Experiment 6

State feedback controller design on MATLAB platform.

Background:

Because of its excessive dependence on matrix algebra and vector spaces, MATLAB functions that are useful for state space control are somewhat scattered between the **control systems** toolbox and the **symbolic math** toolbox. Here we will try to put together the functions that are of primary use to us for time domain (that is, eigenvalue based) control designs.

There can be alternative approaches to state space based control design – topics that are beyond the scope of the present course.

Objective:

To design the state feedback gain matrix for a given analog state-space system to satisfy required performance specifications..

Tutorial:

In the MATLAB platform, go through the procedural steps as described for:

- *Create state-space model:* https://in.mathworks.com/help/control/ref/ss.html
- *Eigenvalues and Eigenvectors:* https://in.mathworks.com/help/symbolic/eigenvalues-and-eigenvectors.html?searchHighlight=eigenvalues&s_tid=doc_srchtitle
- *Creating Discrete-Time Models:* https://in.mathworks.com/help/control/examples/creating-discrete-time-models.html
- *Pole placement design:* https://in.mathworks.com/help/control/ref/place.html?searchHighlight=place&s_tid=doc_srchtitle
- *Observability:* https://in.mathworks.com/help/control/ref/obsv.html
- *Controllability:* https://in.mathworks.com/help/control/ref/ctrb.html

Elements of the software for familiarisation:

a. ***Functions/keywords:*** ctrb; obsv; eigenvalues; eigenvectors; jordanform; place; ss.

b. ***Tools:*** Symbolic math toolbox: https://in.mathworks.com/help/symbolic/index.html?searchHighlight=symbolic%20math&s_tid=doc_srchtitle

Project:

An *autonomous underwater vehicle* (AUV) is a robotic submarine that can be used for different underwater studies. The *horizontal plane movement* of a certain AUV has the *sway speed*, *yaw angle*, and *yaw rate* as state variables x_1, x_2, x_3 respectively, and the *rudder angle* as the single input.

Upon linearisation about a nominal operating point, the analog system is characterised by the following matrices:

$$\mathbf{A} = \begin{bmatrix} -0.14 & -0.69 & 0.0 \\ -0.19 & -0.048 & 0.0 \\ 0.0 & 1.0 & 0.0 \end{bmatrix} \;;\quad \mathbf{b} = \begin{bmatrix} 0.056 \\ -0.23 \\ 0.0 \end{bmatrix} \;;\quad \mathbf{C} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}$$

State feedback gain matrices are to be designed so that:

- *Settling times* of individual states are retained at those of the *nominal* eigenvalues.
- *Maximum magnitude* of all eigenvalues are as in the *nominal set*.
- The CL system is *always observable* and *controllable*.

As far as possible, all three requirements are to be met simultaneously.

For observations and discussions:

Record and discuss the combination of feedback gains, showing how they ensure the performance required as above.

In situations where the no designed value of the gain matrix is possible, explain and discuss why this is so.