Module 2, Lesson 4 – Linear approximation and calibration of the temperature sensor

Student

Purpose of this lesson

- Linear approximation of a function.
- Find the equation of a straight line.
- Calculate calibration parameters for the temperature sensor.

Materials

Copy of the lesson

Computer with Mindstorms software

1 NXT with Thermistor

1 Beaker

Hot water

Ice

1 thermometer

Graph paper (or Excel)

Background – approximating a curve with a straight line

Straight line relationships are convenient to work with, because the equation that describes them $y = mx + b$ is very simple. In contrast, equations which describe curves can be much more complicated and difficult to work with.

Unfortunately, most real data does not lie on a straight line when it is plotted on a graph. In general, when you plot data on a graph you will find that the data points lie on some kind of curve.

However, it is often the case that some parts of a curve are fairly straight. In such cases, it may be reasonable to represent part of a curve as a straight line. This has the advantage that you can describe this data with a very simple equation ($y = mx+b$). Although the data does not really lie on a straight line, the straight line equation may still represent the data reasonably accurately. This technique is called representing the data with a "straight line approximation", or "approximating the data as a straight line". Figure 1 on the following page shows an example of approximating part of a curve as a straight line.

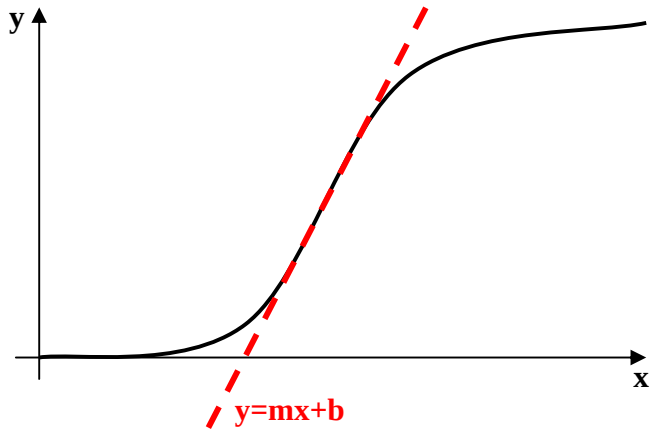

Figure 1. Approximating part of a curve as a straight line.

Procedure – Part 1

Linear approximation of sensor behavior

Review the graph from the previous lesson, which predicts how NXT output numbers vary with temperature. We are now going to make the useful and simplifying approximation that these values increase *linearly* with temperature.

Assessment 1

1) How valid is this approximation?

2) Is it more valid over some temperature ranges than others?

3) If you use this linear approximation as the basis for your temperature measuring system, over what range of temperatures do you think you will be able to measure temperatures accurately?

Part 2

1) Using the graph plotted in the previous lesson, choose a range of temperatures over which you think the behavior can be accurately approximated by a straight line.

2) Using the program you wrote in Lesson 3 (outputting 1023 – raw value), make a series of readings, e.g. in a cup of water, over the range of temperatures which you have chosen. For each reading, measure the true temperature carefully with your thermometer, and then write down the corresponding number output on the NXT screen.

Temp °C									
NXT number									

3) Now plot a graph of true temperature versus NXT reading. Use the vertical axis (y-axis) for true temperature, and the horizontal axis (x-axis) for the "1023 – raw value" numbers that are displayed on the NXT screen. On your graph, use a ruler to draw the best fit straight line for the data points which you have plotted.

4) The end goal is to have the NXT display the temperature on the screen in degrees Celsius. To do this, we must program the NXT to convert the (1023 – raw value) numbers into temperatures. We will do this by assuming that true temperature is approximately a linear function of (1023 – raw value). Thus, we need to express temperature versus (1023 – raw value) in the form of the equation of a straight line. Looking at the graph which you have just plotted, use the equation of the straight line as:

$$y = mx + b \qquad \textbf{equation 1}$$

where:
y is Temperature (vertical axis)
x is (1023 – raw value) i.e. horizontal axis
m is the gradient of the line
b is the "y-intercept", or the value at which the straight line crosses the vertical axis.

Assessment 2

Calculate values for:

1) m (gradient)

2) b (y-intercept)

for the straight line which you have plotted on your graph.