0	70
	Female	25.5	3.2	49.9	25.5	64.8	64.8

Table 2 – Data gathered on Elite HRV platform shows rMSSD, ln(rMSSD), and "HRV Scores" for Elite HRV and is calculated for other HRV software applications based on published calculations. The data does not necessarily represent the user populations for the other HRV platforms.

Conclusion

In conclusion, VariScan represents a significant advancement in continuous heart rate variability (HRV) monitoring. We've developed a reliable system for real-time analysis through meticulous hardware integration and efficient data processing. Moving forward, we aim to incorporate ECG-based and PPG-based sensors and conduct studies involving diverse age groups to further enhance our understanding of heart health across demographics. By embracing these future endeavors, VariScan has the potential to revolutionize heart health monitoring and empower individuals to take proactive steps towards improved cardiovascular well-being.

Reference Links and Papers

https://imotions.com/blog/learning/best-practice/heart-rate-variability/

https://elitehrv.com/normal-heart-rate-variability-age-gender

https://www.researchgate.net/publication/6687018_Heart_rate_variability_A_review

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6141929/

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