ISE 589-006 Introduction to Modern Industrial Automation

Homework Assignment 1

Due: February 2nd, 2023

In industrial automation, sensors are an essential component of a system's performance. Sensors can measure temperature, pressure, or any physical properties and help ensure the system works efficiently. This homework assignment focuses on sensors and how they are used to optimize performance in industrial automation.

Problem 1. **(20 points)**

The Baxter robot manipulator is a revolutionary innovation in industrial robotics. It is an intuitive, reliable, and affordable robot manipulator that can be used for various applications, including pick-and-place operations, machine loading and unloading, assembly operations, parts sorting, and testing. The Baxter robot has two arms- a six-axis articulated arm and a more straightforward four-axis articulated arm- to allow it to perform manipulation tasks efficiently. Its advanced sensors provide precise feedback on its position and path accuracy so it can carry out its task even in challenging environments. Additionally, the Baxter robot is highly safe to work around as it stops automatically if it detects unexpected physical contact with a human or object. With its user-friendly interface, the Baxter robot can easily be programmed and adjusted to fit any application's needs.

Figure 1 Baxter Robot

Given the following desired task:

1. Detecting the presence of the part
2. Detecting the location and orientation of the part
3. Detect the velocity of the workspace.

Determine the best sensors for completing each of the above tasks—things to consider contact vs. non-contact, material properties, performance, and accuracy.

Solution

For the task of detecting the presence of the part, an infrared sensor would be best. This type of sensor is sensitive to the presence of objects without any physical contact, making it ideal for quickly detecting a part's presence.

A vision system or laser range finder can be used to detect the location and orientation of a part. A vision system utilizes cameras to capture images which are then processed to determine the desired information, such as position and orientation.

A laser range finder uses lasers to measure distances between points to measure an object's location and orientation accurately. Finally, an encoder can be used to detect the workspace's velocity. An encoder is a device that measures angular or linear velocity by counting pulses produced with every rotation or movement. This type of sensor provides accurate velocity measurements in both directions over long distances.

Problem 2. **(25 points)**

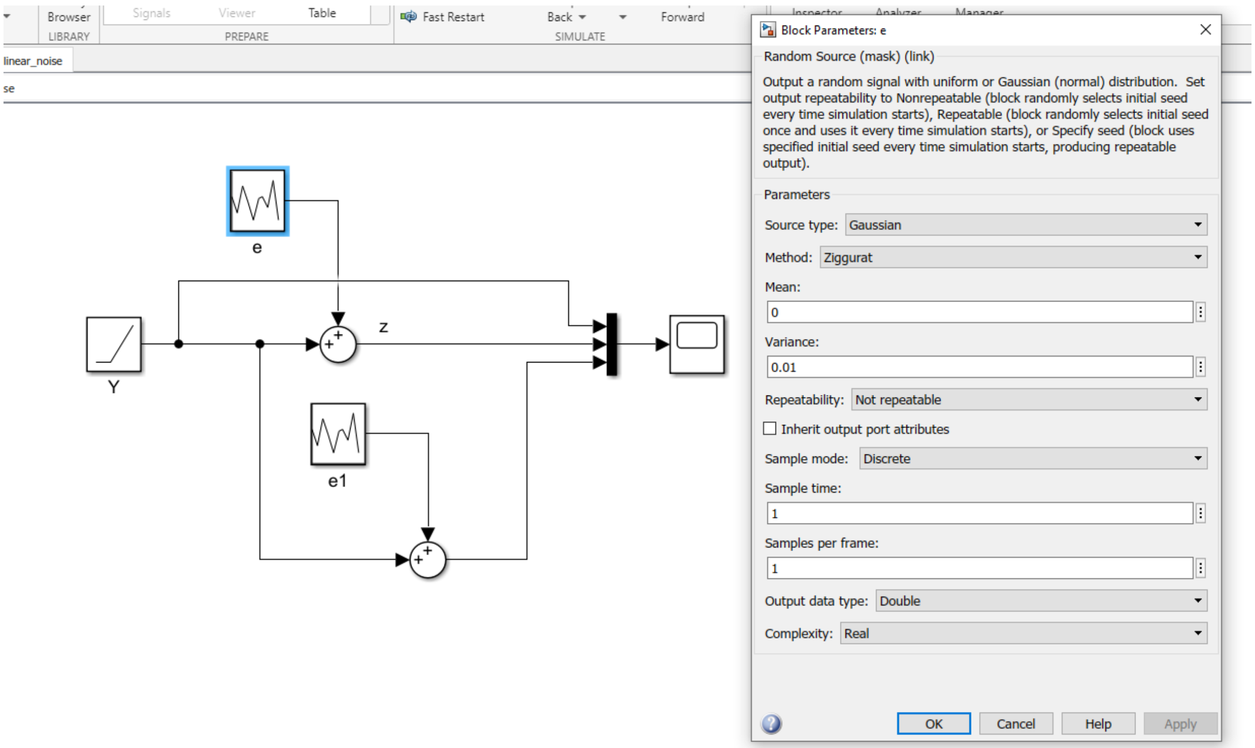
To detect an object, a proximity sensor could be the best option. Proximity sensors use radio frequency or infrared waves to detect objects in the vicinity without any physical contact. This makes them ideal for quickly and accurately determining an object's presence. Additionally, they can detect several objects at once and quickly integrate them into existing robot designs. Given the following datasets, which sensor is best suited to detecting an object 2 m away and why? Things to consider, error, range, linearity, etc. (Please show your work)

Ideal (m)	**Sensor 1 (m)**	**Sensor 2 (m)**
0	-0.022566824	0.194624823
3.16E-30	-0.022566824	0.194624823
0.06	0.037433176	0.254624823
0.12	0.097433176	0.314624823
0.18	0.157433176	0.374624823
0.24	0.217433176	0.434624823
0.3	0.277433176	0.494624823
0.36	0.337433176	0.554624823
0.42	0.397433176	0.614624823
0.48	0.457433176	0.674624823
0.54	0.517433176	0.734624823
0.6	0.577433176	0.794624823
0.66	0.637433176	0.854624823
0.72	0.697433176	0.914624823
0.78	0.757433176	0.974624823
0.84	0.817433176	1.034624823
0.9	0.877433176	1.094624823
0.96	0.937433176	1.154624823

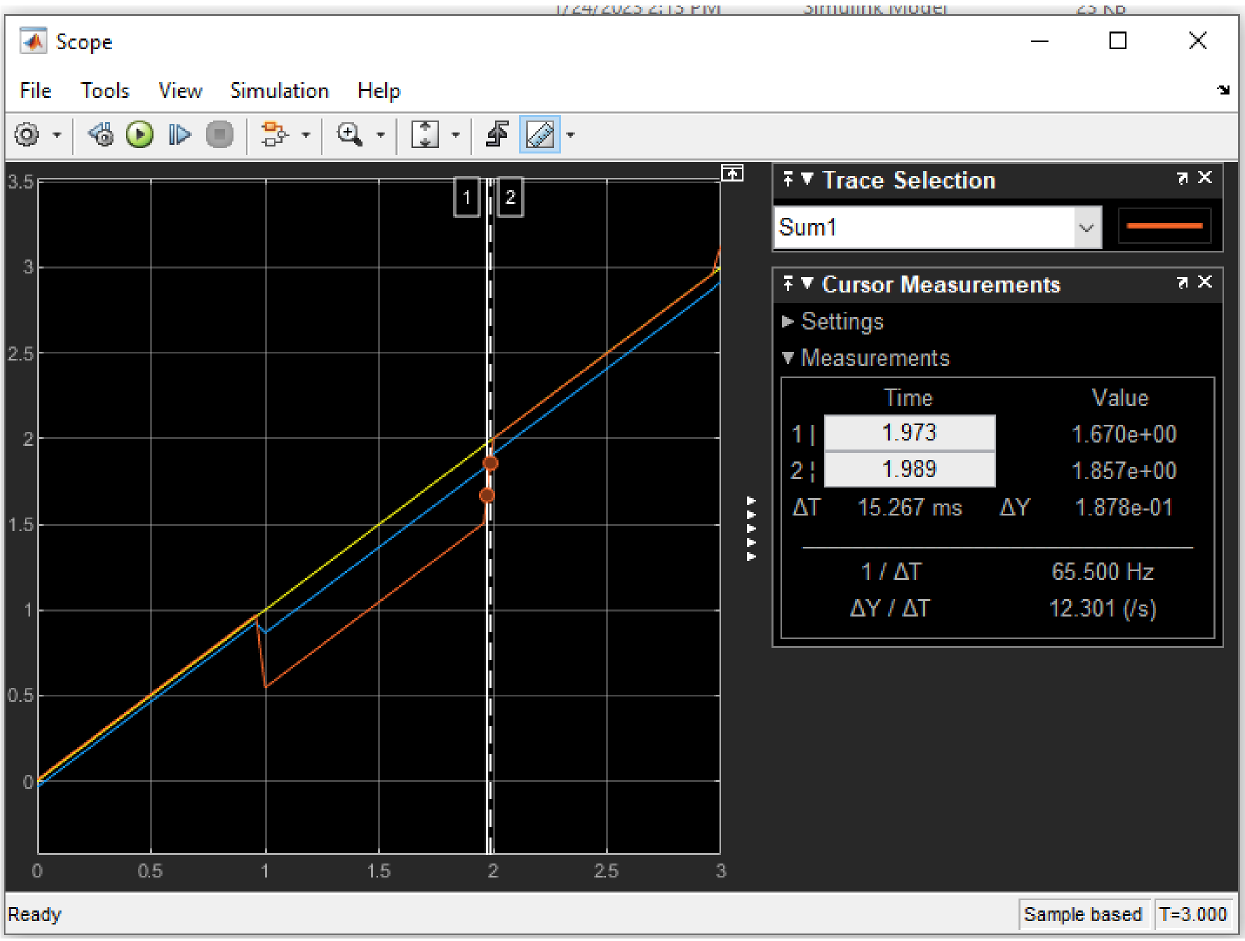
1	1.099967936	1.263146896
1.06	1.159967936	1.323146896
1.12	1.219967936	1.383146896
1.18	1.279967936	1.443146896
1.24	1.339967936	1.503146896
1.3	1.399967936	1.563146896
1.36	1.459967936	1.623146896
1.42	1.519967936	1.683146896
1.48	1.579967936	1.743146896
1.54	1.639967936	1.803146896
1.6	1.699967936	1.863146896
1.66	1.759967936	1.923146896
1.72	1.819967936	1.983146896
1.78	1.879967936	2.043146896
1.84	1.939967936	2.103146896
1.9	1.999967936	2.163146896
1.96	2.059967936	2.223146896
2	2.055134744	2.115797507
2.06	2.115134744	2.175797507
2.12	2.175134744	2.235797507
2.18	2.235134744	2.295797507
2.24	2.295134744	2.355797507
2.3	2.355134744	2.415797507
2.36	2.415134744	2.475797507
2.42	2.475134744	2.535797507
2.48	2.535134744	2.595797507
2.54	2.595134744	2.655797507
2.6	2.655134744	2.715797507
2.66	2.715134744	2.775797507
2.72	2.775134744	2.835797507
2.78	2.835134744	2.895797507
2.84	2.895134744	2.955797507
2.9	2.955134744	3.015797507
2.96	3.015134744	3.075797507
3	2.953854402	3.245836247

Solution:

This problem was designed using the following Simulink model:



Signal e has a noise variance of 0.01m and e1 has a noise variance of 0.09m; resulting in the below plot.

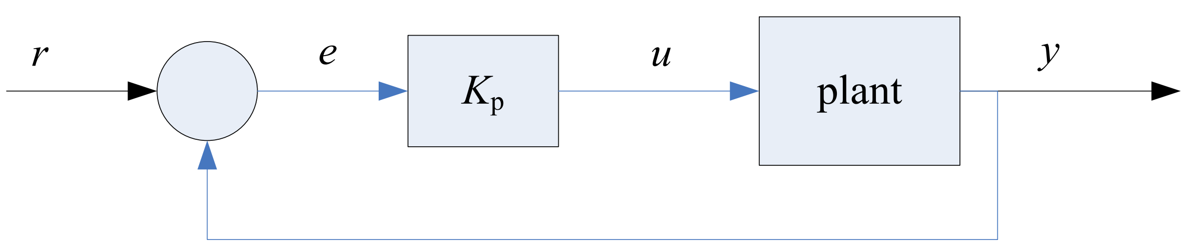


At time 2.0s Sensor 1 has less error than Sensor 2.

Problem 3. **(25 points)**

We are using the following data acquired from the sensor. Derive a first-order system model G(s) from the response time. Hint determine the steady-state value (Gss) and rise time tau (63.2%) of the final value by plotting the data Excel, MATLAB, etc. We will discuss Kp, the proportional controller, in future lectures.

$$G(s) = \frac{\mathrm{Gss}}{\tau s + 1}$$

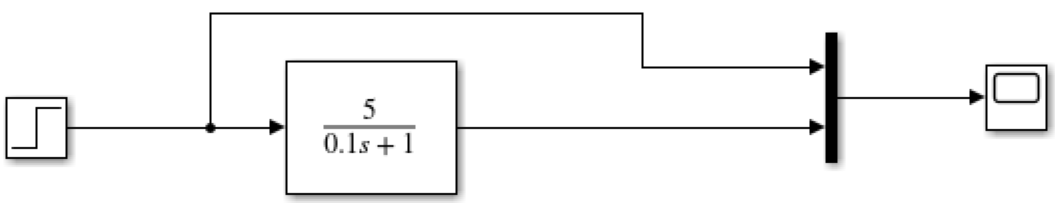


time (s)	output
0	0
3.16E-30	1.58E-28
2.01E-04	1.00E-02
0.001206	0.059923
0.006229	0.301971
0.026229	1.153579
0.046229	1.850817
0.066229	2.421667
0.086229	2.889039
0.106229	3.271691
0.126229	3.584981
0.146229	3.84148
0.166229	4.051484
0.186229	4.223421
0.206229	4.364191
0.226229	4.479443
0.246229	4.573804
0.266229	4.65106
0.286229	4.714312
0.306229	4.766099
0.326229	4.808498
0.346229	4.843211
0.366229	4.871632
0.386229	4.894901
0.406229	4.913953
0.426229	4.92955
0.446229	4.942321
0.466229	4.952776
0.486229	4.961336
0.506229	4.968345
0.526229	4.974083
0.546229	4.978781
0.566229	4.982627
0.586229	4.985776
0.606229	4.988355
0.626229	4.990466
0.646229	4.992194
0.666229	4.993609
0.686229	4.994767
0.706229	4.995716
0.726229	4.996493
0.746229	4.997128

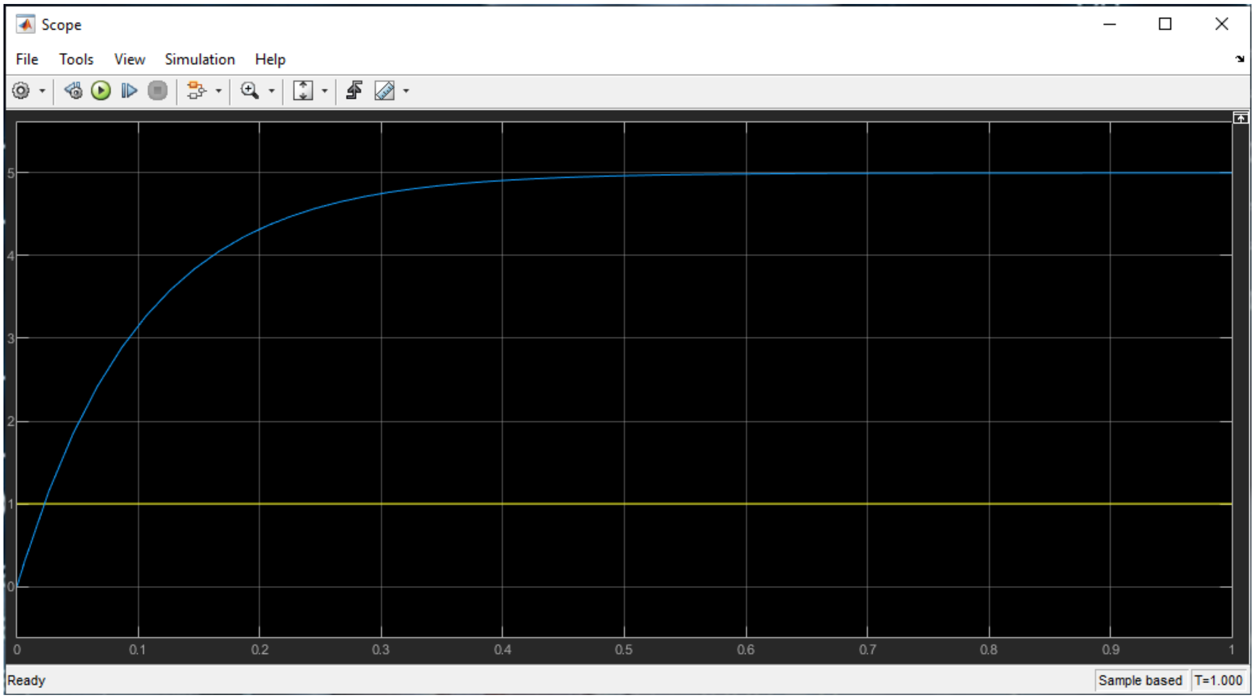
0.766229	4.997649
0.786229	4.998075
0.806229	4.998424
0.826229	4.99871
0.846229	4.998944
0.866229	4.999135
0.886229	4.999292
0.906229	4.99942
0.926229	4.999525
0.946229	4.999611
0.966229	4.999682
0.986229	4.999739
1	4.999773

Solution:

This problem was designed using the following model.



Resulting in the following plot.



This first-order model has a steady-state value of 5 and a tau (63.2% of final value) of 0.1 seconds.

Problem 4. **(30 points)**

Describe the sensor technologies in the following article:

Bin picking for ship-building logistics using perception and grasping systems

Cordeiro, A., Souza, J. P., Costa, C. M., Filipe, V., Rocha, L. F., & Silva, M. F. (2023). Bin Picking for Ship-Building Logistics Using Perception and Grasping Systems. *Robotics*, *12*(1), 15. https://doi.org/10.3390/robotics12010015

Solution:

This paper uses 3D perception to segmentation for pose estimation of 3D object in a bin. The estimation is sent to a robotic manipulator for grasping and relocation of the object.