R-One Swarm Robot: Developing the Accelerometer and Gyroscope

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Abstract

Mobile robots are becoming more relevant and an essential part of our everyday lives. They are increasingly taking their place in service oriented applications including domestic and entertainment roles. They are beginning to open up many potential opportunities, but they still come with challenges in terms of their limited sensing capability and accuracy. In this project, we addressed these fundamental problems with mobile robotics and demonstrate our approach to each of the problems with a mobile robot equipped with low cost and low end devices. The r one swarm robot is a low cost multi robot systems platform that is advanced enough for multi robot research, robust enough for undergraduate and graduate education and cheap enough for K 12 outreach. As robots become more and more useful, multiple robots working together on a single task will become commonplace. Many of the most useful applications of robots are particularly well suited to this "swarm" approach. Groups of robots can perform these tasks more efficiently, and can perform them in fundamentally different ways than robots working individually. However, swarms of robots are difficult to program and coordinate.

Introduction

The robots, dubbed "r-one," were developed at the Multi-Robot Systems Lab at Rice University (Campbell et al. 2011; see Figure 1), providing the opportunity for students to research multi-robot engineering systems at a low cost. R-one robots have the ability to communicate with the user and with one another using an internal computer, motors, lights and sounds. The robots can be programmed to accommodate different levels of learning.

In building a balancing robot, you need a gyroscope unit and an accelerometer unit in order to get it to balance. But it should also to be reasonably low in cost with high performance and easily interfaced to a MCU (Micro-Controller Unit). Some of the other solutions are prohibitively expensive, even if they may work well.

The solution we had in mind had to be fairly small and use up little space and little power. Hence, ADXRS150 (Bartolini, 2005) and ADXRS300 gyroscopes are our pick to low cost and low power with high performance. The gyro is very small at about 5mm square (or 0.3 inches square). The robots have 3D gyro and 3D accelerometers. The plastic skirt actually floats atop the bottom circuit board that has switches that detect contact with an object.

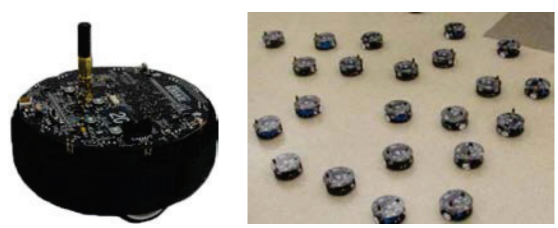

Figure 1. r one (individual vs. multiple r one robots)

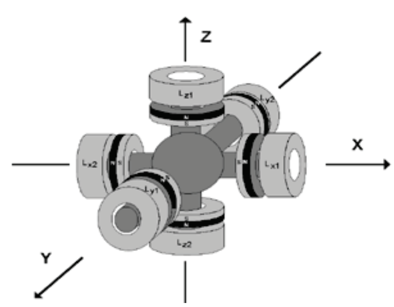

Figure 2. Accelerometer 3 Axes

The Hypothesis

For a robot such as this to perform efficiently, as well as keeping it balanced, the ability for the robot to understand its surroundings is absolutely necessary. An accelerometer is an electromechanical device used to measure the tilt of an object in 3 different axes (see Figure 2). These forces may be static, like the constant force of gravity pulling at your feet, or they could be dynamic - caused by moving or vibrating the accelerometer. By measuring the amount of static acceleration due to gravity, you can find out the angle the device is tilted at with respect to the earth. By sensing the amount of dynamic acceleration, you can analyze the way the device is moving. At first, measuring tilt and acceleration doesn't seem all that exciting. However, engineers have come up with many ways to make really useful products using them. An accelerometer can help your project understand its surroundings better. Is it driving uphill? Is it going to fall over when it takes another step? Is it flying horizontally or is it dive bombing your professor? A good programmer can write code to answer all of these questions using the data provided by an accelerometer. For example, an accelerometer can help analyze problems in a car engine using vibration testing.

The gyroscope has the capability of measuring the rate of rotation. This is important to the robot because it provides a sense of direction and also helps understand its' surroundings. The gyroscope demonstrates the earth's rotation. A freely rotating disk, called a rotor, was mounted on a spinning axis in the center of a larger, stable wheel. As the earth spun on its axis, the stable wheel rotated with it, but the rotor did not move. The movement of the mounted wheel followed the rotation of the earth, rotating around the center disk and demonstrating the earth's spin. The gyroscope creates a range of guidance and stabilization systems such as those used in airplanes and submarines.

The Tasks

We were assigned the task with writing the software that would handle data values coming from the accelerometer and gyroscope from one circuit board to another. Serial Peripheral Interface, also known as SPI (Microchip, n.d.), is used to communicate data to and from the microcontroller (computer chip) on the motherboard. Below is a graph from an oscilloscope displaying the signal voltages over SPI. Each line represents a different signal on the robot which all work together to transfer data through bits. SPI is a synchronous protocol that allows a master device to communicate with a slave device (accelerometer or gyroscope) through clock signals. When data is exchanged between these devices, the clock signal is provided by the master to provide synchronization. As data is being clocked out, new data is clocked in. Early on, we come across Code Composer Studio, an integrated development environment for processors such as the MSP430, from Texas Instruments. Microcode, a layer of hardware-level instructions involved in the implementation of higher level machine code instructions, is written in the C programming language. Code Composer Studio basically opens the doors for a programmer to experience real-time coding and actual debugging to solve errors. When we first discovered this, we went step-by-step in the code and checked the oscilloscope, a type of electronic test instrument that allows observation of constantly varying signal voltages.

SPI is a Data Exchange protocol. As data is being clocked out, new data is also being clocked in. When one "transmits" data, the incoming data must be read before attempting to transmit again. If the incoming data is not read, then the data will be lost and the SPI module may become disabled as a result. Always read the data after a transfer has taken place, even if the data has no use in your application. Data is always "exchanged" between devices. No device can just be a "transmitter" or just a "receiver" in SPI. However, each device has two data lines, one for input and one for output. These data exchanges are controlled by the clock line, SCK, which is controlled by the master device.

In order to start building our necessary setup for the Serial Peripheral Interface to initiate, we connected lines from a device on the circuit board, like an accelerometer, to the MSP430 microcontroller, and then connecting them back to an oscilloscope. An oscilloscope reading can tell you whether or not lines are communicating, and if so, you can figure out what data is being sent and received.

Figure 3 shows the oscilloscope reading, each line represents four signals: clock (SCLK), master output/slave input (MOSI), master input/slave output (MISO), slave select (SS). Three signals are shared by all devices on the SPI bus: SCLK, MOSI and MISO. SCLK is generated by the master device and is used for synchronization. MOSI and MISO are the data lines. The direction of transfer is indicated by their names. Data is always transferred in both directions in SPI, but an SPI device interested in only transmitting data can choose to ignore the receive bytes. Likewise, a device only interested in the incoming bytes can transmit dummy bytes.

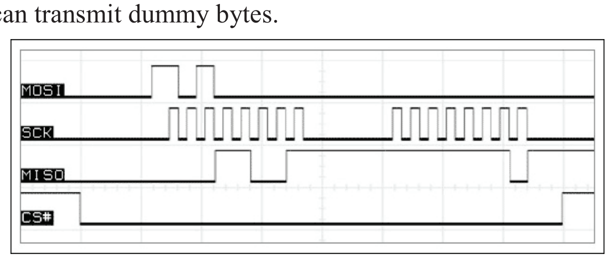

Figure 3. Oscilloscope Reading

In this poster, we will present the work that was accomplished in developing the accelerometer and gyroscope on the Rice University R-one Swarm Robot.

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