Concordia University

Department of Computer Science and Software Engineering

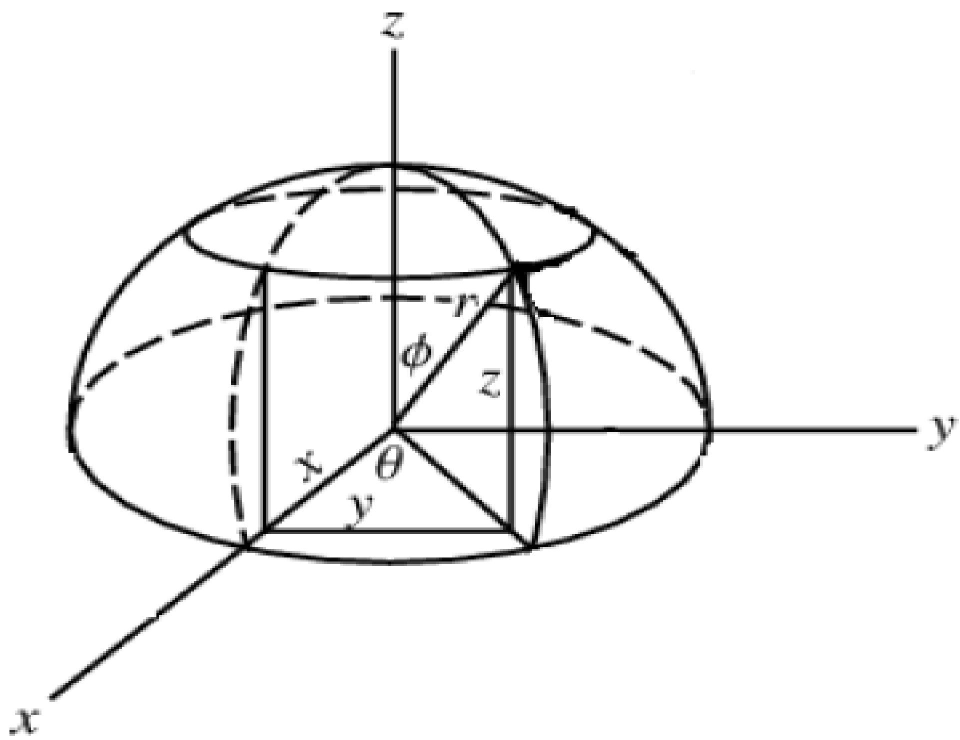
SOEN 385 – Team Project (Winter 2018)

Space Telescope Control System

Project Description:

This is a team project; each group (team) consists of maximum 4 students. The final presentation of all groups will be at the end of the term and before the final exam period.

In this project we want to simulate a controllable telescope to take digital photos from the stars at different positions in the sky. Assume there is an exceptional opportunity which can be a specific night in the year, that the sky is very clear and dark, and you have a short period of time to take digital photos from different stars (for example a few hours). You want to take photos of N (=100) stars in the sky. Your telescope has a digital camera that can take photos at an average rate of one photo per T=5 seconds (including the time of focusing on the star and taking the image and saving the photo). You have to design the telescope such that it can find each star in the sky, then focus on that star and take two different photos of that star (with a delay of $T = 5$ seconds between the two photos.) Then it saves the photos in a hard disk and continues to find another star. This process goes on and on until all stars on the list are photographed. Assume that the stars are randomly scattered in the sky, and the sky is a semi sphere above you. Also assume that you and the telescope are at the center of that semi sphere. Each star has a specific position, which is described in spherical coordinates by a triple (r, θ, ϕ), as shown in Fig. 1.



$$\rho = \sqrt{x^2 + y^2 + z^2}$$

$$S = \sqrt{x^2 + y^2}$$

$$\phi = \arccos\left(\frac{z}{\rho}\right)$$

$$\theta = \begin{cases} \arcsin(y/S), & \text{if } 0 \le x; \\ \pi - \arcsin(y/S), & \text{if } x < 0. \end{cases}$$

Fig. 1. Relationships between Spherical and Cartesian coordinates. Assume the telescope is exactly at the origin of this coordinate system

At the beginning assume that the telescope is always pointing to an initial position (r_0, θ_0, ϕ_0). According to the position of the first star at (r_1, θ_1, ϕ_1), the direction of the telescope is changed from $\theta_0 \to \theta_1$, and from $\phi_0 \to \phi_1$, to point to the first star. This process is repeated to reach all the other stars. The system has two similar DC motors one for rotation in θ-direction, and another in ϕ-direction. Your control system must send proper commands to each DC motor separately at the proper time. Each motor will receive a sequence of commands in time. Commands can be very easily designed such as $\theta = -\frac{\pi}{4}$ which means the DC motor θ must turn 45 degree counter clockwise, or $\phi = \frac{\pi}{3}$ which means DC motor ϕ must turn 60 degree clockwise.

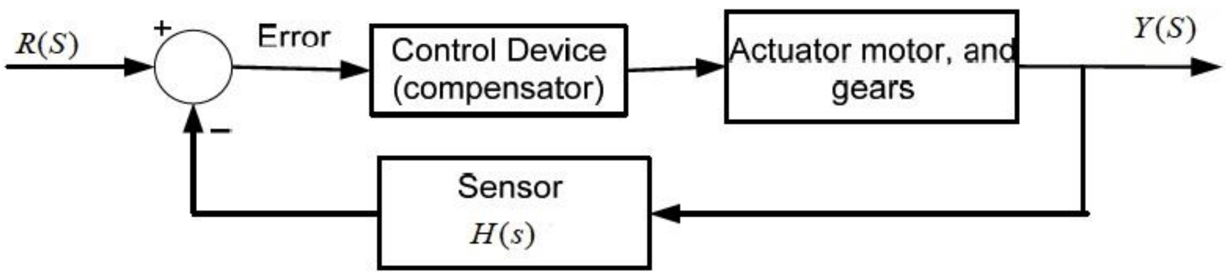


Fig. 2. Block diagram of each motor, its sensor and controller

The controller (hardware) parts of the system for both DC motors are exactly the same, and each motor and controller has a block diagram as shown below. Each module of the system (motor + controller) can have a maximum overshoot of 2%. Assume the minimum amount of rotation in θ, *and* ϕ directions are 5 degrees ($\frac{\pi}{36}$). The required time for these minimum rotations, including the settling time must be less than 2 seconds. Assume transfer function for each motor is G(S) and transfer function for each sensor is H(S) (they are given below)

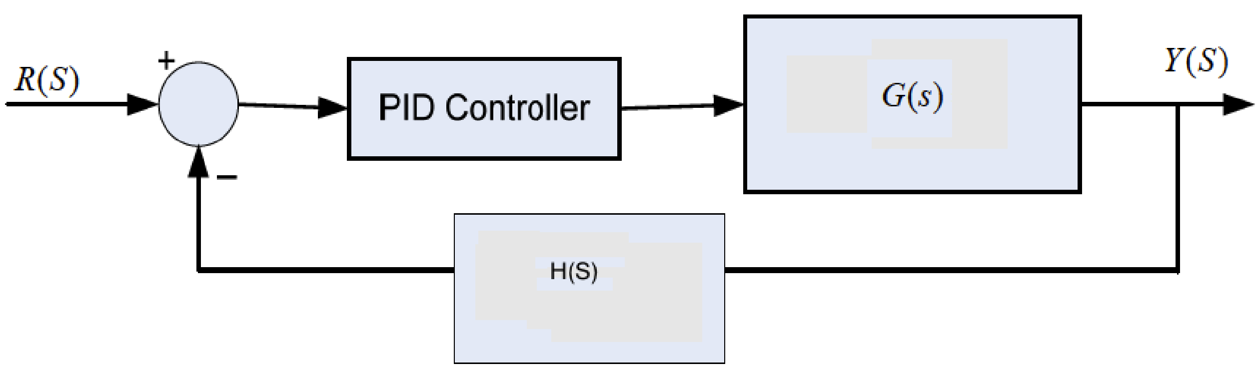


Fig. 3. Block diagram of PID controllers, plant and sensor for each motor of the telescope

Requirements:

1) Using Matlab, and Simulink, or any other appropriate tool in Matlab or out of Matlab:
   a. Choose your **G(S) = 1/(S-1)(S-3), and H(S) to be equal =1** (unity feedback system). Design the system with different PID controllers (P, PI, PD, PID) and find out which controller can satisfy the requirements mentioned above. Compute the total

time you need to take the photos of N (=100) stars at the specified locations. Find out which design is the best in terms of the total required time. For each controller, analyze the stability of your system.

b. Choose your Change **G(S) = 1/(S+1)(S-3), and H(S) to be equal to =0.1** and repeat your design with the above controllers (P, PI, PD, and PID). In each case compute the total time you need to take the photos of N (=100) stars at the specified locations. Find out which design is the best in terms of the total required time. For each controller, analyze the stability of your system.

c. Choose your **G(S) = 1/(S-3) and H(S) to =0.1/(S+1)** and repeat your design with the above controllers (P, PI, PD, and PID). In each case compute the total time you need to take the photos of N (=100) stars at the specified locations. Find out which design is the best in terms of the total required time. For each controller, analyze the stability of your system.

2) Show a 3D animation (using virtual reality and 3D animation model), which simulates the whole system. Your system must have a user-friendly interface (GUI) to enable users to change some important parameters (Such as T mentioned above) of the system and see the results.
3) Write a structured report and include all the details of analysis, design, implementation, and testing results of your system

* The data file containing the locations of the stars will be provided through the course web page.

Some resources for help:

1) Office hours: By the professor (Tuesday/Thursday @ 16:10-17:00)
2) POD hours: Presented on Mon., @13:00--16:00, @ H-827,
   By: Parviz Khavari , Email: parvizkhavari91@gmail.com
3) Tutorial hours as listed here:
   URL: https://aits.encs.concordia.ca/aits/public/top/courses/20174/05/SOEN385.html
   By: Parviz Khavari, Email: parvizkhavari91@gmail.com

Deliverables:

Each team has to submit only one copy of the project report, plus all the required source codes and a read me file all in a zip folder. The report will include all the details of analysis, design, and implementation of your system. All project-related files plus its complete report (plus the readme file) must be adequately archived in a ZIP folder using your ID(s) and last name(s) as file name. Also, the cover letter of the report must contain your name(s) and student ID(s), and the report must follow a structured format, which will be explained in the lectures/tutorials. Inappropriate submissions will be heavily penalized. Only electronic submissions on EAS will be accepted. A demo of your simulated control system will take place between the group members and the marker for about 20 minutes in the last week of classes. Different marks may be assigned to teammates based on the markers judgment. The demo time will be determined and announced by the marker, and students must reserve (arrange directly with the marker) a particular time slot for the demo. No demo means zero marks for this project for the whole team.

Project Due date:

The project demo sessions will be scheduled between April 10, 2018 to April 16, 2018. The exact schedule for each team will be determined by our TA and will be posted on our course web page (by the end of March 2018).