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Dynamic Self Stabilizing Mobile Platform

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Abstract: This paper presents the design and implementation of dynamic self-stabilizing mobile platform with 2-degrees of freedom on a mobile platform using low-cost material. The self-stabilizing control system presented in this paper can be used in various medical, military applications and logistic devices and is objectively suitable for working in outdoor where the ground surface is not flat or uneven. The platform can freely rotate due to its mechanical structure within 2-degrees of freedom. The complete control system of stabilizing the platform has been designed on the Arduino UNO microcontroller. Longitudinal and lateral movements are controlled via servomotors for X and Y-axes. The algorithm has been developed to interpret the digital data from the gyroscope to the angular position of the system and applying complementary filter and proportional controller on it subsequently. The magnitude is then compared to a preset function to infer the angle of tilt of the platform. The tilting angle is then converted to rotation angle for the servomotors to act on.

Keywords: Self-balancing, Stabilizing, Gyroscope, Accelerometer, Servomotor, Filter, Controller.

I. INTRODUCTION

With the latest technological advancements, transportation, delivery systems in the industry, military and medical assistance in hospitals are being automated. Designing and implementing the robots according to the desire and automating the given tasks with high accuracy is making robots more demanding and talk of the century with advancements being made in the robots. self stabilizing robots have a number of advantages, especially when it comes to its simple mechanical designs, where they do not require a steering mechanism. Due to demanding situations, research on control methods for complex systems and nonlinear systems are being done [1]. The paper aims to present the design and its implementation, implementing only the proportional controller for a dynamic self-stabilizing mobile platform with 2-degrees of freedom on a small-scale mobile robot, which is a nonlinear control experiment, has been analyzed [2]. It has been kept in view that the cost of the whole project is minimal for installations in almost as many applications as when needed. The platform is to remain parallel to the reference i.e. floor when provided disturbance. Despite advancements in wheeled robots, vibrations and shocks are still inevitable. Resultantly ensuring the safety of goods in case of transportation is a priority [3]. The paper aims to present the design and practical implementation, implementing only the proportional controller for a dynamic self-stabilizing mobile platform with 2-degrees of freedom on a small-scale mobile robot.

The platform control of the 2 degrees of freedom manipulator so that it will set the parallel platform horizontal. The X & Y movements also referred to as lateral and longitudinal movement respectively are controlled via two links in this case. The Fig. 1 shows the block diagram of the Dynamic Self Stabilizing Mobile Platform [4].

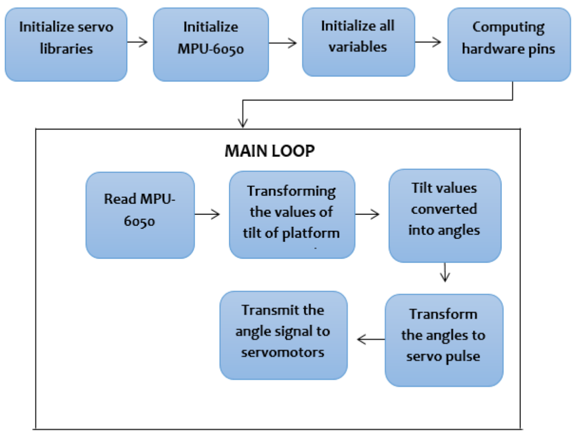

Fig. 1 Block diagram of the dynamic self stabilizing mobile platform

When the mobile robot is moved or driven into rough terrain or slope surface, the movement of the mobile platform makes it unstable that is sensed by the MPU-6050, which is given to the proportional controller further, which is sent to the complementary filter to smoothen the signal of the dynamic self-stabilizing mobile platform [5].

II. MECHANICAL DESIGN

The design of the square-shaped self-stabilizing platform has each side measuring 15.3 inches at the front and back, 13.2 inches at the left and right with a height of 16 inches. The material used in the construction of the platform is wood, since it is inexpensive due to its lightweight and ease of drilling and attaching supports, as in the case of holding the servomotors. The self-stabilizing platform has been simply mounted on the mobile robot that has four tires. The Fig. 2 shows the trimetric view of the mobile platform designed in the CAD. When the mobile robot starts to move on different plains, the self-stabilizing platform placed on it experiences translations and vibrations.

Fig. 2 Trimetric View of CAD model of mobile platform.

The system has 2-DOF (i.e. Pitch & Roll axes) which means it has 2-independent variables that outline its pose, that is orientation and function. Due to its physical isolation, the system has its own kinematics and is ideal as it allows the system to translate and allow the movement of the dynamic self-stabilizing mobile platform in the 2-DOF.

Despite the restriction to just 2-degrees of freedom, the system works perfectly while maintaining the function and orientation of the stability of the dynamic self-stabilizing mobile platform.

III. ELECTRICAL SYSTEM

A. MG-996R Motors:

The MG-996R servomotor has been used due to its less weight; accuracy along with improved dead bandwidth and centering. The metal gears provide the ergonomics with load and torque. It has a fast speed, which is the most important specification of our system since it is a dynamic self-stabilizing mobile platform. The Table 1 shows the product specification parameters taken in account of the servomotor for the system.

Table 1 Motor Specifications

S.No.	Parameters	Values
1.	Weight(grams)	55
2.	Torque(kg)(4.8v)	9.4
3.	Speed(sec/60deg)	0.19

B. MPU-6050 drift:

The MEMS (Micro Electro Mechanical Sensor) used to track the motion of the platform in our self-balancing platform is the MPU-6050 sensor, also called IMU (Inertial Measurement Unit). The IMU's have independent sensors incorporated like (accelerometers, gyroscopes or magnetometers) which may work dependently and independently to attain the parameters of motion. Unlike the conventional compass, the modern day gyroscope and accelerometer all put in one sensor i.e. MPU-6050, that is that the IMU device, does not seek for the North Pole only.

IV. CONTROLLER DESIGN

A. Strategy of execution:

It is clear that every mechanism or actuator can enforce completely different movements, also as positioning itself in several angular tilts for configuration of the platform. Within the same means, it infers movements which are completely different for the manipulator. However, the management parameters of every manipulator can bear identical cycles.

B. Architecture of control system:

Fig. 3 shows the basic control block diagram of a plant where the error in the system is removed through a controller. The desired value is set through a set point and the error is manipulated through the controller by mathematical representation Eq. (1). [6].

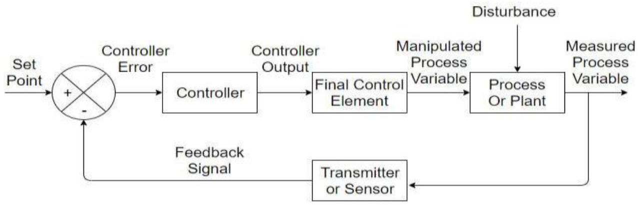

Fig. 3 Basic control diagram of plant.

C. Our control scenario:

In our project control scenario, as shown in the Fig. 4, the control block diagram follows the same pattern where the set point is set, which is 180 in our case. The error is computed in the controller through the reverse acting method and a PWM signal is sent to the actuators. The servos then rotate accordingly to the signal provided. When a disturbance is created at the platform, the gyro sensor sends feedback.

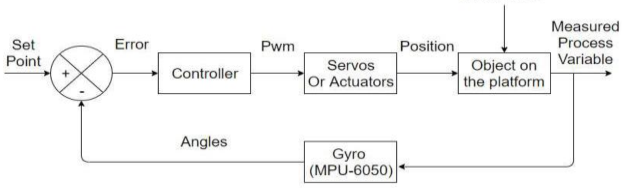

Fig. 4 Control diagram of our system.

V. IMPLEMENTATION

Loads of small-scale electronic parts, sensors, and single-chip microcomputers exist with great execution by insignificant power utilization. One zone of innovation is Micro Electro Mechanical System devices and sensors [4]. This makes marking of innovation or sensors straightforwardly. They are in conforms to the necessities of minimal effort, measurement, low vitality and weigh. The inspiration for making the dynamic self-stabilizing mobile platform is to utilize this innovation for exhibition and for gathering encounters with practical use. The dynamic self-stabilizing mobile platform can have added some genuine uses for instance in car, industry, flight, apply robotics and so on. This paper depicts the hypothesis and production of the independent platform with standard parts accessible. The greater part of them is minimal cost and simple to purchase. The aftereffect of this undertaking is to hold in balance after an object is placed on the platform. In the usage, we met likewise a few issues that have been unraveled. Sensor for movement data estimation is MPU6050. The control part is set independent that is it can be for instance AVR 8bit or ARM 32bit. In our case, we preferred Arduino UNO.

Its advantages are the following:

- It provides stability at a comparatively low cost with a less complex system.
- Higher leveling of the supported masses.
- Precision, because the positioning errors of every motor is damped.
- Mechanical phenomenon forces are sufficiently small to be ignored in almost all applications.
- Additional rigidity.

The dynamic stability platform consists of the upper platform (small wooden plank), which controlled, based on disturbance and intermediate top servo lying across the bottom servo. The MPU-6050 is placed just below the top platform through which the tilt angle is being measured.

This servo placement is a more efficient use of space & limits the slop compared to linkages and hinges. The Y-axis motor or pitch angle servo is controlled by the Y-axis data stream from the gyroscope accelerometer & vice versa for the X-axis or roll angle motor.

The view of reconsidering more than a few models for considering fundamentally the frame factor & possibility. Among many, there is having the base and the platform with respect to a similar level and the other having a more regular sort of configuration having platform vertically over the fundamental base. Thinking about it & being well known we, at last, conceded to the second plan. Setting servomotors perpendicular to each other gave us a real edge in stabilizing the system.

VI. TEST RESULTS

The formula used for Controller Output is:

$$Controller\ Output = Kp * error \quad (1)$$

where,
error = Set Point – Process Variable
Kp = Proportional Controller

The resultant graphs obtained from serial plotter for the dynamic self-stabilization mobile platform are shown below for the roll and pitch in positive and negative X & Y axes.

Blue wave: It represents the input of Roll angle (x angle) from the gyro (which can be positive or negative).
Red wave: It represents the input of Pitch angle (y angle) from the gyro (which can be positive or negative).
Green wave: It represents the error1 for motor x (which can be positive or negative).
Yellow wave: It represents the error2 for motor y, (which can be positive or negative).

The graph in Fig. 5 shows that when there is no disturbance on the platform, then there will be no change in gyro angles due to which errors will be zero for both motors x and y and they will retain their position that is 90 degree.

The graph in Fig. 6(a) shows that when we provide disturbance on the positive x-axis of the platform, gyro gives the tilt positive angle i.e. roll (x) which was subtracted from set point and gives an error, which was negative. The error was further given to the motor x, that negative error will rotate motor

The graph in Fig. 6(b) shows that when we provide disturbance on the positive y-axis of the platform, gyro gives the tilt positive angle i.e. pitch (Y) which was subtracted from set point and gives the error, which was negative. The error was further given to the motor y, that negative error will rotate motor anticlockwise.

The graph in Fig. 6(c) shows that when we provide disturbance on the positive y-axis of the platform, gyro gives the tilt positive angle i.e. pitch (y) which was subtracted from set point and gives an error, which was negative. The error was further given to the motor y, that negative error will rotate motor anticlockwise.

The graph in Fig. 6(d) shows that when we provide disturbance on the positive y-axis of the platform, gyro gives the tilt positive angle i.e. pitch (y) which was subtracted from set point and gives an error, which was negative. The error was further given to the motor y, that negative error will rotate motor anticlockwise.

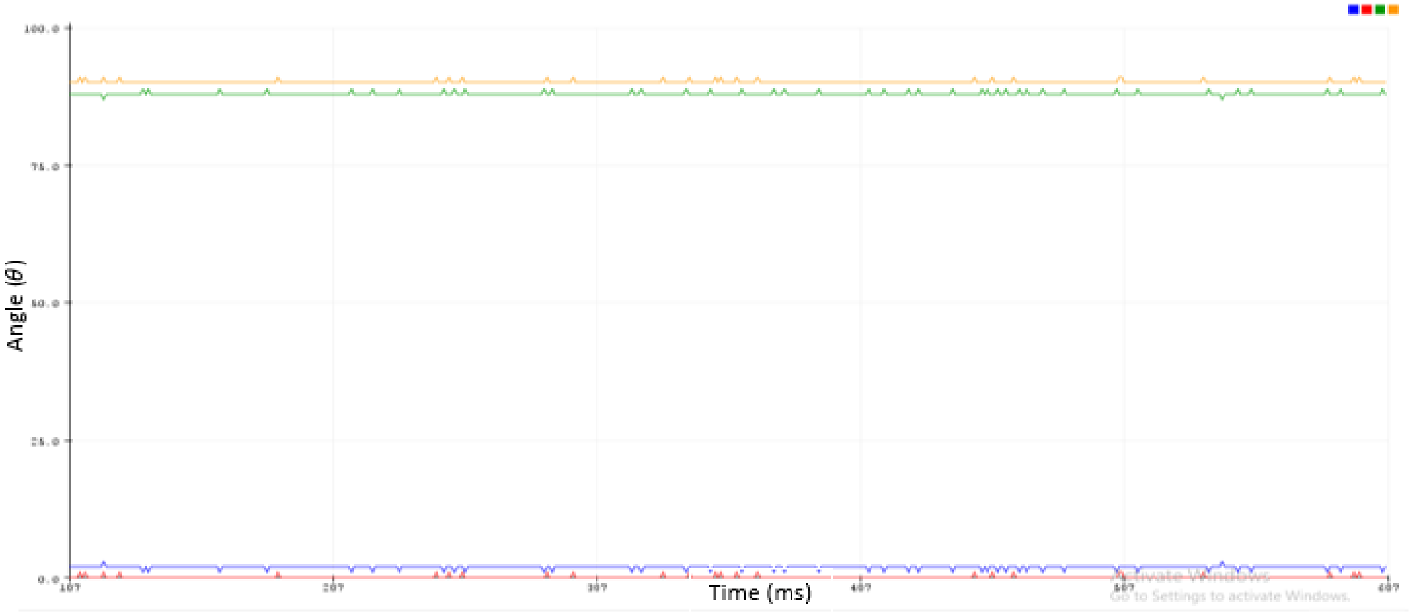

Fig. 5 No disturbance on platform

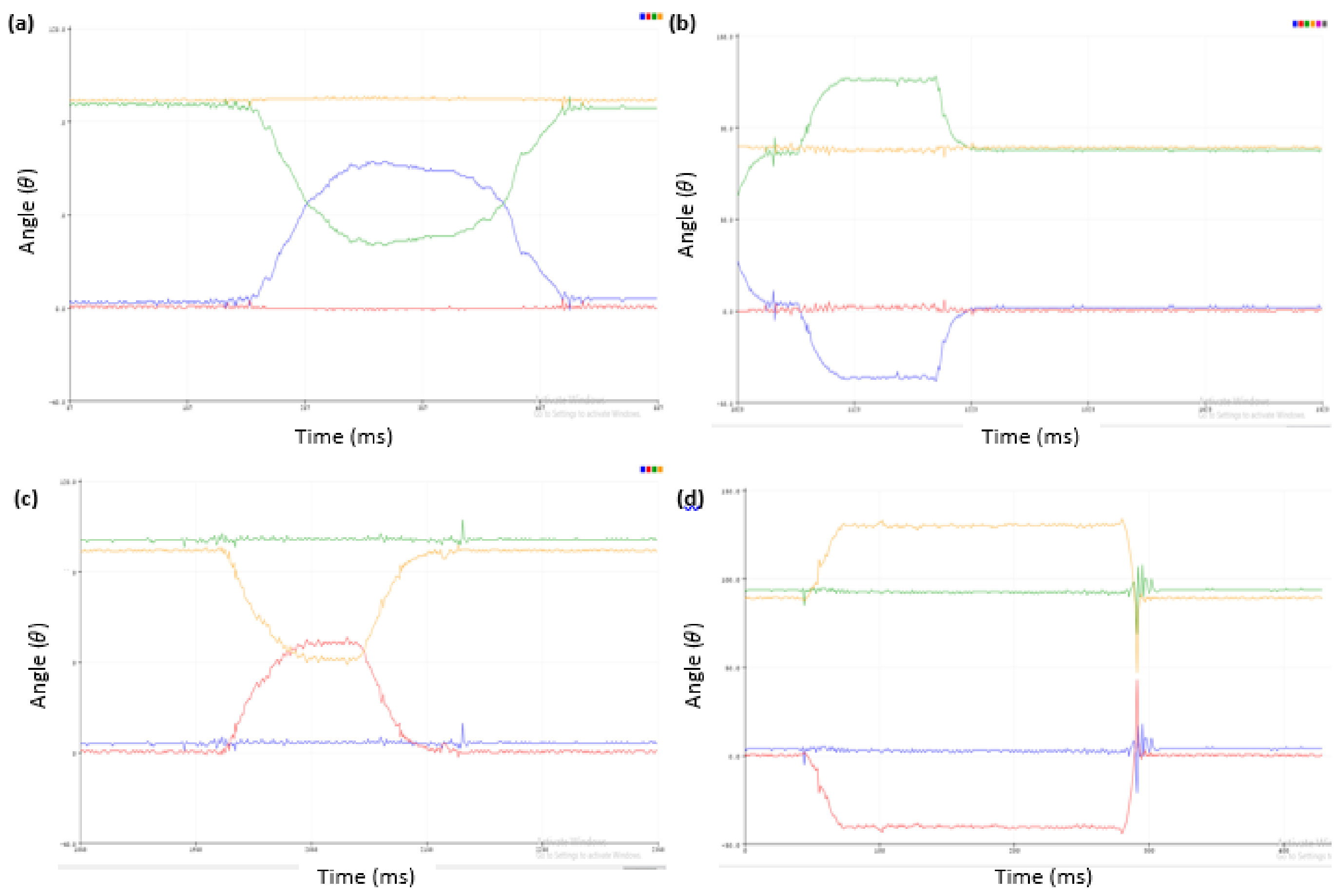

Fig. 6 **a** Disturbance on positive X-axis of platform, **b** Disturbance on negative X-axis of platform, **c** Disturbance on positive Y-axis of platform, **d** Disturbance on negative Y-axis of platform

Testing demonstrated the platform to execute as expected for dynamic stabilization.

VII. CONCLUSION

In this paper, the complete low-cost design and implementation of a dynamic self-stabilizing mobile platform has been discussed to balance the object placed on the platform in dynamic conditions. The platform is designed utilizing economical materials, wooden pieces, Arduino, the MPU-6050 and two servomotors.

The paper has put forward the process in which the mechanical, electronics and programming have been integrated making it extremely interdisciplinary and in fields of robotics and mechatronics. The future work includes increasing the degrees of freedom to as far as 6-DOF increasing the level of stabilizing the platform along with implementing in various systems where the aim is dynamic stability.

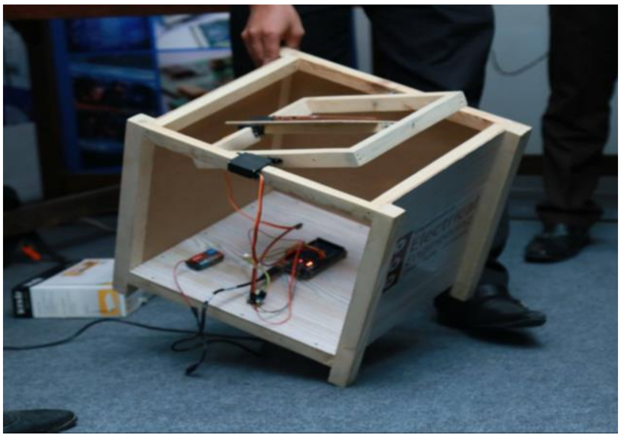

Fig. 10 Final Implementation of dynamic self stabilizing mobile platform

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