LAB 2:
ON/OFF CONTROL

Overview

Many industrial control systems have approximately first order dynamics and are controlled simply by switching an actuator ON and OFF. Liquid level control systems and heating processes are examples of such systems. The experiments in EE757 are oriented towards mobile robots and we have designed an experiment illustrating the attributes of such systems (although some of the characteristics may be more complex.) Furthermore, the lab task will have to also cover a number of issues related to initial work on sensing and actuation and the related software.

In this laboratory experiment, a wheeled mobile robot will be used to illustrate ON/OFF control. First speed control will be tested with longitudinal motion. Second position control will be tested in trying to follow a wall. Each will entail using different sensors. After static testing, data will be collected using wireless access to the robot.

Preparation

1. Study the timers on the microcontroller and learn how to generate periodic interrupts.

2. Know how the shaft encoder and infrared sensor work.

3. Derive a first and second order mathematical models for the switching systems for lateral and longitudinal motion, with ON/OFF control to keep them within bounds.

4. Prepare a *Matlab* program to simulate your control system. (What are the *minimum* number of parameters whose values you need to guess?)

5. Prepare all required programs.

Task Description

In this task you are to control a real process: a mobile robot. BE VERY CAREFUL with the connections on the robot, especially possible ground loops, power supplies, etc.

Before running the mobile robot pay attention to how to upload your program, how to run it and how to collect data.

The purpose of the experiment is to control the speed and distance from wall so as to obtain given set points. You are to try using ON-OFF feedback control to accomplish this task. You should investigate the effects of varying the sampling rates, set points, size of deadbands, and length of artificial delay introduced in the software controller.

There are several sub-tasks involved, however, the basic purpose is writing and running the program to accomplish the control algorithm. You are being provided with a set of packaged programs so as to be able to get to the main goal of this experiment. Later on in the course you will find opportunities to return to write your own routines and use more sophisticated control approaches.

The Control Algorithm

In an ON-OFF feedback controller the control input to the system will be set ON while the output is below a certain threshold and will be set OFF when it is above a certain threshold. Often, the two thresholds are different creating a deadband about the desired set point. (When we mention input from now on, we will be referring to the *input* of the system to be controlled --- in this case the robot wheel torques, either their sum, or their difference; and when we mention output, we are referring to the output of the system to be controlled, i.e., either the longitudinal speed or the distance from the wall.)

Assume

Output Error = Output value - Set point

Now if

Output Error > LIMIT1 ..... Turn actuation OFF
Output Error < -LIMIT2 .... Turn actuation ON

The above fits well with the concept of speed regulation.

As for distance regulation (lateral movement), we can assume two different actuation situations (motors moving at different speeds) being substituted for the OFF/ON states above.

Use different values for LIMIT1 and LIMIT2 and observe how variations of these values about a given set point affect the control process and the response.

Measuring the Speed

There are quadrature encoders mounted onto wheels of the mobile platforms you will be using in the experiments. Quadrature encoders have two output channels called channel 1 and 2, which give sequences of pulses with a variable frequency and a fixed 90° phase shift. The position data can be obtained by counting the number of pulses generated by these channels. The direction information can be determined from the phase difference of these two channels. If channel 1 leads channel 2, the wheel is turning in a clockwise direction, and if channel 2 leads channel 1, the wheel is turning in a counterclockwise direction. The TMS320FL2407 DSP, which will be used in our experiments possesses circuitry to process the data coming from quadrature encoders via the use of timers 2 and 4. The necessary setups have been made to get you to use these timers easily. The detailed information about the quadrature encoder pulse circuit can be found in Appendix B.

To measure the speed of the wheels, you will count the number of pulses generated in a constant time interval (your sample period) and then you will subtract their previous time-step values from them. This result will give you the traveled distance of each wheel in one period. From the sampling period and distance traveled in that period, you should be able to find the speed just dividing that distance to your sampling period. The quadrature encoder pulse circuit gives 2000 pulses per revolution of the wheel. Therefore, the number you will get from the division has the unit of pulses/second. You can convert the result from pulses/sec to rad/sec by multiplying it with $2\pi/2000$.

Measuring the Relative Distance

The relative distance of the mobile platform to the wall will be measured using an infrared sensor mounted on the right side of the robot. The infrared sensor emits light in the infrared region and receives its reflection with a receiver built in it. According to the received light, it determines its distance to an obstacle. This distance information can be used to drive the robot into a desired region by giving the necessary signals into DC motors driving the wheels.

The range of infrared sensors used on mobile platforms is maximum 30 inches and minimum 4 inches. Therefore your set point should be lower than 30 inches and higher than 4 inches.

Control of speed

The control algorithm has been explained in the control algorithm section above. In this algorithm, your output error will be the difference between the set point and the measured speed. You will determine the limits with intuition and experimentation.

Control of lateral position

The same ON/OFF algorithm will be used in lateral position control. The error in this case will be the difference between the set point and the distance of the robot to the wall next to it.

Data Collection

The measured data will be sent through a transceiver mounted on the mobile platform to a host computer. By going to File -> Data2File in Agent_PC.exe program, you can save your received data into a "data.m" file.

Preparation Before the Experiment

As usual, you have to prepare and possibly type all your programs. However, this experiment requires that you are perfectly aware of what is going on. You are dealing with expensive equipment.

Think about:

- How you are going to initialize and start the experiment?
- What do the values you read from the sensors really mean?
- What values should you pick for the sampling rates? What are the maximum and minimum effective sampling rate for this system? What is the limiting factor?
- What values should you pick for limit levels and set points?

The Experiment

This experiment is divided into three parts:

1. Preliminary exercises
2. Speed control
3. Wall following

The preliminary exercises are very important and teach good habits related to step by step initialization of any complex experiment.

1. Start with the robot "on blocks", i.e. in a situation where the wheels can turn but the body does not move. Check

- You can start, stop, adjust individual motors
- You can read the speed
- You can calculate position
- You can perform the ON/OFF feedback action
- Umbilical cord can be removed

2. Put the robot on the floor. Select a very low speed and do the speed control with true ON/OFF control of motors. Repeat with switching at two speed levels.

3. Pick your wall! Pick a distance from wall. Do wall following.

You are to run the system with different set points and different sampling times. Repeat the same with added delay in the feedback loop. For each case, monitor both the input voltage switchings and the resulting position variations. Save the interesting cases and transfer them to Matlab for plotting and analysis.

Run your Matlab simulation for the closed loop system and try to adjust the parameters so that the plots resemble your experiment.

The Report

As usual, the report has to cover procedure, theory, results, and observations from the experiment and give listings of programs and plots obtained.

Furthermore a detailed theoretical analysis of the system to be controlled including a thorough analysis of the x-y position must be made.

Compare experimental results with your Matlab simulations and comment.

Finally, comment on the effects of varying the sampling rate, set points, size of deadband, and artificial software delay. Also, comment on the maximum and minimum effective sampling rates for this system and why, theoretically, these maxima and minima exist.