# Semi-Autonomous Hover Board

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**Abstract -** *Semi-autonomous hover board is an innovative approach in medical field, which offers a helping LEG for those who struggles to walk. Hover boards are generally used for personal transportation. This paper proposes a modification of the basic hover board structure to another dimension for medical purposes. Surveys says that about 54 million adults are affected by arthritis. These patients are suffering from high body pain and they are not even able to walk for a small distance without getting hurt. So many people including women and children are suffering from this pain and they are struggling to complete even their household activities. So we specially concentrate our work for arthritis patients for reducing their hardship in daily life. It is also comfortable for normal usage. This hover board can be used both inside the house and on roads. Semi-autonomous hover board is a 4 wheeled structure. So stability and comfort of patients will be satisfied. It include proper security systems along with add on features. Automatic speed control, display systems, warning systems, add on stability using handles, long battery backup, electronic speed control etc. are the features to be emphasized in this hover board. It comes along with a helmet and headset which will deliver security warnings and ensures security. Maximum weight of 200 KG can be handled by this hover board. And the dimensions of the hover board is estimated as maximum of 650 mm width and 1000 mm length. And the foot base dimensions are assumed as maximum of 380 mm width and 420 mm length.*

***Key Words*: Autonomous, Speed control, PWM (pulse width modulation), Protocol switching, Security warnings.**

## 1. INTRODUCTION

A hover board is an electronic hands-free self-balancing scooter. This hover board have an average speed of 10Kmph. Once fully charged, they can travel a distance up to 15miles. All we have to do is step on and the hover board starts moving. We can control the speed, turn and also other factors by small movement of feet, legs and torso. The purpose of hover boards is to make you look cool while you have fun riding them and that purpose is being rightly served.

The semi-autonomous hover board is an advanced version of the existing hover board. The main attraction of this hover board is that, it offers increased stability and safety features. This is done by modifying the dimensions and mechanisms of normal hover board. This hover board will be an asset for the medical field, because it will be a helping leg for those who struggles to walk. It mainly focused on safe, stable and reliable chance for short distance transportation.

The semi-autonomous hover board is specially designed for arthritis patients. Even though it is comfortable for normal usage by changing the protocols. This hover board works on two protocols. One serves for normal usage and other for medical purposes (limited speed and secure drive).Increased stability and safety measures will aid for the safe transportation. It comes along with a helmet and headset for delivering security warnings.

The rest of this paper is organized as follows. The related works are illustrated in section 2. System overview including block diagrams and main functions and features are described in section 3. In section 4, the system design and requirements are discussed which is followed by the system implementation part in section 5. Detailed illustration of result, discussion of challenges and future scope followed by conclusion is explained at section 6, 7 and 8 respectively.

## 2. Related works

The hover board was initially used for personal transportation. The self-balancing scooter is an enhanced version of hover board which can be adjusted by using the movement of legs. In 1950s a 'Flying platform' which was similar to the concept of hover board was developed by Hiller aircraft. The hover board was first described by M K Joseph in 1967. These type of devices are mainly used in science fiction films in early days. The hover board shows a close resemblance with skateboard without wheels.

In 1990s director Robert Zemeckis stated that, hover boards are not marketed because it was too risky for kids, so the hover boards are deemed too dangerous by parent's groups. However in 1998 the hover board is used by Dean Cain's character in the film Future sport. In 2000 Summer Olympics opening ceremony in Sydney, Air board air-cushion vehicle is used. The air-cushion vehicle created to look like hover boards, but they does not have similar experiences to the kind of levitation that hover boards have.

In 2001, a self-balancing two-wheeled scooter was developed by Dean Kamen and is named as 'Ginger'. Later Jamie Hyneman and his team developed makeshift hovercraft from a surfboard and leaf blower. But it was not that much effective. In 2005, Jason Bradbury developed a hover board using wooden board which was not propelled and not be steered but was levitated by means of a leaf blower. Later in 2009 an enhanced version of this with two more powerful leaf blowers was made and which can be propelled by small jet engine.

In 2011, a hover board that floats by magnetic repulsion between the hover board and its base was developed by Nils Guadagnin. It has an electromagnetic system for levitation and laser system for stabilization but it cannot carry a load. Another product named 'Mag surf' was developed by Universite Paris Diderot in France in October 2011. It is a superconducting device. It can levitates 3cm above two magnetized repulsing floor rails. And it can carry up to 100kg (220 lb).

An American inventor Greg Henderson presented a prototype of hover board in October 2014 which is working a magnetic levitation principle. It can carry a load up to 140kg and hovering 2.5cm above the surface. It needs a surface of non-ferromagnetic metal like copper or aluminum for its operation. On 24 June 2015, Lexus presented a hover board which works using permanent magnets and liquid nitrogen cooled superconductors.

The ARCA Space Corporation in 2015 developed a hover board and is named as ArcaBoard. It can hover up to 30cm for six minutes. Batteries are used to provide energy for this. The ArcaBoard has 36 fans which are powered by 36 electric motors. Franky Zapata in 2016 developed a jet powered Fly board Air hover board. Later in 2019 he developed 'jet-powered personal aerial vehicle' and is named as EZ-Fly. But it was not sustainable for military use because it creates noise.

## 3. SYSTEM OVERVIEW

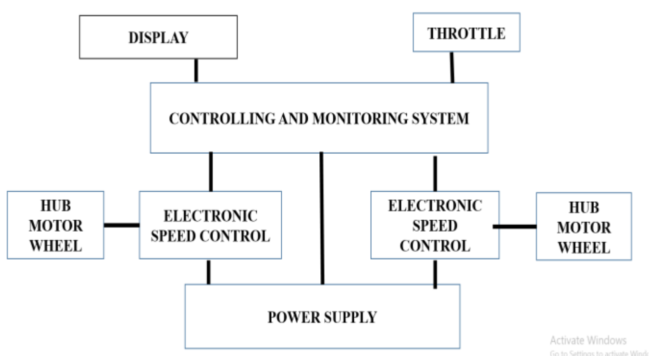


**Fig-3.1**: Block diagram

The semi-autonomous hover board is mainly focused on arthritis patients. The device can also be used for normal purposes by making small variations in the protocol. The material used for making the frame is stainless steel. The Chassis design can be done through design software's like AutoCAD, SolidWorks etc. Motor hub wheels will be of 10 inch in size. The wheel needs 350watt power to work properly. These are tubeless tyres. The BLDC (brushless DC motors) motors typically have three Hall Effect sensors mounted either to the stator or to the rotor, and use what is known as six-step commutation [1]. When the rotor passes a sensor, it produces either a high or a low signal to indicate which rotor pole (N or S) has passed. This switching of the three Hall Effect sensors provides rotor position information every 60 degrees. As shown in Fig-3.1 two rear wheels are controlled by two distinct units of Electronic Speed Control (ESC) having the same rating as the BLDC motors. The Electronic Control System maintains the stability and safety based on the sensor input viz. Gyroscope, Heart Beat censor, etc. Lead acid battery is used here to provide a maximum of 1 KWatt power at 48V. Even though it have a heating problem, it is considered to be more efficient and cost effective than Li-Po battery. The most importance part is the handle designing. The handle should provide to and fro motion in elevation and demotion for stability. The design of the handle provides an easy and smooth handling ability for users. The to and fro motion capability is provided in order to make the person who rides the vehicle stand straight in both elevation and demotion cases. The semi-autonomous hover board works on 2 basic protocols: limited mobility access protocol and master access control protocol. The limited mobility access control protocol is used for custom PWM generation [2] for speed control. It provides a maximum speed of 10-15 kmph. The master access control protocol has no speed limitations. It is highly secure and it provides a maximum speed of 30-40kmph.

### *Protocol based working*

Semi-autonomous hover board can be operated in two protocols.

- Master access control protocol.

-Limited mobility protocol.

Protocol switching can be easily done by user with the help of a switch located at handle. Master access control protocol or normal mode is set for normal riding of hover board. There is no speed limitations in this mode. The vehicle can reach up to a maximum speed of 30-40 Kmph. Here the control is completely manual. Limited mobility protocol is the default mode. In this protocol the speed is limited to 10-15Kmph. This is for diseased users. Since the speed is limited, the users are much secure and comfortable with the ride. Over speed and misbalancing are also avoided. So the patients can enjoy a stable ride.

### *Automatic speed control*

It is the remarkable feature of semi-autonomous hover board. Speed control is activated in limited mobility protocol. It will ensure safe drive for users. As shown in Fig 3.2. The electronic speed control unit will ensures to limit the throttle voltage to a particular limit, which will drives the hub motor wheel. Even if the user try to increase the throttle voltage or accelerates more than the limited level, the electronic speed control unit will limit this voltage value and the limited output is given to hub motor wheels. Thus the speed is controlled. The maximum speed is limited to 10-15 Kmph and the maximum throttle voltage is limited to 2.5 volt.

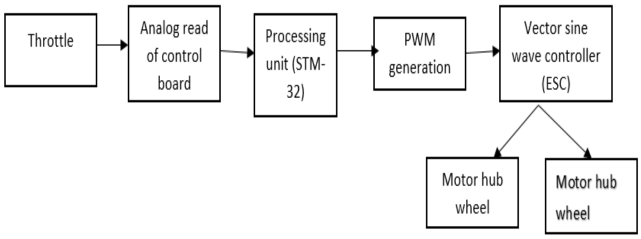


**Fig-3.2:** Automatic speed control system

The throttle is a mechanical device which determines the user defined speed of the vehicle. Here, based on the throttle input, the speed of the vehicle is decided by the system, the throttle voltage varies between 0 to 5V, when the user turns it. The working of the throttle is same as a potentiometer. When the rider turns the throttle, the input voltage varies and it is read by the analog reading port of the STM32 controller, then PWM signal [3] is generated according to the protocol. In Limited Mobility access mode the maximum value of the PWM signal is 2.5V, which corresponds to a maximum speed of 15 kmph. But in Full access mode the maximum value is 5V which corresponds to a speed of 40kmph. These values are decided by the controller, based on the program we embed in it. The PWM signal is fed to the throttle input of the vector sine wave controller port or the electronic speed control unit, which then rotate the BLDC hub motor wheel at the system defined speed.

### *Detection of elevation and demotion*

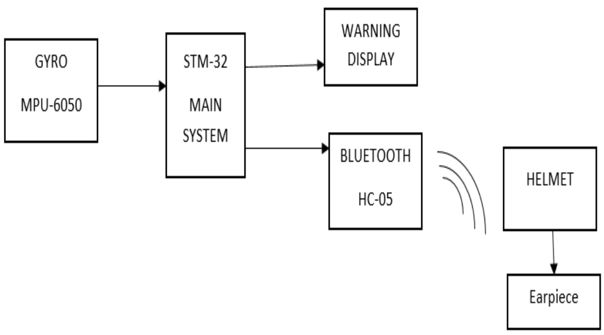


**Fig-3.3:** Detection of elevation and demotion

MPU-6050 gyroscopic sensor is used for the level detection purpose of the vehicle, especially the elevation and demotion detection. Consider the example of a vehicle that moving through an inclined bridge and descending through the same. As shown in Fig-3.3, these situations can be detected by the system using the gyro sensor and can provide warning to the rider via voice as well as on the display. In these two situation, user may feel some instability due to their standing position. So, in order to maintain the comfort and stability of the system, the handle can be pushed out and pulled in to a certain extend. When elevating a bridge, to maintain the stability, the user can push the handle and can lean forward. And during the demotion state, rider has to pull in the handle towards him. Gyroscope will detects the angle of elevation and demotion from the ground. When this angle of elevation exceeds 150 °above the ground level; system will instruct the user to push the handle and lean forward. This will reduces sudden jerking. In case of demotion, when the gyroscope detects −150°, the system will instruct the user to lean backward and to pull the handle inwards. The sensor is directly interfaced with I/O pins of STM-32 controller, which have the I2C capability. The gyro communicate with the STM-32 controller via I 2C protocol. Power supply for the 5V sensor is provided directly from the controller setup. In order to maintain a stable and better clock frequency of 400 KHz (basic clock in I 2C) additional pull up resistors are provided along with the inbuilt sensors. The sensor gives X-Y-Z values within specific time intervals. These values are read and corresponding elevation and demotion angles are calculated by the system.

### *Helmet system*

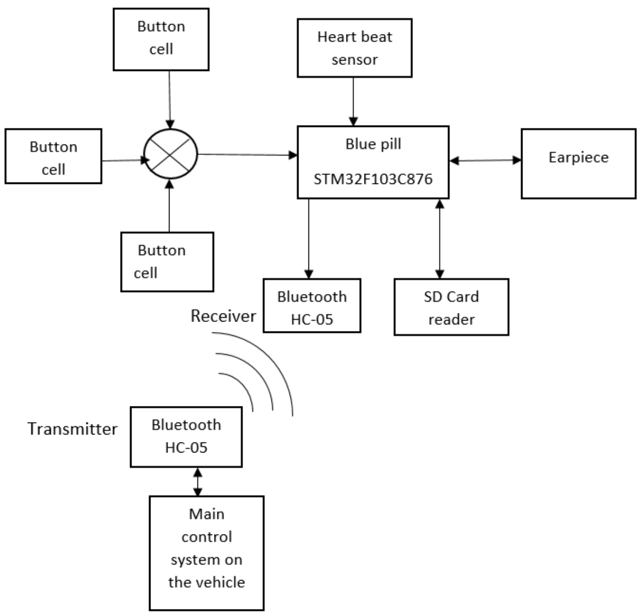


**Fig-3.4:** Block diagram of helmet system

Helmet is always a priority when it comes to a matter of safety. This Semi-autonomous hover board works along with a typical smart helmet. The helmet includes some features ensuring 100% safety for the rider. As shown in Fig-3.4, three button cells, a heartbeat sensor and an earpiece speaker which can be used in mono as well as stereo mode along with helmet and Bluetooth system constitute the smart helmet system. The button cell ensures that the rider wear the helmet. If the helmet is not worn, the vehicle won't start. The heartbeat sensor provides the vital information and based on that we check mental as well as physical condition of the rider, eg: panic, normal etc. in the panic condition of the rider, the vehicle will automatically set to standby state and allow the rider to take time and calm down. In order to provide warnings to the rider via voice, we have two earphone speakers on either side of the helmet. Prerecorded audio is stored in a SD card, which can be read by a SD card reader. For better performance and speed, a dedicated control setup in the helmet using STM 32F103C876 is also provided along with a HC-05 Bluetooth [4] connectivity. Out of the 3 button cells, at least 2 outputs are mandatory. When the rider put on the helmet, the proximity sensors (button cells) get activated and this signal is read by the controller via basic I/O ports. Heartbeat is monitored via interrupt pin. Based on the conditions and the data transferred from the control system on the vehicle via Bluetooth, warnings are provided through headsets. The SD card reader is interfaced with the controller and communicate with SPI protocol [5]. The data available from the helmet sensors are also transferred to the main system for a better safety purpose.

### *Stable structure*

The structure of semi-autonomous hover board is a modified or advanced version of existing hover board. The form factor is 650x1000mm.It is a 4 wheeled stable structure, i.e., 2 front wheels for stability and 2 rear hub motor wheels. Unique handle design will ensure safe and comfortable drive. User can adjust the position of handle in accordance with elevation and demotion. That is, handle can be move to forward when there is an elevation and to backwards when there is demotion. Maximum capacity of this hover board is 200kg.

### *Warning and display system*

Warning and display systems are provided to ensure security for the users. Warning will be given;

- If the user doesn't wear helmet.
- Warning for users having high or low pressure value or pulse rate.
- If the user is trying to increase the speed beyond the limited value. Apart from the warnings,
- Battery level indicator.
- Digital speedometer.
- Instructions while elevation and demotion (to move handle). Will be provided

## 4. SYSTEM DESIGN

### *Battery*

Battery specifications: 12V, 26Amh (per cell)

Number of cells used: 4

Overall output: 48V, 26Amh

Battery type: Sealed lead-acid battery

Battery information: Standby use: 13.5-13.8V.

Cycle use: 14.4-14.8V

Initial current: <3.5A

### Charger specification

Input voltage: AC 170-300V (47-63Hz)

Input current: 1.0A (max)

DC output voltage: DC 59V±0.5V

Output current: 2.7A ± 0.5A

### Battery charging calculation

Charging time for battery (T): Battery Ah / Charging current.

T= Ah/A = 26Ah/2.7 =9.629 (Particularly it takes 8-10hrs.)

Charging current should be 10% of the Ah rating of the battery.

### *Power requirement of vehicle*

To design an electric vehicle of 150kg and to run at a maximum speed of 40km/hr, the vehicle has to overcome the below mentioned forces.

F total= F rolling + F gradient + F aerodynamics

**F rolling;**

F rolling can also be indicated as rolling friction.

F rolling = Cr × m × a

Where 'Cr' is the coefficient of rolling resistance and is 0.01 for normal platform, 'm' is the mass of the vehicle in kg and 'a' is the acceleration due to gravity.

Therefore rolling = (0.01) × 150 × 9.8 = 14.7N

Power required to overcome the rolling resistance. = F rolling × (max velocity of the vehicle in m/s). = 14.7 × 40 × (1000/3600). = 163.33 watt.

**F gradient**

Gradient force comes into play when there is a slanting surface. Here for optimized design we are considering only the plane surfaces. F gradient= m × a × sin u. Consider u=0, when the vehicle travels in flat surface.

Therefore, F gradient= 0N

**Aerodynamic Drag**

F aerodynamic drag= 0.5ρ × 2 × Ca × Af

Where 'ρ' is the density of air medium and its value is 1.28kg/m, 'v' is the velocity of vehicle in m/s (40km/hr= 11.1m/s), 'Ca' is the coefficient of air resistance and its value is 0.888 and 'Af' is the frontal area of the vehicle.

Frontal Area of Semi-autonomous hover board;

Frontal width= 42cm= 0.42m, Frontal height= 20cm= 0.2m. So frontal area=42 × 20 = $840cm^2$= $0.084m^2$ .

But there exist some unmeasurable curved surface in the frontal area, by considering this also,

Effective frontal area= (height × width) × adjusting value (for corners) = Frontal area × adjusting value

The adjusting value for semi-autonomous hover board is taken as 60%. So the effective frontal area;

Af = 0.084 × (60/100) = $0.0504m^2$

F aerodynamic drag = 0.5 × 1.23 × 11.1 × (0.888) × 0.0504 = 3.4N

Power required to overcome this air resistance = 3.4× (velocity of vehicle in m/s) = 3.4 ×11.1 = 37.74Watt

So total power required to overcome these air resistance forces will be equal to the total power required to move the vehicle.

i.e., Power needed for motion = 164 + 0 + 38 = 202Watt.

To design an electric bike of 150kg and to run at a maximum speed of 70km/hr, we need 0.2KWatt power.

Power required= 202 watt.

Power of system= 700 watt.

Factor of safety=700/202=3.46

## 5. SYSTEM IMPLEMENTATION

### Main control system

This Schematic shown in Fig-5.1 is the very basic structure of the main control system. It constitutes the STM32F303 microcontroller which perform the necessary task in the system, HC-05 Bluetooth module used for communication with the smart helmet and the MPU-6050 Gyro sensor which is used for detecting the elevation and demotion status. The power supply and clock frequency generating crystal oscillator circuit are also provided. This schematic shows only the basic interfaces with the standalone microcontroller and the peripheral interfaces. The peripheral devices are shown only with the power supply and the communication interface used. The system also provides a dedicated PWM generator for speed control, which is not affected by the delay function and other tasks in the program and it is set to the highest priority stage. Switch interface is provided for protocol switching.

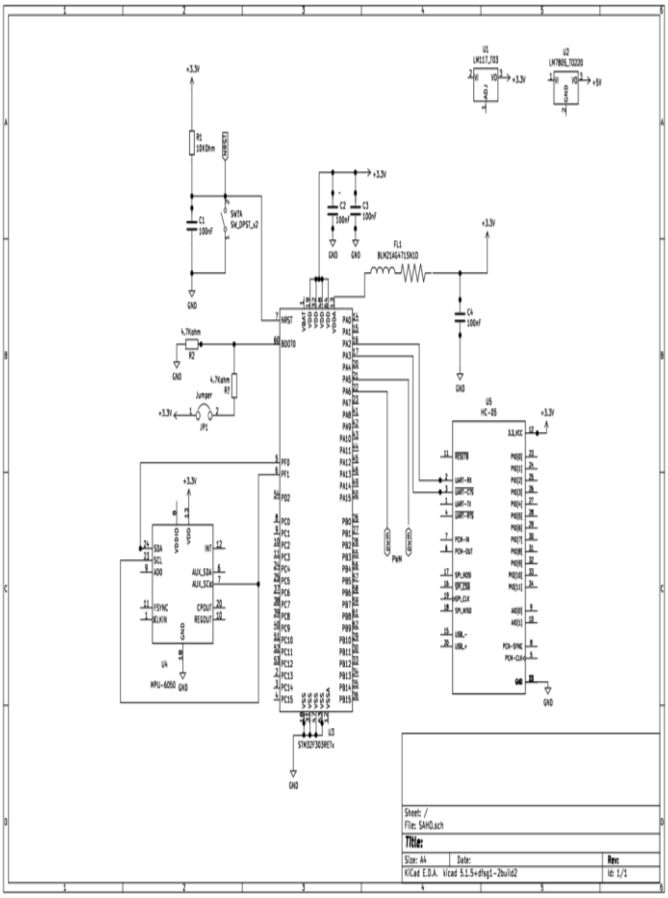

**Fig-5.1:** schematic diagram of main control system

### Helmet system

Fig 5.2 shows the basic components and interfaces used for the communication in helmet system. It comprises STM32F103 microcontroller, which locally perform necessary task in the helmet and send the information to the main system via HC-05 Bluetooth interface. This diagram shows the basic information about the module interfacing, power supply and the clock frequency generator. The system retrieve the voice warnings from the local storage via SPI interface, using the SD card module. The heart beat sensor input provides vital information of the person wearing the helmet at a particular interval. The switches on the right side SW1 SW2 SW3 are soft button cells. This whole setup can be called as a SUB-SYSTEM. With the bluetooth connectivity between the main and sub-system, the communication becomes much quicker and responsive.

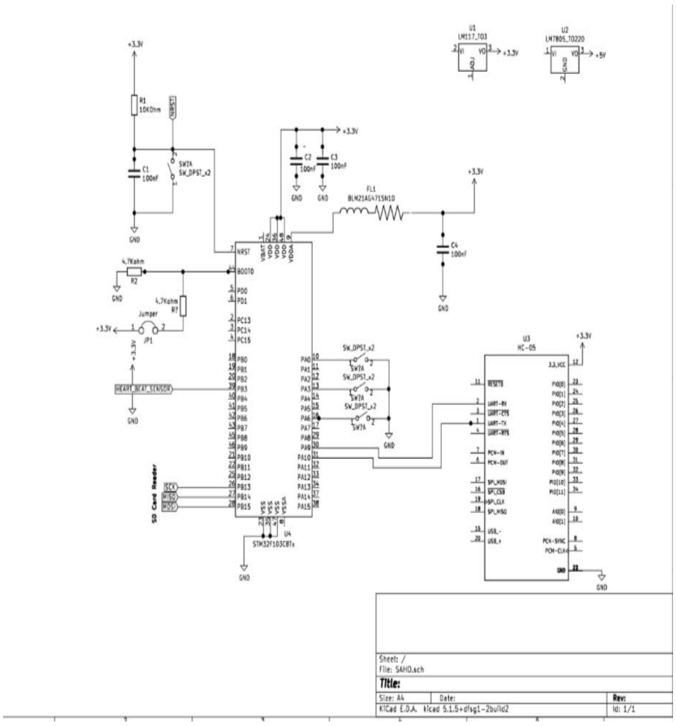

**Fig-5.2:** Schematic diagram of helmet system

## 6. RESULTS

### A. Full access speed status

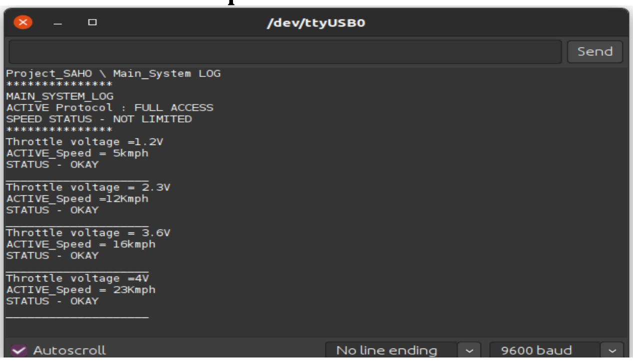


**Fig-6.1:** Full access speed status

### B. Limited mobility speed status

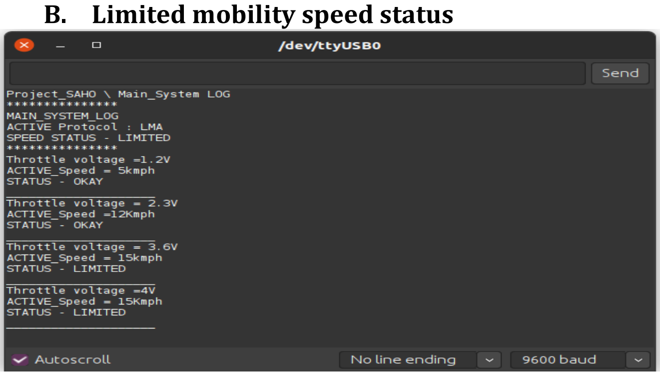


**Fig-6.2:** Limited mobility speed status

### C. Level detector status

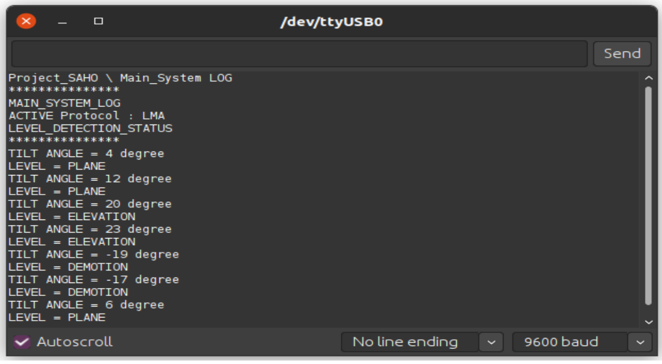


**Fig -6.3**: Level detector status

### D. Helmet NOT OK status

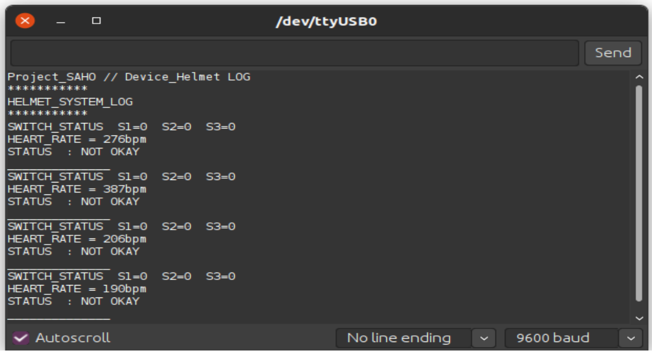


**Fig -6.4**: Helmet NOT OK status

### E. Helmet OK status


**Fig -6.5**: Helmet OK status

### F. Heartbeat NOT OK status

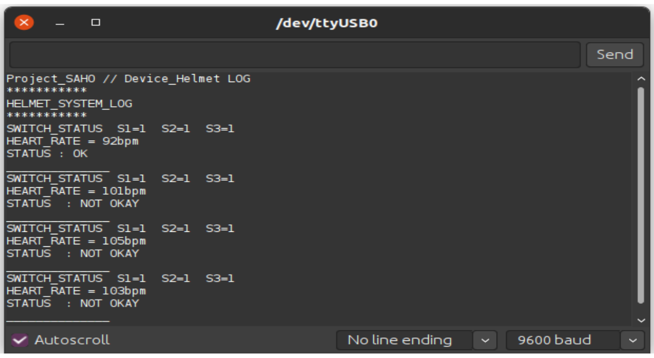


**Fig -6.6**: Heartbeat NOT OK status

### G. Final view

**Fig -6.7**: Final view of semi-autonomous hover board

## 7. CHALLENGES AND FUTURE SCOPE

Semi-autonomous hover board is designed for arthritis patients. It is designed to provide a comfortable and safe drive to the user. As for now it is designed only for short distance transportation. Long drives are not comfortable in this vehicle. . In future, this can be modified for long distance transport also, the advanced version can also have a seat for the user to provide a comfortable drive for long distance transportation. The shock absorbance quality of the vehicle is compatible only for small jerks and dips. So the user may get disturbed while driving. The braking and balancing of the vehicle in the inclined plane is a bit difficult. Even though, this is easy for small inclinations, steep roads will bring challenges while driving. Better shock absorbance mechanisms can be added to the system to provide more reliable and safe drive. Also, the weight and form factor can be reduced with the help of emerging Nano equipments.

## 8. CONCLUSIONS

Semi-autonomous hover board maybe more likely to called as helping legs. It is designed for arthritis patients and for the persons who are suffering from difficulty to walk. The design and structure of the vehicle provide a greater stability and security for users. The safety measures like proper warnings, instructions and displays while driving will provide a confident and efficient drive for the users. More than that the automatic speed control mechanism of the vehicle had provided extra security to avoid dangerous driving of nervous people. The protocol switching mechanism will allow the users to enjoy the normal driving of hover board too. The core part of system is a control unit which controls and coordinates the activities of the vehicle, like detection of elevation and demotion, speed control, control of communication etc. This can be done with the help of STM-32 micro controller. It is clear that this will be a great care and help for the disabled ones. This will definitely help them to make their life much easier.

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