A Lesson on Calibration:
Interfacing PocketLab *Voyager* with Modular Robotics *Cubelets:*

Richard G. Born
Associate Professor Emeritus
Northern Illinois University

Introduction

Sensor-based inquiry is a dominant force in today's science education, with the calibration of sensors being essential for high-quality measurement. Wikipedia® defines **calibration** as "the comparison of measurement values delivered by a device under test with those of a calibration standard of known accuracy." In this lesson students will study the *process* of calibration:

1. By comparing bars on a Cubelet BARGRAPH block and the resultant angular velocity of a Cubelet ROTATE block with those of the PocketLab Voyager's Gyroscope as the standard of known accuracy. (Calibrate the number of lighted bars to the angular velocity of the ROTATE block in °/s.)
2. By comparing bars on a Cubelet BARGRAPH block and the resultant light intensity of a Cubelet FLASHLIGHT block with those of the PocketLab Voyager's Light Sensor as the standard of known accuracy. (Calibrate the number of lighted bars to the light intensity of the FLASHLIGHT block in Lux.)

Calibrating Lighted Bars to Angular Velocity

Figure 1 shows how the author interfaced Voyager and Cubelets to calibrate the lighted bars of a BAR GRAPH Cubelet with the angular velocity of a ROTATE Cubelet. The BATTERY Cubelet supplies power for the construction. The KNOB Cubelet allows varying the strength of the signal to the BARGRAPH Cubelet. PocketLab Voyager is mounted to the top of the ROTATE Cubelet. The ROTATE Cubelet's angular velocity changes depending on the strength of the signal. A video accompanies this lesson.

Figure 1

Figure 2 is an Excel chart of angular velocity vs. time that has been constructed from the *csv* file produced by the PocketLab app. Each region has been labeled with the number of lighted bars on the BAR GRAPH Cubelet and an eye-balled average of the angular velocity of the ROTATE Cubelet from Voyager's Gyroscope. We note that with 2 bars lighted, the angular velocity has become zero. Apparently, a minimum signal of 2 bars is required just to *start* the rotation of the ROTATE Cubelet.

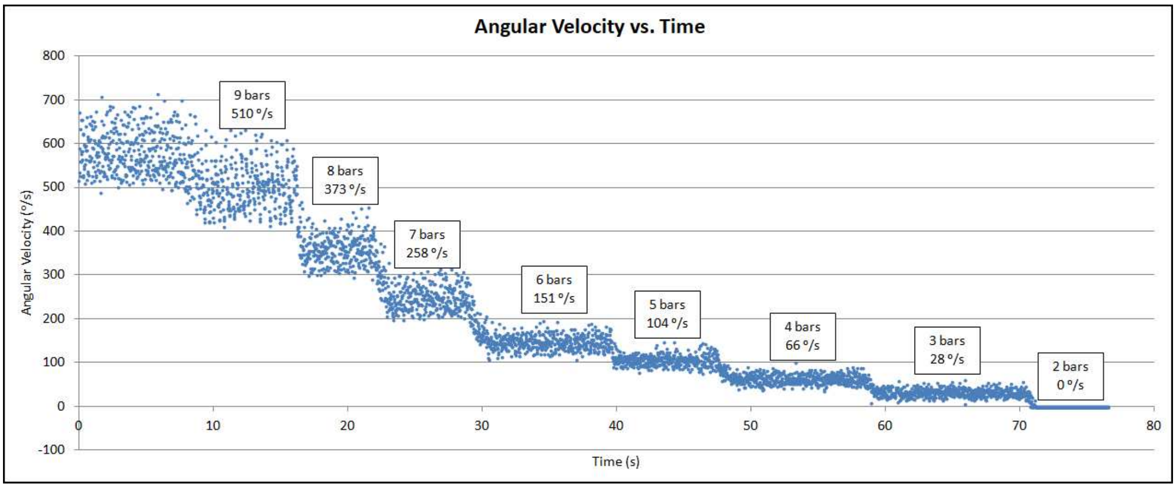

Figure 2

Keeping in mind the discussion of Figure 2, Figure 3 (left) shows a graph of *angular velocity* vs. *Number of Lighted Bars-2*. A quadratic fit is quite good with a correlation of 0.9953. This suggests that a plot of *angular velocity* vs. (*Number of Lighted Bars-2)*^{2} should be linear. This is verified by the graph on the right of Figure 3, which shows a linear fit *y = 10.375x*.

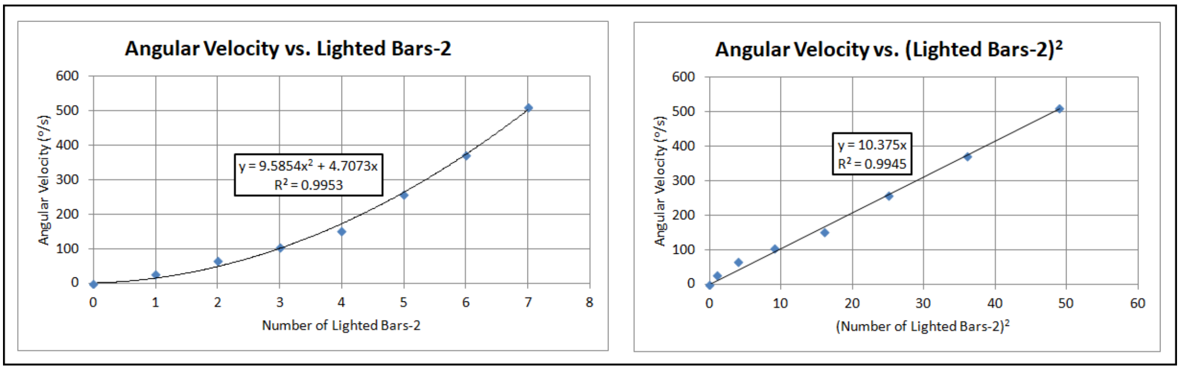

Figure 3

We conclude with a calibration as follows:

1. Take the number of lighted bars on the BAR GRAPH Cubelet and subtract 2.
2. Square the result and multiply by 10.375.
3. This will give the angular velocity of the ROTATE block in degrees/second.

Calibrating Lighted Bars to Light Intensity

Figure 4 shows how the author interfaced Voyager and Cubelets to calibrate the number of lighted bars of a BAR GRAPH Cubelet with the light intensity of a FLASHLIGHT Cubelet. The BATTERY Cubelet supplies power for the construction. The KNOB Cubelet allows varying the strength of the signal to the BARGRAPH and FLASHLIGHT Cubelets. The PASSIVE Cubelets simply supply stability and a place to mount PocketLab Voyager. The FLASHLIGHT Cubelet's light intensity changes depending on the strength of the signal. Voyager's light sensor faces the FLASHLIGHT Cubelet.

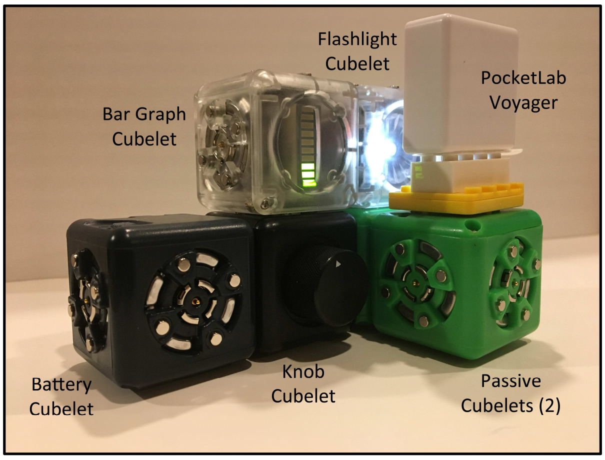

Figure 4

Figure 5 is an Excel chart of light intensity vs. time that has been constructed from the *csv* file produced by the PocketLab app. Each region has been labeled with the number of lighted bars on the BAR GRAPH Cubelet and an eye-balled average of the light intensity of the FLASHLIGHT Cubelet from Voyager's light sensor. The calibration appears as though it is somewhat more complex than the calibration for the rotate block.

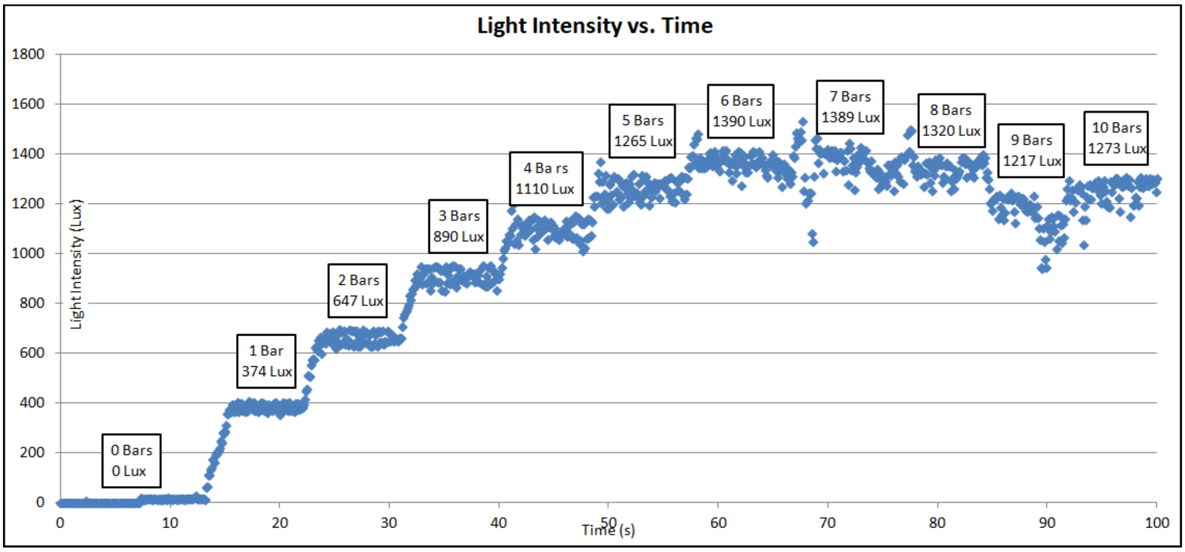

Figure 5

Figure 3 (left) shows a graph of *light intensity* vs. *Number of Lighted Bars*. A quadratic fit is quite good with a correlation of 0.9903. Since one would *also* expect the light intensity to *change with distance* from the sensor to the light source, it is probably a good idea to express light intensity in relative terms—with a relative intensity of 100 for the maximum Lux value achieved. The right side of Figure 4 shows the resultant relative light intensity. The pattern shows an especially good fit for 0 to 5 lighted bars, but is less stable for 6 to 10 lighted bars. The quadratic best fit provides us with an equation that calibrates the number of lighted bars to relative intensity.

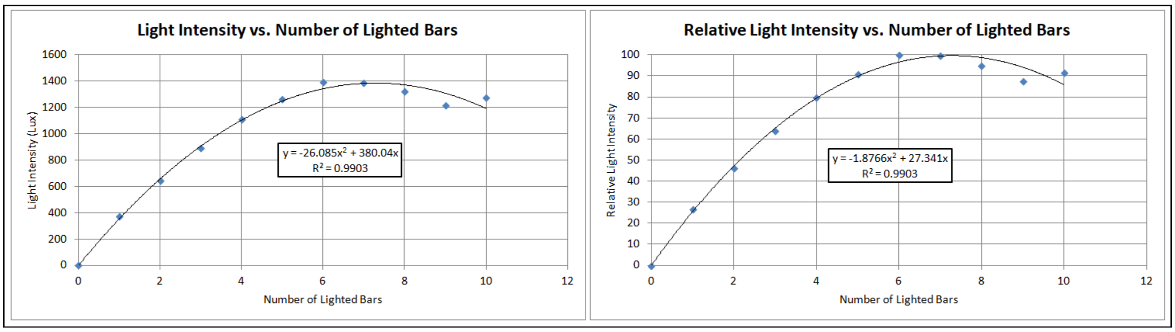

Figure 6