SPY ROBOT USING SELF-BALANCING ALGORITHM WITH PAN AND TILT CONTROL OF CAMERA

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ABSTRACT

The aim of the proposed project is to design an effective spy robot which can be used for reconnaissance, border security and many more. Since the robot's application is on uneven terrain so to make the robot effective, its design should be unique and can be applied to any terrain. Spy robot should be designed in such a way that it should occupy minimum space, should possess high maneuverability and high agility. Self-Balancing robots are special type of robots which occupy minimum space and are proved to be highly maneuverable and highly agile. The robot contains two main units, one is the self-balancing section and second is the PAN and TILT control of camera both controlled using a RF controller. The balancing unit is responsible for the stability of the inverted pendulum structure of robot. The PAN and TILT control of camera is responsible for the effective feedback of video. The self-balancing unit will be controlled by a PID controller or a LQR controller to improve its stability. The angle tilt will be measured using IMU sensor; since the IMU readings are noisy an appropriate filter would be employed such as Complementary filter. The IMU uses I2C protocol with AVR microcontroller for data transfer. MATLAB will be used to tune PID controller, simulate the robot using SimMechanics and to create a GUI for video feedback.

Keywords: IMU Sensor, Complementary Filter, PID, Inverted Pendulum, PWM, AVR, MATLAB, SimMechanics, PTC CREO, Stepper Motor, High Torque Motor

INTRODUCTION

Defense is a booming market in this modern world. The more power a country wields when the country got more information. Spy robot is a proposal to meet these requirements to gather foreign information for the host country’s interest. Since spy robots are applicable in rough and uneven terrain because of this an optimal design of platform has to be formulated. Self-balancing robots are famous for its maneuverability, agility and its minimum space occupation. There are several commercial self-balancing robots available such as Segway and some other Chinese products. Basically self-balancing robots are robots which occupy minimum contact with ground and can balance itself. At any terrain whether it is slanted, uneven or anything, self-balancing robots can balance itself and thus making it high recommended for applying the idea on Spy Robots.

How a self-balancing robot balance itself is very simple. Driving the wheels in the direction of robots tilt will make sure the robot balance itself. The wheels will be driven in such a way that the robot stay under its center of gravity. It would be designed by the theory of inverted pendulum in control theory. To navigate the robot, the angle of tilt is a highly valued constraint. These tilt angles are measured using IMU, which is a combination of both accelerometer and gyroscope.

The design of robot has to be sleek and has to occupy minimum space since the proposed robot is a Spy robot. There will be two wheels which would be placed parallel to each other. The body comprises of four platforms, the bottom one for the battery, the second for the circuitry, third for the camera and uppermost will be used as a protective shield in case of a self-balancing failure. The circuitry contains the microcontroller, motor driver, etc. The bottom platform also supports the two motors for the robot and also the IMU sensor would be placed in that platform.

The microcontroller which would be recommended is 16 bit AVR controller. MPU6050 would be used to measure the tilt angle and high torque motors are to be used for navigation of robot. Two stepper motors would be recommended for pan and tilt control of camera. Since camera has to be wireless, IP camera would be employed for the simulation purpose. The video will be fed to MATLAB GUI.

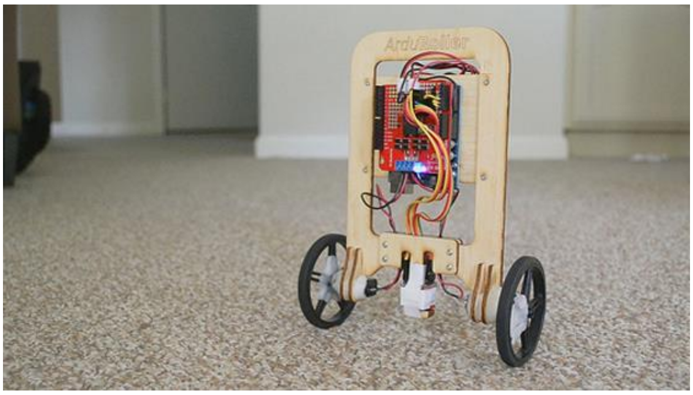
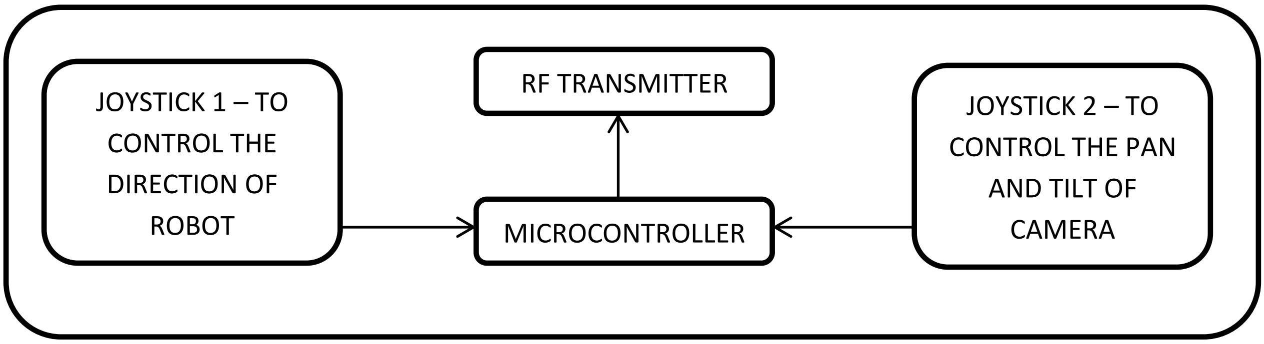


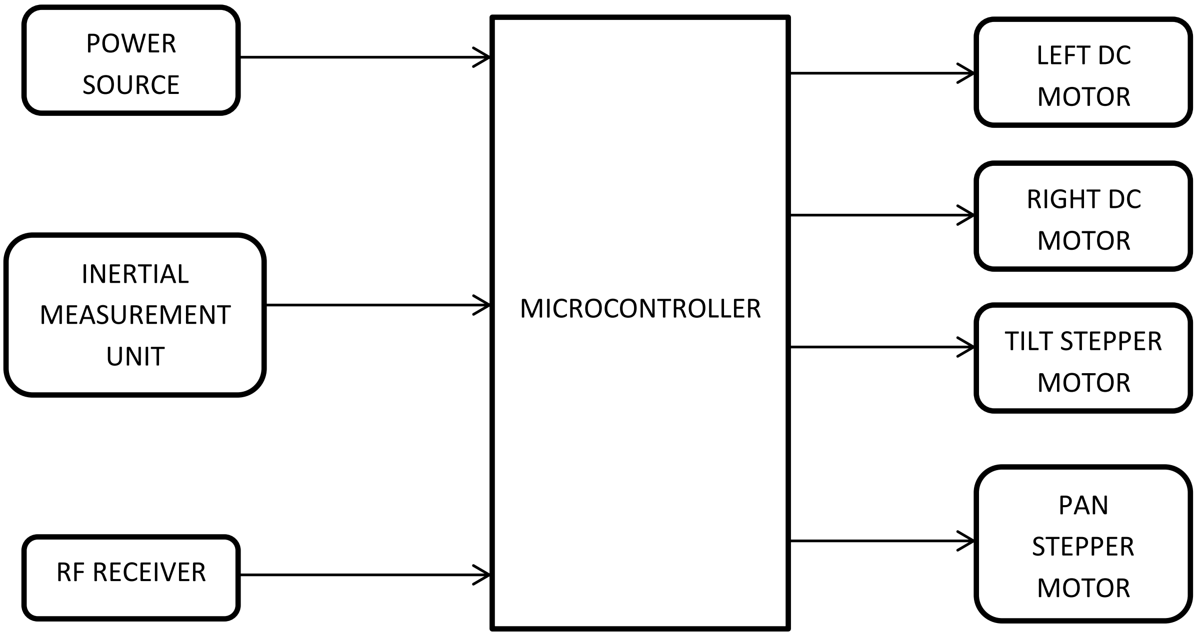
Figure 1: Self-Balancing Arduino Based Robot

Block Diagram:

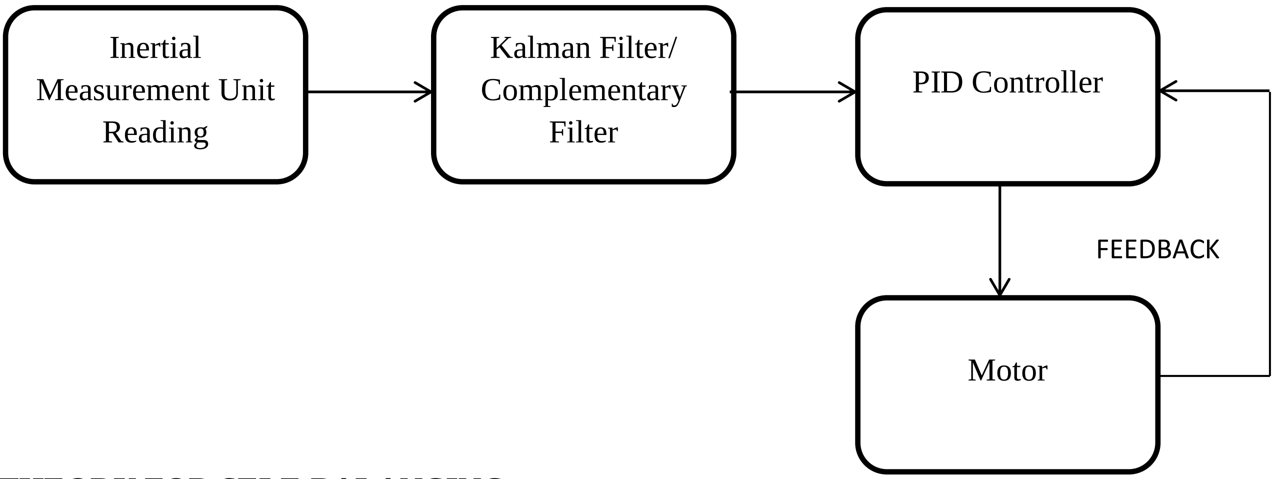
Controller Unit



Schematic of Robot



Block Diagram for Self-Balancing:



THEORY FOR SELF-BALANCING

Angle Estimation:

The main objective of the robot is to balance itself. The only input variable for this process is the angle in which the robot is tilted. The angle is determined using an IMU sensor. IMU sensor comprises of both accelerometer and gyroscope. In theory, either one can help you to measure the angle but in practical sense the combination proves to be effective. Accelerometer provides accurate reading for an interval of time. Since accelerometer is a micro electro mechanical sensor, when slight jerking from the robot threw the accuracy for accelerometer away. Then comes the gyroscope which measures the angular velocity. Gyroscope experience drift and its error get integrated with it. The reading becomes too noisy. This robot uses the combination of both sensors; the readings are combined using filters like Kalman filter and Complementary filter. Kalman filter is also known as Linear Quadratic Estimation which is an algorithm that uses a series of values observed containing noises and produces the values that are tend to more accurate than the values fed to it. Complementary filter is combination of high pass and low pass filters, it is simpler and requires low processing power to implement. The high pass filter will be employed for readings of gyroscope since it will be used for short term and low pass filter will be used on accelerometer which will be used as absolute reference.

According to complementary filter equation:

Angle=0.98*(Prev angle + Gyro angle) + 0.02*(acc.Angle) where, 0.98 is the High Pass constant, 0.02 is Low Pass constant, acc.Angle is the accelerometer angle .

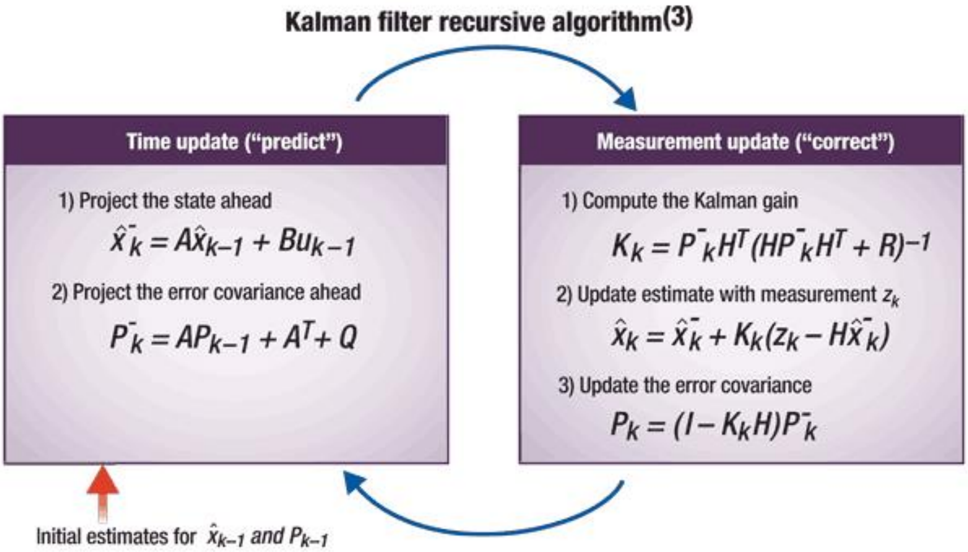


Figure 2: Kalman Filter Estimation

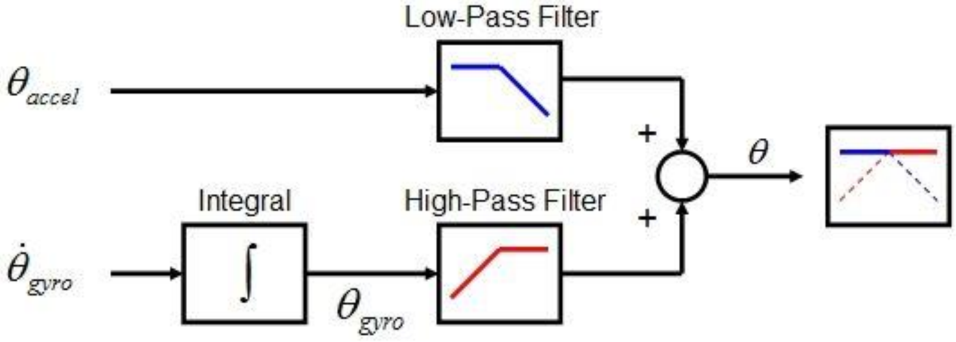


Figure 3: Schematic of Complementary Filter

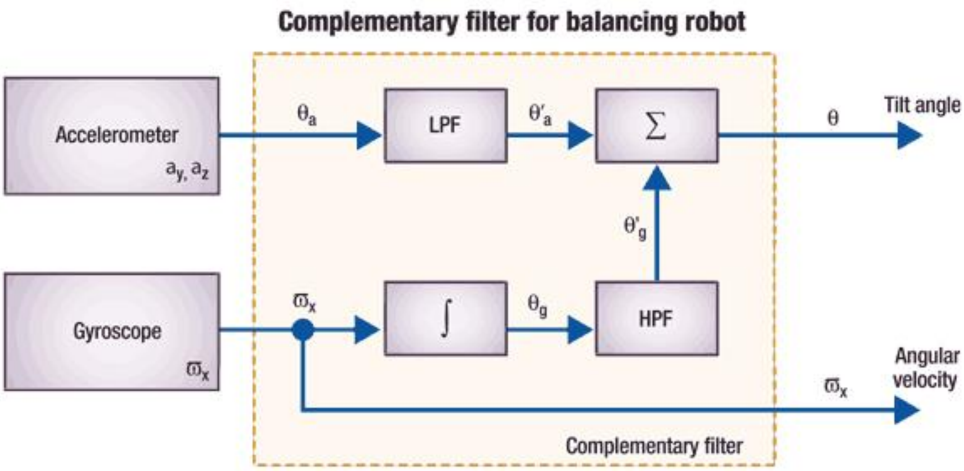


Figure 4: Block Diagram of Complementary Filter

Balancing Algorithm:

The balancing is achieved by PID controller. PID is short form for Proportional, Integral and Derivative controller. Each provides distinct characteristics to the system. Proportional controller is the easiest to implement and proportional part of PID controller corrects the errors which occur at the present. Integral part of PID controller is used to add long term precision to a control loop and it eliminates the accumulation of errors. Derivative part of PID controller is used to predict how the system can behave.

$$u(t) = \underbrace{K_p e(t)}_{\text{Proportional}} + \underbrace{K_i \int_0^t e(\tau) d\tau}_{\text{Integral}} + \underbrace{K_d \frac{d}{dt} e(t)}_{\text{Derivative}}$$

Figure 5: PID Equation

CL RESPONSE	RISE TIME	OVERSHOOT	SETTLING TIME	S-S ERROR
Kp	Decrease	Increase	Small Change	Decrease
Ki	Decrease	Increase	Increase	Eliminate
Kd	Small Change	Decrease	Decrease	No Change

Figure 6: Characteristics of Co-efficient of PID Controller

So PID controller will be used to stabilize the robot by giving suitable PWM signals to the motors. The mathematical modelling of the robot would be done and it would be transformed using Laplace transform. Using MATLAB the equation would be used in PID controller and its behaviour can be observed. After careful observation, this would be implemented on hardware too.

PAN AND TILT OF CAMERA

The ultimate objective of a spy robot is to give video surveillance to a remote area. So to fulfil this purpose a camera is mounted on a dual axis platform. Two stepper motor would be used to control it. One stepper motor for PAN and other for TILT purposes. It is controlled via an analogue joystick; the movement of joystick would be exactly mimicked by the stepper motors. The joystick can give a variety of values in a particular direction which will be sampled and would be given a single output value. This single output value further transmitted to microcontroller and accordingly microcontroller actuates the stepper motor. Analogue joystick is simply two potentiometer whose values are then fed to ADC of microcontroller for further processing.

VIDEO FEEDBACK

The proposed project is the fabrication of spy robot. Remote video feedback has to be shown. IP camera will be used for remote capture of video and audio. Since it is an IP camera the video feedback can be seen in a web browser. In this project MATLAB would be used to make a GUI with password so that the video can be seen to authorised personals. The frames would be collected from IP camera and in MATLAB these frames would be made into a video and store it in the computer.

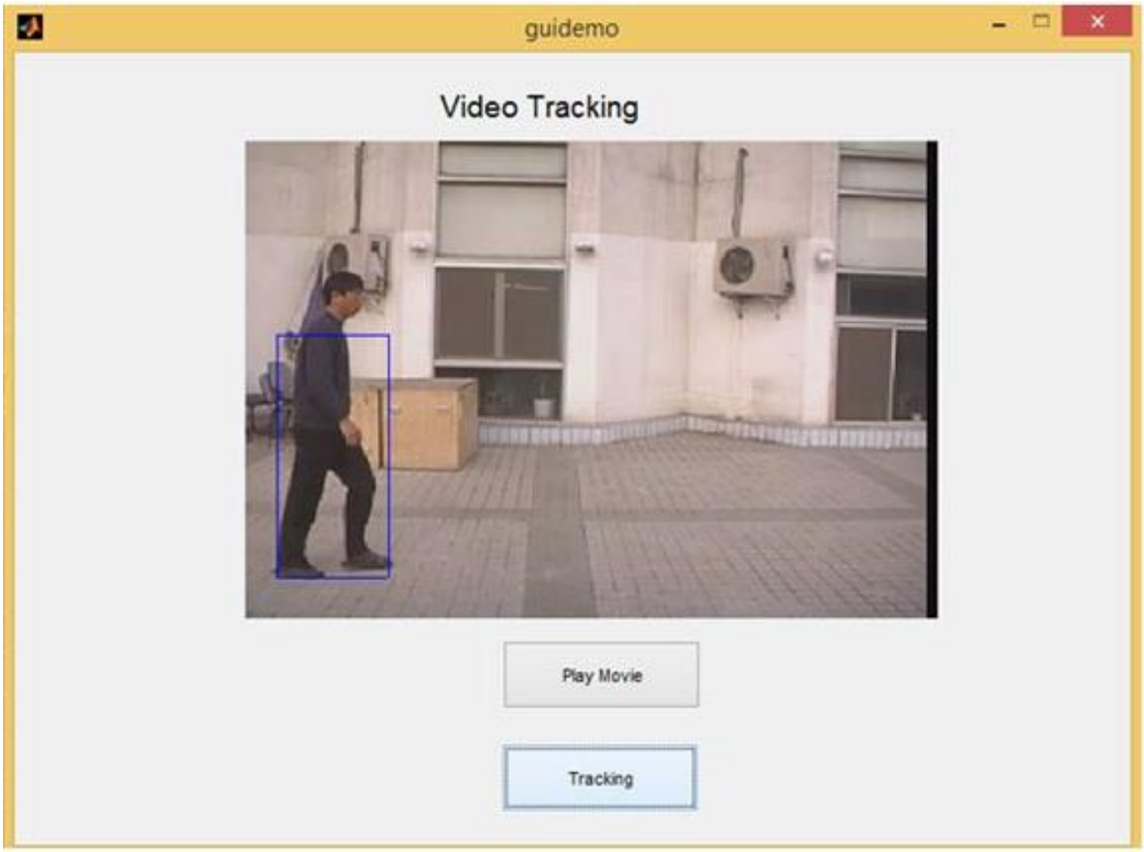


Figure 7: MATLAB GUI FOR LIVE VIDEO FEEDBACK

CONCLUSION

Self-Balancing robot is all about combining values from IMU and applying control theories. This research shows the difference between LQR and LQE. The efficiency and complexity of Kalman filter and Complementary filter is found out. By this research the combination of electronics, mechanical and control systems is implemented efficiently. Through the MATLAB GUI interface with IP camera, one can come to the knowledge of GUI programming and to implement password based security for the GUI. The entire system was observed using MATLAB and then it was implemented using hardware.

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