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STABILITY ANALYSIS OF BALL AND BEAM SYSTEM USING PID CONTROLLER

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Abstract - The ball and beam system is laboratory equipment with high nonlinearity in its dynamics. The fundamental thoughts of the paper are to display the ball and beam system thinking about nonlinear factors and coupling impact and to plan Corresponding Indispensable Subordinate (PID) controller to control the ball position. The system comprises of an Arduino microcontroller. It gets the ball position from ultrasonic separation sensor and contrasts it and the ideal separation which can be set by the client. PID calculation has worked in Arduino to process the distinction in signal among wanted and genuine situation into control signal. Arduino sends control sign to the DC servomotor which turn to change the ball position and meet the desired set point. MATLAB programming program has been utilized to plot moment system reaction by interfacing Arduino with PC to decide the system attributes with various estimations of controller parameters so as to pick parameters esteems which acquired best execution for the system.

***Key Words*:** Ball, Beam, Servo Motor, Ultrasonic Sensor.

1. INTRODUCTION

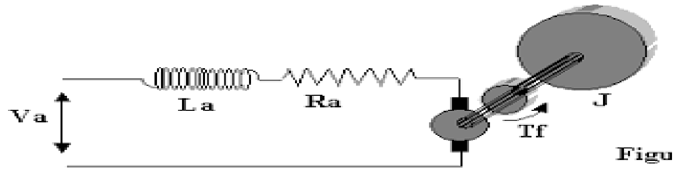
The control of unstable system is critical for a few control issues. Since such System show unsafe to check in vertical position control of flight and planes, we will just examination them in inquire about focuses by showing the System. The ball and beam System is moreover called 'Balancing a Ball on Beam'. It's commonly connected to genuine control issues like on a level plane settling a plane during landing and in tempestuous wind stream. The point of the System is to control the ball position to an ideal set point, and reject external disturbance like a push from a finger. The control signal are frequently inferred by taking care of back the position data of the ball. The control signal goes to the (DC) servomotor, that point the torque created from the motor drives the shaft to turn to the shaft and adjust the angle of beam.

2. Mathematical Modeling

The system contains two separate system , the fundamental one is the DC servo motor, which is an electromechanical system, that gets an electrical signal from controller and gives output as a rotational movement (edge). The second is ball and beam model which is a System that gets rotational evacuating (edge) from servo and changes over it into a linear relocation.

2.1. Motor Model

A typical actuator on Systems is that the DC servo motor. It straight forwardly gives turn and, including wheels or drums and links, can give translational movement. The electrical signal proportional to the circuit of the armature and accordingly the free-body graph of the rotor are appeared

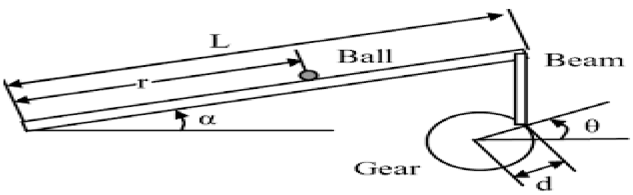


$$\frac{\theta(s)}{E_f(s)} = \frac{K_T}{s(Js + B_0)(R_f + L_f s)}$$

2.2 Ball and beam Model

A ball is placed on a beam, as appeared in Figure, where it's permitted to roll the ball along the angle of the beam. A switch arm is appended to the shaft toward one side and a servo apparatus at the inverse . since the servo apparatus turns by a point θ, the switch changes the edge of the beam by ∝. At the point when the edge is adjusted from the level position, gravity makes the ball move along the beam.

So, the transfer function of ball and beam system is ,



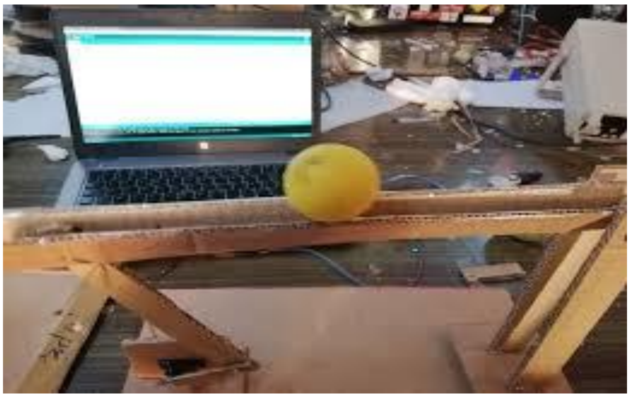
$$P(s) = \frac{R(s)}{\Theta(s)} = -\frac{mgd}{L\left(\frac{J}{R^2} + m\right)}\frac{1}{s^2} \qquad \left[\frac{m}{rad}\right]$$

3. Practical Model

System model is isolated into two sections; the mechanical part consist of shaft, arm and DC servo motor and electrical part which contains DC servomotor, ultrasonic sensor and Arduino microcontroller.

3.1 Mechanical Part

Selection of suitable material for a mechanical part is a significant component of all designing ventures.



Mechanical parts used for the system,

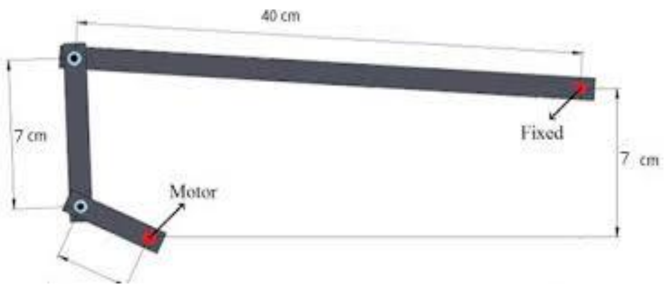
1. Wood for base Support has length of 40cm and Width of 20 cm.

2. Beam length of 34 cm, and width of 2cm.

3. Servo motor.

4. Lever.

The Dimensions for practical model are shown,



4. Electrical part

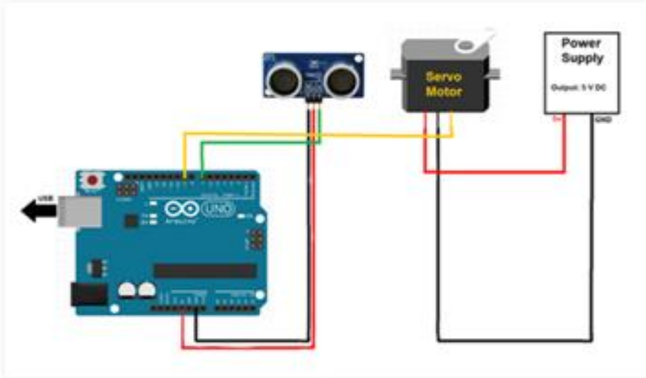
The components used for Electrical part consists of

• Arduino UNO

• DC servo motor

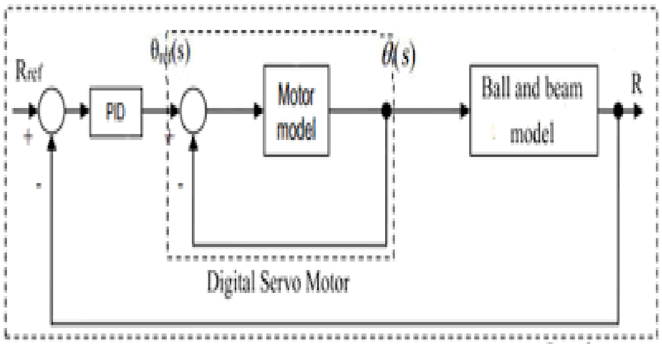
• Ultrasonic sensor.

Ultrasonic sensor connected with digital pin of arduino to get output in digital form. Since, it sends its output during a propelled structure to the Arduino which separate the commitment to 58 to work out the ball partition in centimeters, this value address the commitment of the PID to be differentiated and the point. The servo motor related with pin 9 which is much of the time used as a pulse Width modulation(PWM), it gets its data from PID controller.



5. PID Controller Design

It is difficult to design a controller with Z-N for clarification; it had been found that the general structure may be a fifth solicitation system which mean hard to style controller for a prevalent solicitation structure to shape the control structure basic the entire system is secluded into two information circles; inward circle and outer hover as exhibited the reason for the interior drift is to manage the system mechanical assembly edge position all together that rigging edge (θ) tracks the reference signal (ref θ). The external loop utilizes the internal data circuit to arrange the ball.



As a rule the increments of Kp, Ki, and Kd will find a helpful pace by the client in order to best serve the structure. While there's no a static course of action of presumes that the qualities ought to be utilized for any structure, following the general procedures should help in tuning a circuit to orchestrate one's System and condition. everything considered a PID circuit will usually overshoot the point respect intangibly then immediately absorbed bowed show at the point respect.

Manual tuning of the extension settings is that the least inconvenient system for setting the PID controls. In any case, this strategy is done reasonably and requires some extent of understanding to completely sort out. To tune PID controller really, first the proportional and derivative are set to zero. Addition the comparing increment until watching faltering inside the yield. After the relative expansion is about , the subordinate increment would then have the option to be extended. Auxiliary increment will diminish overshoot and moist the structure quickly to the point regard or near it. If the auxiliary expansion extended an irrational proportion of , gigantic overshoot will be seen. At the point when the backup expansion is about , increase the essential increment until any equalization is changed for on a term reasonable for the structure. In case the expansion extended an outrageous proportion of , enormous overshoot of the point worth and instability inside the circuit will be viewed. the least perplexing presentation depends upon fashioner conclusions.

Experiment No	Kp	Ki	Kd
1	1	0	0
2	2	0	0
3	3	0	0
4	3	0	0.5
5	3	0	1
6	3	0.5	1
7	3	1	1
8	4	1	2
9	4	2	2
10	5	2	2
11	5	2	2.1
12	5	2	2.2

The values of Kp=5, Ki=19, Kd=10 gives the best response for the designed system.

6. Experimental Results

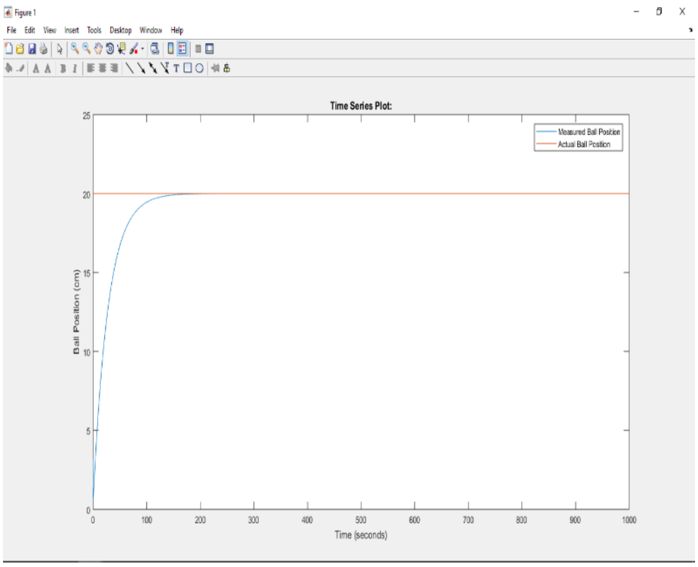
This space shows the consequences of a certifiable time plotting using MATLAB of ball and segment structure using plan of PID controller with manual tuning system. With required estimation of division between ultrasonic sensor and moving ball set to be 15 cm, saw that this value are an extraordinary piece of the time changed by modifying it inside the controller figuring considering it considering the way that the point (reference) of the system .

Setting the estimations of controller parameters as Kp=2, Ki=0, Kd=0 gives the gigantic time plotting of ball position. The structure flounders near the beginning at any rate the affecting rot with time, other than to massive consistent state mess up, ghastly long settling time, dreadful longer rising time and epic overshoot respect.

By subbing the estimations of controller parameters with Kp=3, Ki=0, Kd=0.5. Adding subordinate part to controller [0] r evokes the overshoot and settling time, in addition improving the anticipated state.

Changing the estimations of controller parameters with Kp=3, Ki=0.5, Kd=1. Adding Central part to controller lessens the overshoot and preeminent improves both the settling time and right now dependable state botch.

By subbing the estimations of controller parameters with Kp=5, Ki=19, Kd=10 as appeared. The consistent state mistakes of the reaction got out and overshoot and settling time decreased. to check System precision, the point changed to be 10cm and 20cm by utilizing te least inconvenient controller parameters Kp=5 ,ki=19 and Kd=5.



7. Conclusion

A Functional model of the ball and Beam System was made using physical and electrical laws. An improved smart model was settled through structure parameters. The controller parameters regards (Kp, Ki and Kd) were gotten by using manual tuning method from sensible model so on perform best System response. From exploratory results, it's found that the least marvelous controller parameters which gave the most prompt response of the System are: Kp= 5, ki=19 and Kd=10. The precision of the System is attempted by modifying the state of the ball at three explicit obsessions and it found that the exactness doesn't encountering changing the point .

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