Bullets

- No prerequisites are required; all necessary skills are included in the course.
- Focusses on learning to think and communicate like an engineer or scientist.
- Helps prepare students for university undergraduate engineering programs by introducing students to the tools and techniques they will encounter.
- Employs an industry standard embedded computer and teaches how to program and debug it.
- Teaches basic C/C++ programming and the use of both hobby and professional integrated development systems (IDEs).
- Introduces simple mechanical and optical sensors emphasizing the physics employed.
- Familiarizes students with both real time and store and forward telemetry techniques to upload data for subsequent scientific analysis.
- Instructs students in the use of both dead reckoning and metrology based programming to control motion.

Description

This 8-week course is an introductory mechatronic course. Mechatronics is the intersection of mechanical, electrical, and software engineering. This course covers certain basic mechanical issues but focusses on electrical engineering – particularly the relationship between physics and electrical sensors – and software engineering – particular embedded software engineering as is typically used to control self-driving vehicles, aircraft and spacecraft, power stations, and kitchen appliances and personal hygiene devices.

Preferably, students will be paired, in teams, although a student may choose not to be paired, but to work on their own. Students working on their own will be at a considerable disadvantage, however, as teamwork makes both troubleshooting and recognition of conceptual and understanding errors easier and quicker. Students working as a member of a team will be compelled to develop a method of working in which cooperation, listening, and respect all play a part.

In the first class, students will build, using detailed plans, a small Lego® Technic® robot that is equipped with motors and a variety of sensors.

Their robot will then be used in later classes, sometimes requiring student conceived modifications, to understand how sensors work and how they interact with the real world – particularly calibration and hysteresis – and to understand basic kinematics – particularly motor control and navigation (both dead reckoning and sensor based). The robot includes a battery powered embedded computer that the students will program using the C/C++ programming language to interpret sensor inputs, control motors, display progress and error messages, and to upload telemetry data to a PC for analysis and graphing using Microsoft Excel. In the first few classes the students will use the Arduino IDE (but not an Arduino computer) but will transition to using Microsoft Visual Studio and GCC.

In the final, the eighth, class, the student team's robots will compete against each other to perform some task. The task will be chosen such that the students will demonstrate the skills that they have acquired during the course in terms of building a Lego® Technic® robot and programming its computer. Parents and guardians are very welcome to attend this competition.

The intermediate classes, classes 2 through 7 inclusive, will each focus on a single topic or a set of related topics, as follows.

- Second class: introduction to programming, use of an IDE, and basic robot motor control. The students will program their robots to perform certain simple driving tasks such as driving in a straight line, backing up and turning away if an object is hit, and driving in a particular path using dead reckoning. They will learn about the use of gear ratios to change the robot's speed and will also learn to control speed electronically via computer programming. As a consequence of this they will learn that linear changes in electric power may not produce linear response in motor performance.
- Third class: introduction to infra-red (IR) sensors. Using the robot's downward facing IR sensors, the students will program the robot to perform a number of line following activities. The line – actually a stripe – will comprise a back tape on an unpainted MDF background. Initially the students will learn how IR light reflects off surfaces and how changes in reflection can be sensed and transmitted to a computer and then displayed to a human observer. They will then learn how to calibrate their robot's sensors to differentiate between the line and the background. Because the robot's two sensors are unmatched, they will learn about production tolerances and the need for automatic calibration.
- Fourth class: introduction to telemetry and control via sensor analysis. Students will be presented with an MDF platform with several different colored tape stripes across it; they will be challenged to program their robots to drive across the stripes and, using data from the robot's IR sensors, display the color of each stripe as the robot passes over it. Because the IR sensors can only detect IR light of a very narrow bandwidth, the students will learn that they must determine the color of any given stripe by considering how the chemistry of the tape, together with the tape's transparency to IR light and the IR reflection characteristics of the underlying MDF, create a signature that corresponds to a color. The students will gain a more complete understanding of the nature and frequencies of light and the ambiguity that is sometimes present in data. Before being the able to program their robots to perform the task, the students will learn how to collect data from the IR sensors as the robot crosses the stripes, store it in the robot's memory, and then upload it to a PC for analysis.
- Fifth class: introduction to the use of shaft encoders for metrology in motor control. Students will learn how to use the shaft encoders that they built into their robots to measure how far it has moved and to generate differential movement of the left and right hand wheels to achieve movement along an arc. Because the robot's shaft encoders are of an open frame design, the students will be able to observe and understand the physics of optical beam sensing. Additionally, because of backlash in the robot's drive train and because of jitter in the robot's electronics, the students will come to understand the need for and the use of hysteresis. The students will also learn how the design of sensors interact with measurement resolution and motion repeatability. The students will also learn to use multiple software threads to achieve parallel processing.
- Sixth class: introduction to the use of differential light sensors and their use in tracking light emitting objects. Students will use a differential light sensor from their robot kit that requires a gnomon to cast a shadow and will be required to develop tests to understand how the sensor works. Then they will be required to design and build a structure to rigidly attach the sensor to their robot. Finally, the students will be required to design and implement computer software

such that if a person walks away from the robot while shining a flashlight at its differential light sensor, the robot will follow that person, making turns as necessary and stopping if it can no longer see the flashlight. The students will discover a need to screen the sensor from interfering light and will discover tradeoffs and limitations in such screening.

- Seventh class: dDetails of the final competition will be revealed, and the students will design, build, program, and test a suitable robot. In theory, everything that the students need to know for the competition will already have been covered in the prior classes, but, if necessary, additional tuition will be provided.
- Eighth class: the student's robots will participate in the final competition. All details of the competition will be provided in the seventh class. Parents and guardians are very welcome to attend the competition.

Throughout the course, from time to time, as appropriate and relevant, the instructor will introduce a real-world science or engineering project, incident, or accident and discuss its connection with the current class activity. The intent of this being to illustrate that the knowledge and skills being imparted in this course are relevant to the real world.