Review on Self-balancing Robot Navigation

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Abstract— **This paper deals with self-balancing robot navigation. About the new technologies, software, results, has been used to grow and research more on its technology and make its navigation technique a better for upcoming researcher. In the early it has been started with the technology named as PID, Fuzzy Logic, LiDAR, and different programming languages. This paper helps anyone to understand the proper evolution of the Self balancing robot. Paper has touched deeply upon the topics like the navigation system through the Bluetooth module, Image processing etc. This paper also puts light on applications of self-balancing Robot technology in hotels and hospitals.**

Keywords — self balancing robot, two-wheeled robot, navigation

I. INTRODUCTION (*HEADING 1*)

Mobile robots are becoming popular and are used for various applications in industries as well as for human assistance, research, entertainment etc. Especially two wheeled self-balancing robots are gaining more popularity as it has simpler mechanism and dynamics [2]. A self-balancing robot is based on the principle of inverted pendulum. It has a simple design as compared to legged robots, with two wheels and the body in middle [2]. It has a GY-521 module which helps in stabilizing the robot, the inclination is calculated and this data is sent to microcontroller, according to this data the robot is programmed. This paper deals with the review of navigation of different applications of self-balancing robots. So far, no review is done on this topic.

A lot of self-balancing robot applications is made till date for example Segway, which is an efficient way to travel in polluted urban areas [1], [3], [17], [18] which has five gyroscopes [19]. Paper [3] explores controllers used for balancing, movement in flat and uneven terrain, secondary objectives and additional actuators. The author [4] made robot called Bimbo, which has a navigation function that is controlled by changing system variables via Bluetooth communication [3]. Paper [5] shows a vision-based balance robot navigation to detect the trajectory [3]. Paper [6] proposed a line following system to navigate the two-wheel balancing robot [3]. Paper [6] concludes that by using PID control a robot can balance itself while following track given [3]. Paper [7] presented the design and development of a remote-navigated autonomous two-wheeled balance robot [3]. The author of [8] presents an autonomous two-wheeled balance robot using multilevel PID [3].

The author of [9] made an autonomous navigation system by combining an ultrasonic sensor, camera and lidar which are processed using OpenCV and processing. Li and Zhou [10] mounted an RGB-D camera on a commercial Segway, which was used to navigate autonomously [3]. Paper [11], [12] put forth the use of ultrasonic sensor in self-balancing robot, this sensor enables robot to avoid obstacles. Researches based on ROS navigation are also carried out in [3], [13], [14], [15], [16].

The path planning algorithm for a known environment is based on a classical approach such as CD, **R**A, and APF. These algorithms are traditional and have limited intelligence. Local navigational approaches are known as reactive approaches as they are more intelligent and able to control and execute a plan autonomously [24].

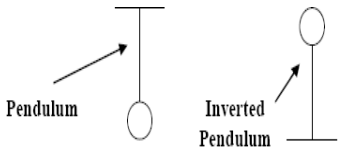

Fig 1: Inverted Pendulum and Non-Inverted Pendulum [25].

II. LITERATURE REVIEW

As we all know the automation of robotics began a very long year before the whole world were curious to know more about the new emerging technology in automations like Artificial Intelligence, navigations and different types of sensors, etc. Let's dive deeper into the history of the automations in regard to the topic of Self Balancing Robot. The first robot was introduced in the year of 1948 by William Grey Walter.

One of the very first attempts of making an inverse pendulum type robot was in 1991 and later in 1992 [21], [22]. In 1996 a

mobile inverse pendulum or inverse pendulum type mobile robot was made which moved in 2-dimensional plane with constant velocity using control algorithms. In the year 2003 R.C.Ooi made a two wheeled autonomous robot based on the principle of inverted pendulum, two control strategies were implemented - the stability of the system was accomplished through the implementation of Pole-placement control, the LQR controller offered an optimal control over the system's input via the weighting matrix R [19].

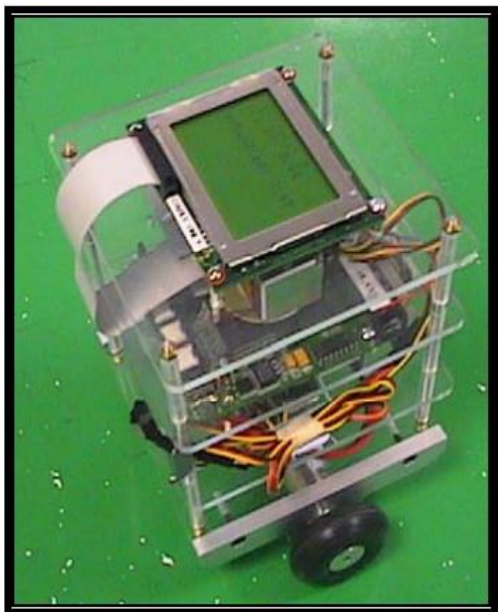

Fig 2: Two-Wheeled Autonomous Robot [19].

In the year 2006 the autonomous robot was developed in order to control the robot the Self balancing robot was made by using the PID technology the navigation of robot was handled by using the RC remote controller. This robot had the ability to stand in the vertical position and withstand its own body weight and move from one place to another place by maintaining its balance. This robot had the ability to move on the flat terrain vehicle but failed to move on the rough surface as its center of gravity gets disturbs and robot loses its balance. This was the major drawback in this paper [7]. Previously the Self balancing technology was introduced and it was observed that the robot was not able to handle the weight on the rough terrain surfaces. In the year 2008 a mobile two wheeled balancing platform was developed by V.Coelho et al with two embedded PCs, athena acquired data from IMU, gyroscope and wheel encoders to obtain tilt angle, tilt rate, speed and turn rate. It executed control algorithm.
In the year 2011 the paper has been published for overcoming the same problem by adopting the IR sensor to make the obstacle avoidable and balance its weight. The programming part for any automation play a great role as lots of software devices are need to connect with the hardware in order to work in a proper functional manner. Later it was observed that instead of just focusing on the IR sensor the use of gyroscope can actually reduce the task of balancing on the rough terrain vehicle. The IR sensor is used as the distance measuring device and it is responsible for the proper communication between the programmable board in this case it is ATMEGA32 [6]. The two -wheel Self balancing robot is a very unstable body for the real-life application and in order to prove this the fuzzy logic review paper has been published by many researchers and by using the different kinematic equation involved in the paper and by doing the analysis with the help of different simulation performed it has been noticed that the equation used can actually be helpful in order to obtain a greater stability and good performance required in the Self-balancing robot [18]. Many research papers got published and every research paper was trying to maintain the proper balance of the Self-balancing robot and some or the other way the technology was getting better this research paper has tried solving the issue of balancing by using the ultrasonic distance sensor. For the moving of the Self-balancing robot the ultrasonic ranging theory has been used by taking the two-wheel Self-balanced robot Hominid 3 as the platform. The DSP is been used to store the data according to the environmental information collected. In this, MATLAB software has been used in order to figure out the actual simulation part of the Self balance robot. The result in the simulation and the experiments proved that the fuzzy logic algorithm has been effective [11]. As time was going on, the researcher was finding a way to implement the Self-balancing robot by trying different theories like using IR sensor in starting from 2006 to ultrasonic sensor in 2011 to coming a way to implement the principle of the inverted pendulum in the year 2015.The theory of inertial navigation platform, which has an ability to carry both people and object. This research paper helped in developing and analyzing of the platform angle, speed, direction control by the feedback circuit. The platform is equipped with the saddle chair and the monitor which display the data. Wi-Fi remote control system has been used. The platform is convenient reliable and stable. The incomplete or more work can be done inside this by using the intelligent sensors with the help of the nine- axis gyroscope the platform can be able to monitor robot posture [1].

Fig 3: Platform walking [1].

In the upcoming evolution of robots, the simulations and the analysis part as been more focused as it was showing the accurate data and as a part of the automation data is an important asset for any time to develop and re-implement the

logics with accuracy and efficiency. This paper has introduced with the simulations environments for the testing using the software and analyzing the robot behavior and control algorithms in different environments. The environments used are the ROS and the Gazebo. The code which is developed can be implemented directly in the Gazebo. The navigation part has been closely looked by the ROS software by 3D mapping. Both the simulations and experiments have given the accurate data and verified results [16]. Despite many attempts in the past history for the stability of the Self-balancing robot, there are still several open gaps which have been tackling by this research paper by implementing the proportional integral derivative, pole placement, adaptive control etc. The robot has been developed by different modules it has named the Bimbo. The Bimbo is going to communicate with the operator by implementing the Bluetooth technology. The selected solutions implemented the PID [4].

With the growing demand of the robot technology in the world there is need to develop the Self-balancing robot for real life applications like in hotels industry. This paper proposed the line follower robot where robot can automatically follow the path and achieve its desire task based on the applications. Here, the MATLAB software is used to connect to the URL of IP camera and use image processing toolbox to detect the image. The robot not only detects the straight line but also detects the curve lines by identifying the dots and follows the same path. Therefore, the cascade intelligence motion control system is proposed to control the balancing and moment of the vision-based robot [5].

Today's industry focuses on two things one is efficiency and the second is how fast the efficiency is. The papers had been started publishing from the year 2018 and it has been noticed that by using high sensors, image processing techniques, and lidar based technology has actually helped in improving the speed of the robots. It channelizes feature of our technique to tackle obstacles in speed [9]. Earlier fuzzy logic has been developed but some papers was continuously worked on to make the inverted pendulum concept well technically advance.

This paper uses the PD-PI system with the 32-bit microcontroller and the programming has been developed in the Java programming language. The robot can easily communicate with the sensed environment and can connect with the mobile devices and the internet of things. The robot is controlled with the Bluetooth device communicator. This advance use of the principle of inverted pendulum has been resulted in better performance [12]. The researches had been made in the technology of the LiDAR and navigation systems. The given papers had done an experiment on the 2D based LiDAR and the camera-based navigation system.

The first experiments carried out on the Raspberry Pi 3 using 2D LiDAR. The second one is performed with the RGB-D camera and the LiDAR [13].

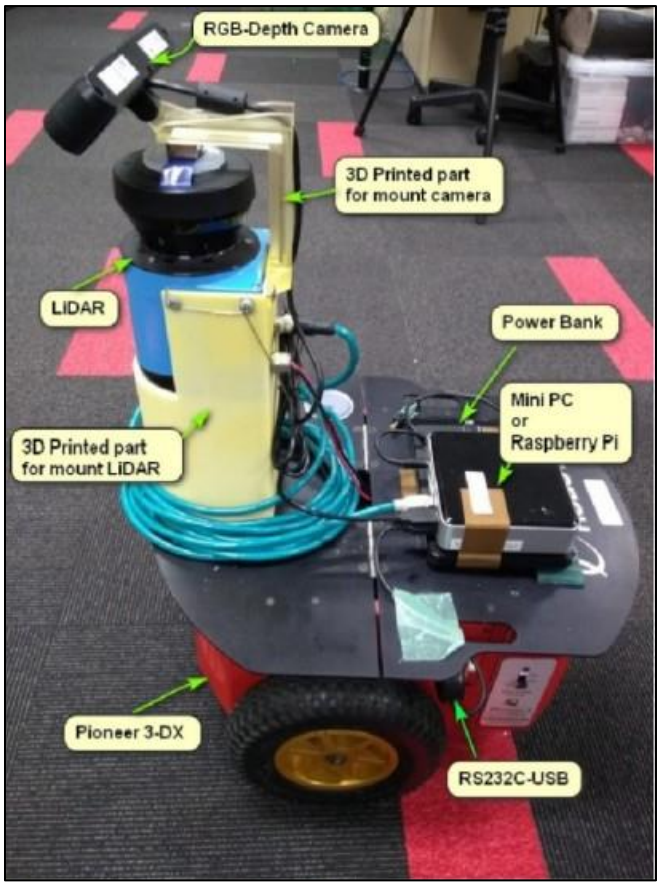

Fig 4: Robot based on LiDAR [13].

In the year 2019 more research has been trying to be developed in the field of the fuzzy logic control for the Self balance robot. The PID controllers are used to control the motion of the robot. The fuzzy PID is ported and execute on the STM32F4 kit [17]. As Self balance was gaining popularity and it was convenience to use therefore it was really important to know the actual path and planned path difference. By what percentage the data in the path has been same. In order to achieve this python programming has been developed which can calculate the actual difference observe between the planned and the actual path [15].

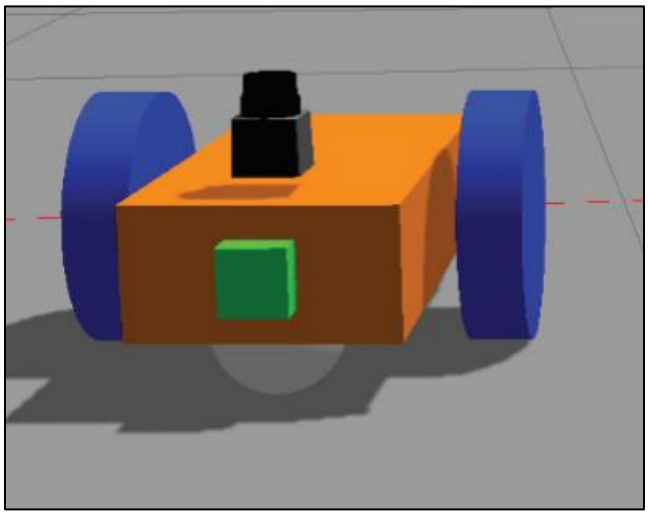

Fig 5: Model made on Gazebo [15].

III. SELF BALANCING ROBOT TECHNOLOGY

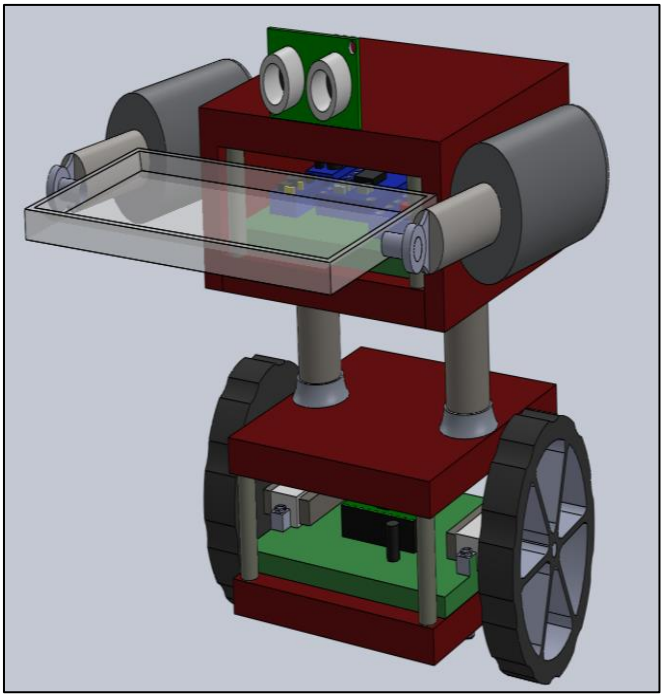

Fig 6. Self-balancing Robot CAD Model

A. *Working*

- The self-balancing robot will be controlled with the help of Arduino microcontroller whose base is fixed at two gear motor.
- The angle of the moving robot is measured by MPU 6050 gyro & accelerometer.
- The gear motor is preferred over the DC motor because of the performance of mechanical and electrical function and have gripper motor can also move in straight line.
- When the motor starts the body of robot move vertically and travel in straight line here inertia of motor plays an important role with help of battery placed upward.
- In brief, in self balancing robot three resistor has been used where one is helpful for uploading program to Arduino Uno.
- While other two used for voltage divider.
- Finally, electronic connections are made and a program has been uploaded to Arduino Uno, the battery is switched on and gear motor will rotate with stability and self-balancing robot will work.

Fig 7. Working of Self-Balancing Robot

This particular robot here is proposed for the application of serving customers in restaurants café or hospitals.

B. *Applications*

- This technology can be used in restaurants for serving customers.
- In hospitals as an assistant to doctors, or for serving patients.
- It can be also used as home assistant, for delivering things from one person to another.

This technology will be of huge help in covid times or during any epidemic breakout. During such testing periods it is very important to maintain sanitization and social distancing. Many industries suffer a huge loss as in order to maintain social distancing they have to shut to minimize their work. Restaurants and cafes just like any other industry suffer a lot, during such times. This self-balancing robot can replace the human waiters and serve customers while thus ensuring minimum human contact. During epidemic breakouts, the main hotspot for the disease to spread is the hospitals, the medical and paramedic staff in the hospitals tend to patients, get infected and even spread it to other places. This self-balancing robot can assist the patients, paramedic staff in small chores like giving medicines to patients, assisting in an OT etc. also when the workforce is limited compared to patients.

Sr.no	Technology Or Principle	Software	Parameters	Results	Remarks	Ref []
1.	PID	Remote control via Bluetooth	Distance Measuring sensors used.	Applicable only to flat Terrain.	Unstable on rough surfaces.	[7]
		PID algorithm. Atmega32 used.	Infrared Sensors used to detect obstacles.	Successful on flat terrain. But performance reduced on rough surfaces.	Performance Issue on rough surfaces.	[6]
		Control via Bluetooth.	Pole, adaptive control used.	Effective results observed.	Technology enhancement can be achieved to a larger extend.	[4]
2.	Fuzzy Logic	MATLAB is used for simulation.	Ultrasonic distance sensor is implemented.	DSA is responsible for storing the data.	Greater use of ultrasonic theory is required for advance functionality.	[11]
		MATLAB is used for simulation and analysis.	Kinematics equations are developed.	Detail understanding with accurate data is the outcome.	Greater functionality and performance achieved.	[18]
		MATLAB is used for simulation	PID and Fuzzy logic implemented together.	Accurate data observed by analysis.	Executed on STM32F4 kit.	[17]
3.	Inverted Pendulum.	Bluetooth is used.	PI-PD is implemented. Can connect with IOT and mobile devices.	Successfully developed with the analysis.	Java programming is executed	[12]
			Speed, angle, feedback circuit is well implemented.	Proper balancing of the Self balancing robot is achieved.	Sensors are not used. With the help of sensor system would be more efficient.	[1]
4.	LiDAR	Image processing	High level sensors have been used.	Speed accuracy has increased.	High speed operation can be possible with LiDAR.	[9]
		Raspberry-PI 3	RGBD- camera has been used.	More efficient system developed.	Experiments have been done with or without camera on LiDAR system.	[13]
5.	Programmin g Language	Python is used for data analysis.	Observed the difference between actual and the planned path.	More accurate data has been observed for application purpose.	Good way for implementing python language to know the accuracy.	[15]
		MATLAB software.	Identified the straight as well as the curve path.	Robot is able to follow the path. Line follower is developed.	Vision based system is been implemented.	[5]

TABLE 1. CRITICAL ANALYSIS ON METHODS OF SELF BALANCING ROBOT NAVIGATION

CONCLUSION

Numerous studies are done on Self-balancing Robot navigation, with improved technologies now the control, balance and navigation have become easier. Newer technologies like Ros, ultrasonic sensor, Lidar etc. has enabled the robot to avoid obstacles and enables a smooth navigation. The analysis part based on the software has given a detail analysis of data which can be further use for the future study. The different programming language has been used for the past history on the development of the robot for example, python, java, embedded C, ROS, etc. The microcontroller helps to communicate proper with the uploaded program code written in the particular language some of them include the use of Arduino UNO, Raspberry pi. This detail analysis and research review paper has been made in the motive to help the advancement and make contribution in the field of niche

Self balancing robot. Applications of Self-balancing robot in hotels and hospitals is discussed. Self-balancing Robot will be of great help in these industries during covid (or any epidemic), or during shortage of workforce.

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