Name: ____________________________

MCE 6646 Intelligent Control Systems
Department of Mechanical Engineering
Idaho State University   Spring Semester 2019

Final Exam

Due Tuesday, April 30th, 2019,5:00 PM LEL Office (Stamped)

Note I: This is a take-home exam. Any reference you use must be listed, including web references. Please do write all your derivations and calculations on these pages down (all steps!). Use your best handwriting. The exam is due on Tuesday, April 30th, at 5:00 PM (have it stamped at the ENGR office). No late submission is accepted.

Note II: The problems listed below are mostly solved using Matlab™/Simulink. Regardless of the computer programs you develop and GUI usage, your solutions MUST contain all steps involved in solving for the answers. A test of completion is as follow for any problems: will any other engineer be able to recreate your work solely based on the material you turn in and a Matlab™/Simulink license (without documentations)? Incomplete information will cause reductions in points, even if the answers are correct.

Note III: This is a take-home exam. I expect no interaction among any of the students in the class for the purpose of solving any of the listed problems. This is not analogous to a homework set, where students can interact in order to solve the problems. The problems must be solved by you and you only. As most if not all problems do not have unique solutions (and many can be approached in different ways), I expect different solutions from any student.

Note VI: You will turn in a complete set of answers, included with this are any print outs from simulations, Matlab™ m-files, Simulink™ models, derivations, answers, etc. Staple all material as one package and have it stamped by the ENGR office to verify the meeting of the deadline (April 30th, 5:00PM). After submitting this package, I also want you to email me a zip folder (one zip file only) that contains all the files for the models, m-files, figures generated, etc. Email this zip folder to schomarc@isu.edu no later than April 30th, 5:00 PM.

Problem No. 1 (30 points)
Consider the following dynamical system given by

$$y(k+1)=\frac{y(k)u(k)}{1+\left[\left|y(k-1)\right|\right]^{0.3}}-\frac{1-e^{-u(k)}}{1+e^{-u(k)}}$$

Where y(k) and u(k) are the output and input, respectively, at time step k.

a) Assuming the control law u(k) to the system is specified, identify the nonlinear plant dynamics using ANFIS.
b) For the desired output of the plant, specified by

   $$y_d(k)=\ y_d(k)==\frac{1}{2}\sin\left(2\pi k\right)\cos(2\pi k)+0.3\sin^2\left(2\pi k/15\right)$$

   How well can ANFIS predict the system behavior?
c) Compare ANFIS results with that of a neural network-based system.

Note: when generating the ANFIS system, make sure to generate separate training and checking data in order to prevent overfitting. Also generate separate testing data.

Problem No. 2 (30 points)

Considering a nonlinear system as defined by $y(k) = f\{y(k-1)\} + [u(k-1)]^3$, where

$$f\{y(k-1)\} = \frac{y(k-1)}{1+y(k-1)^2}$$

Suppose you will need to identify this system. Develop a backpropoagation neural network that can identify the nonlinear system. Examine the performance to the following input:

$$u(k) = \begin{cases} 2e^{-0.02\pi k} & if\ 0 \le k \le 50 \\ 10e^{-0.01\pi k}\sin(0.2\pi k) & if\ 50 \le k \le 150 \end{cases}$$

Compare the performance of the network using two different training algorithms, namely, trainlm (Levenberg-Marquardt optimization) and the traingd (gradient descent based back propagation).

Problem No. 3 (40 points)

Consider the longitudinal motion of an aircraft, which can be represented by a set of linear differential equations:

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} -0.09 & 1.0 & -0.02 \\ -8.0 & -0.06 & -6.0 \\ 0 & 0 & -10 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 10 \end{bmatrix} \delta_E$$

Where

x_1 angle of attack

x_2 rate of change of pitch angle

x_3 incremental elevator angle

δ_E control input into the elevator actuator

It can be observed from the state-space equations that changing the elevator angle affects the rate of change of pitch angle and the angle of attack.

a) Perform open-loop simulations on the system for various inputs, namely, step, ramp, and sinusoidal inputs. What can you say about the performance of the system to such inputs?
b) It is desired that a controller produces a near critically damped system response. Design a PID controller for the system.
c) Based on the knowledge gained from open-loop simulations, develop a fuzzy controller that will maintain stable aircraft performance in the presence of unexpected disturbances (show in your program how the disturbances are modeled and implemented!).