Shell Eco-Marathon 2022: Pitch the Future

Team AVERERA (ID: IN0014001)

Autonomous Health Assistance Integrated Sub-System (HAIS)

EXECUTIVE SUMMARY

The report focuses on the idea to automate the real-life assistance a passenger would get from another human in case of an emergency by incorporating a health assistance system into the vehicle to provide seamless autonomous aid to the patient in a crisis, which will not just improve the health monitoring but also the survivability of the rider. This cognitive ability of the vehicle is to detect the driver's health using autonomous sensing abilities.

The proposed implementation consists of Integrating the Seat Belts with no skin contact sensors, which will detect the mechanical motion of the wearer, and radio frequency-based sensors to detect the heart and respiratory motion and integrating a wrist band with sensors having fitness tracking features like blood oxygen monitoring, heart rate monitoring and Blood Sugar measurement. The data collected from the sensors will then be compared to a passenger's specific profile available with the system. The Passenger's real-time health state will be forecasted using a machine learning algorithm that will make a conclusion report based on the sensed data. When the system detects abnormal symptoms, the vehicle will transmit the data to the hospital and reroute itself to the nearest hospital to provide autonomous assistance to the driver.

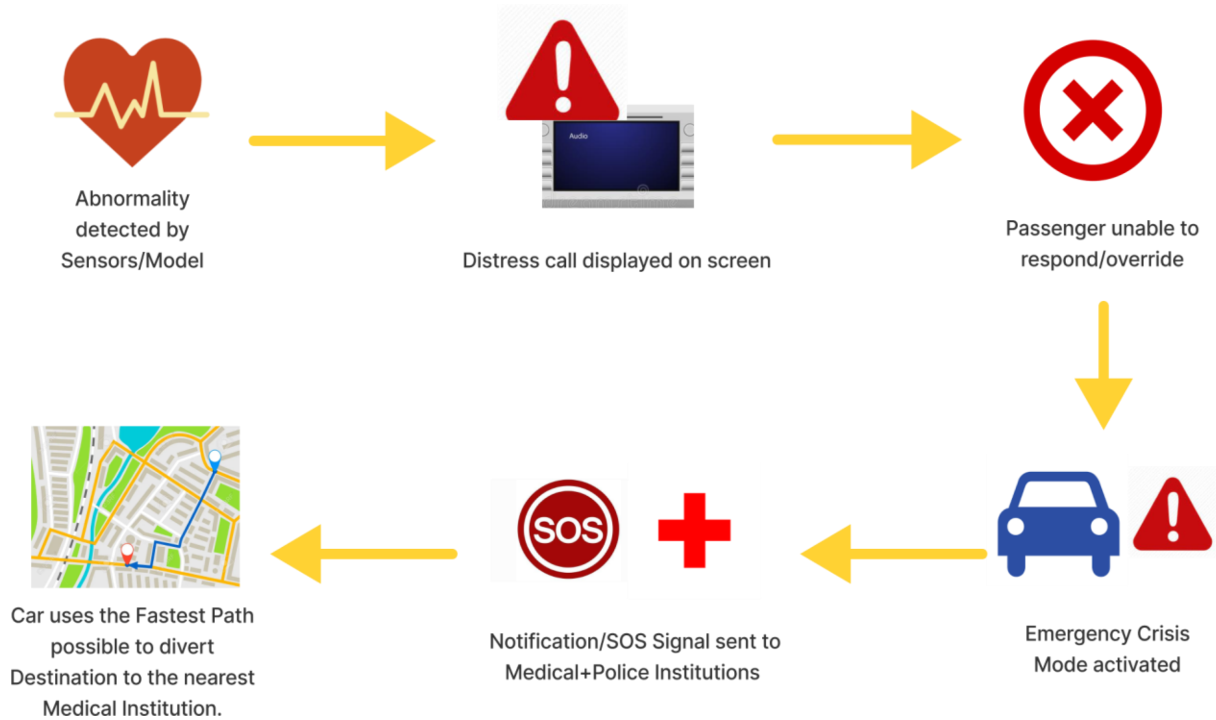
INTRODUCTION

Driving is a cognitively complex task that requires the synchronization of multiple functions, which often might get altered by subacute medical conditions. Numerous studies have addressed the role of medical conditions in the causation of motor vehicle crashes. Conditions such as epilepsy and diabetes mellitus, which can cause loss of consciousness or loss of body control, have always been of special concern with regard to traffic safety. An emergency should require immediate treatment, and in such catastrophic cases, when you find none in your surroundings for the help, our idea of medical assistance by the autonomous vehicle itself comes beneficial.

Examples of conditions that may lead to a blackout during a car accident include Heart attack, Seizure, Stroke, Delusions, Fainting, Unknown diabetic conditions (such as an unexpected drop in blood pressure). This paper documents an apt functionality inbuilt in the Car that could potentially help patients with asthma, chronic obstructive pulmonary disease (COPD), and sleep apnea by continuous monitoring of heartbeat and respiration.

I. Functioning of the Health Monitoring & Assistance System

All our Sensors in the Integrated Seatbelts & Wristbands (discussed in depth later) transmit real-time data to the AI & subsequently, our Mathematical Model processes it to predict if the Passenger is at risk or not. This Model has algorithms for the harmonic convergence of all the Sensor Readings & their Stipulated Emergency Threshold Limits, which will strike an Alarm when these Readings are Dangerously out of the Healthy Ranges.



If some Abnormality is detected, then we have deployed a few stages/cases depending upon the passenger's Condition:

Case 1- Passenger is actually at risk

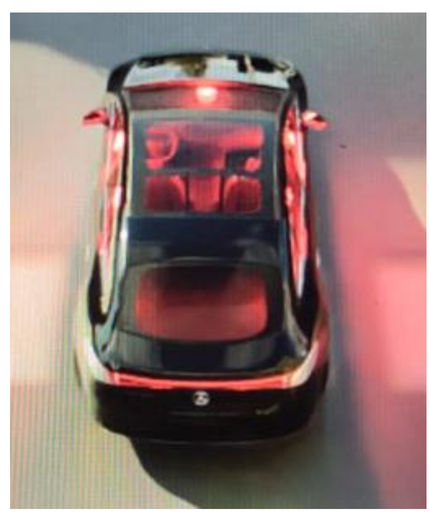
If the Mathematical Model Output (with calculations of all the Sensor Readings) goes over the stipulated Emergency Threshold Limit, the AI displays the Distress Call Notification on Screen, and the Passenger confirms he/she's unwell or is physically unable to respond.

Case 1A: Fortunately, his/her condition isn't very critical and can be stabilized using First Aid/Generic Medication, which the Passenger can help himself/herself guided by the Virtual Assistant.

Case 1B: Unfortunately, his/her condition is critical & the Passenger needs immediate Medical Attention. He/ She can't reply to the AI's Distress Signal, the **Emergency Crisis Mode** activates.

Emergency Crisis Mode

The AI displays a Distress Call/Message on the Screen whenever the Sensor Readings exceed the stipulated Emergency Cutoff/Threshold. In case the Passenger doesn't/can't vocally Override this Call (i.e., Reply with the Confirmation he/she's alright), the Emergency Crisis Mode gets activated.



Ambulance Mode

Once in the Emergency Crisis Mode-

I. Ambulance Mode- The AI, like an Ambulance, is exempted from following specific Traffic Rules such as Red Lights, Speed Limits, etc. The AI will be trained to ensure Optimum Road Safety while utilizing these Privileges, but the main priority is to choose the Fastest Path to the Nearest Medical Institution.

II. A QR Code will be displayed on the **Side-View Mirrors,** which will relay all the Information from our Vitals to the Medical Authorities, helping them save crucial time.

III. AV's Windshield & Windows will flash Blue Red Lights to mimic the Siren of an Ambulance.

IV. Notifications about Passenger's Condition & Location will be sent out to all the Passenger's Emergency Contacts through the Internet.

V. An SOS Signal will be aired to the Nearest Health, Police, and Traffic Authorities & Institutions with the 1st Medical Report & Vitals.

These Measures could prove to be the Difference between Life & Death for many.

SOS Message

Case 2- It's a False Positive

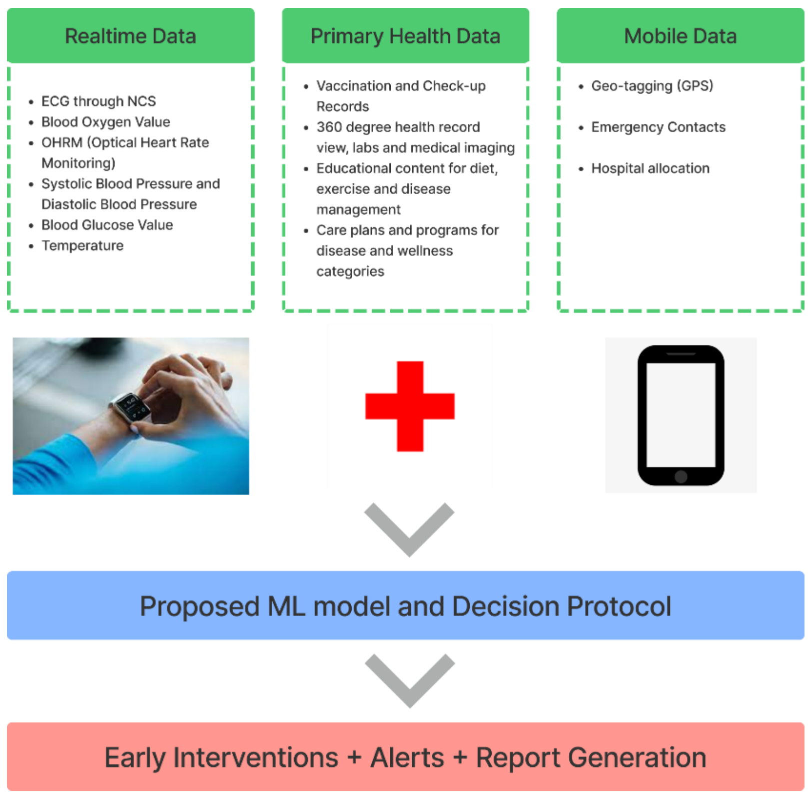
Even though the Sensor Readings go over the stipulated Emergency Cutoff/Threshold, the Passenger is healthy & far from any harm. The AI notifies the Passenger that it's about to activate the Emergency Crisis Mode & asks his/her Input. In this case, the Passenger has the option to vocally Override the Emergency Crisis Mode.

Tackling the False Positives

False Positives are a parcel of Medical Testing & cause huge losses in the Domain. Hence tackling these to the best of our capabilities is a necessity. False Positives can occur for a variety of reasons- Faulty Equipment, Database, Incorrect Calibration, etc.

In Reference to **Case 1**-

In case of a **False Positive**; The Sensor Readings go over the stipulated Emergency Cutoff/Threshold for any of the above-mentioned reasons, but the Passenger is healthy & far from any harm. The AI displays the Distress Call/Message on the Screen, notifies the Passenger that it's about to activate the Emergency Crisis Mode & asks his/her Input. In this case, the Passenger has the option to vocally Override the Emergency Crisis Mode and carry about his/her journey.
The AI runs a thorough Troubleshoot every time False Positive arises. In Case of an **Accident** or any **Damage** to our AV that leaves it unable to follow through to the Medical Institutions in time, the **SOS Signal** sent to the Authorities will immediately request an **Ambulance** to the Location/Accident Site.

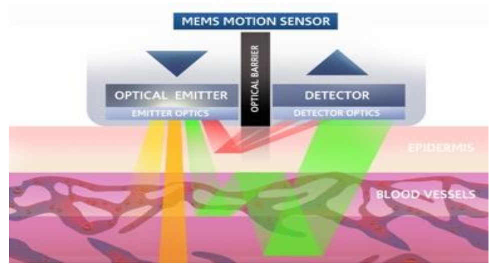


Data Collection & Execution

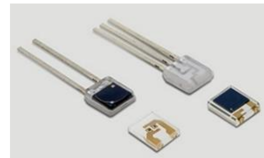
II. Components Of The Health Assisting System

1. Integrated Wristband

Sensors Integrated into our wristband include a Blood Oxygen Sensor, Optical Heart Sensor, a SpO2 sensor, and a VO2 Max Sensor, Body temperature sensor. These sensors have a host of health and fitness tracking features, including blood oxygen monitoring, heart rate monitoring, Blood Sugar Measurement, and more.



Optical Heart Sensor- Optical Heart Rate Monitoring (OHRM). We'll be using photoplethysmography (PPG) to measure heart rate. PPG is a technical term for shining light into the skin and measuring the amount of light that is scattered by blood flow. That's an oversimplification, but PPG sensors are based on the fact that light entering the body will scatter in a predictable manner as the blood flow dynamics change, such as with changes in blood pulse rates (heart rate) or with changes in blood volume (cardiac output).[3]



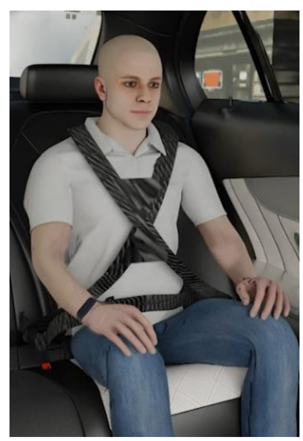
SpO2 sensor- Pulse oximetry measures blood oxygen saturation (SpO_2) non-invasively with an infrared sensor on the fingertip. Before that, the measurement of blood oxygen saturation required arterial blood sampling. Thanks to pulse oximetry, the critical parameter of SpO_2 can be measured painlessly, continuously, and in real-time.

VO2 Max Sensor- VO2 max refers to the maximum amount of oxygen you can utilize during exercise. It's commonly used to test the aerobic endurance or cardiovascular fitness of athletes before and at the end of a training cycle. VO2 max is measured in milliliters of oxygen consumed in one minute per kilogram of body weight (mL/kg/min).

Body Temperature Sensor- NTC (negative thermal coefficient) thermistors are used to measure surface temperature. The sensor is a two-wire connection and uses the resistance properties of ceramic/metal composites to measure temperature. For medical applications, packages are available with right angle or straight ¼" connectors to simplify installation. Common applications for this type of temperature sensor include adult rectal, pediatric rectal, and skin probes.

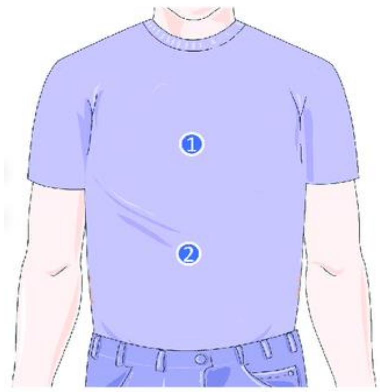
Anti-Theft System for the Integrated Wristbands- In Addition to all the Health Sensors, we also have GPS Anti-Theft Trackers on all 4 Wristbands (Our Package will have Seatbelts & Wristbands for every seat of the AV). These Trackers will trigger an Alarm in the AV whenever taken outside the stipulated radius from the Car.

2. Integrated Seat Belt



I. Integrated seatbelt system using an approach that does not require direct skin contact to modulate the external and internal mechanical motion of the wearer's body directly onto multiplexed Radio Frequency (RF) signals by Near-field Coherent Sensing (NCS).
II. To minimize the deployment and maintenance cost of NCS vital-sign monitoring, passive RF identification (RFID) tags can be integrated into seatbelts at the chest and band for wrist areas, where the two multiplexed far-field backscattering waveforms are collected at the reader to retrieve the heart rate, blood pressure, respiration rate, and breath effort.
III. The unique ID of each tag helps discriminate its signal against interferences from ambient interferences and other tags. NCS utilizes both amplitude and phase of the electromagnetic field to couple the motion, which significantly increases the signal quality.

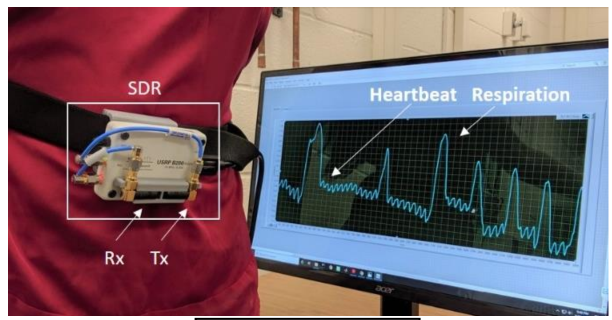
IV. To maximize reading range and immunity to multipath interference caused by indoor occupant motion, active tags could be placed in the front pocket and in the wrist cuff to measure the antenna reflection due to near-field coherent sensing and then the vital signals sampled and transmitted entirely in digital format.
V. Near-field coherent sensing (NCS) is a non-invasive technique that works by transmitting a low-power continuous wave (CW) RF signal into the body with over-clothing antennas. The near-field coupling to the internal dielectric boundary motion results in a direct measurement of the heart, lung, and diaphragm motion. The dielectric composition in the near-field region of an antenna will modulate its characteristics.
VI. The wearable RF sensor design has high ambient motion tolerance with the receiver placed close to the transmitter, making NCS less affected by environmental changes compared to direct far-field reflection, where ambient motion within the antenna radiation pattern can cause significant interference. Multiple sensors can be placed on the body to couple to both respiratory and heartbeat motion with frequency multiplexing.



Positioning of NCS Sensor

Placement of Sensors in the Integrated Seat Belt:

We have placed two NCS sensors on the body with loosely placed belts. The abdomen sensor is placed slightly below the xiphoid process to be close to the diaphragm, and the thorax sensor is close to the heart so that it can couple both heartbeat and lung motion. These lightweight and small sensing units consist of RF Tx and Rx antennas connected to the software-defined radio (SDR) transceiver to perform NCS measurements with a low RF power of less than — 10 dBm. These sensors measure the abdomen and thorax respiratory motion as well as the heartbeat by effectively capturing the geometrical changes in these organs along with other associated muscles.[4]



NCS Sensor

Fig 1. The vital signals from NCS measurements:
(a) Raw breath signal and waveform after the low-pass filter.
(b) Raw heart rates and the average from the moving window of 10 s. green markers show measurements using Photoplethysmography (PPG)from the wrist band.
Waveforms of (c) heartbeat and **(d)**wrist pulse during data collection for 3 min.
The purple lines are the average waveforms of the 3-min data. The box-whisker plots in c. are the statistical results at the minimum point (blue), rising deflection point (red), maximum point (green), falling deflection point (pink), and local minimum point (yellow). The box-whisker plots in d are at the minimum point (blue), rising deflection point (red), maximum point (green), local minimum point (pink), and local maximum point (yellow). **DTW waveform** analyses show the distance in each waveform of the **(e)** Heartbeat and **(f)** the wrist pulse. Insets: box-whisker distributions.
Comparison of median-and maximum-distance waveforms with respective DTW template for the **(g)** heartbeat and **(h)** wrist pulse. The sampling rate for the waveforms: 500 Sps.

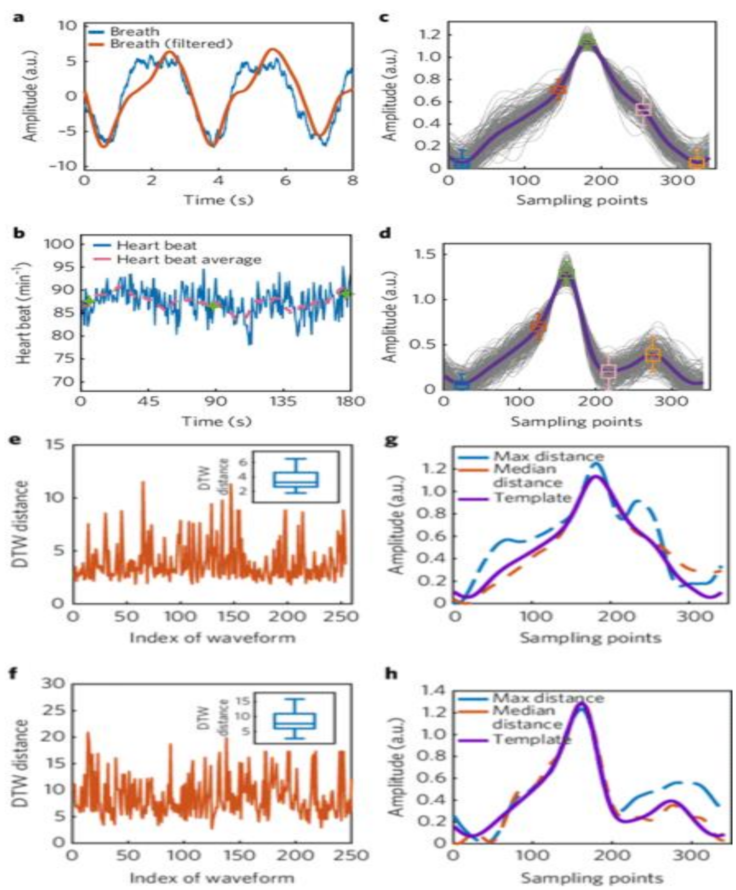
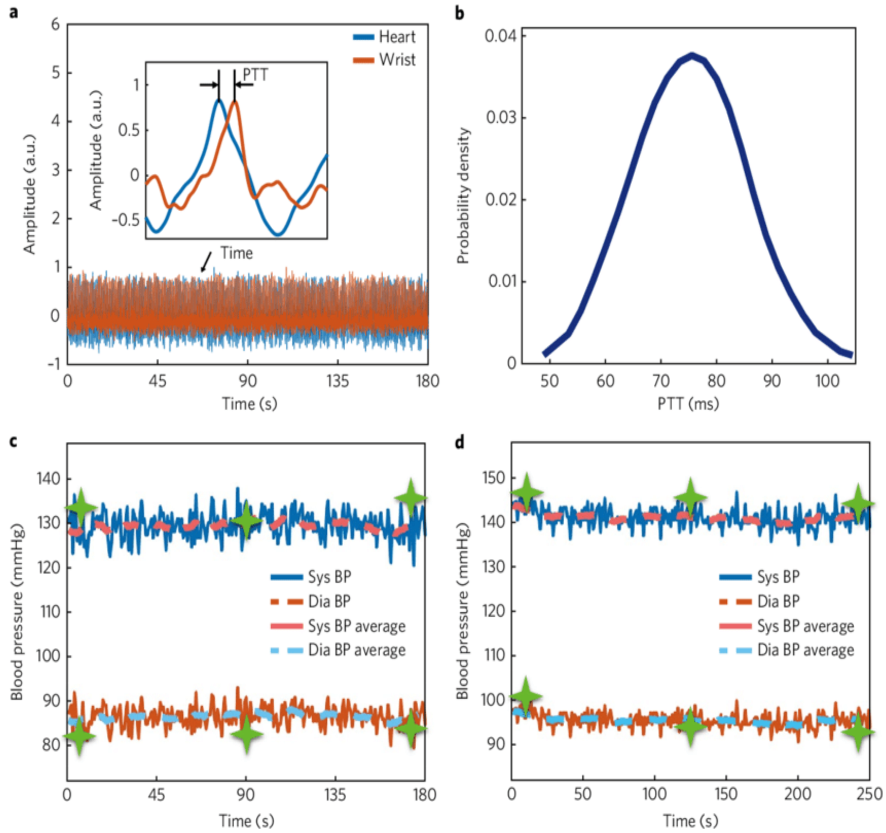


Fig 2. Blood pressure measured by NCS.
(a) Pulse transit time (PTT) estimated from the synchronized heartbeat (blue) and wrist pulse (red) waveforms. Inset: one period of the signals and the extracted PTT.
(b) The Probability density distribution of the PTT over 3 min.
Blood pressure extracted from the PTT
(c) when the person under test is seated
(d) when the person under test goes through moderate activity is standing. Green markers show blood pressures measured using Photoplethysmography (PPG)from the wrist band. Blue and red solid lines are systolic (Sys) and diastolic (Dia) pressures (BP) of every heartbeat. Pink and light blue dashed lines are moving averages from 14 sampling points around 10 s.[1]



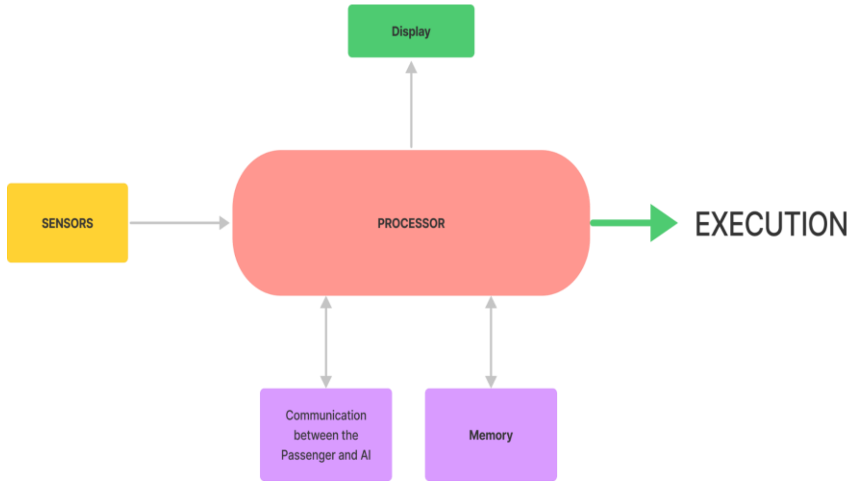
Calibration of Sensors:

Readings	Healthy Person*	Requires Medical Attention
Heart Rate	60 to 100 beats per minute(bpm)	If consistently > 100 bpm (Tachycardia) If consistently < 60 bpm (Bradycardia)
Respiration Rate	12 to 20 breaths per minute**	If consistently < 12 or > 25 breaths per minute (while resting is considered abnormal
Blood Pressure	Systolic ≲ 120mm of Hg Diastolic ≲ 80mm of Hg (120/80)	If consistently > 180/120mm of Hg (Hypertension) If consistently < 90/60 mm Hg (Hypotension)
Oxygen Saturation (SpO2)	95% to 100% SpO2	If consistently < 89% SpO2 (Supplemental Oxygen is required)
VO2 Max	42.5-46.4 mL/kg/min (25-year-old male) 33.0-36.9 mL/kg/min (25-year-old female)	If consistently < 18 ml/kg/min (Highest mortality risks)
Body Temperature	97.8º to 99.1º Fahrenheit or slightly higher	If consistently < 95º Fahrenheit (Hypothermia) If consistently > 98.6º Fahrenheit (Fever)

*These values will depend upon the previous medical history of the person, which will be tracked after the previous medical data is uploaded to the system.
** Females ages 12 and older, in general, tend to have faster heart rates than do males. Athletes, such as runners, who do a lot of cardiovascular conditioning, may have heart rates near 40 beats per minute and experience no problems. [5]

III. Onboard Processing Unit & Power Supply

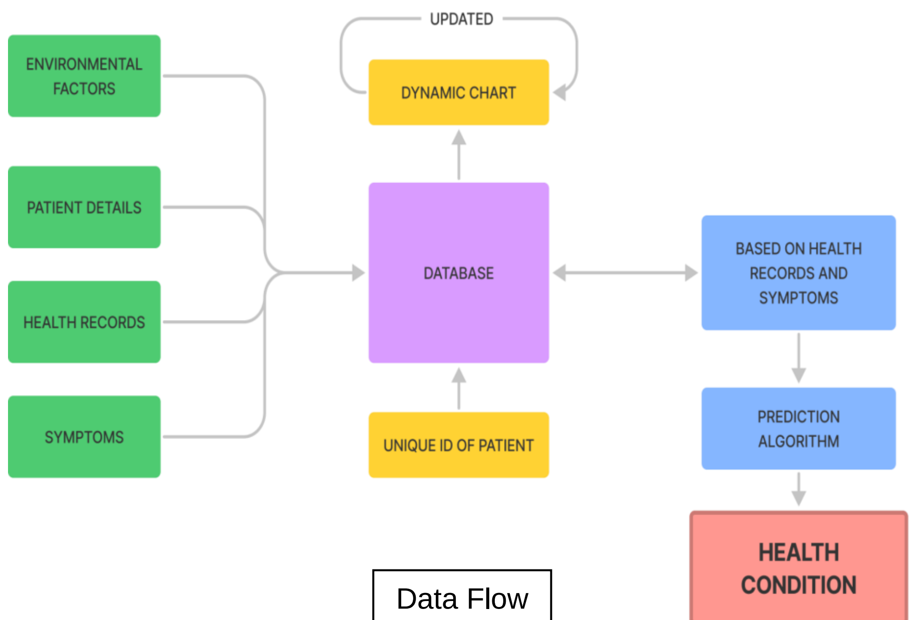
An Auxiliary Secondary Battery is preferred to power our Sensors & the whole Integrated System, as we get the additional Selling Point of a Scalable, Independent Package. Our Integrated System, consisting of the Smart Seatbelt, all its Sensors, Powering System & its Auxiliary Processing Unit, can be attached as a 3rd Party Accessory in any Suitable EV.
Our Complete Package is a Stand-alone Subsystem that can be sold to Manufacturers & Consumers alike. It doesn't interfere with the Mainframe of the AV, ensuring seamless integration & data security.



Onboard Processing

IV. Detection Of Health Using ML Algorithm

The details of the passengers will be present in the database of the vehicle. The particular profile of a passenger will contain the general route, job, normal activities, and the health condition of a person. These details will be connected and interlinked through an IoT network consisting of smartphones other health tracking devices like smartwatch/band if the user is using that particular device. By the Information provided by the user and the data collected from the devices, an overall outline of the health condition of the Passenger is attained.
The data collected from the sensors used will then be compared with the particular profile of a passenger, and the real-time health condition is predicted using a machine learning model. The conclusion arrived at by the ML model will then be evaluated by strict protocols, and further tasks will be assigned to the autonomous system regarding the alert system, data transmission to the hospital, rerouting, etc. [2]

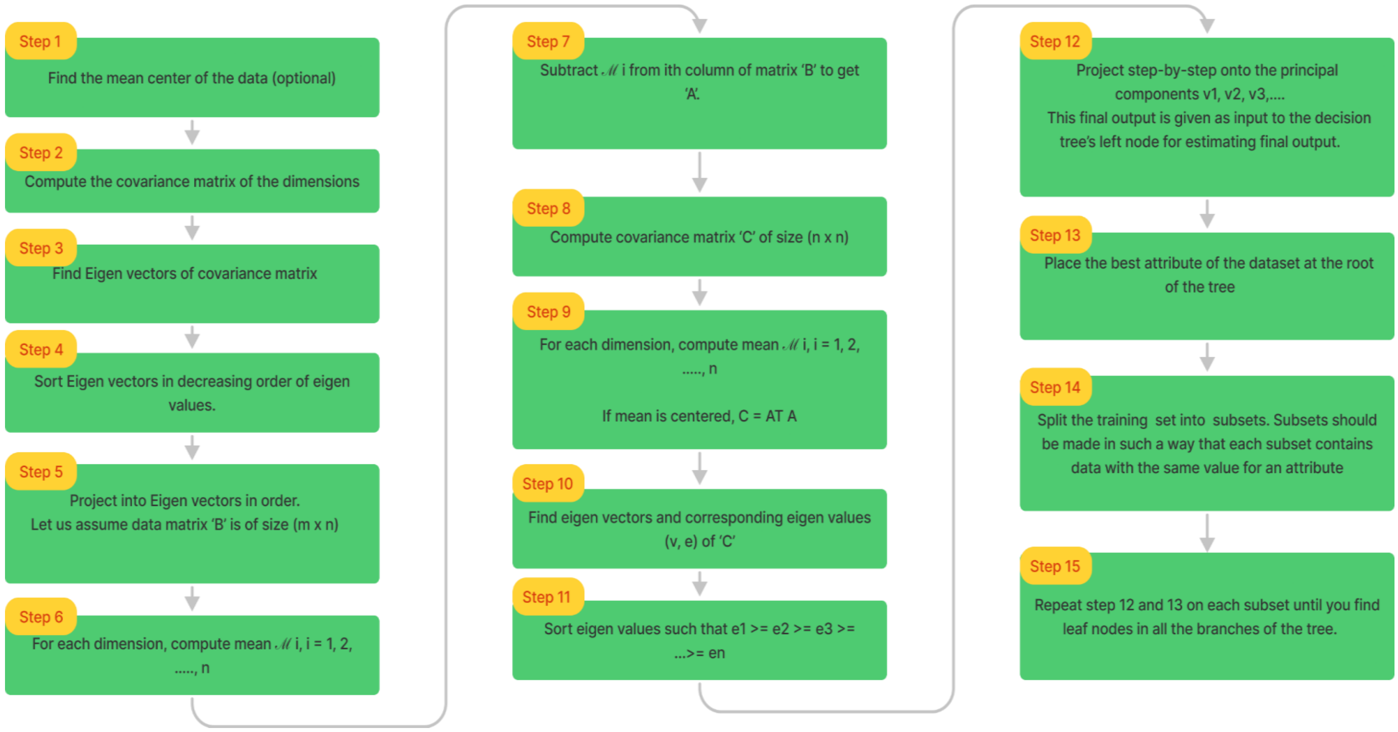


Data Flow

Privacy concerns: If the user denies sharing the previous health records, then the health condition of the user will be considered as a general pre-defined ideal state.

Algorithm:

This is the complete practical approach of the Model:



DISCUSSION

The incorporation of health systems into seat belts and the integration of a wrist band will not only provide a cognitive boost to an autonomous vehicle but will also provide a significant boost in the survivability of the rider due to the fact that the system will work as a stand-alone system and will be independent of situations in which the patient does not receive help from another human in a time or does not receive at all. Also, as our system is completely autonomous, it will serve as a virtual health assistant for the rider. Due to its stand-alone characteristics, it can not only be brought as an addition to new autonomous cars but can also be added on as an "add on kit" on the other vehicles as well. So, based on our conclusions, this will be the most significant and impactful boost to an autonomous vehicle ecosystem because it not only replaces situation-based manual assistance provided by other humans, which is not always reliable, with a reliable stand-alone autonomous assistance system, but it also increases the survivability of the rider.

REFERENCES

[1] Monitoring vital signs over multiplexed radio by near-field coherent sensing
[2] Wireless Personal Communications | IoT for Health Monitoring System Based on Machine Learning Algorithm
[3] News Medical | Photoplethysmography (PPG)
[4] NPJ Digital Medicine | Wearable radio-frequency sensing of respiratory rate, respiratory volume, and heart rate
[5] Cleveland Clinic | Vital Signs