Hands-on engineering education design for UC Merced students

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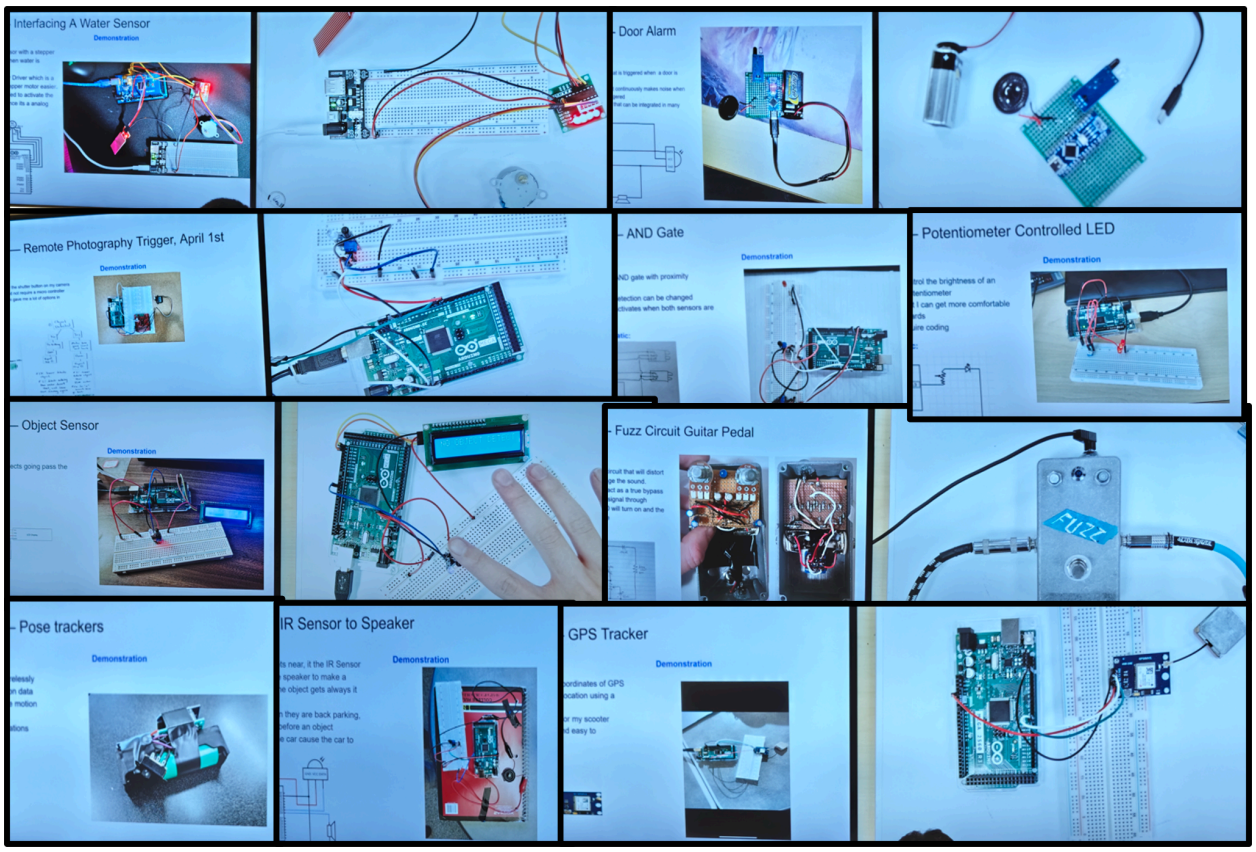
I designed a new course for School of Engineering at UC Merced — EE 005. It is a 2 unit hands-on, projects-based course on circuits design, computational thinking, and building engineering systems. Theoretical topics include basic resistive circuits, programming logic in C, and introduction to signals. Practical topics include soldering, breadboarding, control of actuators, sensors, and interfacing electronic devices. Students in this pilot EE 005 worked on 40 unique electrical engineering projects for their midterm exam. The full list of projects below demonstrates the diversity of student-proposed projects, the varying complexity, and students' success in building working prototypes.

A quick visual summary of student projects



The diversity of hands-on student projects: water sensor, door alarm, remote photography trigger, AND gate, potentiometer controlled LED, object sensor, pose tracker, guitar pedal, pose tracker, speaker, GPS tracker

Project Ideas

Beginner project ideas:

1. A circuit with logic: Build a logic gate with two inputs and one output with appropriate circuit components. Inputs should be push buttons with output shown on an LED. Add a potentiometer to vary the resistance in your LED circuit. The logic may be:
    a. An AND gate: The LED turns on only when both buttons are pressed
    b. A NAND gate: The LED turns off only when both buttons are pressed (unclaimed)
    c. An OR gate: The LED turns on when either buttons are pressed. (unclaimed)
    d. A NOR gate: The LED turns off when either buttons are pressed.(unclaimed)
2. Action recorder: Using an IR sensor, record actions of a human for certain time period, then repeat the actions by displaying them using LEDs for outputs.
3. Motion logic: Two IR sensors sense two different human actions and an LED is turned on according to the logic processing and other appropriate circuit components. Explore the effect of the potentiometer on your logical decision making.
    a. An AND gate: The LED turns on when both IR sensors detect an obstacle.
    b. A NAND gate: The LED turns off when both IR sensors detect an obstacle.
    c. An OR gate: The LED turns on when either of the IR sensors detect an obstacle.
    d. A NOR gate: The LED turns off when either of the IR sensors detect an obstacle.
4. Home automation: Generate a alarm sound when the IR sensor detects an obstacle.
5. Home automation: Blink an LED pattern (with three LEDs) when the IR sensor detects an obstacle.
6. Home automation: Turn on/off an IR sensor based obstacle detection using a push button.
7. A bike light: Power up your LED circuit with a coin battery and integrate a push button to turn the light on or off.
8. Power it up (you may need to purchase a coin battery or :
    a. Use a portable battery to power up your speaker controlled with an Arduino. Add a button to save power.
    b. User a portable battery to power up the IR sensor + LED based obstacle detection. Add a button to save power.
    c. Use a portable battery t
9. Is it open or closed? Using an IR sensor, read whether a box (or door or window) is open or closed. Light up an LED to show the sensor status. Design an appropriate box that will house the circuit and the LED display.
10. Control your LEDs: Instead of a resistor in your LED circuit, hook up a potentiometer so that the brightness of the LED can be hand-tuned.
11. Solder for durability: Solder a circuit on a PCB that you have built in this class. It can be ANY circuit with at least three components. Study the durability and robustness of your circuit. [multiple students can choose this]

12. Motion sensing: Similar to the IR sensor module, you can interface a motion sensing module (like a PIR sensor) to create a motion detection system that lights up an LED when a motion is detected.
13. Guess the resistor value: A known and an unknown resistor is connected to a 5V supply. The user enters their guess for the unknown resistor value using three push buttons to indicate the order of magnitude (100, 1k, 10k). If the guess is correct, an LED lights up (to correctly guess the resistor value, you can read the voltage drop in the circuit).
14. Play the music: Using a speaker and an Arduino, play musical beats that can be turned off and on with a push of a button.
15. Christmas lights: Connect more than 4 LEDs and code up at least two different patterns. Let the user choose the patterns using a button on the breadboard. The christmas light style pattern displays on the LEDs depending on user choice.
16. Morse code: Write a program that displays a given name (any name coded in Arduino) as Morse code with a LED light.
17. Voltage divider: Show how voltage can be divided using resistors of different values. Control the output voltage using a potentiometer.
18. Interface any other new sensor that you can find. [multiple students can choose this]
    a. Piezo buzzer
    b. Heartbeat sensor
    c. Joystick module
    d. Vibration sensors
    e. Knock sensor
    f. RGB LED
    g. Rotary encoder
    h. Soil moisture sensor
    i. Tilt switch
    j. Water level
    k. [More]

Looking for a “simple” project but ran out of ideas? Talk to me in an office hour and we can come up with a new simple project idea. Explore other projects below to get more ideas.

Intermediate project ideas:

1. How far can you see? Interface an ultrasonic sensor module to measure the distance of an object and print out on the serial monitor.
2. Is it summer already? Build a temperature sensing system that turns on an LED when the temperature outside is higher than a pre-defined threshold. For example, the LED glows up during the day and slowly fades away as the temperatures fall into the night. You will need to purchase this small module from Amazon (or any other similar sensor).
3. Humid or not? 0Build a humidity sensing system that turns on an LED when the humidity outside is higher than a pre-defined threshold. For example, the LED glows up during

when its moist outside and slowly fades away as the humidity reduces. You will need to purchase this small module from Amazon (or any other similar sensor).
4. Visualize a rectifier: Visualize the functioning of a bridge rectifier that converts a alternating current waveform to direct current with 4 LEDs and the Arduino as a power supply.
5. How far can you sense? Using multiple IR sensors, build a system that can sense obstacles in a longer range than a single IR sensor. You may mechanically affix your sensors such that they can sense longer distances than what a single sensor can.
6. Bass control for music: Create a circuit with a potentiometer (you can get a potentiometer from the makerspace lab) that can be used to tune the music frequency that is generated from an Arduino.
7. Be a listener: Using a microphone module, turn a light on/off when you clap your hands by building a voice recorder.
8. A movie-rater device: Using the Arduino serial monitor and 3 push buttons, design a movie rater device that asks users to rate a movie (on the serial monitor on the computer). The users can rate the movie in response using push buttons. The users' rating is stored in a file.
9. Power up any project in the beginner project ideas with a battery to create a standalone circuit.
10. Guess the resistor value: A resistor is connected to a 5V supply. The user enters their guess for the resistor value using push buttons to indicate the value of the resistor using binary numbers. If the guess is correct (within a tolerance), an LED lights up.
11. Morse Code translator - Create a morse code translator that takes input of "dit-dash" using push buttons, and translates the word to display it on the serial monitor.
12. Amp it up! Use an amplifier (a transistor might work too!) to amplify the sound produced by your speaker connected to the Arduino.
13. Solder a door alarm with a Arduino nano and an IR sensor and a speaker.
14. A bluetooth speaker: A speaker that is controllable over bluetooth communication.
15. Volume and pitch control for an alarm: Create a circuit with two potentiometers (you can get potentiometers from the makerspace lab) that can be used to tune an alarm frequency and volume.
16. A circuit that beeps an alarm and blinks a LED when an object gets close to it. When the object is sufficiently far away, it turns off and resumes normal state

Looking for building "real-world" systems? Look at the advanced project ideas below that push your learning to the next level as you are challenged to build something that is applicable in the real world.

Advanced project ideas:

1. Show us how far can you see? Interface an ultrasonic sensor module to measure the distance of an object and print out on an LCD display.

2. Universal logic gate! Using a NAND logic chip, illustrate how you can create all other logic gates such as AND, OR, NOT, and XOR. The output should be shown visually with LEDs and the inputs can be push buttons.
3. Speaker enclosure: The audio performance of speakers can be vastly enhanced with a proper enclosure design that balances acoustics and produces higher quality sounds. You can 3D print such an enclosure for your own speaker circuit.
4. Air quality measurement in UC Merced: Build a device that measures the presence of hazardous gases in the air to predict the air quality. You may use an air quality sensor for this purpose or come up with your own creative ways to achieve this task.
5. Make it visual! For any project of your choice described in the intermediate or beginner groups, integrate an LCD display to visualize the text in a much nicer manner instead of the serial monitor.
6. A movie-rater device with a display: Using an LED display and push buttons, design a movie rater device that asks users to rate a movie. A movie name is displayed on an LCD display. The users can rate the movie in response using push buttons. The users' rating is stored in a file and can be displayed back on the LCD..
7. Theft-proof bike/car: Build a GPS trackable circuit that you can install on your bike. Use a GPS sensor that outputs the GPS location on to a serial monitor. For an actual circuit that you can put on your bike, you will need to interface the GPS sensor with a wireless communication module that will write the GPS location consistently to an online website/app.
8. Pose tracker: Imu-based tracker that can be strapped to one's body to track pose information for things like motion capture or virtual reality. It would be built from an open-source project called SlimeVR.
9. Fuzz guitar pedal circuit that changes the modifies a guitar signal
10. Camera control: A sensor and motor connected to a DSLR camera that will trigger the shutter either when a person is detected or runs on an internal clock that will trigger the shutter.
11. Automatic Door Control: A circuit where if an IR sensor detects an object within it's space for a set period of time a signal will be sent to a motor to close the door. Use a stepper motor to demonstrate the proof of concept.
12. Rock-Paper-Scissor: Design a circuit where you can play rock paper scissors with three push buttons and a score display in binary LEDs.
13. A macro keypad with a rotary encoder for volume control. Soldered to an Arduino and programmed such that it works with any computer.
14. A photo sensor that uses servos to move in the direction of a light source and outputs the sensor values (reading) onto a seven segment display
15. Joystick that controls two servo motors to aim a laser at a desired point and the angle of the servos is displayed on an LCD display.

Project guidelines

All students must work on a “system design” project. This project must demonstrate three key elements of building and designing engineering systems that we have discussed in the class. An ideal project that grades 100% will consist of

1. Sensing of environmental surroundings using sensors, human actions, or pre-defined conditions that model the environment
2. Information processing using logical programming to understand the sensed data/conditions/actions
3. Outputs human-understandable data or acts on the environment according to the logical processing of the information.

You will be expected to present your project using one slide to the rest of the class. In this slide, you should identify how you implement the three elements of the project listed above.

What project can I work on?

A few example project ideas are listed below but you are more than welcome (in fact, encouraged!) to come up with your own ideas that satisfy the project requirements. You can also pick up a particular extra credit idea from one of the lab assignments and expand on them for your midterm project.