



MAKER: A One Hour Robot

Dr. Hugh Jack, Grand Valley State University

Dr. Jack is a professor of Product Design and Manufacturing Engineering at Grand Valley State University in Grand Rapids, MI. His interests include robotics, automation, and design.

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Abstract

The paper outlines a simple robot design that uses a 3D printer, two remote control (RC) servo motors, and an Arduino board to build a robot for less than \$45. Plans are provided with details that permit use in classroom projects and laboratory work. The 3D printer is used to make two wheels and a chassis. The chassis has features to support the RC servos, Arduino board, and a 9V battery. The first software example is suitable for K-12 outreach activities. More advanced examples could include low cost light sensors for cat and mouse games. The presentation will include a live demonstration.

Introduction

Designing and building robots is a great source of entertainment for practicing and aspiring engineers. This paper describes a robot designed for fun, that could also be used to help introduce students to engineering and robotics topics. The robot design begins with some quick measurements and notes, Figure 1. If working with students this is an ideal time to take them through an overview of the engineering design process (i.e., need, specification, concept, embodiment, detail, testing, debugging.) It can be effective if the students are put in groups and asked to design their own robots. In this case calipers were used to measure components and select dimensions. The 3D printer (also known as a Rapid Prototyping (RP) machine, Free Form Fabricator (FFF), Fused Deposition Modeler (FDM), etc.) makes parts with a maximum material condition, typically dimensions grow by 0.2mm. This was subtracted from outside dimensions, and added to inside dimensions. To reduce build time the bottom face of the design was not made as a solid flat sheet, instead a circular pattern reduced material use and improved appearance.

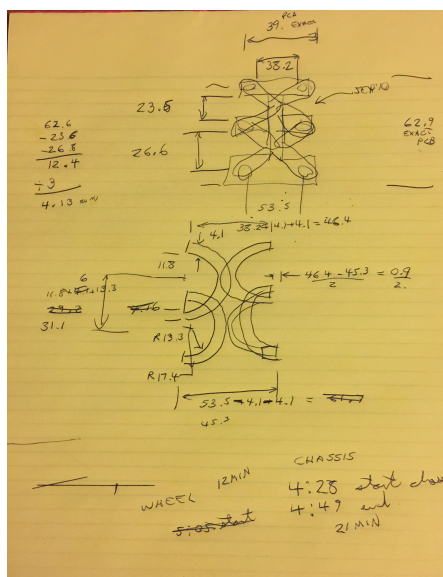


Figure 1 - Sketch of conceptual design (an example of concept development)

Manufactured Parts

The sketch was used to construct the CAD models. Sketchup was used to construct the solid models. It is not an ideal environment for engineering design, but it does run on Apple computers. The CAD models for the wheels and chassis are shown in Figure 2. The posts rise the height of the RC servos, the battery is taller. The two center posts are far enough apart to allow the sides of the servos and the cables to be fed through. The wheels have a wedge shape to hold a typical servo horn, loosely. Additional material was removed to reduce volume and weight. For outreach projects this is a suitable place to do a quick demonstration of CAD.

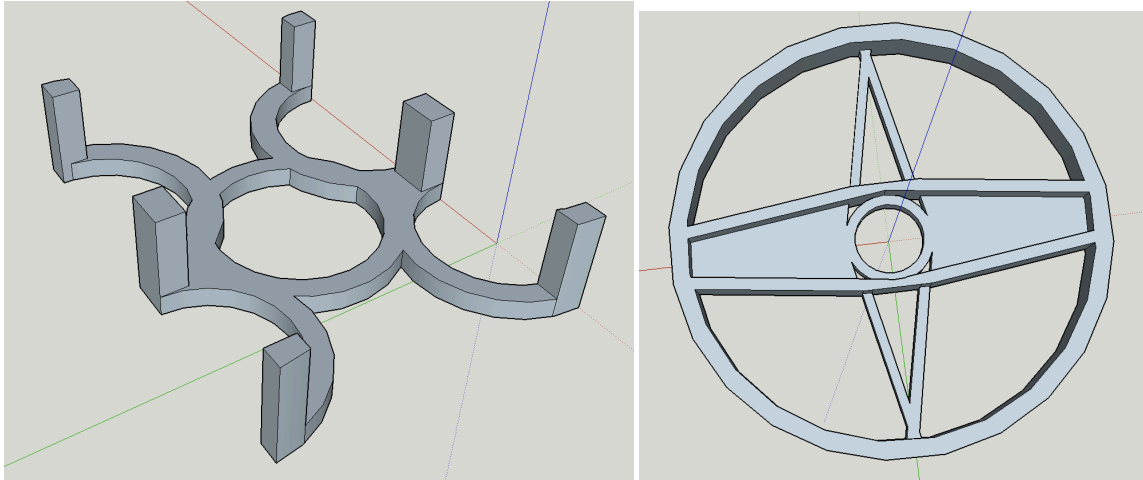


Figure 2 - Solid Models of the chassis and wheels - done using Sketchup

These models were exported to STL files. The STL files, CAD files, and more are available through a Google Drive Site ¹. The parts were fabricated on a Solidoodle 4 3D printer ². The printer has a retail cost of approximately \$700, and the material used for the parts should be less than \$1. The chassis took 21 minutes to build, while the wheels took 12 minutes each. This gave the author more than half an hour to do some soldering and write a program for testing. (Note that the build time on other 3D printers may be as short as 20 minutes total.) 3D printers are fantastic tools for outreach activities. If you are doing this for others give them a chance to see the parts being built.

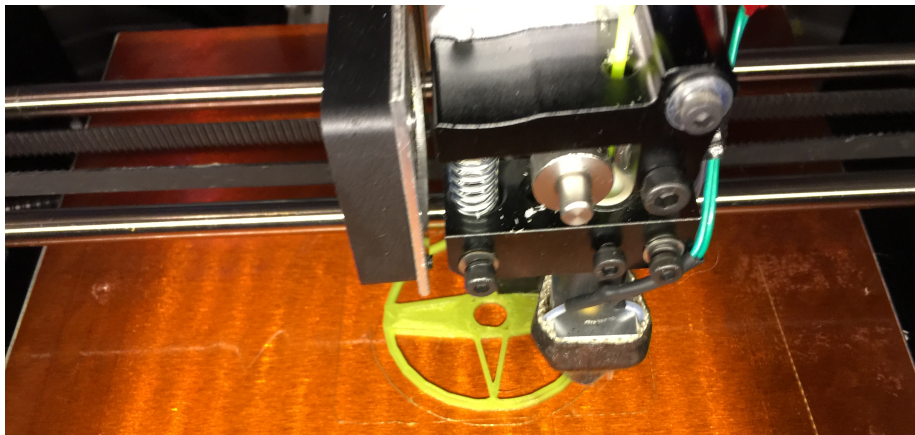


Figure 3 - Wheel mid-build on the Solidoodle 3D printer

Electrical Construction

The parts list is available in the web ¹. This list includes a Sparkfun Protosnap Arduino Pro Mini was used as the controller, with an approximate cost of \$30 ³. An Arduino Uno, or similar board can be purchased for less than \$20, but would have added bulk to the design. Figure 4 shows the core components of the system. The 9V battery strap on the left gives an idea of scale. Notice that two wires were stripped along with six longer pieces of bare wire. The RC servos are worth approximately \$5 each ⁴. The reader should be aware that there are two types of remote control servos, standard and continuous. Standard RC servos turn less than one full rotation, and are useless for wheeled robot drives. Continuous RC servos do not have a limited turn radius, and the input signal adjusts the speed. In addition, the servos used for this project are 'micro' size. The battery strap and wires can be purchased for less than \$1 in large quantities.

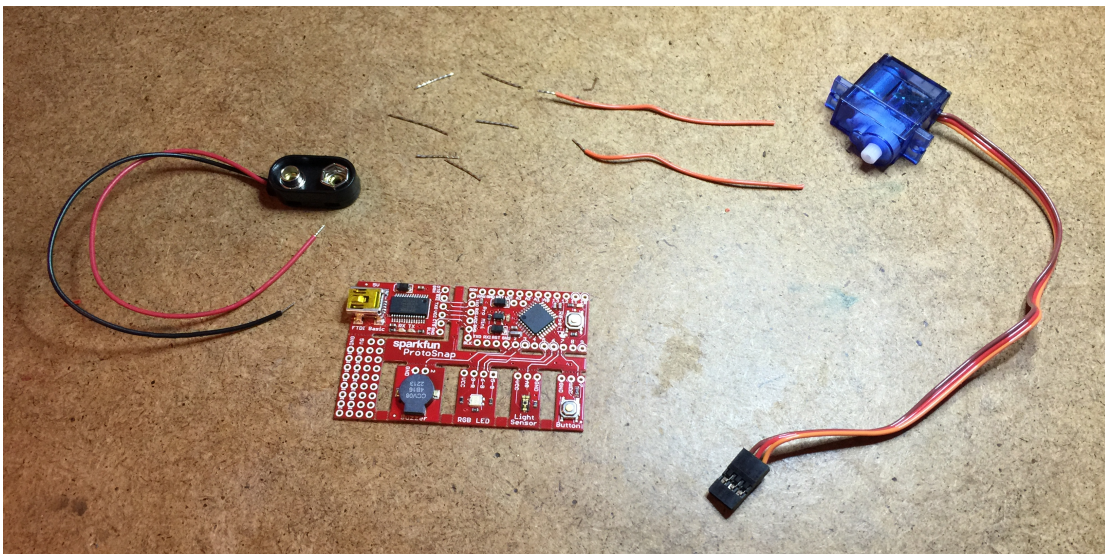


Figure 4 - The components ready for soldering

The servo has a 3 pin female connector. The wires could have been cut and soldered onto the board but that would render the servo difficult to use for other projects. Instead a three pin male header was created by soldering three lengths of wire into the prototyping space, see Figure 5. Looking at the prototyping space, the first row on the left is GND, the second is 5V, and the third is an open pin ⁵. A wire was added and connected to the pin in the third row. The wires were inserted into the servo connector before soldering to keep them aligned. In total two pin headers were created, for two servos. The RC servo connector is a standard with a voltage supply in the middle, ground on one side (orange or black), and the control signal on the other (brown or white.)

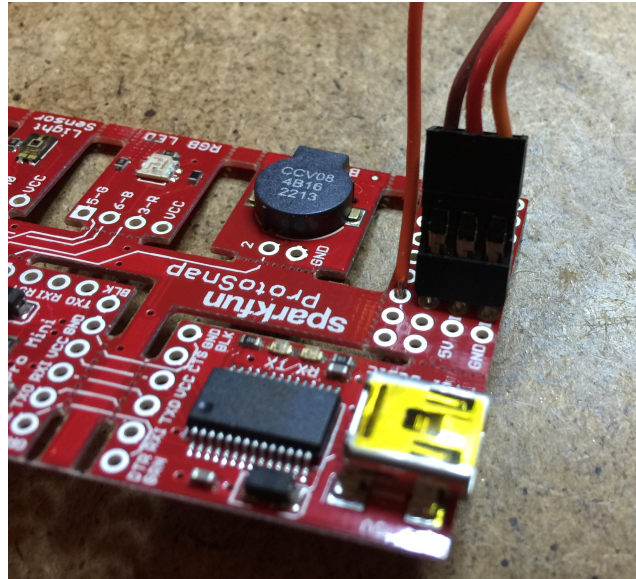


Figure 5 - Home made 3 pin headers

After the pin headers were complete the remainder of the wires were soldered, Figure 6. The +9V lead of the battery strap was soldered to the 'Raw' input. Like most Arduinos, the board contains a 5V regulator. The wires for the pin headers were connected to pins 11 and 12, common choices for servos connected to Arduinos. Looking at Figure 6 the architecture of the Protosnap board is clearer. When a design project is complete it can be broken into separate components, and the components can be removed from the system. The upper left in the figure is a USB to serial adapter, only needed for programming. The upper right is the Arduino Pro Mini. The bottom row, left to right, prototyping space, a buzzer, multi-color LED, light sensor, and push button. (Notice the ad-hoc pin connectors on the prototype board.)

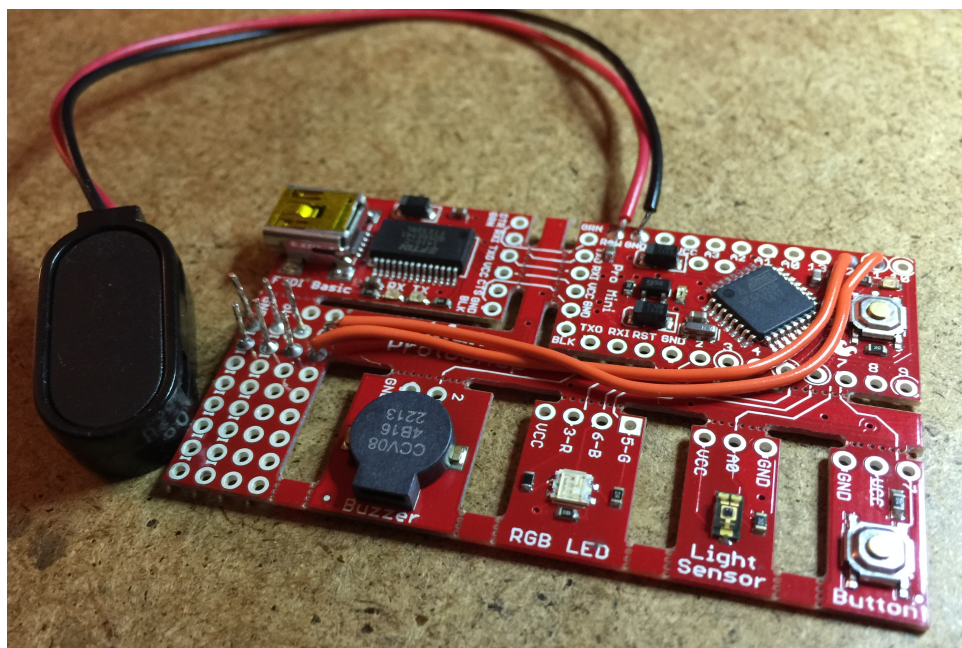


Figure 6 - Finished soldering

The final schematic is shown in Figure 7.

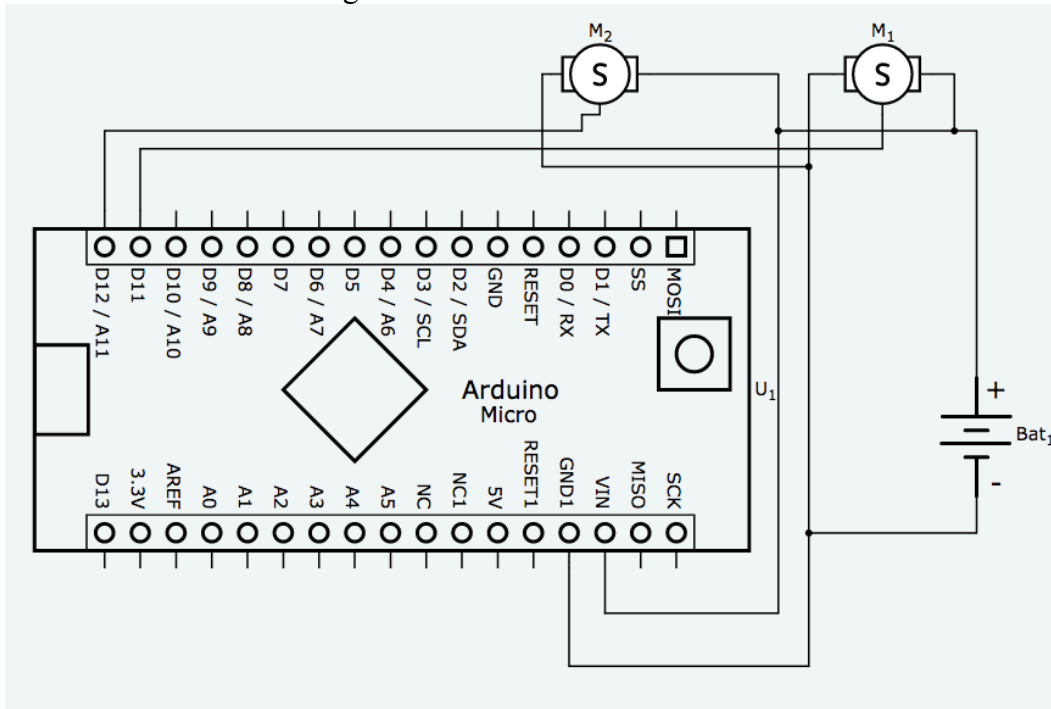


Figure 7 - Schematic

Assembly

At this point the parts were printed, and the soldering complete. The parts were ready for assembly, see Figure 8. The servos and battery were test fit in the frame and fit well.

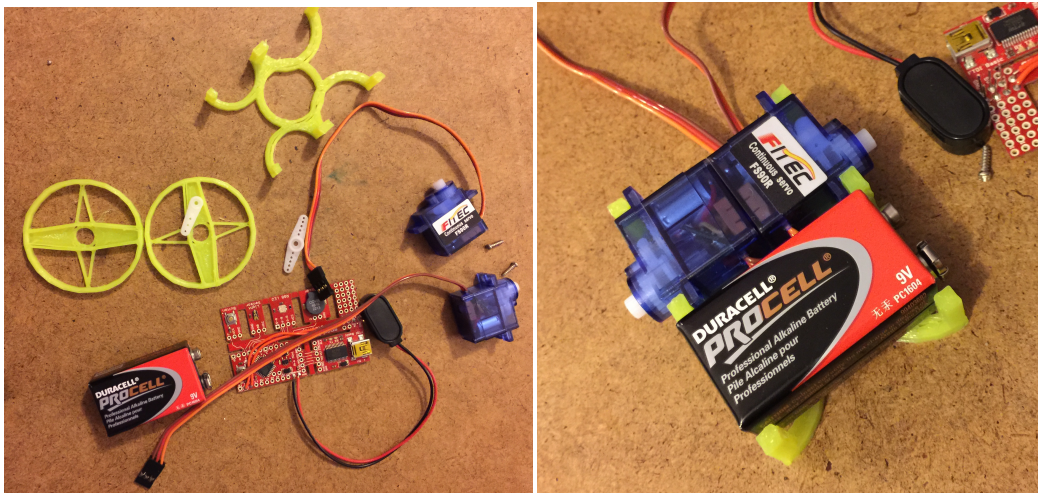


Figure 8 - Ready for assembly

Given the light weight of the robot tape was used to hold the assembly together. The open circles in the frame made it easy to loop tape through for the servos and battery, Figure 9. A better, but more permanent solution would be double sided tape, or hot melt glue.

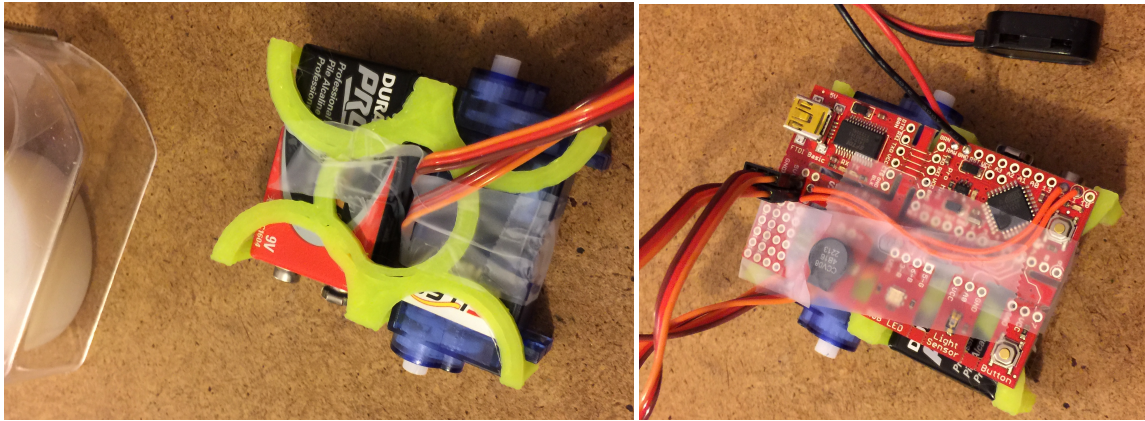


Figure 9 - Assembly using tape.

The final assembly step was the wheels, Figure 10. The hollow channels in the wheel hold the white servo horn, which in turn holds the wheel to the servo. A small screw holds the assembly in place. The channel on the wheel is somewhat loose to accommodate multiple servo sizes, but some padding, packing, or shims can be used. The rear of the robot will slide on the ground, while the two wheels turn for steering and propulsion. Additional modifications could include adding a wheel or skid to reduce friction. Elastic bands could be stretched around the wheels to increase friction. But at this point the build is done.

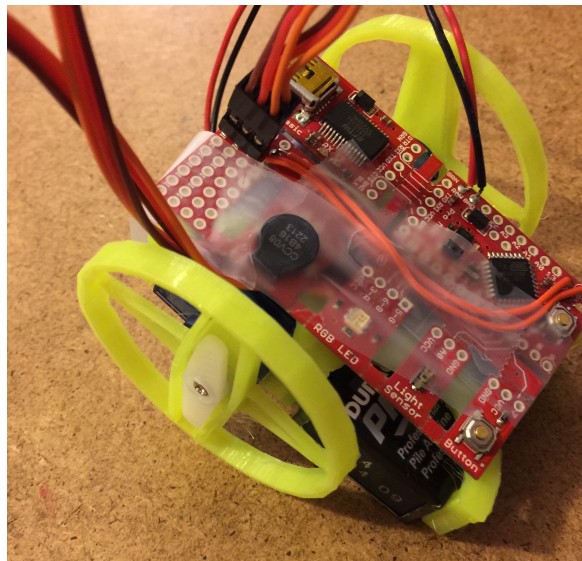


Figure 10 - Assembled and ready to go

Programming

The Arduino software ⁶ was used to write and download a program to test the robot, Listing 1. While simple, it demonstrates the basic motions by turning, moving, and stopping in intervals. The program can be easily extended by beginners.

```

// A simple arduino program to test the simple robot with servo motors
// on pins 11 and 12.
// H. Jack - 2/2/2015

#include <Servo.h>

Servo left, right;
#define LEFT_PIN 11 // where the servo is attached
#define RIGHT_PIN 12
#define LEFT_STOP 96 // the range is roughly 0-180, so the middle is stop
#define RIGHT_STOP 93 // these can be adjusted by trial and error
#define MAX_POS 170 // the maximum is actually 180
#define MAX_NEG 10 // the minimum is actually 0

void setup() {
  left.attach(LEFT_PIN); // this is where the servos are attached
  right.attach(RIGHT_PIN);
}

void loop() {
  left.write(MAX_POS); // turn one direction, remember one servo is reversed
  right.write(MAX_POS);
  delay(500); // do it for 1/2 second

  left.write(MAX_POS); // go straight
  right.write(MAX_NEG);
  delay(1000);

  left.write(LEFT_STOP); // sit idle for a while
  right.write(RIGHT_STOP);
  delay(2000); // a 2 second delay before we do it again.
}

```

Listing 1 - A basic robot program

Conclusion

A one hour robot build was outlined using remote control hobby servos, an Arduino, and 3D printed parts. The robot is ideal for a simple demonstration of a simple build process. Moreover, the build could be enhanced with more advanced sessions to engage learners.

Middle School - Students observe the RP machine making the parts, and watch a demonstration of soldering. They then assemble the pieces and download the sample program.

High School - The students are given the STL files for the parts and operate the RP machine. They solder the Protosnap board, and retype and download the program. Time is left for program modification.

College - Students use CAD software to create the part files, operate the RP machines, solder the circuit boards, use the stock program. Excess time is allowed for program modification and exploration of the other components on the Protosnap board.

References

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