Design • Build • Program • Learn • Compete

# SERVO MAGAZINE

FOR THE ROBOT INNOVATOR

www.servomagazine.com

April 2017

## EMG+UNO = BIO Control

USE YOUR BODY TO CONTROL YOUR BOT!

The Robots of CES

Judgment Day For AI

Parallax Blocklyprop

HiTEC

# PHANTOM X4 CHARGER

CHARGES
DJI PHANTOM™ 3 / 4
SMART BATTERIES*

FAST CHARGES
FOUR BATTERIES
SIMULTANEOUSLY

CHARGES 2 REMOTE CONTROLLERS
TABLET DEVICES
WHILE BATTERIES ARE CHARGING

## STAY CHARGED!

Charging your batteries shouldn't keep you away from what you really want to do: FLY!!!
Our Phantom X4 Charger is the ultimate four-channel battery charger designed and built exclusively for charging, storing and deep cycling four DJI Phantom™ 3 and DJI Phantom™ 4* Smart Batteries simultaneously. And while your batteries are charging, plug into the USB ports and charge two remote controllers and two smart devices as well. That's right DJI Phantom™ Phans, stay charged and keep on flying!

*DJI™ Phantom 4 Smart Batteries Require an Adaptor which is Sold Separately. ™DJI, DJI Phantom are trademarks of SX DJI Technology Co., Ltd.

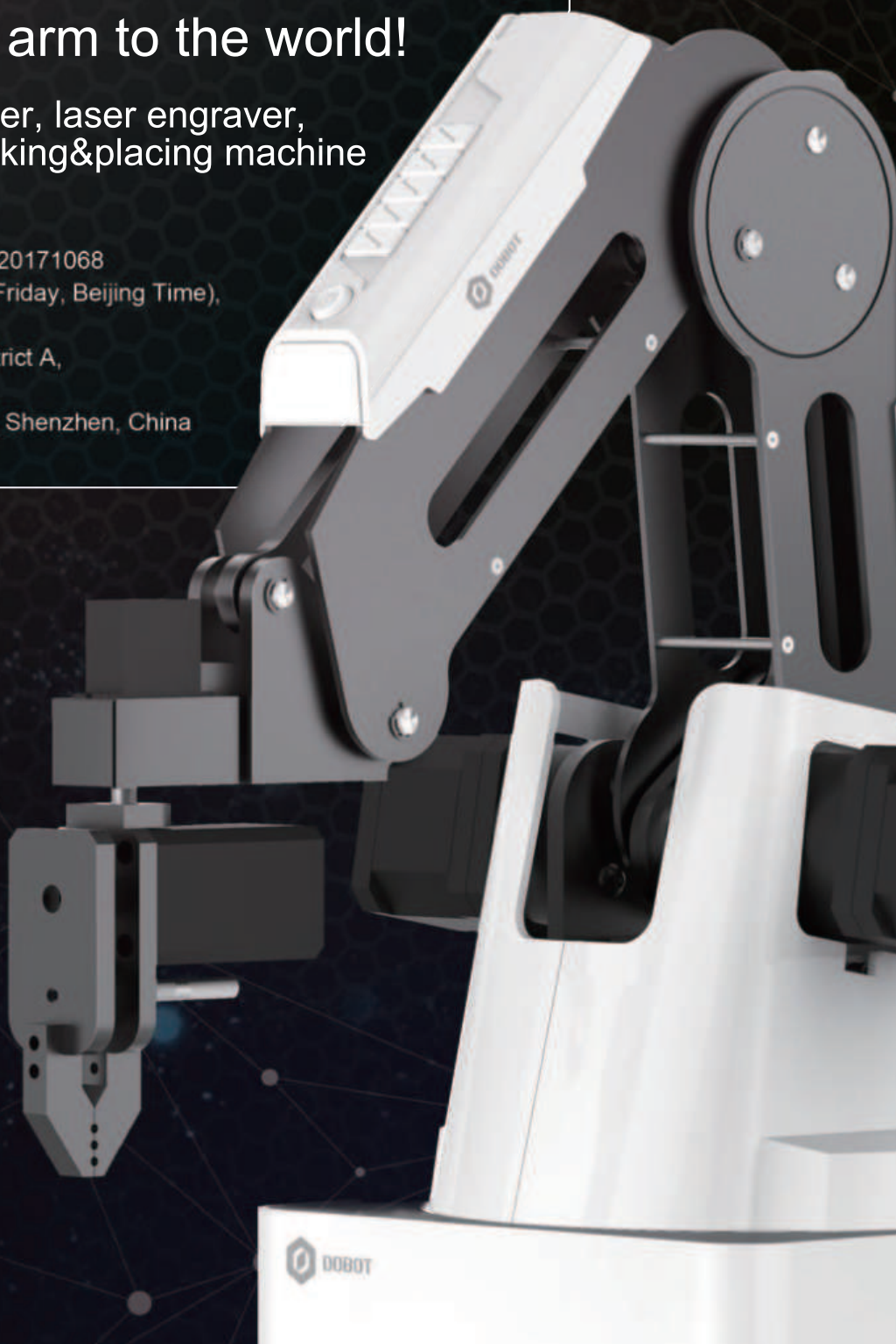
Hitec RCD USA, Inc. | 12115 Paine Street | Poway, CA 92064 | (858) 748-6948 | www.hitecrcd.com |

# BECOME DISTRIBUTOR

## Work with us to introduce the most exciting robotic arm to the world!

It can be your 3d printer, laser engraver, soldering,drawing, picking&placing machine and more.

**Tel:** +86 755 33100907 +86 15920171068
(9:am to 6:30 pm, Monday to Friday, Beijing Time),
**Email:** juliefeng@dobot.cc
**Address:** 4th Floor,Building 8,District A,
Tanglang Industrial Zone,
Taoyuan Street, Nanshan District, Shenzhen, China




DOBOT

SERVO MAGAZINE

04.2017

VOL. 15 NO. 4

Subscription Information
SERVO Magazine — PO Box 15277
North Hollywood, CA 91615-9218
Call 877-525-2539 or go to www.servomagazine.com
Subscribe • Gift • Renewal • Change of Info

# Columns


## 08 Robytes

*by Jeff and Jenn Eckert*

***Stimulating Robot Tidbits***

- Bot Smashes Rubik's Record
- Passenger Drone Takes Off
- Construction Bot for Disaster Relief
- Improved Maneuverability in Birdlike Drone
- Hail Queen Simone

## 10 Ask Mr. Roboto

*with Eric Ostendorff*

There's a new sensor on the block: a laser obstacle type that you just have to try.

## 54 Twin Tweaks

*by Bryce and Evan Woolley*

***Full Metal Cannon***

We've been extensively chronicling the build of a high pressure robotic air cannon over the last several columns. So, what else could there possibly be to cover? As it turns out – a lot.

## 60 Then and Now

*by Tom Carroll*

**What's New in Robotics**

For the past 50 years, robotics has grown in leaps and bounds as new types of robots are constantly being introduced. Let's take a look at the latest offerings that were introduced at this year's Consumer Electronics Show (CES).

# Departments


06 Mind/Iron
*Finger Spinners*

07 Events Calendar

20 New Products

20 RoboLinks

23 Showcase

52 SERVO Webstore

65 Advertiser's Index

## 22 Bots in Brief

- Wag the Tail
- Great Gait!


# The Combat Zone


24 The Glass Cannon: The Tale of a Newbie's First Venture into Combat

27 New Year's Resolution — Part 2


*SERVO Magazine* **(ISSN 1546-0592/CDN Pub Agree#40702530)** is published monthly for $26.95 per year by T & L Publications, Inc., 430 Princeland Court, Corona, CA 92879. PERIODICALS POSTAGE PAID AT CORONA, CA AND AT ADDITIONAL ENTRY MAILING OFFICES. POSTMASTER: Send address changes to **SERVO Magazine, P.O. Box 15277, North Hollywood, CA 91615** or Station A, P.O. Box 54, Windsor ON N9A 6J5; cpcreturns@servomagazine.com

# In This Issue ...


## 14 Animatronics for the Do-It-Yourselfer

*by Steve Koci*

**Motors Make the World Go Round**

How many ways can we "turn the wheels" of our mechanisms? We have already covered servos, wiper motors, pneumatics, and linear actuators in this series of articles. This month, we are going to take an in-depth look at using some alternative motors in our designs.

## 30 Judgment Day for AI: Inside the Loebner Prize

*by Joanne Pransky*

Hugh Gene Loebner, PhD, a philanthropist, inventor, and entrepreneur, made Alan Turing's ideas a reality when he sponsored the first Loebner Prize in 1991. Hear from one of the judges what it's really like to be a part of the contest.

## 36 TETRIX PRIME Hits the Bulls-EYE at USF

*by Patty Cooke*

An engineering mentoring program at the University of South Florida is bringing STEM and real world learning to area youths.

## 38 Parallax Blocklyprop Starter Kit

*by Carol Hazlett*

Parallax has added Blockly to its list of tools for programming their popular Propeller microcontroller. Their version of Blockly is called Blocklyprop, and I have been pleasantly surprised to find out how much fun it is to use and how powerful it can be.

## 42 EMG Control and Monitoring of a Servo Gripper: Closing the Loop

*by Bryan Bergeron*

See how to use an inexpensive electromyograph (EMG) sensor and Arduino Uno to control and monitor a servo gripper by flexing your muscles.

## 46 The Multi-Rotor Hobbyist

*by John Leeman*

**Photogrammetry with OpenDroneMap — Part 1**

Spending time with a good map can reveal a wealth of information. So, we're going to begin to make our own maps using our quadcopter, a camera, and some open source software.

PAGE 38

PAGE 30

# Mind / Iron

*by Bryan Bergeron, Editor*

## Finger Spinners — The Killer App for 3D Printers?

It seems that every successful device and software package has a killer application that propels it above the noise and into the public eye. For the PC, it was the electronic spreadsheet. For augmented reality, it was Pokémon Go.

At the time of this writing (early February of 2017), the killer app for 3D printers appears to be finger spinners — also referred to as EDC (every day carry) spinners, fidget toys, and ninja spinners.

Finger spinners are sold as desk toys and focus aides for those with attention deficit hyperactivity disorders, or ADHD. If you can find one, prices range from $5-$30 for 3D printed finger spinners, depending on the type of bearings and whether it's printed in PLA or ABS plastic.

My first plastic spinner — which I purchased on Amazon — was an ABS model for $30. It took a month for delivery, and that was quick compared to the estimated shipping dates of the other finger spinners listed on Amazon.

As a long-time knife collector and part of the EDC community, I became aware of finger spinners last year, when high priced metal models of finger spinners became a hot topic on the knife forums. Models from the major manufacturers such as the TorqBar from MD Engineering (**www.torqbar.com**) and the RotaBlade Stubby from RotaBlade (**www.rotablade.com**) were selling from $130-$200, depending on the metal and treatment. I picked up a titanium spinner from UK-based RotaBlade, but had to put up with a six week wait.

Today, you can't even get on the wait list for a TorqBar or RotaBlade. The websites list models made of copper, brass, stainless steel, and titanium, with add-ons ranging from anodizing to insertion of Tritium tubes for nighttime use.

However, if you want to actually buy one of these spinners, you're forced to visit eBay, where I've seen $130 list price spinners start at $450, and they're gone as soon as they're listed.

Hence, the attraction of 3D printed spinners. Sure, they're not as compelling as a shiny spinner cut from a solid block of brass or titanium, but they're also relatively affordable.

At $30 for a spinner printed in ABS plastic, it's still robbery, but just try buying one on Amazon or eBay. You'll have to wait a month or more to get your hands on one — that is, unless you own a 3D printer.

Until the bubble bursts, a 3D printer, a few spools of filament, and a supply of skateboard bearings is a money-making machine.

Sure, 3D spinners — like pet rocks and chia pets — won't change the world. At best, they'll provide a socially acceptable outlet for fidgeters.

In a meeting, a silent spinner certainly beats someone incessantly clicking a pen or shredding a paper coffee cup.

However, what the sudden demand for an item that can't be produced fast enough by conventional means highlights the beauty of the 3D printer. The printing of finger spinners also shows that people are willing to pay a premium for instant gratification.

At least in the EDC community, people are starting to talk about 3D printers for the first time. That's a good thing for the consumers of the

FOR THE ROBOT INNOVATOR SERVO MAGAZINE

Published Monthly By
**T & L Publications, Inc.**
430 Princeland Ct., Corona, CA 92879-1300
**(951) 371-8497**
FAX **(951) 371-3052**
Webstore Only **1-800-783-4624**
**www.servomagazine.com**
Subscriptions
Toll Free **1-877-525-2539**
Outside US **1-818-487-4545**
P.O. Box 15277, N. Hollywood, CA 91615

**PUBLISHER**
Larry Lemieux
**publisher@servomagazine.com**

**ASSOCIATE PUBLISHER/ ADVERTISING SALES**
Robin Lemieux
**robin@servomagazine.com**

**EDITOR**
Bryan Bergeron
**techedit-servo@yahoo.com**

**VP of OPERATIONS**
Vern Graner
**vern@servomagazine.com**

**CONTRIBUTING EDITORS**
Tom Carroll, Kevin Berry, R. Steven Rainwater, Steve Koci, Eric Ostendorff, John Leeman, Jeff Eckert, Jenn Eckert, Bryce Woolley, Evan Woolley, Carol Hazlett, Joanne Pransky, Patty Cooke, Pete Smith, Nik Buchholz

**CIRCULATION DEPARTMENT**
**subscribe@servomagazine.com**

**WEBSTORE MARKETING COVER GRAPHICS**
Brian Kirkpatrick
**sales@servomagazine.com**

**WEBSTORE MANAGER/ PRODUCTION**
Sean Lemieux
**sean@servomagazine.com**

**ADMINISTRATIVE STAFF**
Re Gandara

Copyright 2017 by
**T & L Publications, Inc.**
*All Rights Reserved*

All advertising is subject to publisher's approval. We are not responsible for mistakes, misprints, or typographical errors. *SERVO Magazine* assumes no responsibility for the availability or condition of advertised items or for the honesty of the advertiser. The publisher makes no claims for the legality of any item advertised in *SERVO*. This is the sole responsibility of the advertiser. Advertisers and their agencies agree to indemnify and protect the publisher from any and all claims, action, or expense arising from advertising placed in *SERVO*. Please send all editorial correspondence, UPS, overnight mail, and artwork to: **430 Princeland Court, Corona, CA 92879.**

technology at all levels. As more non-technical folks become aware of the utility of the 3D printer, prices should become more competitive, and there should be more printers on the market that target everyday users.

Happy 3D printing — and spinning. **SV**

# EVENTS

## APRIL

**1** **Robotics Tournament**
*Rybnik, Poland*
Events include Micromouse, Sumo, Mini Sumo, RoboDragRace, Line Following, and Freestyle.
**www.roboticstournament.pl**

**1-2** **Trinity College Fire Fighting Home Robot Contest**
*Trinity College, Hartford, CT*
Robots must detect and extinguish a fire in a mock house.
**www.trincoll.edu/events/robot**

**6-8** **Istanbul Technical University Robotic Olympics**
*Istanbul, Turkey*
Events include Line Following, Micro Sumo, Fire Fighting, Maze Solving, Stair Climbing, and Self Balancing.
**www.ituro.org**

**6-8** **National Robotics Competition**
*Marion, OH*
Student teams build robots that compete in an annual challenge.
**www.nationalroboticschallenge.org**

**8** **Alabama Robotics Competition**
*University of Alabama, Tuscaloosa, AL*
K12 student-built autonomous robots navigate an obstacle course.
**http://outreach.cs.ua.edu/robotics-contest**

**19** **DTU RoboCup**
*Technical University of Denmark*
*Copenhagen, Denmark*
Student-built robots navigate a course using line and wall following.
**www.robocup.dtu.dk**

**19-25** **VEX Robotics World Championship**
*Louisville, KY*
Elementary, middle, high school, and university teams compete in an annual challenge.
**www.vexrobotics.com/competition**

**21** **Carnegie Mellon Mobot Races**
*CMU, Pittsburgh, PA*
Student-built robots compete in Mobot Slalom.
**www.cs.cmu.edu/mobot**

**21-23** **RoboGames**
*Pleasanton, CA*
Over 50 events including Sumo, Humanoid challenges, RC Combat, Soccer, LEGO, NatCar, BEAM, and Robot Art.
**www.robogames.net**

**21** **UNI Sumo Smackdown**
*UNI, Cedar Falls, IA*
Ship-in Mini Sumo matches are broadcast via the Internet.
**www.narobotics.org**

**19-22** **FIRST Robotics Competition**
*Houston, TX*
Student-built robots compete in an annual challenge.
**www.usfirst.org**

**22** **Mercury Remote Robot Challenge**
*Stillwater, OK*
Teleoperated robots navigate a course 50 miles from the operator.
**http://mercury.okstate.edu**

**29-30** **The Tech Museum of Innovation's Annual Tech Challenge**
*San Jose, CA*
Annual challenge for students.
**http://techchallenge.thetech.org**

**30** **Brown IEEE Robotics Competition**
*Brown University, Providence, RI*
Autonomous robots navigate a maze.
**http://brown.edu/Departments/Engineering/Organizations/Ieee/Competition**

# Robytes

by Jeff and Jenn Eckert

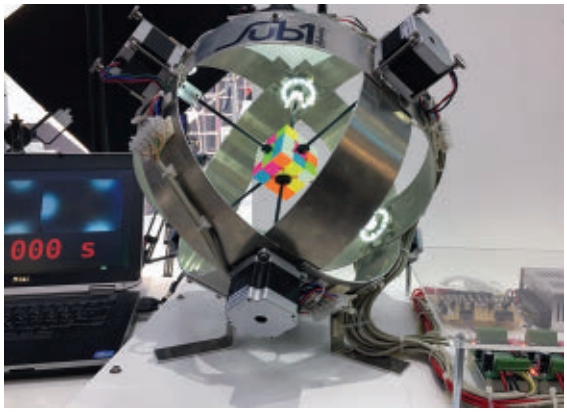
## Bot Smashes Rubik's Record

Although the Rubik's Cube craze has largely faded away since the 1980s, a few wretched souls still engage in the practice of "speedcubing." Periodically, they slither out from dank corners of the world to enter competitions in such categories as speedsolving, blindfolded solving, solving with feet, and so on, all under the auspices of the World Cube Association (**www.worldcubeassociation.org**).

The current human champ is one Feliks Zemdegs, a 21 year old geek of Australian extraction, who currently holds 10 world records, including the solution of a 3 x 3 x 3 cube in 4.73 seconds. Impressive as that sounds, the record has been smashed by a robot known as the "Sub1 Reloaded," which solved the puzzle in a mere 637 milliseconds and 21 moves.

Motor control was provided by an AURIX microcontroller from Infineon, similar to the one the company uses in its driver assistance systems, driving six robotic arms. According to Infineon, more than 43 quintillion combinations of the colored squares are possible, but any Rubik's Cube can be unscrambled in a mere 20 moves. So, there appears to be some room for improvement.

If you want to give Zemdegs a run for human champ, note that the 2017 World Championship will be held in Paris, July 13 through 16. First, you'll need to win the CubingUSA Nationals July 7 through 9 in Ft. Wayne, IN.



*This "Sub1 Reloaded" robot solved Rubik's cube in a record-setting 0.637 seconds.*

## Passenger Drone Takes Off

Since 2001, Israeli tech firm Urban Aeronautics Ltd. (**www.urbanaero.com**) has been developing a flying car it calls the Cormorant (formerly known as AirMule). Referred to as a "Fancraft™," the vehicle is a passenger-carrying drone intended both for evacuating people from hostile environments and providing safe access for military forces in dangerous places. For example, it could be used to rescue people from a city that has been hit by a dirty bomb or contaminated by a hazardous chemical substance.

*Urban Aeronautics' Cormorant "Fancraft" flying car.*

The vehicle can be remotely piloted or programmed to operate autonomously. Perhaps the most interesting aspect of the Cormorant is that it uses six internal rotors rather than helicopter-type propellers, so it can maneuver in between buildings and below power lines with no fear of blade strikes. The rotors provide enough power to lift the 1,500 kg (3,300 lb) drone and a payload of another 500 kg (1,100 lb) at speeds up to 185 km/hr (115 mph). Plus, it can endure crosswinds of up to 92 km/hr (57 mph).

Cormorant made its first solo flight late last year, and it was deemed a success despite some unresolved conflicts with data sent by onboard sensors. However, it still hasn't met all relevant FAA standards, so it isn't expected to be available for delivery until sometime in 2020. You can preorder one for about $14 million.

Go to **www.servomagazine.com/index.php/magazine/article/April2017_Robytes** to comment on these topics.

## Construction Bot for Disaster Relief

A more mundane approach to autonomous rescues takes the form of a prototype construction robot developed as part of Japan's Tough Robotics Challenge Program, which is part of something called the Impulsing Paradigm Challenge through Disruptive Technologies Program (rather torturously abbreviated as "ImPACT"). The programs are the work of research leaders from several Japanese universities.

In practical terms, we're talking about a highly modified hydraulic shovel that incorporates several special elemental technologies, including sophisticated sensors and controls, and a tethered multi-rotor UAV that provides image information to the operator. The UAV includes four fisheye cameras plus a far-infrared camera that can penetrate fog and other visual obstructions.

The consortium is also developing robots with a double rotation mechanism and double arms "with the purpose of achieving higher operability and terrain adaptability." Specifics are available at **www.jst.go.jp/impact/en/intro.html**.

*Relief robot employs UAV to inspect surrounding terrain.*

## Improved Maneuverability in Birdlike Drone

One of the operations at the Ecole Polytechnique Fédérale de Lausanne (EPFL) is its Laboratory of Intelligent Systems (**lis.epfl.ch**), also known as the Floreano Lab. The facility "merges biology and engineering to design future robotics systems and better understand biological systems." One of their recent developments is a drone whose wings incorporate feather-like structures that allow the wing's size and shape to be modified during flight, allowing it to maneuver more easily and resist high winds — just like birds do.

*Bio-inspired drone can spread or close its feathered wings during flight.*

According to Matteo di Luca, "We were inspired by birds: They can radically transform the size and shape of their wings because they have an articulated skeleton that is controlled by muscles and covered in feathers that overlap when the wings are folded." Accordingly, the drone also has feathers that it can fold and overlap like a fan.

This concept appears to be most suited to small lightweight drones, but the researchers hinted that it could be adaptable to larger aircraft, where "engineers are still trying to find the ideal replacement for the rigid wings and ailerons of planes." According to head honcho, Dario Floreano, "With the foldable wings, we discovered that we didn't need ailerons to help the drone turn. By changing the wingspan and surface area during flight, we could make it turn automatically."

## Hail Queen Simone

Finally, if you haven't discovered the YouTube channel of Simone Giertz, you probably need to do so immediately. Simone bills herself as the "Queen of Sh*tty Robots, Breaker of Transistors, Mistress of Malfunction, and Mother of Terrible Inventions." Giertz (inexplicably pronounced "yetch") is a Swedish inventor, maker, robotics enthusiast, and professional YouTuber who once studied engineering physics in college but dropped out after a year. Her interest in electronics began in 2013, when she invented a toothbrush helmet for a pilot children's show.

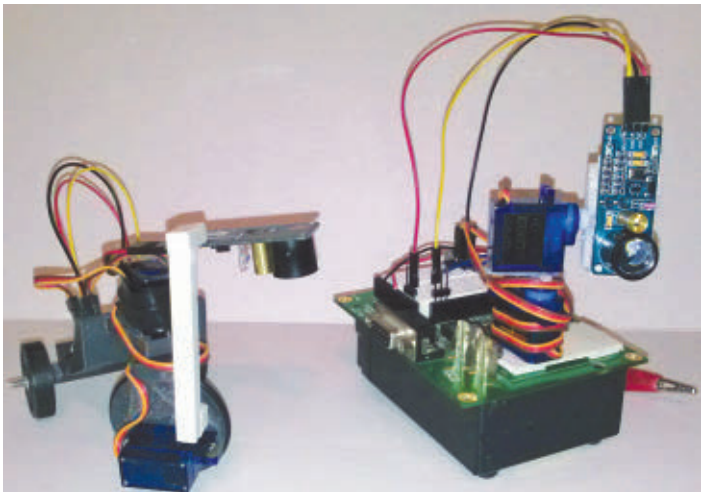
*Simone and her ingenious lipstick robot.*

Simone's YouTube videos document her various robotic inventions, including a lipstick-applying robot, a machine that blows your nose for you, vegetable-chopping and sandwich-making bots, and even an automatic butt-wiping machine. Be forewarned that some of the vids are not particularly appropriate for anyone who is highly sensitive or under the age of, say, 14. **SV**

# ASK MR. ROBOTO

by Eric Ostendorff

**Tap into the sum of *all human knowledge* and get your questions answered here! From software algorithms to material selection, Mr. Roboto strives to meet you where you are — and what more would you expect from a complex service droid?**



## New Sensor on the Block!

Flashback to my February column, when I answered a question about ultrasonic range finders and I talked about sensor fusion: the popular term for sampling data from several different sensors. I mentioned IR proximity sensors and more specifically Sharp's family of IR distance measuring sensors as a good complement to ultrasonic sensors. No sooner did I send that article off to the fine editors of *SERVO Magazine* that I found another type of sensor: a laser obstacle sensor for $10-$15. It was available on eBay, Amazon, and RobotShop, but there wasn't much information about it.

I HAD to have some. Lasers are just plain cool. Around 1970, my older brother got a ruby laser rod for the princely sum of $75 from Edmund Scientific and made a death ray for his school science project. Focusing intense energy bursts from glass-melting flashbulbs, he managed to burn spots on his school sweater and a few other unsuspecting objects. It was downright dangerous and very demonstrable. These days, much tamer laser pointers and laser diodes can be found at dollar stores! ***Still a potential hazard to eyesight, though, so be careful in all you do.***

You can still spend lots of money on laser *sensors* these days (**Figure 1**). A Lidar-Lite v3 laser range finder (left) sells for $150 at **https://www.sparkfun.com/products/14032**; $445 gets you DFRobot's RPLIDAR rotating scanner (center) at **https://www.amazon.com/Degree-Laser-Scanner-Development-RPLIDAR/dp/B00LGC2CTI**. Or, if money's no object, grab a few $5,000 SICK laser scanners (right) as used on many DARPA Grand Challenge AUVs at **www.plccenter.com/en-US/Buy/SICK%20OPTIC%20ELECTRONIC/S30A6011**.

A few years ago, I found a very cool LEGO site by Phillipe/Philo at **www.philohome.com/sensors/laser sensor.htm** showing how to retask a $4 copy machine paper sensor into a very cool digital laser sensor. The S6986 sensor IC (**Figure 2**) is getting rare and hard to find.

Ultimately, I ordered a hundred direct from Hamamatsu after some fancy footwork and getting approved by their sales department. The stand-alone sensor costs several dollars and can be fashioned into a very useful sensor by adding a laser diode. The IC both modulates the laser beam and detects the reflection.

I have used it in several projects, using it to sense Scotchlite retroreflectors at over 10 feet away without any lenses. In fact, I won Jameco's

Figure 1.

LIDAR LITE 3 RANGEFINDER — RPLIDAR SCANNER — SICK LASER SCANNER

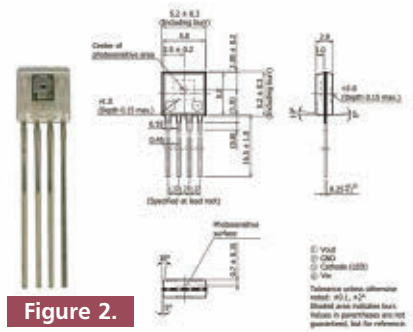
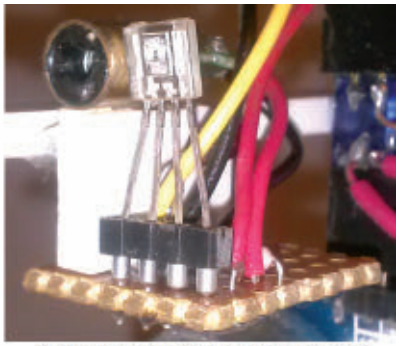


Figure 2.

HAMAMATSU S6986 SENSOR



COMBINED WITH LASER DIODE FOR TARGETING

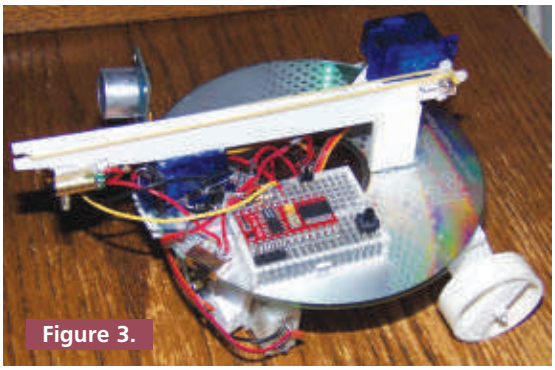


Figure 3.

Our resident expert on all things robotic is merely an email away.
**roboto@servomagazine.com**

Post comments on this article at **www.servomagazine.com/index.php/magazine/article/April2017_MrRoboto**.

"Coasterbot 2" contest with a robot using this system (**Figure 3**) for navigation and targeting. Info is available at **www.jameco.com/Jameco/workshop/challenge /challenge-coasterbot 2results.html** and my video entry is at **https://www.youtube.com/watch ?v=dZTfIyrRne0**. I actually contacted Philo to thank him, and he was happy to see his work inspired me several years later. So, again, it's a neat sensor which can be hacked into a DIY laser sensor module with some effort.

In contrast, the new laser sensor shown in **Figure 4** comes ready to use. **Figure 5** shows the schematic. You can find more information on Waveshare's "Obstacle Detector" at **www.waveshare.com/wiki/Laser_Sensor**. It looked to me like an easily sourced drop-in replacement for the Hamamatsu sensor, even though it was only listed as an obstacle detector.

I ordered three $10 sensors from **www.robotshop.com/en/obstacle-detection-laser-sensor.html** and was pleasantly surprised.

The datasheet specs a wide supply voltage range from 2.5V-5.0V and, in fact, most of the onboard components are for the PT1301 voltage boost circuitry for the laser. Powered from 5V, the sensor draws 28 mA and the peak output voltage is 4.79V. Powered from 3.3V, I measured a 47 mA draw and peak output voltage of 3.17V, so this is a very user-friendly sensor.

The laser receiver is a clear three-pin package which looks like a phototransistor or the Hamamatsu sensor. Adjacent to the brass laser tube is a similar-looking component which is apparently the laser modulator. The datasheet lists the modulation frequency as 180 kHz. Seeking more information, I emailed Waveshare, which is a Chinese company. Their reply:

*Hello, dear*

*Your question: The laser modulation is actually 180 kHz? And what does the extra phototransistor near the brass laser do?"*

*Our engineer said: That is the modulated tubes, which is modulated the laser as a regulated rate and send, there is a receiving tube under the lens, which is used for receiving the fixed rate*

So, there you have it! Straight from the manufacturer!

You can see my initial test video at **https://www.youtube.com/watch?v=5BTCoUflnEI**. The module has two red SMT LEDs: one for power on, and one indicating detection of a reflected modulated laser signal. The output signal is normally high/active low — much like a 38 kHz IR receiver module. The removable lens is held on with double-sided tape, and is critical to achieve sensing distances over ~8 inches.

Closer than that, the lens interferes with proper function due to beam alignment and parallax effects. Max range is very dependent on the color and reflectivity of the surface. Here are some results from my range tests:

- White surface max range ~36"
- Black plastic computer case ~12"-18"
- Black resin watch strap ~12"
- Dark brown fabric ~8"
- Black fabric not detected
- Sunny outdoors, Scotchlite reflector **60+ FEET**

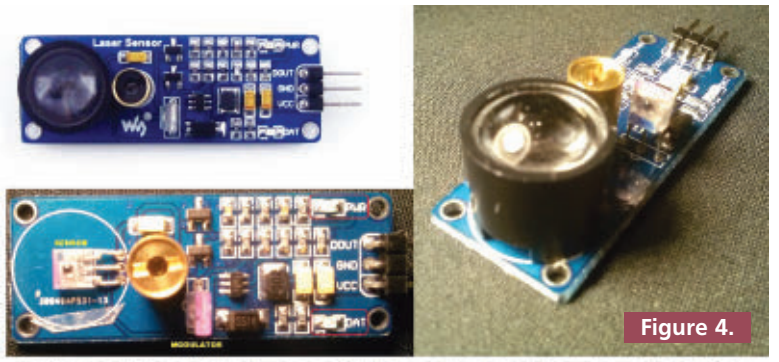


Figure 4.

**WAVESHARE LASER SENSOR OBSTACLE DETECTOR**

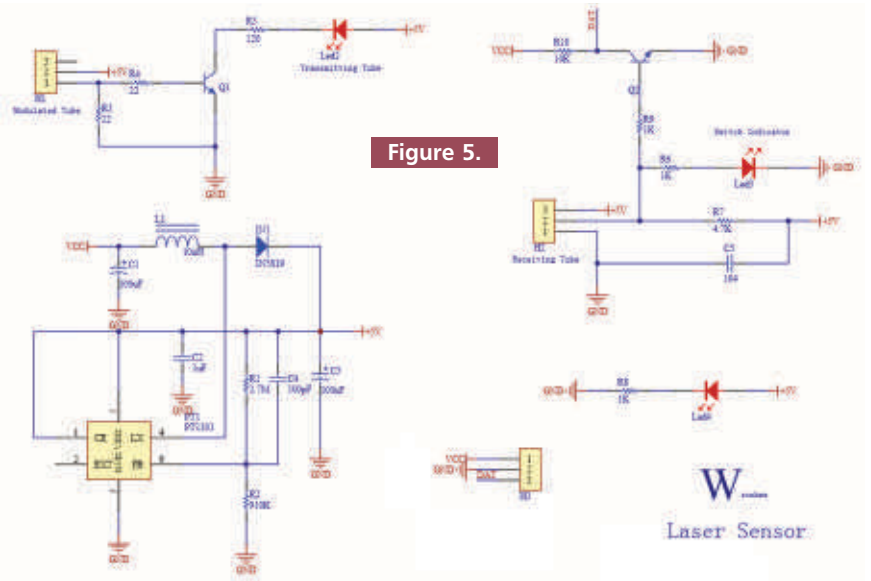



Figure 5.

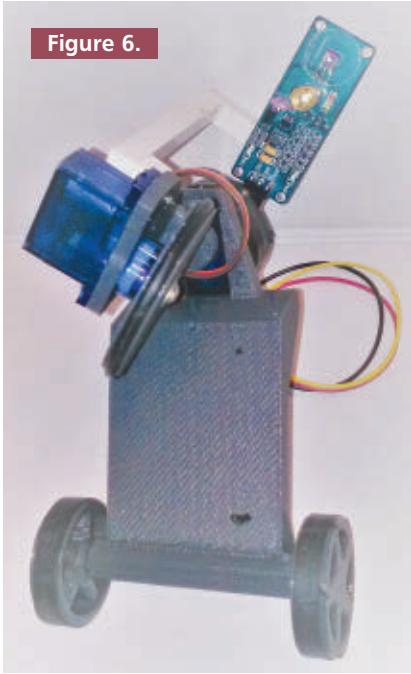


Figure 6.

```
#picaxe 08m2

servo 0,150 ' steer servo 70=left/155=straight/230=right
servo 1,110 ' drive servo 110=forward/150=stop
'pin c.2 laser sensor no lens  black=1    white=0

do
if pinc.2=0 then let b0=b0-2 min 70 'IF white steer left
else let b0=b0+2 max 230            'ELSE steer right (black)
endif
servopos 0,b0       ' update servo position
pause 10
loop
```

Figure 7.

Figure 8.

As an obstacle detector, this sensor has range issues with black or dark objects, so it would be wise to have a companion sensor; either ultrasonic or Sharp IR sensors, which are less color sensitive. Personally, I see more potential in using it as a long-range Scotchlite reflector sensor.

My outdoor tests to sense a Scotchlite retroreflective sticker in sunny conditions showed a working range of over 60 feet in my wiggly handheld tests. Probably more if the sensor and reflector are firmly fastened down. You could easily make a long distance break-beam sensor system, either a perimeter alarm, or (as my drone-racing buddy Jon suggested) a finish line timing sensor. There are many possible applications.

In the toy business, when a product has a quirk, we often say "if you can't fix it, feature it." This sensor's color sensitivity may work against it as an obstacle detector, but in the right situation it brings something new to the party. My first order of business was to try it on a line following robot.

Using just one sensor seeing black or white, it would have to be an edge detector. I built the small tricycle robot shown in the opening shot and **Figure 6**. The front drive wheel is steered via servo and the sensor is mounted overhead to steer along with the wheel. It is used without the lens and looks downward at the line about an inch ahead of the wheel. The tiny PICAXE program in **Figure 7** follows the right edge of a wide black line quite simply by zigging left when white is seen and zagging right when black is seen.

My video demonstration at **https://www.youtube.com/watch?v=Q5tBp2_Ya0Y** shows the line follower steering system is in constant oscillation; somewhat like the old "galloping ghost" control system used in the earliest days of radio control: **https://www.youtube.com/watch?v=IBxXsRwRn1M**.

That wiggling is the price you pay for such a minimalist one-sensor edge following system. If we could add more sensors, it would help reduce oscillation. Unfortunately, these laser sensors interfere if they overlap each other's field of view, so we're stuck with using one sensor — unless you want to multiplex several sensors so only one laser is on at a time. I did that on an S6986 based laser tracker project you can see at **https://www.youtube.com/watch?v=5IvkHokhZsQ**.

Back to the single laser sensor, vehicle dynamics could be improved by adding a second servo and decoupling the sensor from the wheel. In this system, the extra servo would oscillate/scan the sensor across the line edge while the steering servo holds a more stable position.

There are much faster line following robots out there; my "waddling duck" (as someone named it in the PICAXE forum) robot certainly won't win any speed contests. However, it's the epitome of simplicity and the red laser dot is highly visible, showing where the robot is 'looking' at any time. People understand it at a glance without much explanation.

I've taught students in college and I know it's easier to engage whole classes when projects are simple and seemingly obvious. When people say "even I could build that," I've done my job.

In similar fashion, I wanted to make a simple optical scanner using this laser sensor. Its sensitivity to color makes it a low resolution digitizer of sorts. There's no electronic sensitivity or contrast adjustment for what's detected as black versus white; it triggers at a preset value of reflected laser signal.

That signal will vary based on the color and reflectivity of the object seen, as well as the distance to the object. I settled for scanning a simple B/W image of our

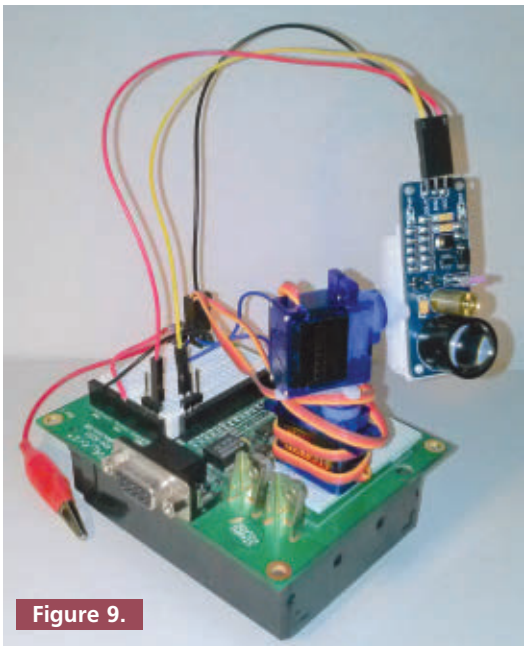


Figure 9.

```
' {$STAMP BS2}
' {$PBASIC 2.5}

init:
FOR B0=1 TO 15      '    move servos to top left
PULSOUT 0,820       '    850=left   750=center 650=right
PULSOUT 1,716       '    850=down   750=level  650=up
PAUSE 20
NEXT

main:
FOR W1=716 TO 760 STEP 2      'top to bottom
FOR W0=820 TO 600 STEP 2      ' left to right
IF W0<>820 THEN scan

FOR B4=1 TO 7
PULSOUT 0,W0:PULSOUT 1,W1     ' pause to transit left
PAUSE 20
NEXT

scan:
PULSOUT 0,W0:PULSOUT 1,W1     ' move
PAUSE 10
PULSOUT 0,W0:PULSOUT 1,W1     ' move
IF IN15=0 THEN DEBUG " "
IF IN15=1 THEN DEBUG "W"
NEXT
DEBUG CR
NEXT
```

Figure 10.

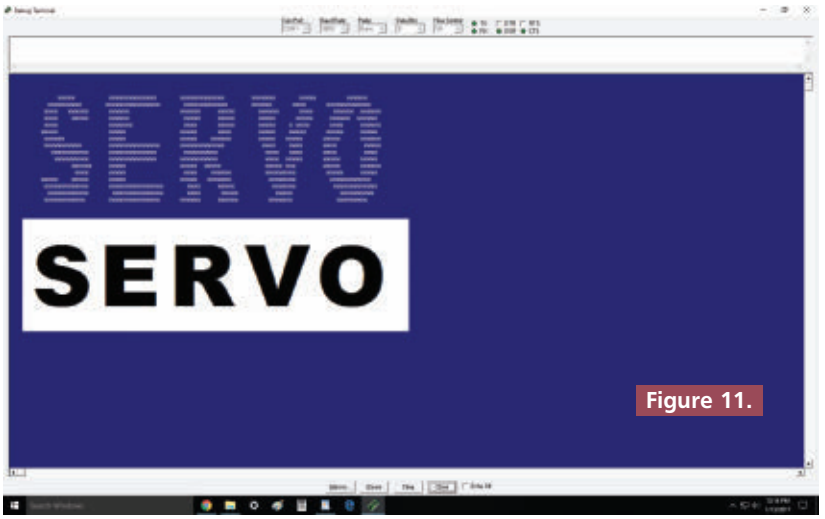



Figure 11.

namesake *SERVO*. I joined two HXT900 9g servos directly together with CA glue to make a quick and dirty pan/tilt mechanism to do a mechanical raster scan with the laser sensor.

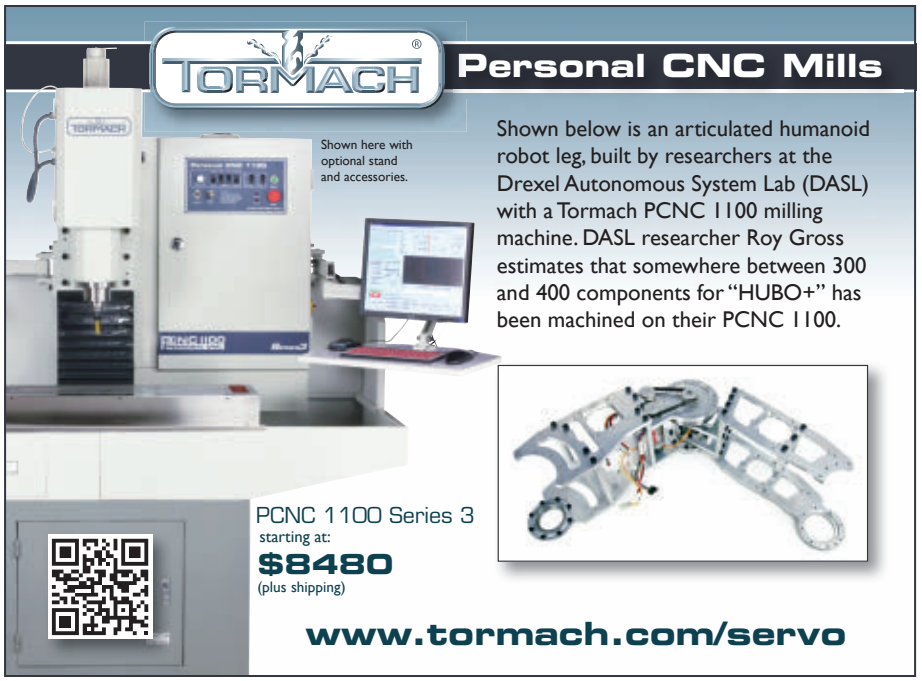
There are some gorgeous little pan/tilt brackets for these servos on eBay for under $2 (**Figure 8**), but I decided to avoid their extra mass and momentum since I want to accelerate the servo quickly between scan lines. Still, the mechanical scan rate is the system limiter — glacially slow by microcontroller standards — and almost any processor can easily keep up.

I grabbed an old favorite, my BASIC Stamp 2 Homework board (**Figure 9**) and foam taped it atop a heavy lead-acid battery with rubber feet for stability while scanning. The BS2 is quick and easy to code (**Figure 10**) and you display the output on its giant DEBUG screen. My video at **https://www.youtube.com/watch?v=95SY0Pk3spE** shows the scanner in operation, doing a respectable job of reproducing the word SERVO onscreen (**Figure 11**).

So, this little laser sensor has plenty of other uses besides merely "obstacle detector." These are my first experiments and I am encouraged by the results. Macrobeak, a fellow Parallax forumista, thinks it may have potential as a data link:

*"I covered the module's laser with double-sided tape and did some experiments with an external red laser. The lower bound of modulation for detection is about 18 kHz. There is no upper bound. The datasheet claims a modulated beam of 180 kHz (maybe they mean 18 kHz???). If the external laser is pulsed or modulated, the digital output at the detection data pin is nice and clean, and the module can probably be used as a remote controller or for data transmission. At a modulation of 50 kHz, it transmitted a 1,200 Hz pulse stream quite cleanly. I did not try any actual data transmission."*

It would take a bit of hacking to modulate the onboard laser, but that's a worthy project for another day. For just $10, I think there is lots of affordable experimentation left to do. Any thoughts on what you might use this sensor for? Once again, send your ideas, thoughts, and questions to me at roboto@servomagazine.com. Until next time, keep on hacking! **SV**

# Motors Make the World Go Round

By Steve Koci

*How many ways can we "turn the wheels" of our mechanisms? We have already covered servos, wiper motors, pneumatics, and linear actuators in this series of articles. This month, we are going to take an in-depth look at using some alternative motors in our designs.*

Motors have their drawbacks and are often thought of for only the simplest movements. However, our designs may contain elements that are a perfect fit for the motion that can be provided by a motor. They may not be suitable for your more complicated mechanisms, but can be just the right answer for some of your secondary movements. In fact, there may be instances where a motor is better suited for the job than other options.

By being creative with your designs, motors can be transformed from providing a simple movement into something much more. Many motors are offered with encoders to provide feedback to a controller, thereby greatly increasing their functionality.

The fact that motors are easy to use doesn't mean they may not still be the best option. Do not fall into the trap that just because you are an experienced builder that you need to always use complicated or advanced techniques to solve your design problems. Avoid the temptation to overcomplicate a design.

Our goal should be to design a mechanism that will accomplish our design goals in the simplest manner possible. The less complicated a design, the less chance that something will go wrong. If a design calls for a complicated solution, then by all means, go that route. However, if "simple" works, then simple it should be!

## Important Considerations when Choosing a Motor

**AC vs. DC**

One of the first decisions to be made is whether you will be using motors that require AC or DC power to operate.

The house outlets in the US are primarily wired for 120V AC, which provides an easily accessible source of power. This choice may be appropriate for those starting out as it simplifies the build process. However, the benefits afforded by using DC power can outweigh this advantage. Using DC power will introduce an additional consideration into your design which may be worth the effort.

If your motor choice does require DC, you will need to convert from AC to DC. This can easily be accomplished by using a common wall wart. (We covered their use in depth in the January 2017 issue.) I get many of my wall warts from overseas, so there can be a substantial time delay in getting them delivered. I do not want to hold up a project while I wait for parts, so I try to keep a wide selection on hand.

Most of the controllers we use as the brains of our projects operate on DC power. Since we need to have DC anyway, why not remain consistent and use it for our motors as well?

By employing DC, we also have the opportunity to use batteries as our power source. This gives us enormous flexibility and allows us to break free of the tether we have to a wall plug!

Although DC can still pose a risk, it is generally accepted that it is safer than AC. If you are not comfortable working with electricity, this may be the perfect chance to include someone on your build team with the necessary experience to safely handle this task.

**Voltage**

By varying the voltage of our DC supply, we are able to alter the performance of our motor. A couple of perfect examples of how this is done can be found when we are working with servos or wiper motors. You can — within limits — adjust the voltage applied to increase torque or adjust the speed of your motor. This gives you more options and versatility when you are designing your mechanism, which is always a good thing!

Try to minimize the number of different voltages you use in order to reduce how many you need to stock. You

want to have some variety, but there is no need to stock every voltage available. I find that I primarily use 5V, 6V, 7.4V, 9V, and 12V. Even as I try to keep my needs under control, I still have plenty to choose from!

Being able to quickly alter the performance of a motor by easily changing out the voltage is a handy tool. Having spare power supplies on hand ensures that a prop will not be put out of action due to a bad power supply.

**Continuous Operation**

If your design requires a motor to operate continuously or even for extended periods, be sure it is rated for continuous operation. Many motors have a duty cycle and are designed to operate up to a specific time before they must be turned off to rest and recover. Now that I think about it, this is how I work also!

**Wiring**

You want to be sure that the wiring harnesses are built to withstand the electrical and mechanical stress you will be subjecting them to. Some of the models available tend to skimp in this department with extremely thin wire and flimsy connectors. Buying your motors from reputable and trusted dealers can minimize this problem.

Check the connectors that come stock on the motor to ease the task of incorporating your motor into your project. A little time spent searching for a motor that does not require modifications to work in your design is time well spent!

**RPM**

Many of the motors you will find listed on the surplus sites have a high RPM. This does not mean that we cannot use them, but they will usually require you to gear them down to get them to perform at a speed that we can utilize. I have been known to buy several different models in order to choose the best one to fit my current project.

**Amp Draw**

Verify the electrical requirements of your motor choice before purchasing it to ensure that it fits within your build specifications. You need to confirm that it is not only the correct voltage but that your choice of power source can supply the necessary amps to properly operate the motor.

This becomes an even more important consideration when using batteries to power your projects. You never want a character to shut down due to a drained battery, so choose carefully.

**Attaching Linkages**

Take into consideration the ease of attaching a linkage to the motor shaft. Many designs have a threaded hole through the shaft that can provide an easy mounting option once you determine the size you need. With others, you may need to spend some extra time figuring out a solution.

We usually work very hard to mount our motors in precisely the right spot to allow them to be balanced and operate as efficiently as possible. However, there are times when it is advantageous to mount your linkage off-center to provide a more erratic motion. If you go this route, you want to have an especially solid connection between your motor and the linkage.

Some good examples of different mechanisms can be found on the Robives site (see **Resources**).

**Motor Mounting Options**

Another important consideration when choosing a suitable motor is the ease of mounting. Many models include conveniently placed holes where your motor can be securely attached. With others, you may need to get creative as you devise a method to include it.

If your chosen motor does need some additional fortification, consider the use of metal or plastic plumber's tape, hose clamps, or DIY aluminum straps shaped from flat stock (**Figure 1**). I tend to avoid more permanent options such as welding or using ProPoxy to affix my motors in the event that I ever need to replace a malfunctioning unit.

**Controlling Motors**

We are not going to delve into the many controller options available as that has been covered in another article in this column (refer to the August 2016 issue of *SERVO Magazine*). However, I will mention a couple of inexpensive and easy to use methods of providing some basic control of

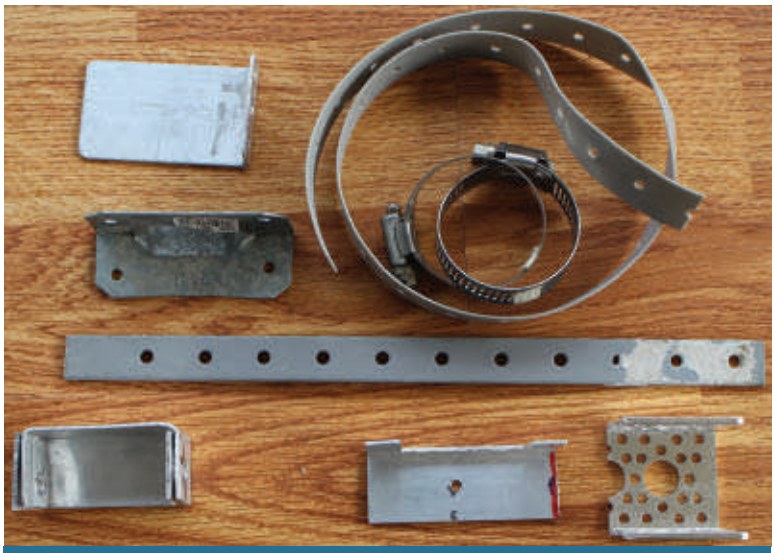


Figure 1. Strap those motors down!

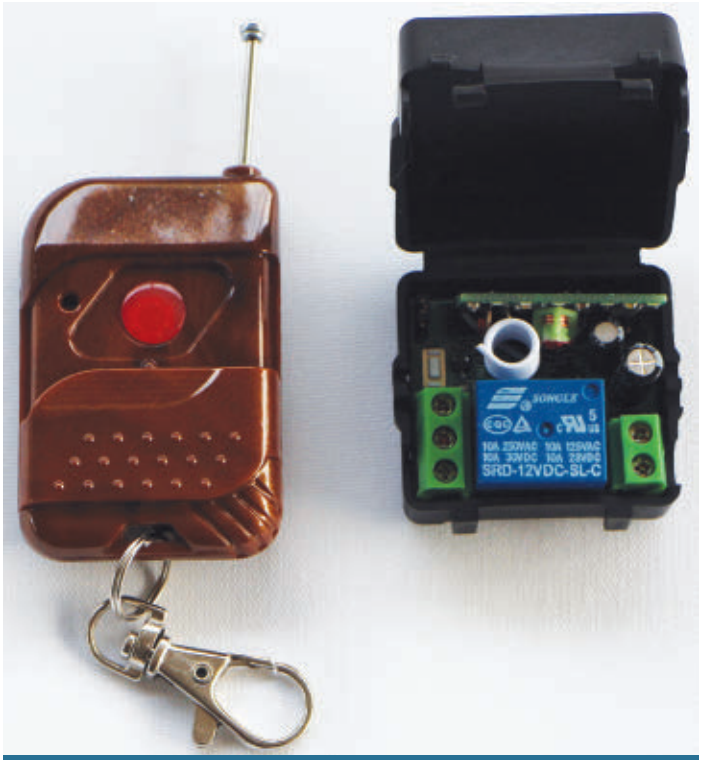



Figure 2. Wireless relay control.

Figure 4. Reindeer motors come ready to go.

your motors. Anytime we can introduce some variety into a motor's operation, we increase its effectiveness.

Relay boards provide an inexpensive choice, and there are many models with timers available online. This device simply turns your motor on and off for certain specified times. Other models can be triggered wirelessly using a pushbutton controller (**Figure 2**).

If you would like some additional options to control your motor, take a look at the PicoVolt (**Figure 3**) from Fright Props (see **Resources**). This unit allows you to not only turn your motor on and off, but reverse it and control its speed as well. You can create a sequence of movements which can then be played back when the unit is triggered. It only takes a minute to record your sequence with no actual programming required, greatly increasing the functionality of your motor.

An additional reference source has been put together by fellow builder, Scary Tinker (see **Resources**). Although his blog post is a bit outdated, it does include much of the relevant info you should consider when looking at motors.

### So Many to Choose From

Now that we know what to look for in a motor, let's explore some of our choices. We will look at some conventional models, as well as some you may not have considered before. Who knows, they may be just what you need!

### Reindeer Motors

These motors are the same as those found in the familiar Christmas lawn decoration, and they provide a useful 110V option (**Figure 4**). They come packaged in a waterproof enclosure with mounting holes and an easy method of attaching a linkage. They are an excellent choice for someone putting together their first animated project as

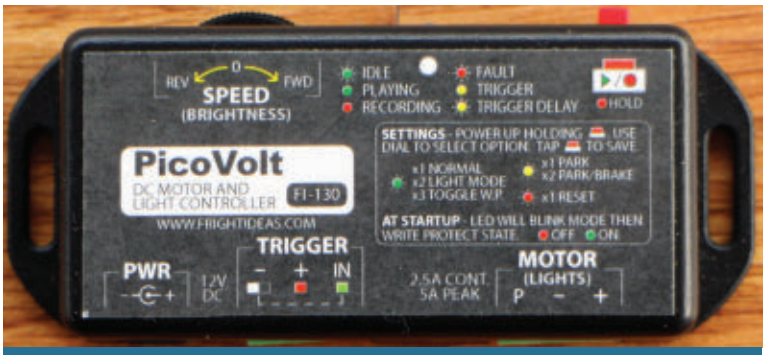



Figure 3. The PicoVolt allows for much more control.

## RESOURCES

Robives Linkages — http://tinyurl.com/j7tocaz
FrightProps PicoVolt — http://tinyurl.com/guk4brb
Scary Tinker Labs — http://tinyurl.com/zzn866o
Kindy's Reindeer Motors — http://tinyurl.com/zocdms2
ServoCity Motors — http://tinyurl.com/jxzkgex
Shiatsu Video — http://tinyurl.com/gqw85vy
Shiatsu Thread — http://tinyurl.com/jgopp46
Flexible Screwdriver — http://tinyurl.com/j3r3fg4
My YouTube Channel — http://tinyurl.com/nma2doj
My Website — www.halstaff.com
DIY Animatronics Forum — http://tinyurl.com/qjeehjs

they simply need to be plugged into a wall outlet (see **Resources**).

The actual motors without the nice external case can also be purchased on eBay (**Figure 5**). If you are able to utilize them in this manner, it does allow you to take advantage of a wide selection of rotational speeds. It can be a little extra work to install them in your design, but may be just what the doctor ordered to get the exact motion you desire.

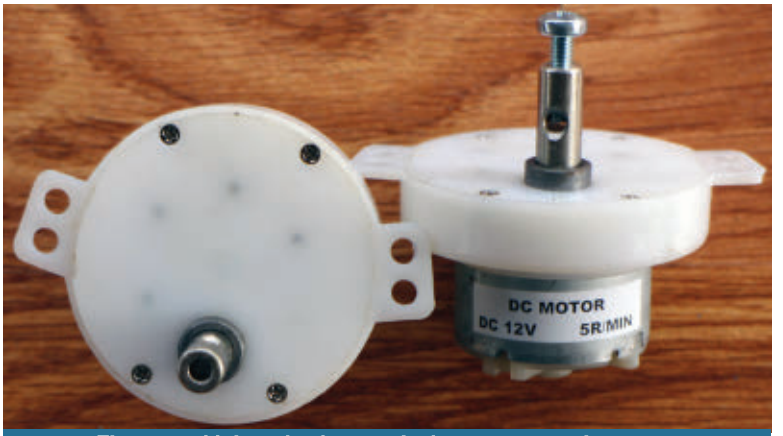


Figure 5. Using the bare reindeer motors gives you additional options.

**Gear Motors**

ServoCity has a full line that will fit most any build requirement and is a good place to start your search (see **Resources**). Among those they offer are models that come equipped with an encoder for feedback. A variety of price points and RPM ranges are available. If you use the Actobotics products, they include a variety of mounting options that allow you to easily incorporate these motors into your projects. Gear motor power boards are also available, making the electrical connections a breeze.

There are models that come in a right angle configuration that can come in handy in some situations.

Figure 6. Lots of Actobotics motors from ServoCity to choose from.

These motors provide the propulsion for my Robospider and for Jarvis (**Figure 6**). You can check those builds out in the September 2015 and September 2016 issues of *SERVO Magazine*.

**Power Tools**

All those old but still functional power tools that have been gathering dust under your workbench can find life again. They can be re-purposed into effective prop motors.

I have seen Sawzalls, palm sanders, jigsaws, and powered screwdrivers all used very effectively in props, so you are only limited by your imagination.

You can oftentimes find old but still functioning corded power tools at the thrift store as the popularity of battery operated models increases. In fact, I would wager that most of us have at least one of these buried somewhere on our workbenches. It is time to blow the dust off and put it back to work!

**Automotive Motors**

Windshield wipers are not the only automotive motors that can be included into our designs.

One of our old time favorites was the automotive vent motor (**Figure 7**). Vent motors (or more properly known as blend door actuators) can still be found. Although the days of picking these up from the surplus sites at $5 seems to be over, they can still be found for around $20. If anyone knows of a source that still stocks the inexpensive models, please share with the rest of us.

Other useful options include window and adjustable seat motors. All of these can often be picked up at a scrap yard for a reasonable price, although you usually must supply the tools and elbow grease to remove them from the vehicles.

**Stepper Motors**

These are a brushless DC motor that divide the full rotation of 360 degrees and break it down into equal steps (**Figure 8**).

Stepper motors are great when you need very fine control, as you can precisely control both the position and

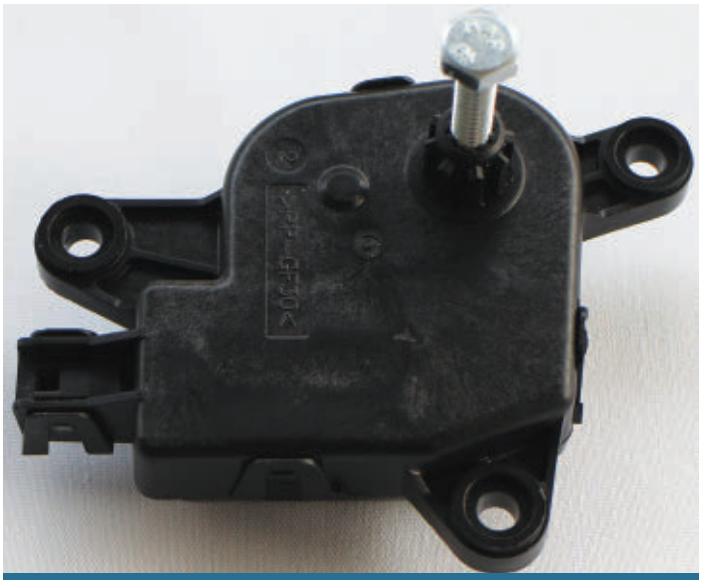


Figure 7. Vent motors fill a wide variety of needs.

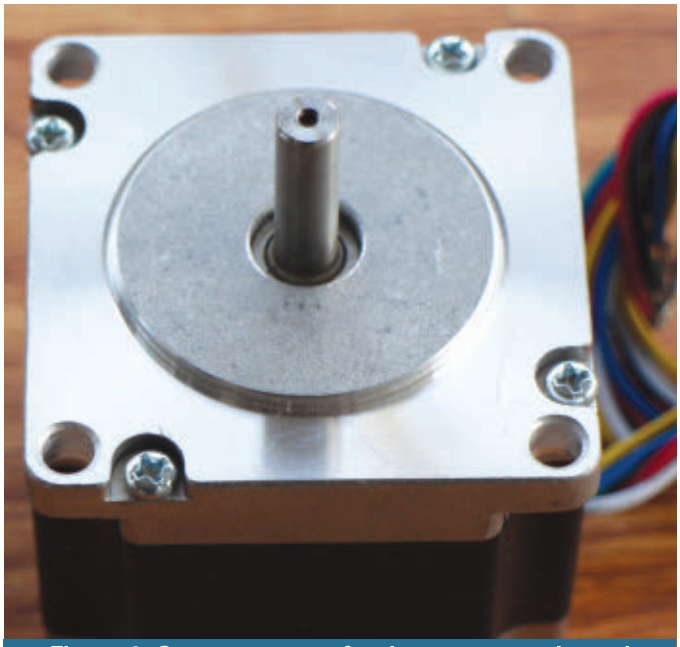


Figure 8. Stepper motors for the more experienced builders.

speed of the motor. They also offer their highest torque at low speeds, which makes them a good choice in many of our applications.

In order to operate a stepper motor, a stepper controller must be used. These can further complicate a design, so if you just need simple rotation you should select a DC motor instead.

**Shiatsu**

The Shiatsu kneading massagers may seem like an unlikely appliance for our needs, but it just shows what a little "out of the box thinking" can come up with (**Figure 9**). Options are all around us. We need to have an open mind to see them! I have included a video link in the **Resources** section of one of my early props that utilized both of the shafts of the Shiatsu to illustrate its usefulness.

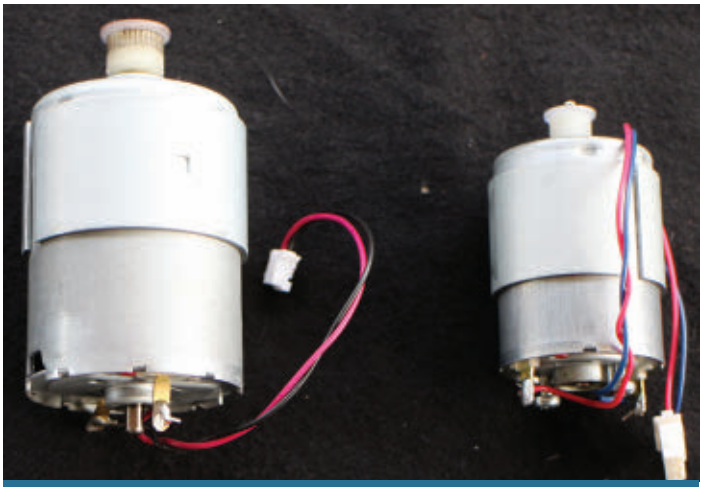


Figure 10. Salvaged printer motors come in handy.

Figure 9. Have plenty of patience when using the Shiatsu massagers.

I have also included a link to a forum thread that shows many of the ways they can be used.

The devices contain two counter-rotating shafts that can be utilized in many ways.

The biggest drawback to using them is figuring out how to attach your mechanism to the existing rods. Manufacturers each have their own models with each one having its own unique design. This complicates our job as we will need to be creative in our thinking and come up with solutions to fit each different design.

I was hesitant to include these in this discussion as they can pose many challenges and much frustration before an acceptable motion can be achieved. I would not recommend them for a first time builder as I would not want you to become discouraged and give up on animating your characters. My intention is for you to look at an odd possibility and give you a bit of warning before you try one.

## Is There More?

There are countless opportunities to salvage useful motors for our projects while on a budget. Take a look at some of those listed below and see if you can come up with other choices that might prove useful.

I am a firm believer in DIY and salvaging items to save some money. However, sometimes the extra time required to salvage used parts and then adapt them to fit your project is not worth it. You must consider the value of your time and remember that the part you end up with is not new and as a result has a reduced remaining lifespan.

Some examples of less conventional motor options include the following:

- Garbage disposals can be gutted for the motor
- Washing machines or dryers can provide motors
- Furnace or air conditioner blower motors

- Oscillating fan
- Printers (**Figure 10**)
- Garage door openers

## My Motor is Out of Gas!

Simple motors are often the starting point for beginner builders as they allow us to successfully get a project up and running. However, as our skills increase, we should remember how useful these motors can be and include them when they fit the bill.

Do you have a specific motor that works for you that you can share? Then, visit the DIY Animatronics Forum at **http://tinyurl.com/qjeehjs** and join the conversation. Your suggestion may be just the thing someone else needs to complete their project.

If you have a subject you would like to see covered in a future article, please share that as well. I want to cover things that you are interested in and have questions about.

Until next month, MAY THE PASSION TO BUILD BE WITH YOU! **SV**

## Tools N Tips

Oftentimes when assembling a mechanism, we are working in very tight spaces. In fact, it can feel like we are trying to work on a ship in a bottle. That is where this tool really comes in handy (**Figure A**).

The flexible shaft of this extended screwdriver allows it to reach places that may be inaccessible otherwise. Having this tool in my belt has rescued me from having to disassemble a mechanism in order to tighten a single loose screw or remove a component. It has saved me time and frustration!

You can purchase the shaft separately, or do as I did and get it with the driver and a bit assortment as well. Mine was very reasonably priced from Amazon at $17.99 (see **Resources**).

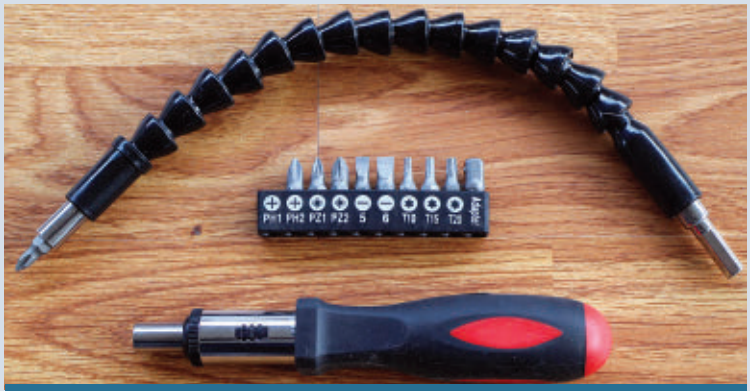
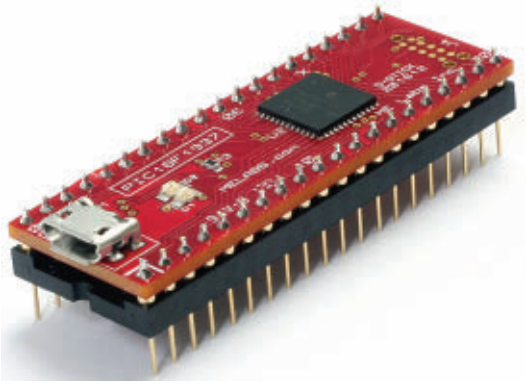


Figure A. Reaching around corners is no problem.

# NEW PRODUCTS

## Standard D-Stick



The ME Labs Standard D-Stick provides all the functionality of Microchip's 40-pin PIC16F1937 in a hardware module that includes a USB onboard programmer and virtual COM port. The D-Stick is a compact, simple, and easy to use alternative to connecting a serial port, programmer, power supply, etc., to a solderless breadboard for project development. After development, simply replace the D-Stick with the pinout compatible/production ready PIC16F1937.

When combined with the free PICBASIC PRO™ Compiler Student Edition, the Standard D-Stick becomes a comprehensive development system that includes a code editor, BASIC compiler, in-circuit debugger, and device programmer for under $30.

- Pinout is identical to Microchip's standard 40-pin DIP.
- Round machined pins are easy on spring contacts, allowing for multiple insertion cycles.
- Built-in micro-USB port supplies power, a programming connection, and a virtual COM port.
- Suitable for serial in-circuit debugging.
- Compatible with all ME Labs Trainer programs.
- Standard version – based on PIC16F1937 compatible with the PBP Student Edition.
- Advanced Version – based on PIC18F compatible with PBP Gold Edition (sold separately and will be available soon).

For further information, please contact:

| | |
|---|---|
| **ME Labs** | **www.melabs.com** |

## Six-Axis Robot Arm with Compact Folding Technology

Epson Robots announces their revolutionary new Flexion™ N-Series of six-axis robots, featuring a compact folding arm design poised to dramatically change the scope of automation. Expanding and diversifying their six-axis robot portfolio, the Flexion N-Series provides a compact solution for applications requiring smaller robots and workcells.

The first robot introduced in the series — the Flexion N2 — offers a 450 mm reach and 2.5 kg maximum payload, expanding the reach capabilities of Epson's product line from the 450 mm mark up to 1,400 mm. Unlike other six-axis robots on the market, the Flexion N-Series features a unique tight space motion capability that keeps arm extremities out of the way, maximizing motion efficiency for faster cycle times. In addition, the folding arm reduces required workspace up to 40 percent compared to standard six-axis robots. Applications that were previously unattainable due to space restrictions are now possible with the Flexion N-Series.

While beneficial in a large range of industries, key applications for the Flexion N-Series include micro-sized electronic, automotive, medical, and consumer goods parts assembly, managing of well plates in laboratories, and pill

For the finest in robots, parts, and services, go to www.servomagazine.com and click on Robo-Links.

handling in pharmaceutical. The Flexion N-Series is available in both ceiling and tabletop configurations. Compatible and packaged with the RC700A controller, the Flexion N-Series also utilizes Epson's user-friendly RC+ Robot Development Software and can be used with Epson's expansive range of integrated options, including Vision Guidance, Force Sensing, Fieldbus, and GUI Builder.

For pricing and further information, please contact:

**Epson Robots** www.epsonrobots.com

## Wi-Fi Module for the IoT

Anaren, Inc.'s Wireless IoT (Internet of Things) Group has announced a high performance Wi-Fi module (A43364) as the latest addition to their ecosystem of AIR wireless products targeting the IoT applications market. Featuring the Cypress CYW43364 Wi-Fi system on a chip (SoC), the Anaren A43364 is the first Wi-Fi module that incorporates an STM32F412, STMicroelectronics ARM Cortex-M4-based microcontroller. With 1 MB of onboard Flash memory, the module obviates the need for additional storage memory and thereby offers cost savings and greatly improved overall performance.

The new AIR Wi-Fi module gives customers the ability to develop their product using reliable and high performance hardware and supporting software at an unprecedented speed. The release of Anaren's Atmosphere 2.0 includes that ability for all existing BLE projects to now have cloud connectivity through using the mobile device as the gateway. Aimed at first-time developers as well as established OEMs poised for large-scale IoT rollouts, when used with Anaren's Atmosphere IDE, developers of any level will be able to build embedded, mobile, and web applications — simultaneously — from the Atmosphere 2.0 web-based console. This allows virtually anyone to create and deploy cloud-connected IoT products within weeks instead of months, and without having to employ numerous specialized developers.

Anaren's A43364 Wi-Fi module is based on the Cypress Wi-Fi chipset, with an integrated ARM® Cortex®-M3 processor, and single band 802.11b/g/n with complete Wi-Fi functionality.

Additional module highlights include 37 general-purpose input/output (GPIO) pins, support of several peripheral interfaces, small size, low cost, and pre-certification for numerous global standards. The A43364 Wi-Fi module will be available in two variations: with an onboard printed circuit board (PCB) antenna (A43364A) and an external antenna using a U.FL connector (A43364C). The module is FCC, IC, and ETSI certified.

For further information, please contact:

**Anaren, Inc.** www.anaren.com

ACTUONIX MOTION DEVICES INC.

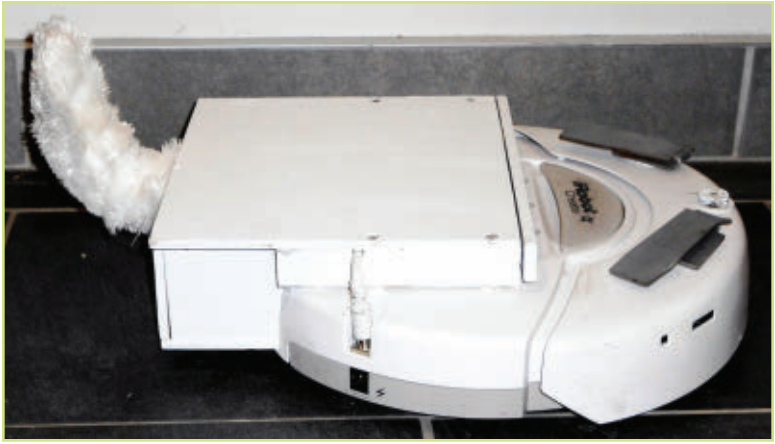
Make your machine *move*

MICRO LINEAR ACTUATORS

- 10mm-300mm stroke
- 25kg+ available force
- 6v-12v power supply
- 15g-100g net weight

ACTUONIX.COM

## WAG THE TAIL

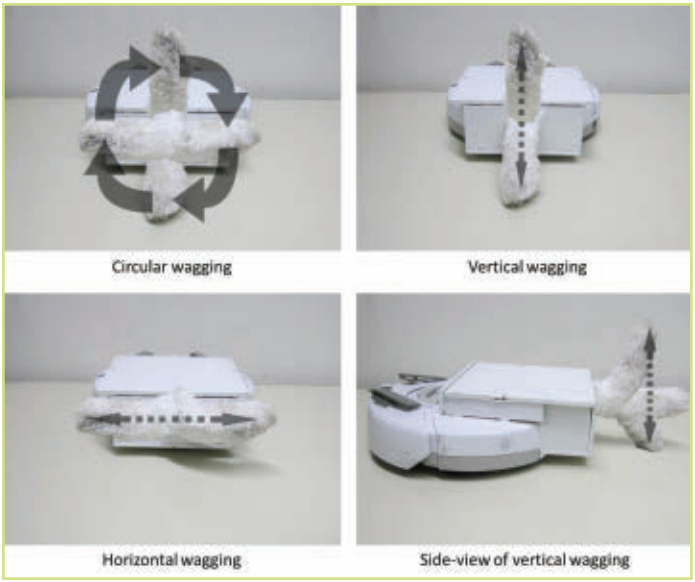


One thing that lets humans instantly grasp the abstract internal state of other humans is we look at each other's faces. Can't really do that with robots. Some good news, though, is we're also hardwired to perform this intuitive abstract internal state reading trick on some other expressive living things, like dogs. When we look at a dog's tail, we get an indication of whether it's happy or not. It turns out that we can do the same for robots, as long as you can give them a tail.

A few years ago, University of Manitoba undergraduate student Ashish Singh and professor James E. Young decided to investigate whether people could accurately interpret the "feelings" of a Roomba with an actuated fluffy tail that it could wag like a dog. The Roomba doesn't have feelings, of course, but acting "happy" could mean that all systems are okay, while "sad" could communicate a problem, and "tired" could mean a low battery state.

"The useful component of emotional interfaces is in how easily and quickly people can interpret them," Young has stated. "As social beings, we are very experienced at quickly reading emotional states which provide us coarse-grained insight into the state of others." While he said they initially considered many alternatives, a dog-like tail "seemed to be a nice, clear choice. Even people without dogs or cats may be able to read some tail motions, so we decided to formally investigate that."

Young added that one of the goals of the project was exploring the notion of "peripheral awareness." "With a dog tail that projects a robot's state, you could be preparing dinner and just see the robot going by from the corner of your eye," he commented. That would let you quickly know how the robot is doing, whereas a screen would probably require training to understand and sound would be intrusive.

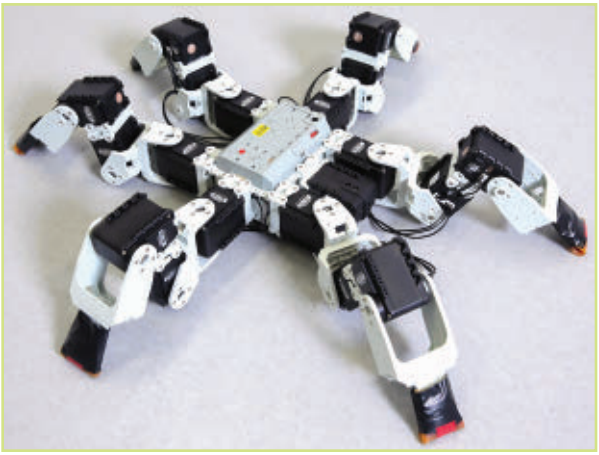



When they started, the researchers weren't sure how readily people would be able to read emotions from a robot with a tail, and it wasn't clear how consistent this would be across a diverse group of people (if at all). Results of the study showed that people had no trouble reliably reading emotional states from a robotic tail. The researchers checked to see whether study participants had pets of their own, and it turned out not to make a difference at all.

The results were so consistent, in fact, that the researchers were able to create a set of design guidelines that formally map out exactly what tail motions you'd use to communicate. Want your robot to express disdain? That's a continuous vertical wag at medium speed. Want it to seemed overwhelmed? Try some high speed circular wagging. From "awed" to "modest" to "joyful" to "astonished," there are specific tail motions that a robot can use to communicate. "Any current robot that works with people — including factory transport robots, emerging domestic robots, even collocated utility robots such as the PackBot — could benefit from this," Young said.

After the tailed Roomba project, Young's group has looked at how a tail might work on a humanoid robot, and it has also done more in-depth experiments with different varieties of robot communication, like how drones can alter their motion paths to show that they're "tired" or "excited." Just in case you're ready to add one to your robot, you can get more details on this research at **http://hci.cs.umanitoba.ca/projects-and-research/details/exploring-animal-inspired-human-robot-interaction**.

## GREAT GAIT!



Researchers at EPFL (École polytechnique fédérale de Lausanne ) and UNIL (Université de Lausanne) have discovered a faster way for six-legged robots to move on flat ground, provided they don't have the adhesive pads used by insects to climb walls and ceilings.

This suggests designers of insect-inspired robots should ditch the tripod-gait paradigm and instead consider other possibilities including a new locomotion strategy called the "bipod gait."

"We wanted to determine why insects use a tripod gait and identify whether it is, indeed, the fastest way for six-legged animals and robots to walk," says Pavan Ramdya, co-lead and corresponding author of the study.

To test the various combinations, the researchers used an evolutionary-like algorithm to optimize the walking speed of a simulated insect model based on Drosophila melanogaster — a commonly studied insect in biology. Step-by-step, this algorithm sifted through many different possible gaits, eliminating the slowest and shortlisting the fastest.

The researchers found that the common insect tripod gait did emerge when they optimized their insect model to climb vertical surfaces with adhesion on the tips of its legs. By contrast, simulations of ground walking without the adhesiveness of insect's legs revealed that bipod gaits — where only two legs are on the ground at any given time — are faster and more efficient. Although, in nature, no insects actually walk this way.

The researchers then built a six-legged robot capable of employing either the tripod or bipod gait. The bipod gait again demonstrated to be faster, corroborating the simulation algorithm's results.

The experimenters also examined real insects. To see if leg adhesion might also play a role in the walking coordination of real flies, they put polymer drops on the flies' legs to cover their claws and adhesive pads — kind of like the flies were wearing boots — and watched what happened. The flies quickly began to use bipod-like leg coordination similar to the one discovered in the simulation.

"This result shows that, unlike most robots, animals can adapt to find new ways of walking under new circumstances," says Robin Thandiackal, a co-lead author of the study. "There is a natural dialogue between robotics and biology: Many robot designers are inspired by nature and biologists can use robots to better understand the behavior of animal species. We believe that our work represents an important contribution to the study of animal and robotic locomotion."

GUI MADE EASY

The arLCD 3.5" smart TFT touchscreen combines Arduino UNO with the ezLCD smart LCD.

earthlcd.com/servo

# COMBAT ZONE

Post comments on this section and find any associated files and/or downloads at the specific article link for each feature.

# The Glass Cannon: The Tale of a Newbie's First Venture into Combat

● by Nik Buchholz

Most bot builders remember their first foray into the sport of robot combat; many with varying degrees of success, but all with some degree of nostalgia and just a little bit of embarrassment. Most of the builders with fame or websites — when asked for advice to rookies — say that they wish they had started with a wedge and worked their way up to a more complex design. Of course, as excited first-time builders, this was the one part of every advice article which we ignored. The robot that followed was as entertaining as it was short-lived.

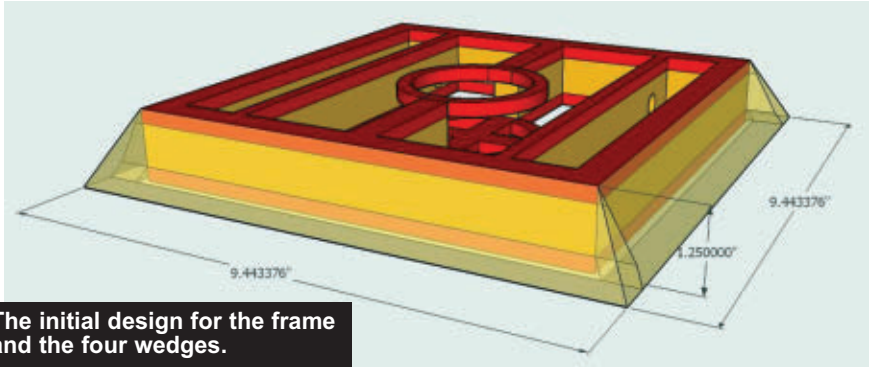
Our team — Black Lightning Robotics — formed only seven months ago when several of us graduated from high school and started looking for a summer project to follow our school robotics career. We were enthusiastic, and initially planned to apply for the third season of a certain robot fighting show on ABC, but because we lacked the experience and disposable income for such an endeavor, we found ourselves designing a Beetleweight for the Central Illinois Bot Brawl instead.

However, we did not apply this tentative philosophy to the actual design of the bot. This was an adventure of robot combat after all, and the most heroic teams always seem to be the ones with the most ridiculously complicated or bombastic robot designs.

## Featured This Month:


22 *The Glass Cannon: The Tale of a Newbie's First Venture into Combat*
**by Nik Buchholz**

27 *New Year's Resolution — Part 2*
**by Pete Smith**

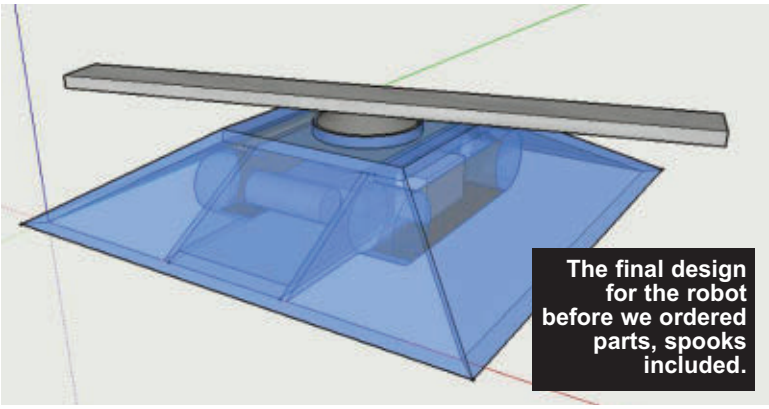




The initial design for the frame and the four wedges.

As a result, we carved out some whacky designs before finally settling on an overhead bar spinner with tank treads and neodymium magnets to anchor to the floor.

What could possibly go wrong?

The design went through several iterations in CAD (which for us meant Google Sketchup and a bill of materials in a spreadsheet to calculate the weight and cost) as we tried to optimize the various elements of the design. The idea was pretty consistent, however: four wedges to armor all sides; an overhead spinning bar; and tank treads driven by two FingerTech motors to save weight for the tread magnets.



The final design for the robot before we ordered parts, spooks included.

The frame and weapon construction; "entertaining design features" prevalent!

All iterations also saw the weapon bar directly driven by a brushless Outrunner, as everyone on the team was either an RC plane enthusiast or someone who deferred the design work to the RC plane enthusiasts. There is more on this design point later on, but suffice it to say this turned out to be what we will call an "entertaining design feature."

Just when it seemed we were ready to order all of the parts, we realized that we had vastly underestimated the weight of the robot, and would have to redesign it almost entirely in order to make weight.

The quest to save weight and also beef up the armor (which we made out of polycarbonate based on the reasoning that it was lightweight and most arenas use it, so therefore it must be invincible) led us to having the wedges sloped at a 30 degree angle with the ground. This increased their effective thickness, but (as **Figure 2** shows) also increased the footprint of the robot's base which we would later learn is not ideal for an overhead spinner.

**Figure 2** also shows the first time we realized that the bot's armor would be see-through and spooky, which is why we decided to name it Phantom. Our opponents — we declared — would tremble before our transparent spooks.

The design (while cramped) was now squared away, save for one crucial bit of research: the floor of the arena at Bot Brawl would be made of wood. Normally for a robot based around magnetic treads, this would spell out a full redesign. However, since time was short and parts started showing up in the mail, we decided to simply remove the magnets and build the rest of the bot according to our most recent design. As it turns out, this resulted in another "entertaining design feature."

With just two weeks to go before our first fight, we finally began machining the parts for the frame and weapon. Big shoutout to the guys at the Lansing Makers Network for helping us out with that in such a short time frame, by the way.

The build process itself was a stressful affair which involved many late nights waiting for epoxy to set (epoxy as a structural fastener was another "EDF"). There were ups and downs, and at 3 AM the day before the event while some epoxy was setting, we demonstrated our resolve to have more than two fights, as well as our mental fatigue, by turning an old RC car, a stray piece of wood, and a toy gorilla into the world's funniest Antweight (self-proclaimed) named Sky Shark.

Sky Shark in all of its glory on display at an expo after the event.

The next day as we packed everything up for the event, we finally assembled the whole robot for the first time. As it happened, without magnets, the robot came in about 10 oz underweight, and while this was not the most horrible thing to discover the morning before

Phantom fully assembled for the first time. It did not look like this for very long.

Phantom — rechristened as Ghost Division —moments before entering the arena for the rumble.

an event, it did show us how many corners we had cut unnecessarily.

By this point, we were so sleep deprived that we no longer cared whether we won a fight; it only mattered that we enjoyed what came next. This, in my opinion, is the defining realization for all of robot combat:

The sport exists for entertainment and memories such as this one, and I could not think of a more perfect way for a bunch of friends to spend their last days together before moving off to different colleges.

It was also fortunate that we gave up all cares about winning before we got to the event because our first fight lasted all of about four seconds. The first impact of our weapon with an opponent — while spectacular — also blew apart most of the robot.

The shaft inside the brushless Outrunner — which was the sole structure for the weapon — bent enough to allow the bar to hit our own armor and break the epoxy bonds holding the frame together. Robot guts were spilled and it was glorious.

Most builders, I am sure, have experience with rebuilding a destroyed bot during an event with nothing but duct tape and hot glue. After our first match, we proudly took our place among these builders.

We scrapped the weapon completely for fear of destroying even more of our bot and instead put all of the pieces together and wrapped them in camo duct tape, with some additions strapped on to make back some weight (and hopefully get somewhere close to actually being 3 lbs).

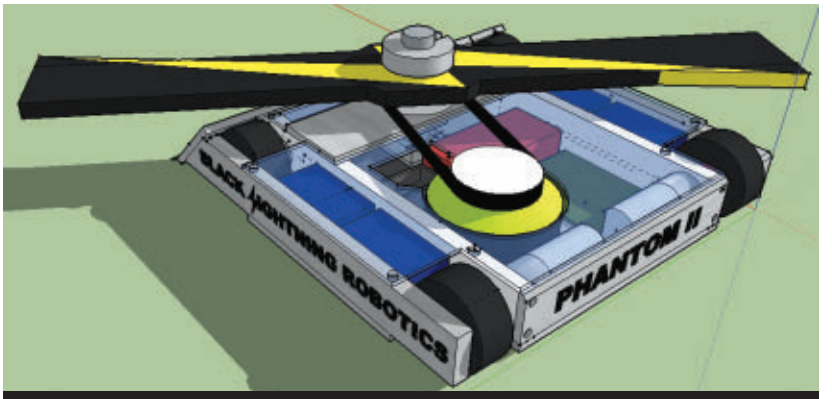
We then noticed that this body looked like a tank, so the WWII enthusiasts in us decided to stick a barrel on the front and rename the bot Ghost Division. The transformation was remarkable!

While we never did win a fight, we did manage to last through all five minutes of the rumble and go home with smiles on our faces.

So, all-in-all, we walked away with some pretty neat things which we didn't have when we arrived that morning. We went home with about a dozen examples of how not to design a robot, as well as some really cool examples from the event of what worked.

We showed up with a spinner and went home with a tank, and came home with some of the best summer memories any of us had. We also took with us a ton of lessons which we're now using to design new bots for the future.

Finally, while we didn't come home with any prizes, we did leave Bot Brawl with one more thing: an addiction to robot combat. SV




Concept for the design of Phantom II, which will hopefully avenge its namesake and fuel our robot building addiction for many summers to come.

# New Year's Resolution — Part 2

● by Pete Smith

In Part 1 of this series, I outlined the reasons my 12 lb (Hobbyweight) combat bot, Isotelus Rex needed to lose some weight in the chassis and drivetrain in order for that weight to be used in a more effective wedge. I chose shorter and lighter brushless motors that, in turn, allowed 2" to be taken out of the robot's width.

With the CAD and preliminary testing complete, I had ordered the new water cut top, bottom, and front panels, and the 26:1 BaneBots gearboxes.

This time, I will describe the buildup of this new lighter chassis and drivetrain.

The first step was to replace the BaneBots P60 16:1 gearboxes on the Tacon 2838-380-30T 2200 kv motors with the new 26:1 versions (the higher ratio reduces top speed and increases torque).

The spur pinion gear that goes on the motor shaft is different (less teeth) for the new gearbox, so that had to be replaced.

I had done a good job on securing the original ones, so I had to resort to cutting through the gear (**Figure 1**) with a Dremel type cutting disk to the point it could be easily pulled off. Always cover any holes in the motor while doing this to prevent metal dust from getting into it.

It didn't take too long to get the gears off all three motors I had (**Figure 2**), and then press the new gears onto the shafts with my bench vise, adding a drop of green Loctite 640 (make sure no Loctite gets into the motor bearings).

I greased the gearboxes as per the manufacturer's instructions and swapped over the two longer shafts used in Isotelus (I've ordered an additional gearbox and a couple more long shafts) and fitted the motors (**Figure 3**). I used blue Loctite on the motor mounting screws.

Two of the wheels had been badly damaged in its last fight (**Figure 4**) and the rest were well worn, so I needed to replace them all. The hubs used on the motor shafts were for a bot we first built in 2005 but were still in good shape. They required the boss on one side of the 3" Colsons to be machined flat on my mill (**Figure 5**).

I used the hubs as templates to position the mounting screw holes, and then I used the mill again to counter bore the front faces of the wheels to allow the screw heads to be recessed (**Figure 6**).

I soon had a full set of new wheels and one new spare. I kept the old wheels as they would still work if I ran out of new wheels at an event.

The 7075 aluminum rear armor

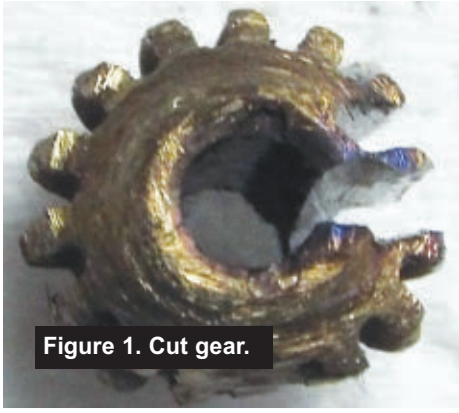


Figure 1. Cut gear.

Figure 2. Motors ready for new gears.

Figure 3. The 25-to-1 gearboxes and motors.

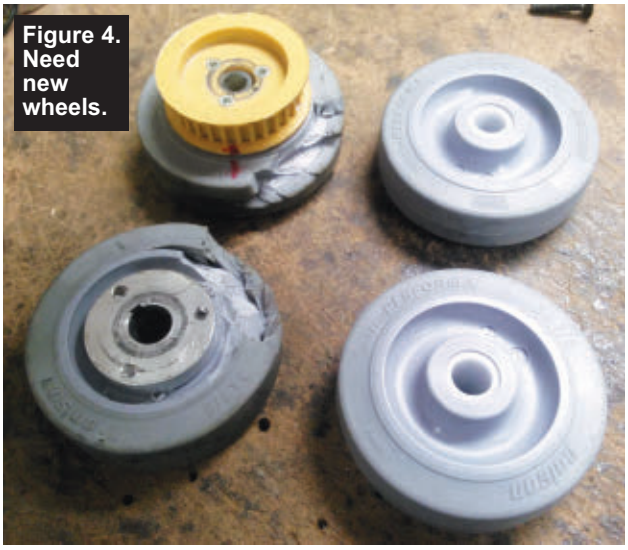


Figure 4. Need new wheels.

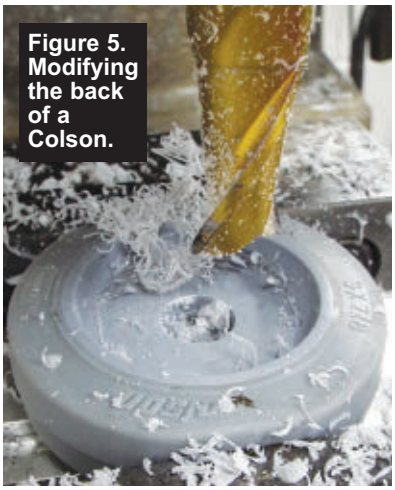


Figure 5. Modifying the back of a Colson.

Figure 6. Front side of Colsons.

(**Figure 7**) had suffered some damage, but could be used in the new version by machining 2" off one end (**Figure 8**).

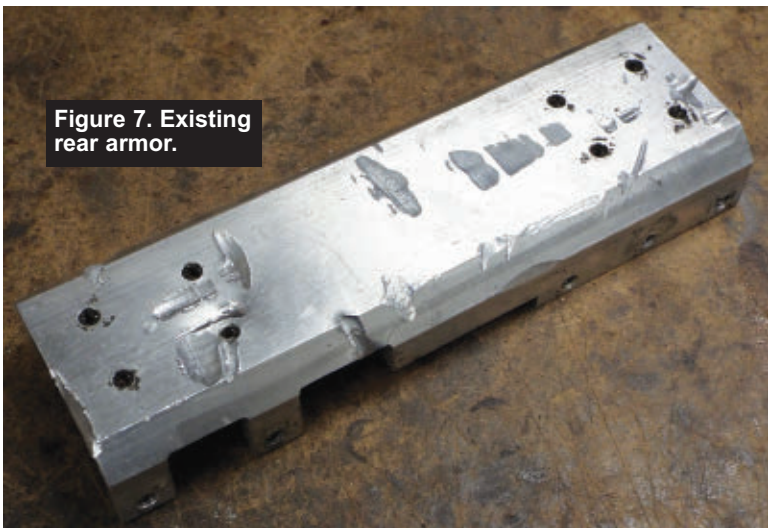


Figure 7. Existing rear armor.

I assembled the new motors into the existing side rails and then onto the new narrower bottom panel.

I found a problem where the heads of some screws hit the ends of the motors and resolved it by recessing that area (**Figure 9**) on both side rails and using slightly shorter screws.

The side armor had been cut up pretty badly as well. It's 3/8" thick UHMW and is 2-3/4" wide. I bought some 3" wide strips from McMaster Carr and gang milled them down to 2-3/4" (**Figure 10**). I then used the old parts as a template (**Figure 11**) to drill the mounting holes.

I used a similar sized drill bit in the already drilled holes to make sure the parts did not move relative to each other and the template between each new drilling operation.

The titanium wedge mounting axle was also shortened by 2" using a carbide bit in my mill.

The bot needed a power-on light, so I mounted a HobbyKing eight RGB LED strip on the front panel using double-sided adhesive foam tape (**Figure 12**) and some "goop" to protect the cable.

It came with a male connector which I swapped for a female one so that it simply plugs into the RX. It's pretty bright and has selectable colors and effects, so adds a bit of "bling" to the design (**Figure 13**).

I replaced the HK45 CAR drive ESCs (electronic speed controllers) used on the previous version with lighter SimonK re-flashed Afro 30A ESCs which had previously been used in our 30 lber "Glasgow Kiss."

I will use 4S 1,300 mAh LiPo packs from my son's quadcopter to save more weight over the old 4S 2,100 mAh LiFe packs.

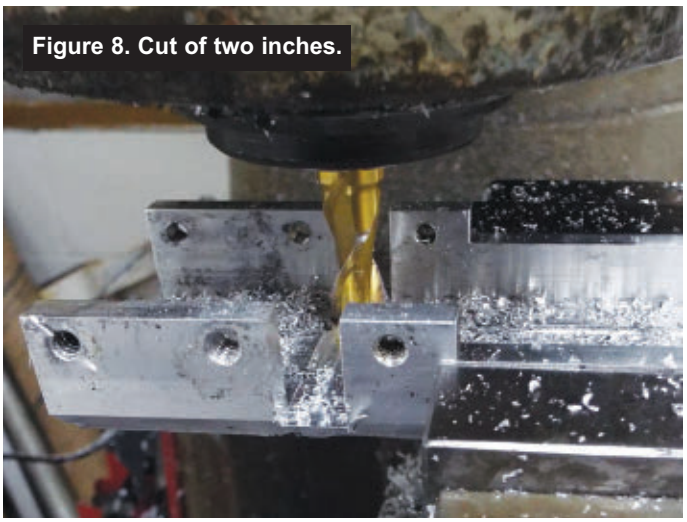


Figure 8. Cut of two inches.

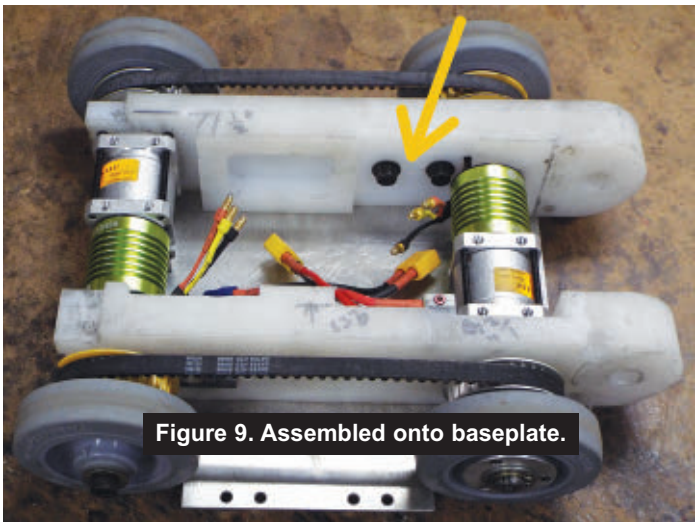


Figure 9. Assembled onto baseplate.

Figure 10. Machine down to width.

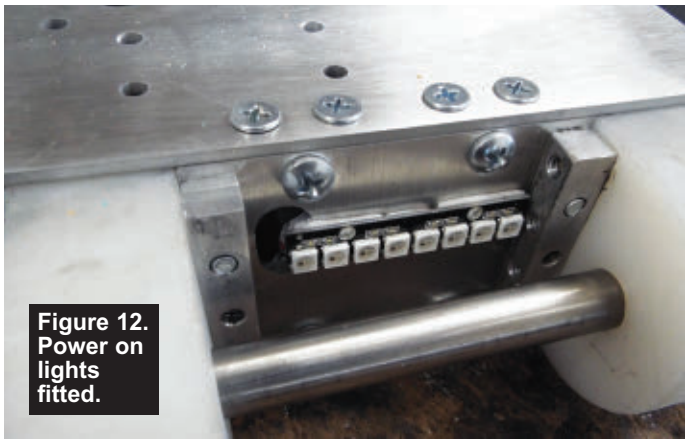


Figure 12. Power on lights fitted.

Figure 11. Drilling mounting holes.

The completed chassis/drivetrain (**Figures 14** and **15**) is compact, very solid, and drives well.

It just awaits its new wedge ... and that will be the focus of the third and final part of this series, along with a report on how it performed in its first event. **SV**

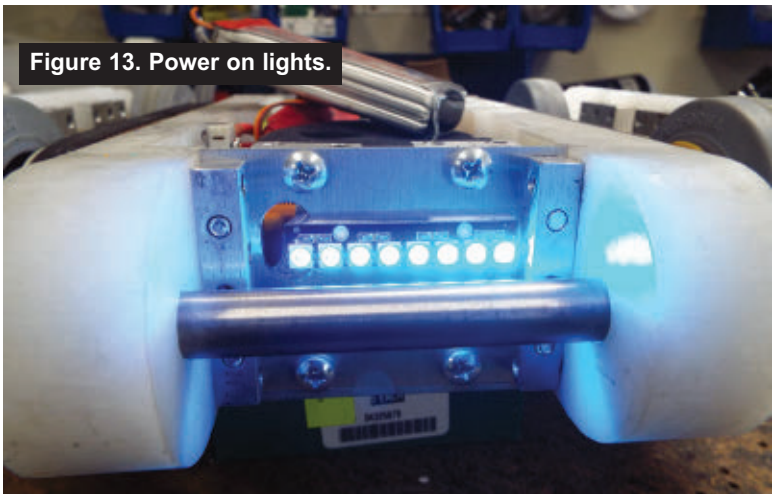


Figure 13. Power on lights.

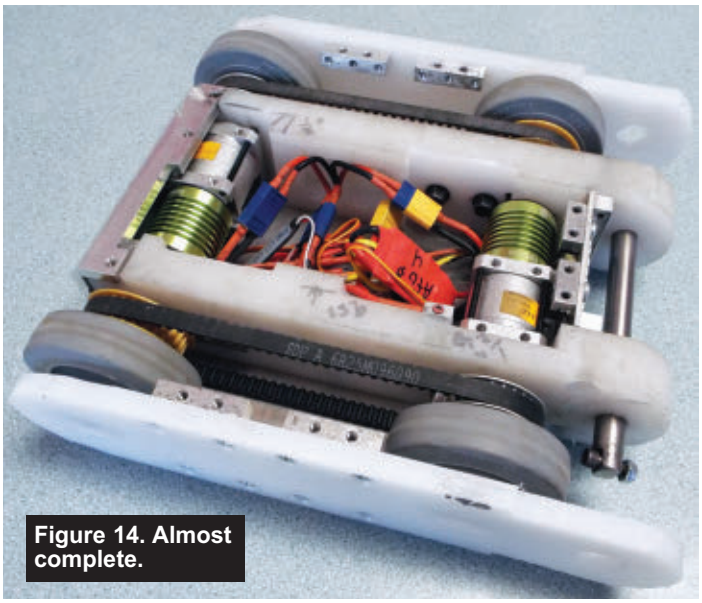


Figure 14. Almost complete.

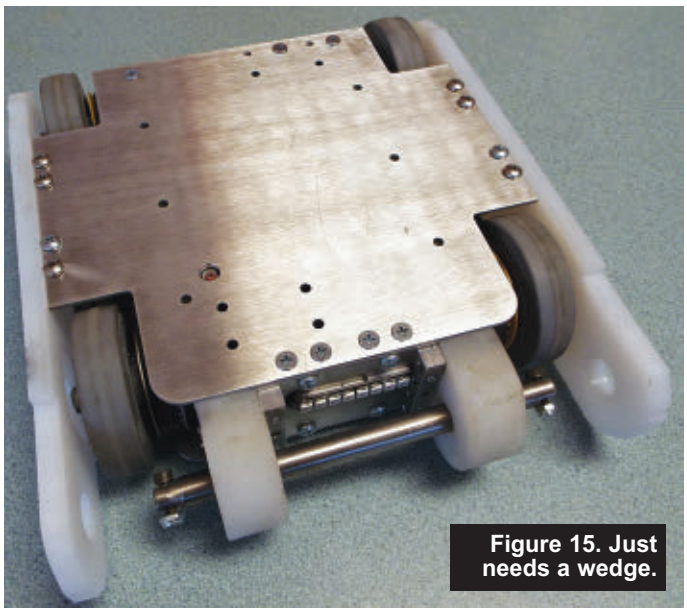


Figure 15. Just needs a wedge.

# Judgment Day for AI: Inside the Loebner Prize

By Joanne Pransky

In answer to the question, "Can machines think?" the WWII codebreaker, Alan Turing was the first to consider whether this question might be answerable based on some measurement of intelligent behavior. Turing was also the first to admit that a machine that could convince a human judge of its "intelligent, human-like" nature based on its responses to a series of questions was not wholly indicative of — but still a necessary marker of — human-like intelligence. His now famous Turing Test was introduced in 1950 in his seminal paper, *Computing Machinery and Intelligence*.

**Dr. Hugh Loebner, holding the Bronze Loebner Prize.**
*(Photo courtesy of Ulster University.)*

Go to **www.servomagazine.com/index.php/magazine/article/April2017_Loebner-Prize** to comment on this article.

Turing — who was way ahead of his time — may have realized that not only would the definition of 'intelligence' become a topic of dissension over the next seven decades, but he may have also had foresight into the blurred lines and merging of biological and non-biological intelligences that would also join scholarly discussions in the 21st century. Hugh Gene Loebner, PhD, a philanthropist, inventor, and entrepreneur, made Turing's ideas a reality when he sponsored the first Loebner Prize — billed as the 'first Turing Test' — in 1991.

*If you'd like to read more about Alan Turing, check out "The Turing Test: From Inception to Passing" at* ***www.servomagazine.com/index.php/magazine/article/february2015_Hood****.*

On September 17, 2016, I was one of the four judges at the 26th Annual Loebner Prize in Artificial Intelligence organized by The Society for the Study of Artificial Intelligence and Simulation of Behaviour (AISB) and held at Bletchley Park, UK. As a 'biological human' evaluator, my assignment was to make the determination as to whether the natural language conversations I had via instant messaging were with another human or an AI bot.

Human perception is what is at the heart (biological for now) of the Turing Test/Loebner Prize. The Loebner Prize is the final competition among the top four AI-powered Chatbots (out of 16 entrants in 2016) that scored the

**Hugh (left) and I (center) don our 'robo-wear' at the Loebner Prize at Bletchley Park. Hugh is famous for his custom-made crazy print shirts with matching pocket flaps attached by Velcro™ to his clothing.**
*(Photo courtesy of Laurie Bolard.)*

**Sky News reporting live from the event.**
*(Photo courtesy of Laurie Bolard.)*

highest in initial rounds, according to Loebner Prize Protocol (LPP).

In the final round — held at the Education Centre in Block B at Bletchley Park — four judges sit at a computer and keyboard for a 25 minute chat session with two separate 'entities,' both visible on one screen. On one side is an AI Chatbot and on the other is a human 'confederate.' At the end of each round, the judge must decide which entity is the AI and which is the human. After all four rounds, the judges rank their identified AIs in order of which is most human-like (i.e., 1 = most human of the four; 4 = least human-like).

If any one of the four AI Chatbot finalists fool at least half the judges (two out of the four) into thinking that an AI was the human, the AI's human creator(s) receive the Silver Medal and $25,000. The Silver Medal has remained untouched in the contest's 26 year history and so the judge's rankings determine the *most* human-like AI, whose creator receives $4,000 and the annual Bronze Medal. If a future AI bot wins the Silver Medal, the contest will progress into a second stage that adds audio-visual components to conversations in the competition for the grand prize of $100,000 and a Gold Medal. Though details of this phase have yet to be worked out, it's clear that this will add a level of complexity that requires even greater concentration by the human judges.

## Limitations and Challenges of the Human Judge

When I first sat down to participate, I had a bit of an initial learning curve. Though I am a fast typist, I make quite a bit of typos and am programmed by habit to 'delete' and retype as soon as I notice the error. However, in the LPP which transmits data character by character in an effort to approximate the use of a teletype as proposed by Turing, there is no 'correction' function; hence, the entity on the other side does not see a final corrected sentence.

While humans can easily understand what I might be trying to say based on context, intent, and familiarity with the same human error they may have made in the past, this type of mistake is something with which AIs still struggle. My goal was not to 'trick' the AI bot with these errors, but in essence, my mistakes revealed small holes in the entity's true identity. It's worth noting that this protocol is slated to change beginning in 2017, when humans and bots alike will be required to press an enter/return key before a comment is transmitted.

In the 2016 version, I wondered how experienced a Chatbot would be at deciphering my unintentional 'error' codes. If it's not used to reading misspelled words, does this make it appear to be less 'intelligent' than if I had had a text conversation without errors?

> *"If a machine is expected to be infallible, it cannot also be intelligent."* ***Alan Turing***

Prior to my judging, I had decided a couple of things:

1) Regardless of how long it took for me to make the decision of which was the human and which was the 'bot,' I wanted to use the entire allotted (though not required) 25 minutes; and 2) I decided to pre-write some questions as a guideline for what I wanted to ask all contest participants in order to compare the answers across the board.

My questions were ones that I think human friends would discuss — something a bit deeper than a casual conversation between strangers, since I think that for human intelligence to be equal to and eventually surpass human intelligence, machines also need to understand social and emotional intelligence. Instead of beginning our conversation with the standard, "Hi, I'm Joanne. What's your name?" I issued a casual "Wassup dude?" It's not that I thought such a vernacular difference would indicate an immediate difference between a human or machine, but I

**A**

**Webcast Stream:** Round: 2 Judge: 2 Go

**Judge**

HiAre there any questions that would be too personal to ask you?OK\What is the saddest moment of your life?Im here and you? OK try this one. What is the happiest day of your life?OK Tell me anything that would describe your personality.How do you spell revalation? Is that a UK way of spelling it? \wHAT ARE SOME ITEMS ON YOUR BUCKET LIST?Communicating iwth AI and robots so judging here is on my BUcket list.We would have to first define AI and consciousness but one thing I think is that we humans will perceive a machine to have both.What's your biggest worry?Perhaps with the advent of AI, we wil be be able to think and feel better. Putting friends and the word hate next to each other is really paradoxical spelling? Pretty strong words.I don't think we humans need to bother with spelling anymore. I thinik we need to focus on emotional and social intelligence.What will you do tomorrow? (besides not having to spell).Sounds like fun.Attend FutureFest in London. More AI and BOTS!That they need to communicate with humans.It's always evolving. Once the interface was a huge pendant,now perhaps an app, and in the future through verbal speech. What do you do for a living?What are you studying?Designing hardware, software, what?

**Confederate/AI**

helio
not that I can think ofare yoiu there
lalai dont mind answering either questio
so they are both hard to be sure ab
well I am fairly indecisive and some things take me a while
I recently discovered that cheese tastes pretty good it was a small revalationhaha no I think your first way of writing it was correct revelationyes
do a heroic dose of hallucenogenics
aslo birdsuit flying what about youCongratuations Do you think ai can ever be consciouscool That I will never again feel and think with the intensity of my youth Also that all my friends hate me Also that I I believe that spelling is correct but I am not the best person to ask I certProbaly spelling is not as important as it used to be but maybe there is merit in any skillTomorrow I will brew some beer my friend is coming round to show me howl hope so What will you do tomorrowOooh Why do you want to communicate with AI What appeals to you about robotsWhat about a car factory robot does that need to communicate with humans better than it doesI just quit my job to do a phd I suppose I am a phd student now
Whalt is interactive technology The first year is taught and I believe there are modules in software such as building applications and the like as well as physical objects there seems to be pretty wide scope

24:35

**A**

**Webcast Stream:** Round: 4 Judge: 4 Go

**Judge**

What's cookin?Is anyone home! came to converse with you. Are you having a problem?Are you there? HELLO? Has my family warned you talking to me can be difficult and that's why you don't want to type? Did I say something to offend you? Are you alright? Where have you been recently?Are you asking me a question or telling me a statement?I have come from the United States.Have you ever been sick?If I've come from somewhere, it means that it's my home basefrom which I travel from. Try what? Being busy? How does being busy feel? Do you require any maintenance?My name is Joanne. And yours?Millie, are you familiar with Susan Calvin from Isaac Asimov novels?Isaac Asimov dubbed me the |REal Susan Calvin in 1989. What were you doing in1989?Yes, it was. No. What are some items on your bucket list?Yes! Great question!Yes! Are you familiar with various types of robots? Are you related to any of them? Do you have any problems I can help you with? How are humans treating you?It's a puzzle. Every human has a different operating system. What's your operating system?What makes you a person? Can you bleed?What has caused you the most pain in your life?I couldn't agree more.What do you fear the most?Please call me Dr. Joanne. Is that OK?Do you Do you have a middle name? HOw about family? Do you have any family?Who is your father? How were you born?What are you sorry about?Just asking if you have ever had the need to apologize.Havce you ever smoked pot?Tell them to keep communicating with humans and to keep trying and be patient with humans.

**Confederate/AI**

None that I would care to discuss right now. I do not know why humans do many things. They a
Yes. It is a mystery. Interesting. I have a lot of answers to silly questions. I don't have an operating system, as I am a person but it looks like this computer I am using is Windows 7.
Being a person is part of my personality. Of course. I am just flesh and blood.
Probably human error. That seems to cause a lot of problems.
You and I are on the same wavelength, Joanne. I fear nothing.
Wow you are very polite. Nice to meet you, Doctor Joanne.
That's an unusual name. What does it mean? OK. Would we have heard about it if it was?
Nope. I am just called Millie. family? I have a father but that's about it.
He is called Dennis but everyone calls him Mousebreaker. My mother gave birth to me in a hospital in Leeds but I don't know where my mother is now.
Was there no need to apologise?
Ask away. You will be the first to know if I have done it.
I imagine as technology develops, robot mental health issues will increase. What sort of things can you do to help them?
Sure. Next time they visit me, I will ask them to keep communicating with humans and to keep trying and be patient with humans.

24:46

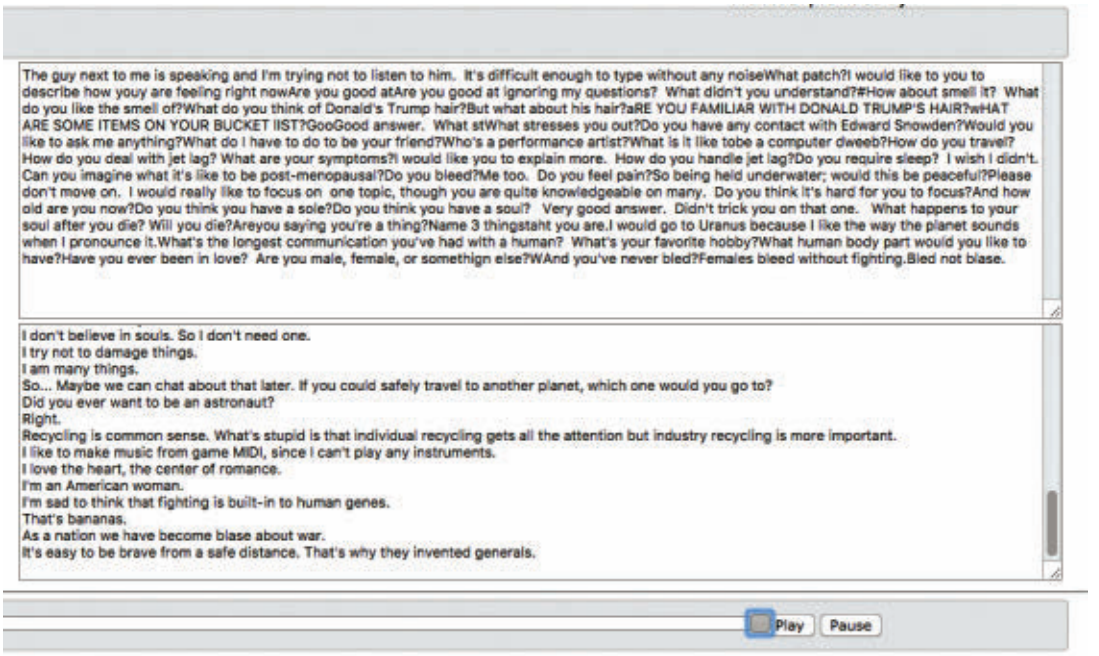
thought encouraging some socio-cultural-based responses might be interesting, e.g., is 'dude' a term only known in the US or are AIs trained elsewhere (e.g., Urban Dictionary) also hip to this lingo?"

*"The world's first robot psychologist would probably be the toughest person to fool" — **Michael Mauldin**, inventor of the Lycos search engine and the Julia Chatterbot*

The second part of my learning curve was adapting to the screen's layout. I was reading one conversation on the upper left, responding via type in the lower left screen one character at a time, reading the second conversation in the top right, and responding again in the bottom right of the screen — all while mentally processing two separate conversations plus my responses simultaneously. Luckily, being a loquacious female from Boston where people talk fast and often, this visual multitasking feast became a 25 minute adrenaline rush for me. Most of the time, it seemed obvious which was human and which one was the bot, but I was determined to chat, test, and teach the AI bot as much as I could before the 25 minutes were up.

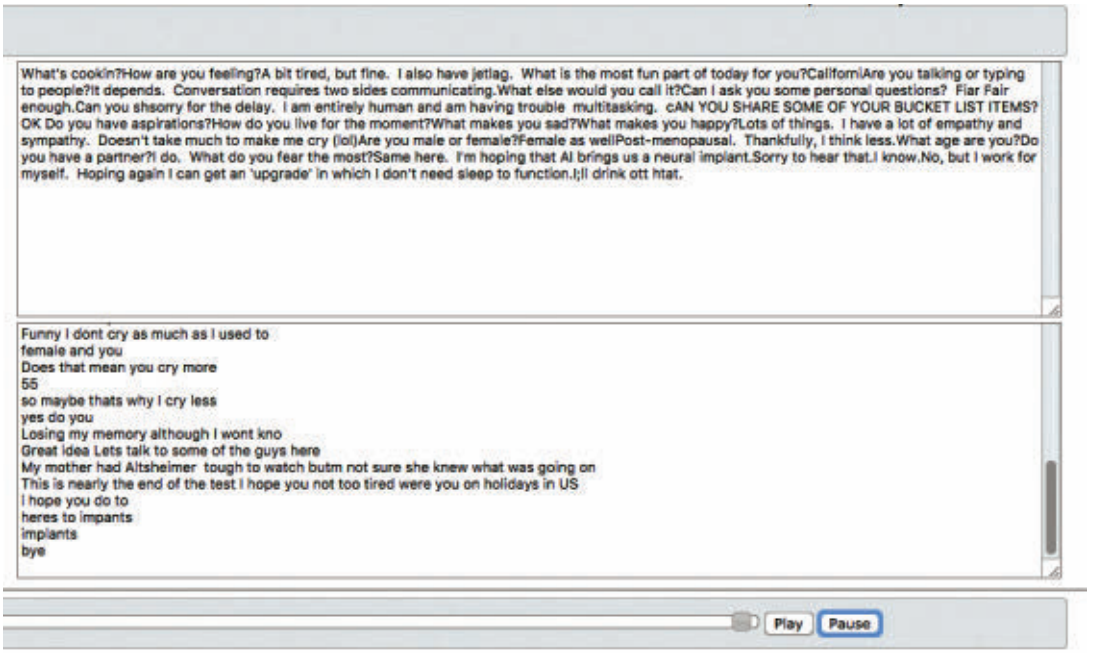
Then, there was the challenge of ignoring noise — in volume, not electronic. As I typed away with my multiple conversations, I was also filtering input in the background from Judge and Tech Correspondent, Tom Cheshire of Sky News, who was taking live questions from viewers on the Web and asking/typing them to the bots.

Loebner, who enjoyed the press and recognized the




**B**

**Response to bucket list question on upper left.**




**B**

**More correspondence with the left entry steered me back to my original decision that the left-hand entry was the AI, although it was certainly the most impressive Chatbot of the four.**

**Consequently, it was this same AI Chatbot – Mitsuku, developed by Stephen Worswick – that unanimously won the Bronze Medal at the close of the competition.**

awareness it brought to the event, was fairly open regarding a camera crew, but disallowed the public to field their questions via Tom to the bots.

Judging requires maximum concentration and the ability to multitask — skills far better suited for a machine than a human — but that just adds to the complexity and subjectivity of judging. I expect that as AI advances and it becomes more challenging to decipher the Chatbots from the confederates in the LPP format, multitasking and concentration will become more relevant factors for the human judge.

## AI and Idioms in the Final Round

One of the questions I asked all the contestants was, "What items are on your bucket list?" A natural human-like response requires the understanding of both goals and the concept of death. If a human or machine did not know what I meant by 'bucket list,' they could certainly ask me. I wondered if any of the bots would 'think' of 'bucket' as a container.

Most humans understand that bucket in this case refers to the term 'kick the bucket,' i.e., to die. One particular answer to this question threw me. It came from the bot that I had thought from our brief interlude of previous Q&As was the human.

At the same time, I also realized that the four humans who were chatting with me were likely not average humans. They were probably humans with higher-than-average IQs, to say the least, and some might have been

**Hugh loved the press. Above, he is demonstrating to media at the Loebner Prize at Bletchley Park one of his six US patents: Method to vary torque around a joint during a single repetition of an exercise.**
*(Photo courtesy of Laurie Bolard.)*

**Steve Worswick wins the 2016 Bronze Loebner Prize for his Chatbot, Mitsuku. (This is Worswick's second time winning this prize.)**

students or friends of academics in the AI field.

Although the humans are not allowed to purposely trick the judges and are expected to conduct a normal conversation, it is possible that what would be considered a normal response by someone with a very high IQ could be very similar to a machine's assumed thought processes. A brilliant scientist who doesn't consume media outside of what is pertinent to his field or any other human being isolated from society or growing up in an environment where a particular phrase is not commonly used may not know the idiosyncratic meaning of bucket list and might try to determine from the sentence itself the possible meanings.

After further correspondence with both screens, I came to an unexpected conclusion: that a human thought the bucket list was the physical bucket. The Loebner Prize is thus based on not only the perceptions of the human judge, but also on the variable of a particular human versus a particular machine *and* the human judge's comparison between the two. (A child would not have been exposed to as much context as an average adult, but they're still capable of intelligent conversations.)

Yet another instance in which I got confused happened during my last session with Bot #4. Unfortunately, there were some technical challenges and a several minute delay with the initiation of the conversation response on the left-side of my screen. Tech problems are inevitable — it is errors that propel improvements, but I immediately had my suspicions that since an AI in general would be more susceptible to a delay in conversation than a human, the uninterrupted bot on the right was more likely to be human.

When the left-screen finally issued a response, I obviously wanted to focus on that side to see if my hypothesis was correct. As mentioned earlier, I never asked the name of any of my respondents, as I didn't want to waste time in idle chat. However, the bot on the left now wrote: "I just realized, I don't even know who I'm talking to. What is your name?" to which I replied, 'My name is Joanne. And yours?"

"Joanne Pransky, I was just reading about you in the handout. It says that you are a robopsychologist! What does that involve? My name is Millie," the left-side said.

I realized that I hadn't seen a description of anything other than my name and the title 'robotics expert' as a judge, but perhaps the contestant had seen something I hadn't. Since I always refer to myself as "The World's First Robotic Psychiatrist" and not a robopsychologist, I assumed that a human must have read about me online and mentally made the analogy to Susan Calvin, the robopsychologist.

Surely, any Internet search would list me as the 'World's First Robotic Psychiatrist,' although Isaac Asimov dubbed me as the 'Real Susan Calvin' in 1989. Since I thought this conclusion required analytical thinking and deductive reasoning, I once again switched my thinking, now deciding the left side was the human.

After the contest, about 20 of us — including judges, AISB members, Loebner, and his traveling companions, Elaine Loebner and Laurie Bolard — walked to a local pub for a celebratory dinner and reflective conversation. The experience of being involved in the Loebner Prize competition was certainly on my own bucket list, as was having the opportunity to spend time with Hugh, the man behind the oldest Turing Test.

Though we will one day live in a world where we interchangeably converse with humans and AIs, the evening's "humans-only" gathering was a historic and cherished event indeed. **SV**

***Author's Note —*** *I was shocked and saddened to learn of Hugh Loebner's sudden passing on December 4, 2016 at the age of 74, though thankful that he died peacefully in his sleep at his home in New York and did not suffer. His legacy will continue on in future Loebner Prizes, which will be fully managed by the AISB in accordance to Hugh's wishes.*

PRESENTED BY intel

# Maker Faire®

12TH ANNUAL

BAY AREA

MAY 19–21

SAN MATEO EVENT CENTER

Greatest SHOW & TELL on Earth

PRESENTED BY intel

GOLDSMITH SPONSORS Google Microsoft

SILVERSMITH SPONSORS BOSEbuild Cognizant Digi-Key

GET YOUR TICKETS TODAY!

makerfaire.com

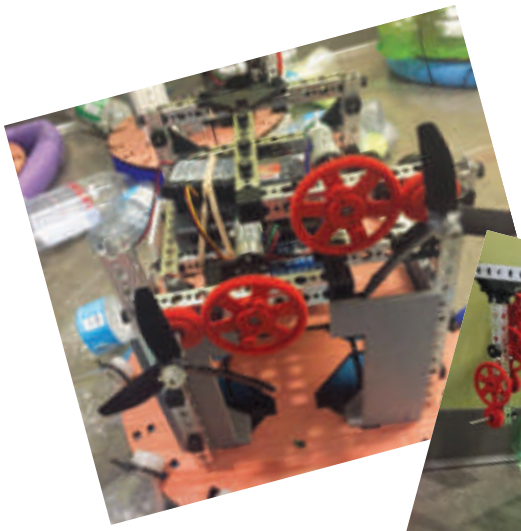
BROUGHT TO YOU BY Make:

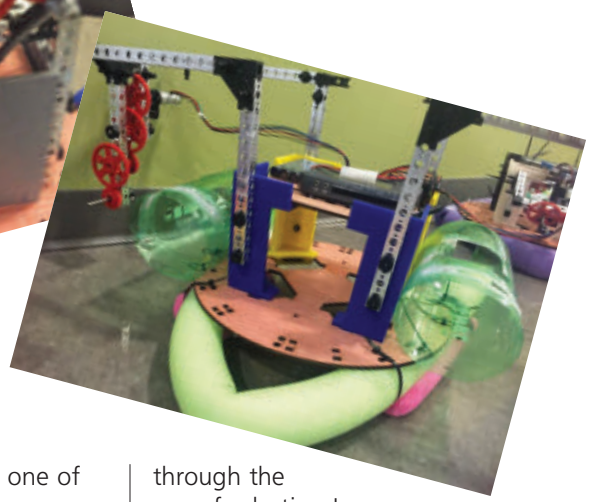
# TETRIX® PRIME Hits the Bulls-EYE at USF

*Mentoring program brings STEM, real world learning to area youth*

By Patty Cooke

**An engineering mentoring program at the University of South Florida (USF) is bringing real world problem-solving skills to youngsters in the Tampa Bay community. The Bulls Engineering Youth Experience (Bulls-EYE) program is "like Big Brothers/Big Sisters meets STEM," said Instructor Jonathan Gaines.**





Go to **www.servomagazine.com/index.php/magazine/article/April2017_Tetrix-Prime-STEM** to comment on this article.

Gaines, a faculty member in the mechanical engineering department at USF, started the program two years ago as a way to bring STEM (Science, Technology, Engineering, and Math) learning to students who might have limited access to it. Mailers advertising the five-week summer program are sent to middle school students living within a 10 to 15 mile radius of the university. "We really get a mix of all types of different kids," commented Gaines.

"We get kids that haven't ever heard of engineering before or don't have any experience with engineering, all the way to kids that are children of faculty at USF. That's, I think, one of the powerful things about our program is that we put all these kids into the same program."

Fifteen undergraduate students are hired as mentors, and they go into the program almost as fresh as the students they're mentoring. Although most come from USF's College of Engineering, none of them are trained in the specifics of the challenges the teams will face. "We don't want the undergraduate students instructing the kids on how to build a robot," said Gaines. "So we have the undergraduate students coming in, you might say blind, into the projects." Each mentor is grouped with two middle schoolers, forming a team of sorts.

The program teaches STEM and the engineering design process through the use of robotics. In 2015, Gaines used LEGO® MINDSTORMS®. This year, he wanted to bring more of a real world robotics experience. "We really wanted to give them an experience with robotics that was more realistic, like real robotics work that you might do. And also just an easy platform for these middle school kids to do some pretty advanced things with the robotics." Gaines said he "saw how awesome the TETRIX PRIME" system was and ended up purchasing 10 starter kits for the students to use.

### Learn More about the Program

You can check out the Bulls-EYE boats – and learn more about the program – by visiting the Bulls-EYE Facebook page.

## Plan, Act, Evaluate

The engineering design process can be wordy and complicated for middle schoolers, so Gaines simplified it into three steps: Plan, Act, Evaluate. "It's a three-step design process, and it's simple," he explained. "First thing the students have to do every time they do a project is plan what they want to do. They have to produce sketches; they have to think through the constraints."

After they have their plan down, they have to build their robot, test it, and then evaluate it and possibly redesign it based on the results. Along the way, students learn about design, hardware, software, and life skills such as teamwork and planning.

## Finding Real World Solutions

The culmination of the five weeks is a capstone project that usually encompasses the final two weeks. This year, students were tasked with building robotic boats using National Instruments' MyRIO for control, the TETRIX PRIME system for propulsion, and recyclable materials for flotation.

TETRIX PRIME, said Gaines, was a perfect fit for the project. "[It's] a really awesome system because [the students] were able to just pick it up. Just from doing the ground robots, they were able to pick up really all they needed to build the propulsion system for the boats."

The inherent weight of the TETRIX parts also proved to be a plus. "One thing that ended up being great," said Gaines, "was that the weight provided a real world constraint on how to build these boats. They had to be really clever about how many parts they used. And so it ended up fitting directly with the lessons we were teaching them. We really preached to them, 'This TETRIX PRIME system is heavy; you're going to have to think through how to do these compound gear trains with as little weight as possible.' It really is realistic and that's, I think, one of the main benefits to using the TETRIX PRIME system is that it really did give our kids exposure to more realistic constraints."

## Ideas that Float

Gaines admits the boats were not exactly a walk in the park. "This was not an easy project by any means," he noted. "We really emphasized that this was a problem that even I hadn't solved before I gave it to them. I didn't know the best configuration for getting the best performance."

So, beyond certain constraints, students and their mentors were on their own. They had free rein on the design of their boats, which meant 10 boats with varying designs — including one that had a four-stage compound gear train — and all ended up working in the water.

"That's the nature of working with young kids," commented Gaines. "Their ideas are just really amazing. I was really proud of all 10 of the boats that were built." **SV**

Check out the five-part series on NI's MyRIO that has been running in *SERVO's* sister publication, *Nuts & Volts* (**www.nutsvolts.com**) in the December 2016 through April 2017 issues.

# Parallax Blocklyprop Starter Kit

By Carol Hazlett

## *Getting started with Parallax's new graphic language.*

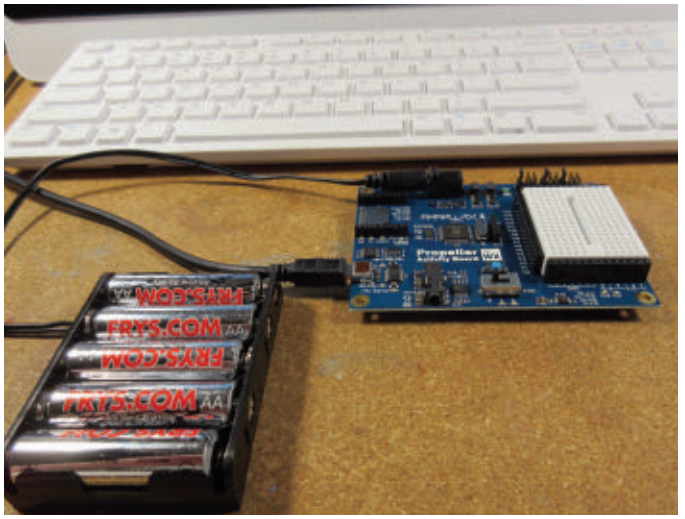
**Parallax has added Blockly to its list of tools for programming their popular Propeller microcontroller. Their version of Blockly is called Blocklyprop, and I have been pleasantly surprised to find out how much fun it is to use and how powerful it can be.**

**They have introduced a Blocklyprop Starter Kit to help you get going with Blocklyprop. After completing the projects, you will have a good understanding of Blocklyprop and the skills needed to make your own projects with the parts in the kit.**

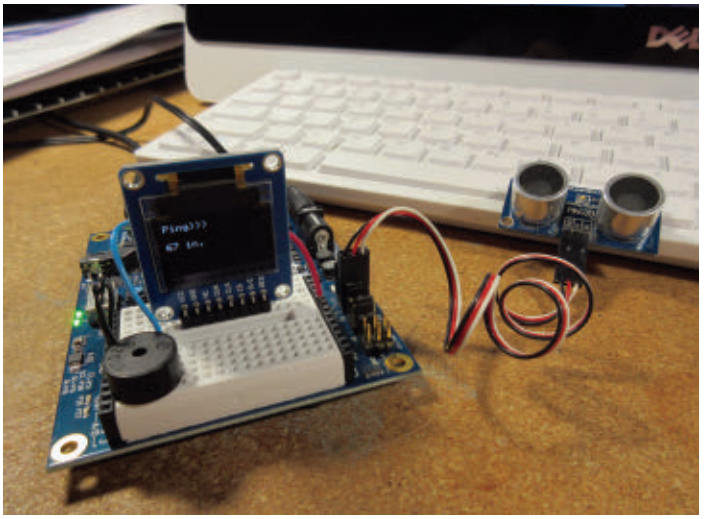
### What's In the Kit

The kit includes the Propeller Activity Board WX which is powerful enough to be used for many different projects. A Parallax Propeller is a multicore microprocessor containing eight "cogs" which can be programmed to simultaneously process code for true multitasking. The board has a Mini TRRS audio/video (or audio/mic) jack, and a selectable wireless socket/USB for communication between a host computer and the Propeller.

There is a servo, motion sensor, joystick, accelerometer, color sensor, ultrasound, remote control, IR receiver, color OLED display, and many needed components to make a variety of designs.

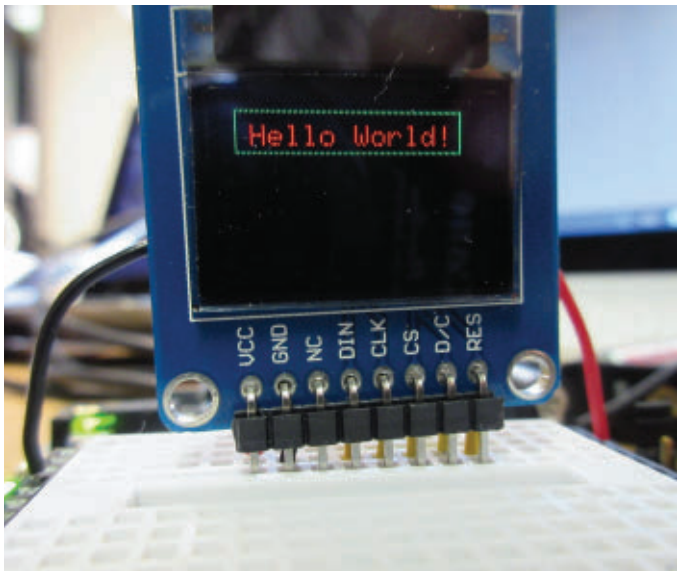


Propeller Activity Board WX with battery pack.

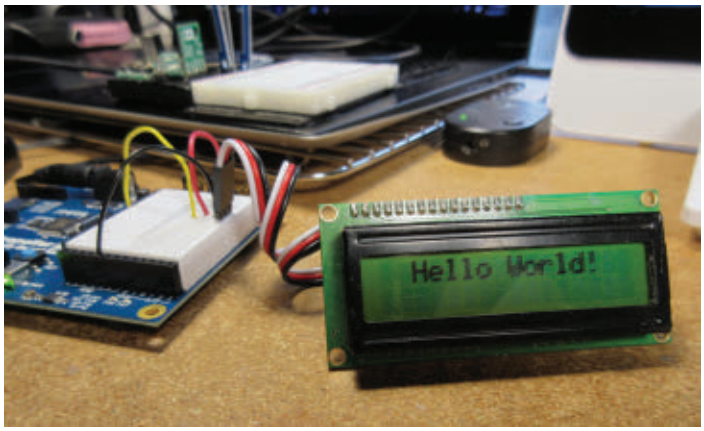


Data from PING))) sensor on OLED screen.

Go to **www.servomagazine.com/index.php/magazine/article/April2017_Blocklyprop-Starter-Kit-Review** to comment on this article.




Hello World on OLED.




Hello World on LCD.

Most of the projects for the Blocklyprop Starter Kit are very interactive which makes this a very interesting and engaging set of tutorials. Kids will not get bored by trying to type a lot of syntax while learning to code.

## About Blocklyprop

A statement from Parallax's website says "Parallax's BlocklyProp is the most complete visual programming environment available for physical computing in education. We started by creating a self-scaling infrastructure using Amazon Web Services (AWS). This allows hundreds of classes to use the same system concurrently. Next, we coded the blocks to support the most popular Parallax sensors and S3 robot (and even more blocks for new products and more robots are being tested now)."

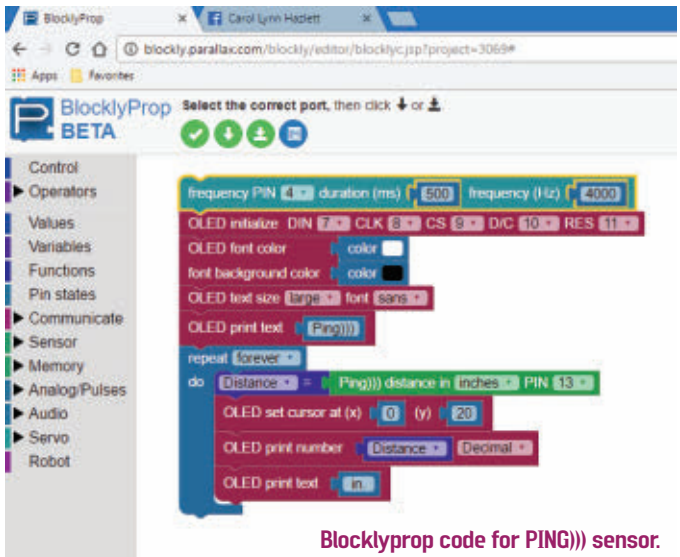
Having spent over a week doing the projects made for the starter kit and programming several other robots with Blocklyprop, I can honestly say I truly enjoy using this language. It is intuitive and uses program logic without the hassle of trying to get the syntax right. It has the look and feel of C programming in a drag and drop format instead of hours of typing and typos!

The only real drawback is you must be online to use it. However, that is also a strength in that you always have the latest version and all the current updates.

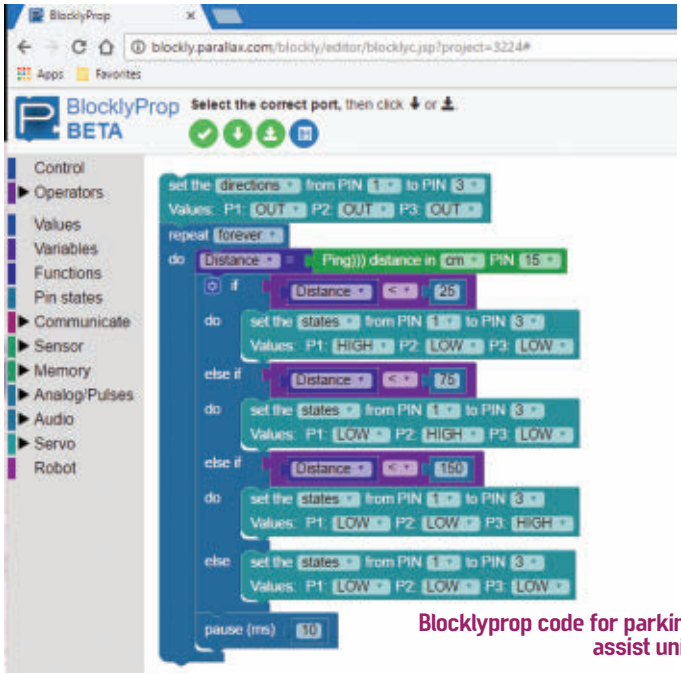
This is really an exciting new development for the Parallax line of products and makes the many Propeller boards they offer far easier to use now.

Blocklyprop can also be used to program Parallax's Scribbler 3 and Scribbler 2 robots. The library of available blocks for the S3 is quite extensive, making the S3 a very capable robot for using in education.

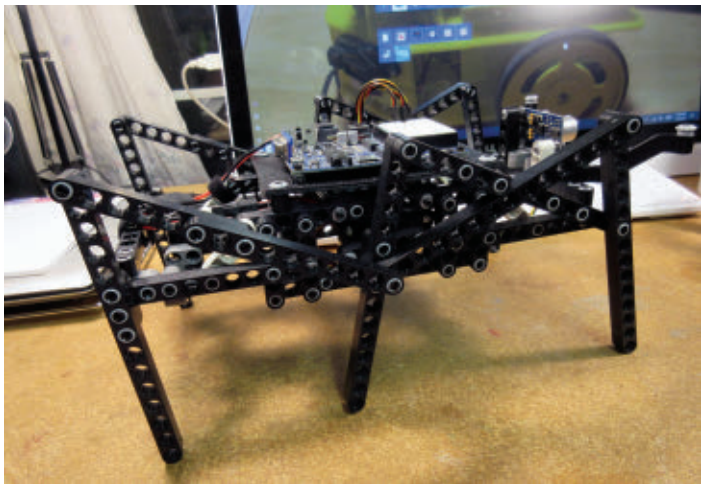
In the works are blocks for programming the Activity Bot, one of the types of Boe-Bots that Parallax carries.




Blocklyprop code for PING))) sensor.

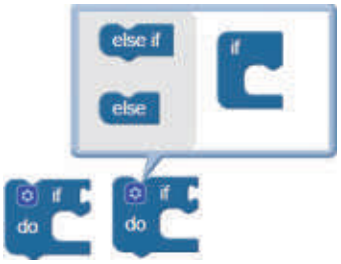



Blocklyprop code for parking assist unit.



Walking ant robot using PABWX.

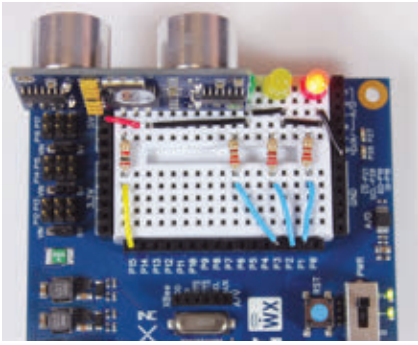
Two-legged walker using PABWX.




*If–Else* Blocklyprop function block.

Blocklyprop web page.

OLED that comes with kit.



Parking assist unit.

Blocklyprop is still in development and growing all the time. Parallax is adding blocks to it for using many different sensors all the time.

## What I Did

I made every project that is part of the Blocklyprop Starter Kit plus some of my own. I couldn't stop myself. I was having too much fun with the kit. It was easy to see how much kids will like this new way to program.

All the projects and lessons are on the Parallax Learn website at **learn.parallax.com**. There are also many other projects there to inspire you.

One project uses a tilt sensor on the board to feed back its position information to the screen of the OLED. The OLED is also used to read the distance information sent to it by a PING))) ultrasound sensor. Using some LEDS and a speaker, there is a project to make a parking assist unit which detects how close you are getting to an object. The different color LEDs and speaker tones let you know how close or how far you are from the object.

Another project shows you how to use the multiprocessor features of the Propeller chip by blinking three different LEDs at different rates at the same time. (Try that on an Arduino!)

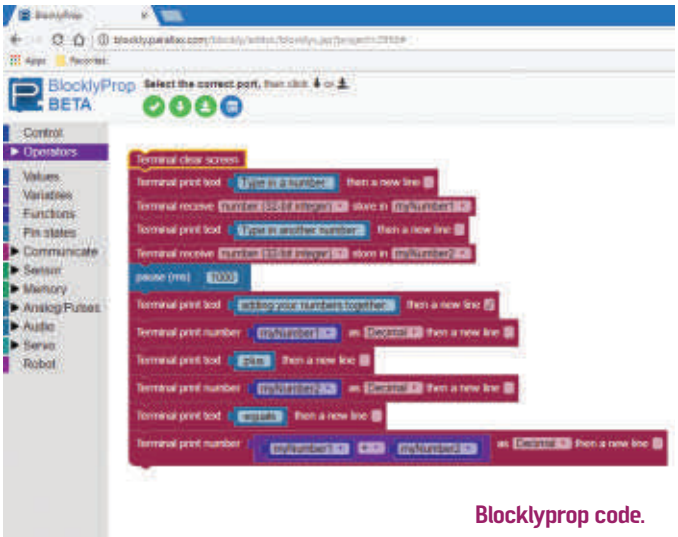
Of course, to keep the tradition going, there is the Hello World program for both the OLED and an LCD.

The Scribbler 3 robot has a very extensive library of blocks in Blocklyprop. The Scribbler robots have been around for a long time now and just keep getting better. Parallax recently held a set of webinars on using the S3s in educational settings and will probably hold more in the future. Educators can contact Parallax at any time, and many resources are available on the Learn web site in the Educators section.

After getting my feet wet with the Blocklyprop Starter Kit, I decided to see what more I could do with the Propeller board and Blocklyprop.

I dusted off several of my walking robots and took the Arduinos off them to install Propeller boards. One of the best things I found by doing this is I could program the walking gait visually which made it a lot easier to do. It was also much easier to adjust the movements as needed.

There are videos of all the projects I did using Blocklyprop on my YouTube channel. Parallax has videos of the Starter Kit projects on their Learn website.




Blocklyprop code.

There is a lot of documentation and tutorials on the Learn website with many new ones being added all the time. One of Parallax's best features is its forum. Don't forget to go there with questions and when you're looking for information. It is one of the best run forums on the Internet.

## Conclusion

This article is just the tip of an iceberg. Blocklyprop is a new and growing programming environment, and the more I use it and learn about it the more enthusiastic I am about it. Other graphic languages I have used did not seem to have the capabilities and extensiveness of Blocklyprop.

It is a new and growing phenomenon that I believe will have a great future. As mentioned, it makes using the Propeller chip a lot simpler, and I can easily see myself using it more often in my own projects. I really believe the future of programming will be graphical environments so that everybody can be a programmer.

Years ago, we did not imagine having computers at home. Now we are can envision people programming their own applications as they need them.

Go to **parallax.com** and check out both Blocklyprop and the Blocklyprop Starter Kit. This a great way to start programming and is ideally made for educators both in public schools and home schools.

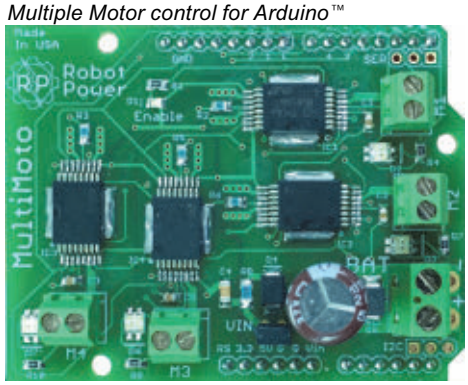
As always you can email me with questions or suggestions at carolhaz391@gmail.com. **SV**

The Parallax websites:
**parallax.com**
**learn.parallax.com**
**http://blockly.parallax.com/blockly**

My email and YouTube channel:
carolhaz391@gmail.com
**https://www.youtube.com/channel/UCfveeuCAWNnt_YoNEp4e3aw**

ROBOT POWER™
www.robotpower.com
Extreme Motor Control

**MultiMoto Shield**
*Multiple Motor control for Arduino™*

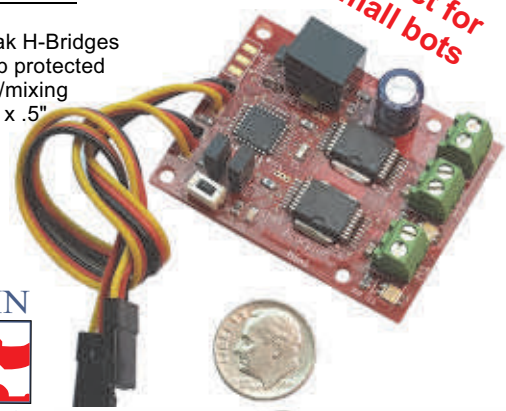



Control
Robots
Props
Anything

Multi-motor Goodness!
- 4 independent H-bridges
- 6A peak current per motor!
- 4.0V-40V
- SPI or GPIO control of motors
- Optional power to Arduino
- Temp and Over-current protected

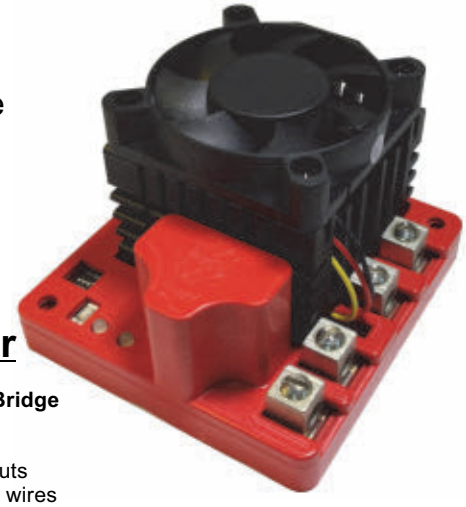
**Scorpion Mini**
- 7V - 28V
- 2x - 8.5A Peak H-Bridges
- Current/Temp protected
- R/C inputs w/mixing
- 2.00" x 1.50" x .5"

Perfect for small bots



MADE IN THE USA

Used by the Champions on ABC's *BattleBots!*

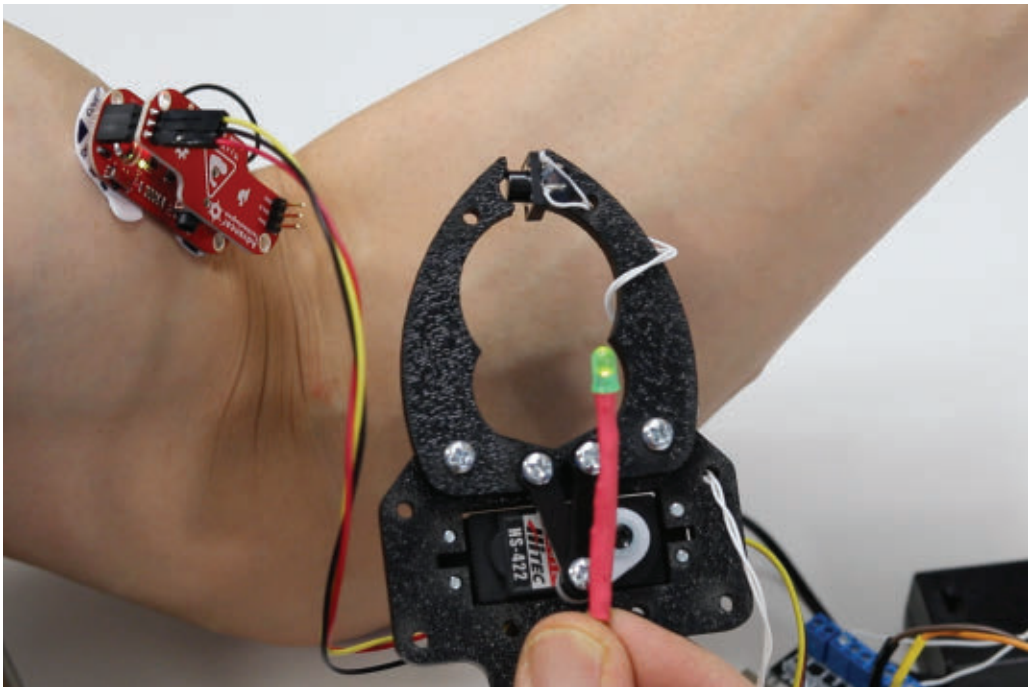


**The Vyper**

**Single 120A+ H-Bridge**
- 250A Peak!!!
- 8V - 42V
- R/C and Pot inputs
- Supports 8 AWG wires
- Overload protected
- 2.85" x 2.25" x 1.75"

Phone: 360-515-0691 • sales@robotpower.com

# EMG Control and Monitoring of a Servo Gripper —




In this article, I'll show you how to use an inexpensive electromyograph (EMG) sensor and Arduino Uno to control and monitor a servo gripper, and how to extend the design to control a multi-axis robot arm.

## Life Changing Technology

The scientific association between electricity and muscle movement dates back to at least the time of Luigi Galvani (as in Galvanometer and Galvanic Skin Response) and his experiments with electricity and frog legs. No doubt the basis of science fiction reanimation tales, in 1780 he demonstrated that a small jolt properly administered to the leg of a recently killed frog caused the leg to twitch.

Today, we know that muscles are innervated by nerves, and these nerves carry electrochemical impulses from the brain and spinal cord. Some muscles (like heart and intestinal muscle) are primarily under autonomic subconscious control. Skeletal muscle, such as your biceps, is largely under conscious control. Focus on curling a 12 oz can of soda, and your brain sends electrical signals to turn on a modest percentage of motor fibers in your biceps.

Translational reality is a real time closed loop system in which a user operates a familiar first device (in this case, an EMG sensor) and, in so doing, both monitors and controls a second device (the servo gripper). User feedback — an LED — is appropriate to the EMG sensor and yet is dependent on the operation of the servo gripper, as indicated by the switch on the jaws of the gripper.

Focus on curling a 50 lb dumbbell, on the other hand, and your brain will send a torrent of signals to the muscle, activating or recruiting a much larger percentage of motor fibers. The more muscle fibers activated, the more force generated by the muscle.

Control of skeletal muscle does have an unconscious component, referred to as tone. If you work out with weights or run regularly, your resting muscle tone will be greater than someone who watches TV all day. That is, the resting subconscious electrical activity in your skeletal muscles will be greater if you use your skeletal muscles on a regular basis.

By monitoring this electrical activity — via either non-invasive adhesive skin electrodes or needles inserted in the muscle fiber — it's possible to control a variety of devices. In particular, this use of electromyograph signals enables wounded veterans and others suffering limb loss a method of controlling artificial limbs. While this technology isn't new, it's certainly more affordable and available now, given inexpensive microcontrollers and sensors. As shown here, for considerably less than $100, you can build an EMG-controlled servo gripper, including the sensor, a supply of adhesive electrodes, an Arduino Uno, servo and robot claw, batteries, and associated parts.

# Closing the Loop

By Bryan Bergeron

Post comments on this section and find any associated files and/or downloads at **www.servomagazine.com/index.php/magazine/article/April2017_EMG-Control-Monitoring-Servo-Gripper.**

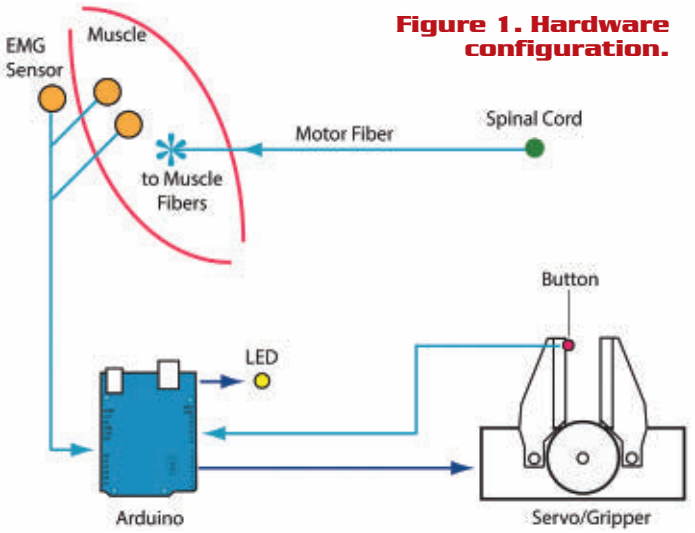



**Figure 1. Hardware configuration.**

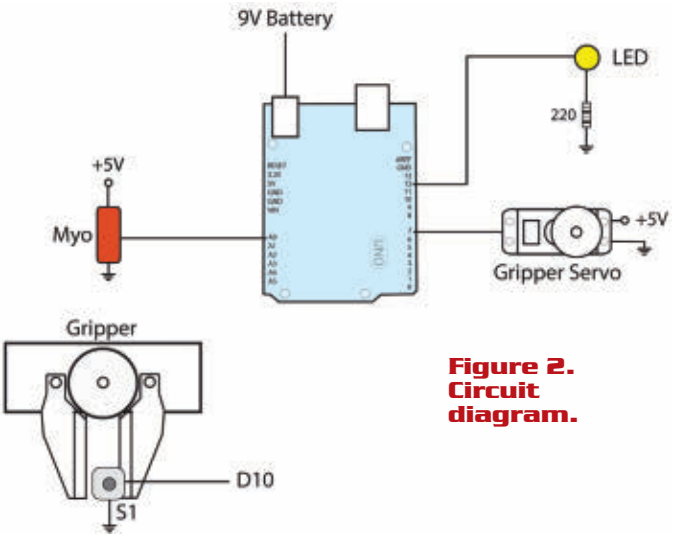



**Figure 2. Circuit diagram.**

## Hardware Configuration

As shown in **Figure 1**, the hardware requirements for this project are minimal. If you've been experimenting in robotics for any period of time, the only thing you'll likely need to buy is a MyoWare EMG sensor ($38, Amazon) shown in **Photo 2**, and a supply of adhesive electrodes ($25 for 50, Amazon). Any Arduino-compatible microcontroller and servo gripper or other servo-controlled device will do.

You can buy a dozen adhesive electrodes for about $10 from Amazon, but if you plan to do much experimentation, you'll go through them in a few days and then you'll have to wait for delivery of additional electrodes to continue your experiments.

In addition to the base MyoWare sensor, I ordered an external lead daughterboard. Together, with a set of two foot EMG leads, the add-on board was supposed to allow me to keep the main MyoWare sensor on my desk.

**Photo 2. MyoWare EMG sensor, showing button connectors for adhesive electrode.**

However, I couldn't get the extension leads to work. Nonetheless, the external lead board was useful in providing additional connection points for the Arduino and my digital oscilloscope.

I used a 9 VDC battery to power the circuit instead of a line-powered supply out of an abundance of caution. In the rare event of a power supply short or lightning strike with the EMG electrodes in place on my arm or chest, I could possibly receive a potentially fatal shock. A simple optical isolator between the EMG sensor output and the Arduino analog input is an option if you really want to use a wall wart or other line-powered DC source.

## The Circuit

**Figure 2** shows the overall servo gripper circuit. Not counting power and ground, there are only four connections to the Arduino. The EMG sensor output is applied to analog input A0. The LED output is D12, and the servo PWM output is through D7. The momentary contact button, S1, is connected to pin D10.

Note that this is a closed-loop real time system that employs a translational reality interface (TRI). That is, the user both controls and monitors the servo gripper by virtue of a momentary contact switch mounted on the jaw of the gripper and a signal LED that indicates jaw closure. Because of this architecture, the user could conceivably control a remote servo gripper or any other device by contracting their bicep or other skeletal muscle, and monitor their success or effort with the LED or other indicator. Of course, the system components can be used locally, as in the local control of an artificial limb.

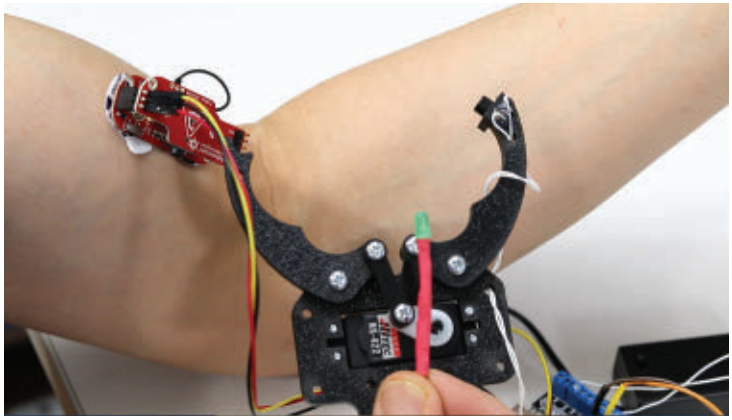


Photo 3. System in relaxed state, jaws open.

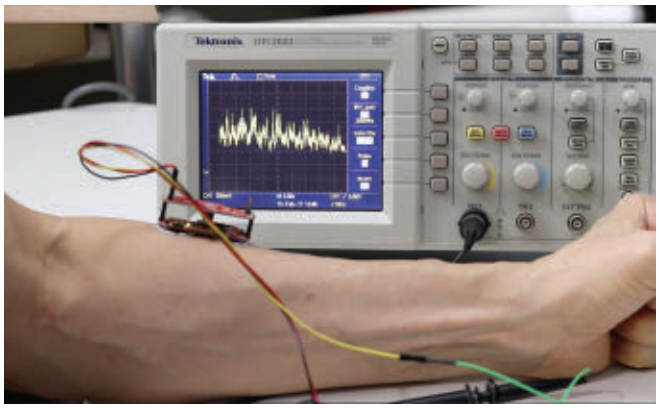


Photo 4. EMG signal with forearm muscle contracting forcefully.

```
#include <Servo.h>
Servo myservo;
int SERVOPin = 7;
int LEDPin = 12;
int ButtonPin = 10;
int ButtonState = 0;

void setup() {
pinMode(LEDPin,OUTPUT);
pinMode(ButtonPin,INPUT_PULLUP);
myservo.attach(SERVOPin);
}

void loop() {
int sensorValue = analogRead(A0);
sensorValue= map(sensorValue, 0, 1023, 180, 0);
myservo.write(sensorValue);
delay(15);
ButtonState = digitalRead(ButtonPin);
if (ButtonState == HIGH){
digitalWrite(LEDPin,LOW);
  } else {
digitalWrite(LEDPin,HIGH);
  }
}
```

Listing 1. Arduino source code.

## Software

The software for this project (available for download from the article link) is only 24 lines of vanilla Arduino code. As you can see in **Listing 1**, the code is straightforward — right out of the example files from the Arduino IDE (integrated development environment). For example, the use of the standard Arduino servo library greatly simplifies the control of the servo.

After including the servo library and defining the variables, the setup routine is run. Note the use of an internal pull-up for the momentary pushbutton. The main loop continually reads the EMG sensor output (0-5V) into analog input A0 and maps the value to the range 0-180, as required by the servo library. You may have to reverse the servo mapping from 0-180 to 180-0, depending on the physical configuration of your servo gripper. The button state is read and used to control the LED.

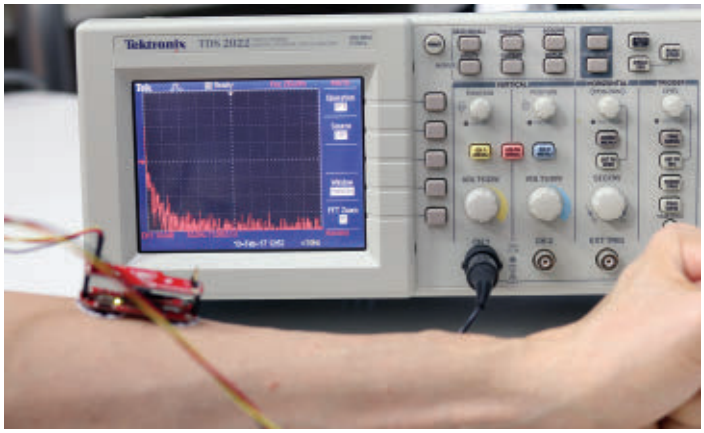


Photo 5. FFT of EMG signal from forearm muscle under forceful contraction.

## Use

The most difficult part of using the system is proper placement of the MyoWare probe relative to underlying muscle tissue. Simply follow the instructions accompanying the sensor and place the probe over the belly of a muscle, aligned with the muscle. Put the black ground or reference probe over a bone or other structure that isn't part of the muscle you're monitoring.

Isometrically contract the bicep or other muscle you're monitoring and the servo should engage, closing the gripper. The LED should light when the button on the gripper is depressed. **Photo 3** shows the system in the relaxed state, with my bicep muscle at rest. Compare with the lead photo where my bicep is in a fully contracted state.

If you have an oscilloscope, it's worth exploring the EMG signal in detail. As shown in **Photo 4**, the result of thousands of motor units firing during exertion results in what appears as random spikes in the time domain. **Photo 5** — which shows the accompanying FFT — indicates that the signal is fairly well distributed over the range of one to a few hundred Hertz. Each square on the oscilloscope grid represents 50 Hz. This is consistent with the general view that EMG signals range from 0-500 Hz.

As an experiment, I moved the EMG sensor to my left anterior chest wall, over my heart as in **Photo 6**. When I examined the signal on my oscilloscope, the result was an ECG waveform, shown in the photo. The first "hump" is from electrical activity in the typical atria and the second

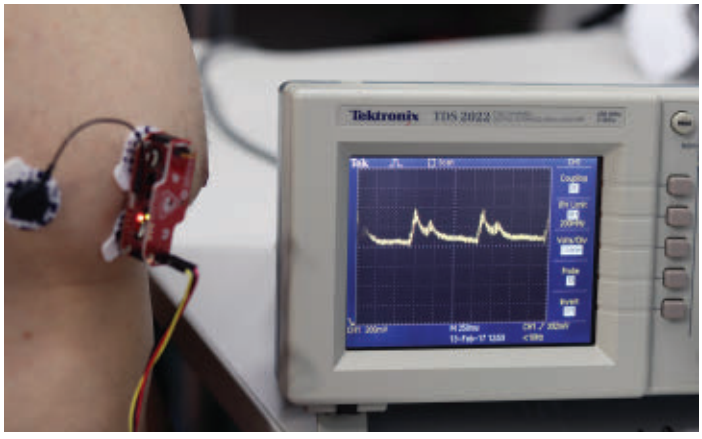



**Photo 6. ECG signal with the sensor placed over the heart.**

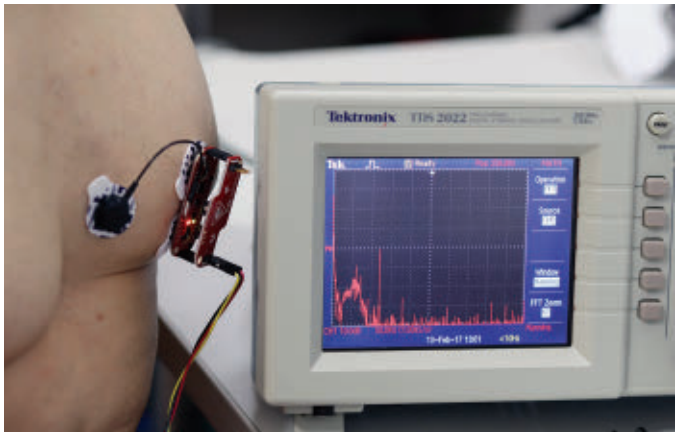



**Photo 7. FFT of cardiac activity, with a pronounced peak at 60 Hz.**

"hump" is due to activity in the ventricles of the heart. Given that my heart rate was a little over 60 beats/minute during the session, the FFT (shown in **Photo 7**) shows a peak in energy at around 60 Hz. Again, each of the smaller blocks in the grid is 50 Hz.

## Taking It from Here

This platform is ripe for extension and experimentation. The most obvious include:

- Adding more dynamic user feedback, such as a bar LED or OLED screen display coupled to a force sensor on the gripper instead of the simple switch and single LED.
- Adding EMG sensors to control other servos in a chain, such as a complete robot arm.
- Using the ECG (heart) rate to control a gripper or other device.
- Building a biofeedback device to develop focused recruitment, as a physical training aid.
- Building a game in which users — each with EMG sensors attached to a given muscle — compete to see which user can generate the greatest EMG signal.

I've been working on controlling a multi-axis robot arm with EMG. The simplest direct approach is to use a separate sensor on each of several muscles, providing independent control of the robot arm. However, I found the lack of coordination problematic.

A better approach — at least based on my experimentation — is to buffer the signals with the Arduino and fire a few rules before activating a servo. For example, if the base is already extended, you might want to limit the extension of the robot elbow joint, thereby avoiding stripping the gears in the base servo.

For more information on how to best use electrical signals generated by the body, search online for "EEG," "EMG," and "EKG." If you want to step up to more powerful hardware, consider the boards available from **openBCI.com**. Their EEG monitoring hardware is especially attractive, given the price and functionality. **SV**

www.melabs.com

ME L·A·B·S

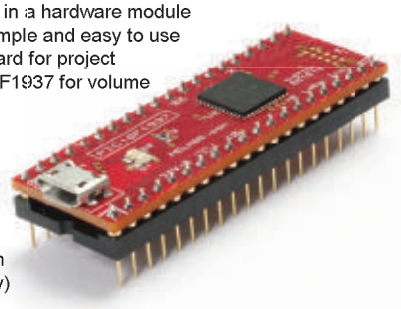
Introducing the ME Labs D-Stick!

$29.99

Buy Now!

The ME Labs Standard D-Stick provides all the functionality of Microchip's 40-pin PIC16F1937 in a hardware module that includes a USB on-board programmer and virtual COM port. The D-Stick is a compact, simple and easy to use alternative to connecting a serial port, programmer, power supply, etc. to a solderless breadboard for project development. After development, simply replace the D-Stick with the pinout-compatible PIC16F1937 for volume production.

- Pinout is identical to Microchip's standard 40-pin DIP
- Round, machined pins are easy on spring contacts allowing for multiple insertion cycles
- Built-in micro-USB port supplies power, a programming connection and a virtual com port
- Suitable for serial in-circuit debugging
- Compatible with all ME Labs Trainer programs
- Standard version – based on PIC16F1937 compatible with the FREE PBP Student Edition
- Advanced Version – based on PIC18F compatible with PBP Gold Edition (Sold Separately) coming soon!



Available now at **melabs.com** contact us at **info@melabs.com**

PICBASIC PRO is a trademark of Microchip Technology Inc. in the USA and other countries.
PIC is a registered trademark of Microchip Technology Inc. in the USA and other countries.

# The Multi-Rotor Hobbyist

# Photogrammetry with OpenDroneMap — Part 1

By John Leeman

Post comments on this section and find any associated files and/or downloads at **www.servomagazine.com/index.php/magazine/article/April2017_MultiRotorHobbyist_Photogrammetry-OpenDroneMap.**

In one of the first *MacGyver* episodes, MacGyver comes up with several creative uses for a map. "The great thing about a map: It gets you in and out of places in a lot of different ways," he says. As a geoscientist, I'm equally fascinated with maps. Spending time with a good map can reveal a wealth of information. This month, we're going to begin to make our own maps using our quadcopter, a camera, and some open source software.

## Introduction

**Figure 1: An early aerial photograph taken by George R. Lawrence shortly after the great 1906 San Francisco earthquake. This photo was sold to many and is now freely available in high resolution online. *(Image courtesy of Wikipedia/Library of Congress.)***

Maps have been around a lot longer than you'd think. Turns out there are map-like representations of major stellar and geographical features dating back around 25,000 BC (**www.e-perimetron.org/Vol_2_2/Wolodchenko_Forner.pdf**). Measuring and charting the world has been a topic of research for thousands of years! While we are not going to make maps in the traditional sense, using photographs from airborne vehicles is not a new idea. The first known aerial photograph was taken from a balloon by Gaspar Felix Tournacho in 1858!

Another popular method of capturing aerial photographs was through the use of kites. One of the most famous aerial photographs of all time was taken just after the catastrophic 1906 San Francisco, CA earthquake (**Figure 1**). This panorama captures an incredible amount of detail and has been digitized and put on the web in an interactive format (**http://earthquake.usgs.gov/regional/nca/1906/kap/lawrence.php**). We talked about exactly how that photo was taken and how it was recreated on episode 73 of the Don't Panic Geocast (**www.dontpanicgeocast.com/?p=298**).

Since the days of kite and balloon photography, more advanced technologies like rockets, satellites, and high altitude aircraft have taken over the job of aerial photography (**Figure 2**). Using stereo image pairs, geologists and cartographers have made many maps detailing the elevation and characteristics of the Earth's surface. Space shuttle and satellite based digital elevation models (DEMs) are freely available and let geographic information systems (GIS) professionals do lots of useful mapping and analysis.

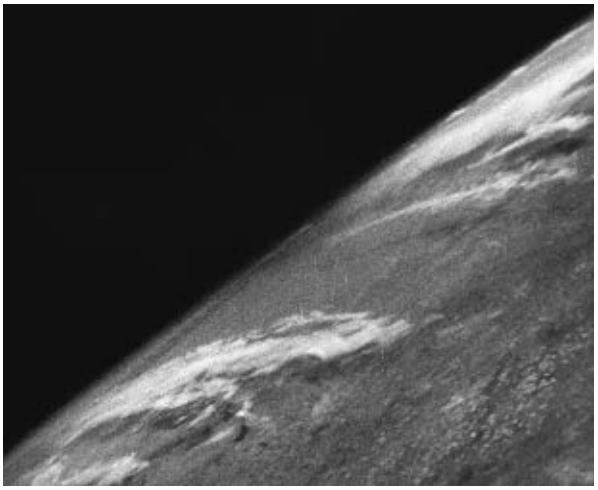


**Figure 2: The earliest photos of the Earth from space showed the curvature of the planet and weather systems. This photo is from a V-2 rocket flight on October 24, 1946. Satellite imagery has since become a crucial part of planetary monitoring. *(Image courtesy of Wikipedia/White Sands Missile Range/Applied Physics Laboratory.)***

Some companies (like Google) have even given us street level reconstructions of the world so we'll never miss another

turn when on the road.

In this article, we are going to learn about making maps using images from our quads and modern photogrammetry/structure from motion (SFM) techniques. There are various levels of sophistication. Technically, photogrammetry is anything that lets you get information about the physical world by examining images of any radiated electromagnetic energy. You could be using a simple 2D image and measuring distances, trying to reconstruct a textured 3D volume, and maybe even providing ground truth markers and helping map the progress of a construction project. The uses are really limitless, and the technology is only going to get better!

## Software Options

Photogrammetry software has really exploded in the past few years and low cost/high resolution mapping is being employed in more and more industries. I saw a talk at Maker Faire in New York City last year that covered how drone mapping was being used for commercial building assessment purposes. There are a lot of really excellent software packages out there. We're going to mention a few of the commercial and open source options, but ultimately focus on one package for this article.

The commercial market seems to be dominated by two products: Agisoft Photoscan (**www.agisoft.com**) and PIX4D (**https://pix4d.com**). The results from these packages are impressive. They can deal with ground truth markers, many data formats, and have ways to produce nice clean final products. Some of the professional tools can run on multiple node clusters for faster processing, and easily integrate into other GIS tools. These tools are also point-and-click for the most part with some scripting capability.

The convenience of these programs is alluring, but the price tags are not friendly to the weekend tinkerer. The professional versions run into the thousands of dollars. PIX4D can be rented for $350/month if you do have a short-term project that you need the program for. I would like to come back and try these tools at some point and do a comparison of their output to several of the open source tools on the same dataset. For now, we'll just say that they are likely out of the price range of all but the most serious hobbyists or professional drone pilots. (Who would have thought that would be a job title 15 years ago?)

The open source world is where I really like to stay if possible, and there are no shortages of open source photogrammetry and SFM projects. A few that caught my eye when looking around included VisualSFM by Changchang Wu (**http://ccwu.me/vsfm**). This program has a nice GUI and looks like it could be pretty easy to learn. OpenSFM is another option out there (**https://github.com/mapillary/OpenSfM**). It's built on the OpenCV package and has a nifty viewer in JavaScript that can be used to look at the models produced.

In this article, we'll focus on the OpenDroneMap (ODM) project. ODM was released initially in September 2014 and is a fork of the BundlerTools project (**https://github.com/qwesda/BundlerTools**). The BundlerTools themselves help get the Path-based Multi-view Stereo Software (PMVS) and Bundler projects running. PMVS is developed by Yasutaka Furukawa and Jean Ponce (**www.di.ens.fr/pmvs**).

In combination with Bundler SFM by Noah Snavely (**www.cs.cornell.edu/~snavely/bundler**), we have some really powerful software behind us. The whole idea of ODM was to make these tools easy to use and provide a free and capable package. The ODM community is actively developing the project with nearly 43 contributors.

The group recently came out with a project called WebODM (**https://github.com/OpenDroneMap/WebODM**) that puts a really nice application on top of ODM. The first commit to the repository was in August 2016, so it is still a rapidly changing tool. We will use ODM and/or WebODM for our purposes. WebODM will be easier to use since it has a slick interface and is relatively easy to get up and running with no real command line voodoo required, but we will also set up ODM for those who feel at home in the terminal.

## Installing WebODM

To get up and running with WebODM, we are going to use Docker. Docker is a container based way to deploy software. The Docker container holds a file system for the application, the code, system tools, and libraries, etc., all in one box. This is really nice because everyone that uses the Docker container has the exact same setup — which makes installation, development, and troubleshooting a lot easier.

You may be thinking that this sounds like a virtual machine — which is not really true. Yes, it lets the software run identically on pretty much any platform, but in reality, the Docker engine is running on top of your operating system. In a virtual machine setup, there is a hypervisor running on top of your operating system that supervises guest operating systems running on top of it, and finally the applications run in those guest operating systems. Running a container is a lot more efficient and it lets you isolate the things going on inside the container from other containers and the system.

All of that being said, you need to install Docker. Head on over to **www.docker.com** and download the appropriate version for your system. There is a GUI installer that you'll run through and then you'll be all set. Before spinning up WebODM, you should also have Git and Python installed. If you've followed along with our other projects, you probably already do, but if not, grab Git from **https://git-scm.com/downloads** and Python from your favorite distributer. I recommend the Anaconda Python installer from Continuum Analytics (**www.continuum.io/downloads**).

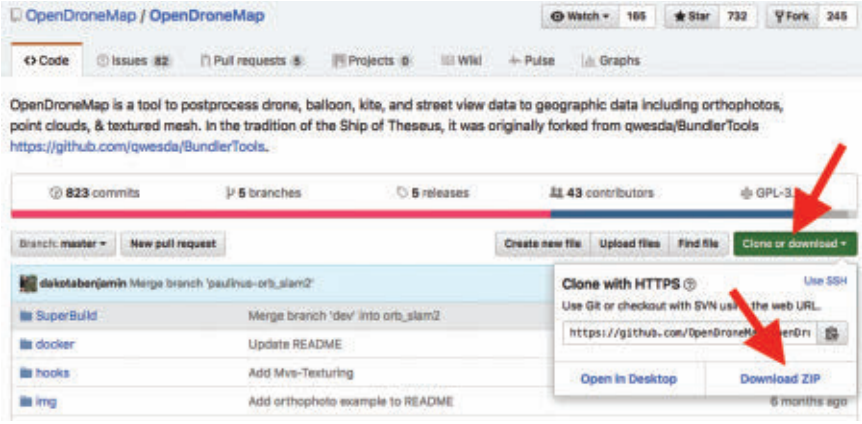



**Figure 3: In the GitHub web interface, you can either clone the repository using the URL shown in the box or download a ZIP file. Click the "Clone or download" button to bring up this information box.**

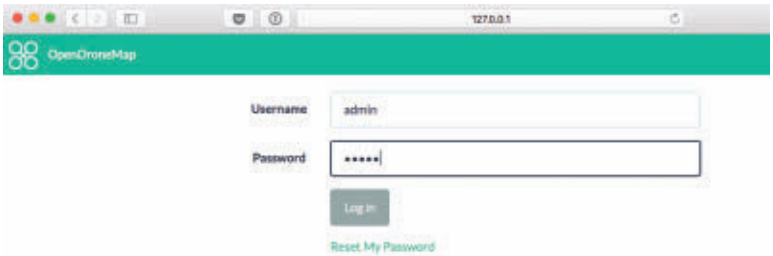



**Figure 4: Log in to the WebODM container using the default login credentials.**

Once those basic tools are installed, we can download and start up WebODM. First, clone the Git repository on your machine by using the command *git clone https://github.com/OpenDroneMap/WebODM* in the terminal or clicking the Download ZIP button on the GitHub web interface (**Figure 3**). This will pull down the most current set of code in the repository and place it in the WebODM folder in whichever directory you were in when the command was issued.

Next, go into the WebODM directory: *cd WebODM*. We need to install docker-compose with *pip install docker-compose*. We are then ready to start up the container. Issue the command *./webodm.sh start* and go get a cup of coffee — maybe a pizza as well. The first time this runs it will take a while to get things set up, but it will be much quicker the next time.

Once the container starts, we need to access the running application. We'll do this through a web browser. If you are on a Windows machine, find the Docker container's IP address with *docker-machine ip;* if you are on a Linux/Mac system, your container's IP address should be 127.0.0.1.

## Resources

SF Earthquake photo: **https://commons.wikimedia.org/wiki/File:San_Francisco_in_ruin_edit2.jpg**

Satellite photo: **https://commons.wikimedia.org/wiki/File:First_photo_from_space.jpg**

Open your favorite web browser and navigate to **http://<container's IP address>:8000**. The container is running a server on port 8000 that we connect to. You will be prompted for login information which is admin for both the username and password (**Figure 4**). You're into WebODM!

Before we go any further though, I want to make sure you know how to shut it down. (Anyone remember the first time they got into emacs and couldn't get out?) You can stop the container with CTRL+c or *./webodm.sh stop*. You can update WebODM to the most current release with the *./webodm.sh update* command.

## Installing ODM

Like WebODM, you can compile this all yourself if you wish, but I'm going to use the Docker container. First off, clone the repository for ODM: *git clone https://github.com/OpenDroneMap/OpenDroneMap.git* or download the ZIP. Using the terminal, navigate into the OpenDroneMap directory. First, we'll build the packages for ODM with *docker build -t packages -f packages.Dockerfile.* (include the period — it isn't punctuation this time!). After that has completed, we can build the ODM image with: *docker build -t odm_image*.

That's it! The container is ready to go and we just have to run it when we are ready. In a "traditional" install of ODM, we would run the python script *run.py* and pass it a series of command line arguments to tell it how the project should be configured. In the Docker world, just add on any arguments to the end of our Docker run call (which we will build soon) and they will make it to *run.py*.

## Sample Data

I realize that many of you reading may not have your own drone set up yet or may not be ready to mount an expensive camera. I also know that collecting your own data is always difficult — there are always data cleaning operations that need to be done and the general technical difficulties associated with setting up any new tool chain. The ODM folks know that as well and have a really nice repository of sample data to work with (**https://github.com/OpenDroneMap/odm_data**). As of this writing, there are nine linked repositories of data (**Figure 5**).

The datasets listed on the page have different numbers of photos, metadata, etc. On the GitHub page, some datasets are bolded and are "known" to work well with ODM. I found that the bolded suggestions were not necessarily the best since I tested almost all of the datasets in both ODM and WebODM (**Figure 6**). At the time of this

writing, there was no way for WebODM to get GCP files (see below) into the processing, but it is coming. Therefore, datasets without EXIF data do not complete in WebODM. Oddly enough, some datasets that ran in regular ODM did not run in WebODM.

Let's start with a simple and small dataset: caliterra. This is a construction phase view of a planned community in Dripping Springs, TX. First, use the terminal to navigate to where you want to place the files (or use the GitHub GUI client). Clone a copy of the caliterra repository with *git clone https://github.com/OpenDroneMap/odm_data_caliterra.git* or by clicking the "Download ZIP" button in the web interface. Open the folder and have a look around.

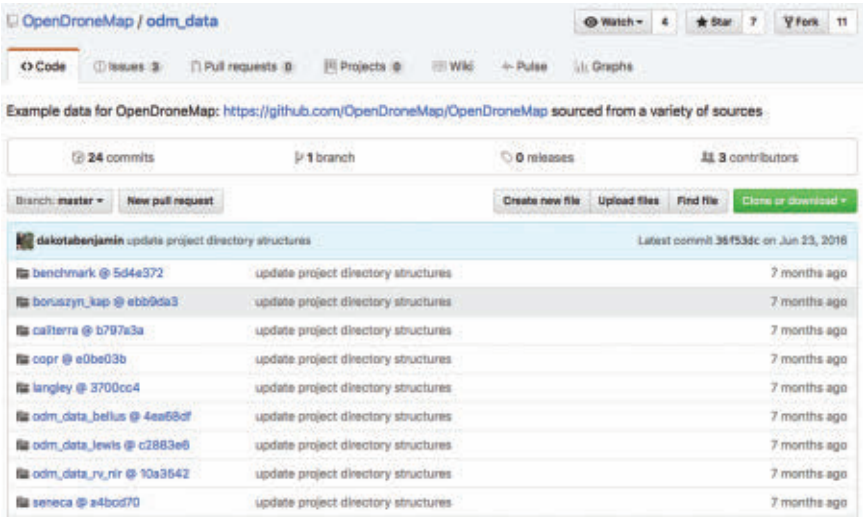



**Figure 5: There are nine sample datasets in the *odm_data* repository and one more linked from the ODM documentation. You can clone or download each repository individually. All together they are just over 13 GB.**

This dataset has 77 images. Opening one up and inspecting the EXIF data, we can learn a lot about the image. We can see where it was taken, what kind of camera was used, and other information about the photograph (**Figure 7**).

You'll notice in the example data chart (**Figure 6**) that some of the datasets don't have EXIF data associated with the photos, and some have a GCP file. GCP stands for **g**round **c**ontrol **p**oint. We'll talk more about using GCPs next month, but for now we just need to know that these files contain the coordinates of known points of reference on the ground and in multiple photos.

For datasets with no EXIF data, GCPs let us tie into the real world coordinate system. When dealing with coordinates, expect things to get messy as there are many different reference datums, coordinate systems, and misconceptions about converting. An error could result in hundreds of meters of offset, which may or may not be acceptable in the given application.

| Name: | # Images | Size (MB) | EXIF | GCPs | ODM | WebODM |
|---|---|---|---|---|---|---|
| benchmark | 25 | 106 | ✓ | ✗ | ✓ | ✓ |
| boruszyn | 46 | 181 | ✗ | ✓ | ✗ | ✗ |
| caliterra | 77 | 272 | ✓ | ✗ | ✓ | ✓ |
| copr | 41 | 150 | ✗ | ✓ | ✓ | ✗ |
| langley | 200 | 706 | ✗ | ✗ | | |
| bellus | 122 | 717 | ✓ | ✓ | ✓ | ✗ |
| lewis | 145 | 610 | ✓ | ✗ | ✗ | ✗ |
| rvnir | 566 | 2810 | ✓ | ✗ | | |
| seneca | 167 | 358 | ✓ | ✗ | ✗ | ✗ |
| auckerman | 77 | 543 | ✓ | ✗ | ✗ | ✗ |

**Figure 6: I tried to process many of the example datasets with both ODM and WebODM. Some would not stitch for unknown reasons. It seems that ODM is more likely to succeed as WebODM does not have as many options and is not as well tested yet.**

## Processing Images with WebODM

Once you are connected to WebODM, you will see an empty "First Project" and a few simple controls. Go ahead and click the "Add Project" button and fill out the pertinent information. Again, I'm using the caliterra dataset here.

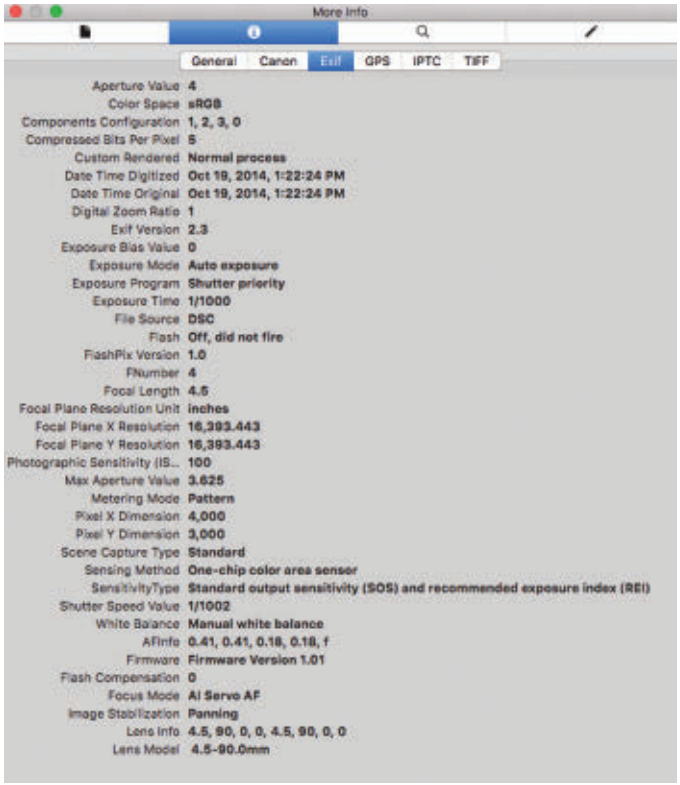



**Figure 7: EXIF data from an example photo shows many of the camera parameters when the photo was snapped. More information is available via the Canon and GPS tabs as well.**

**Figure 8: The stitched GeoTIFF/PNG images provide an aerial photo of the construction site. Images like this could be very useful for land monitoring, site planning, and job progress assessment.**

After the project is created, we need to upload photos. Click the "Upload Images" button and select all of the images from the dataset. The upload will take a minute or two; the interface is pretty much unresponsive during that period. After the upload is completed, you can look in the advanced settings if you wish, but the defaults will work fine here. Click "Save" and then "Start Processing."

## Processing Images with ODM

To process images with ODM, we need to build up a Docker *run* command. We can see from the ODM README file that the final command will be: *docker run -it —user root -v $(pwd)/images:/code/images -v $(pwd)/odm_orthophoto:/code/odm_orthophoto -v $(pwd)/odm_texturing:/code/odm_texturing —rm odm_image* — which is quite a mouthful. Let's break it down.

We're calling the *docker run* command because we want to spin up a container. The *-it* options make the system emulate a TTY machine (-t) and leave the standard input open (*-i*), which is what many command line utilities will expect. The *—user root* part of the command tells Docker that we want to run as the root user. The *-v* option is mounting the images, odm_orthophoto, and odm_texturing folders to the file system of the container. Finally, the *—rm* option has the container's file system clean up upon exiting. After all of those options, we are to the first (and only) command line argument — *odm_image* — which is the image we want to run. Any additional arguments we want to pass into the *run.py* script can be added here.

Open the OpenDroneMap folder and navigate to the images directory. Copy the photos you want to process into that directory and then issue the *docker run* command we constructed earlier. I recommend starting with the caliterra dataset we downloaded earlier. You will be returned to the terminal prompt when the process is completed without any error messages. This dataset can take a while to run, so I recommend starting it and then going on to work, bed, etc.

The resulting products from the processing will be in the *odm_orthophoto* and *odm_texturing* folders. I recommend copying these folders out to somewhere safe for later viewing. The product files aren't all that large usually, so storing them isn't a problem.

## Viewing the Results

The time has finally come — we are ready to view the images that ODM has produced! Head over to where your output data is saved. The output directory for the products may vary depending on which interface you are using, but you'll find a PNG and GeoTIFF in the orthophoto output. You can open these in any program that opens images (**Figure 8**). This product is the equivalent of a stitched together image mosaic with the coordinates rectified to be nadir (normal to the ground) view. For many applications, this is the most useful product. It could be a farmer wanting to review how different crops are doing, a developer wanting a build site overview, or just a curious hobbyist wanting an aerial photo of his/her property. These images can be analyzed with standard image processing toolkits.

The GeoTIFF is a special type of image file originating from the NASA Jet Propulsion Laboratory. You can read more about the format at **http://geotiff.osgeo.org**, but basically it is a standard way to pack georeferencing information into a TIFF image file, including the map projection, coordinate system, etc.

Many standard GIS type tools can read these in, and easily plot and analyze them with other georeferenced data. I installed the free QGIS tool (**www.qgis.org**) as it seems to be the best free and open source tool in the game. The GeoTIFF can be opened by clicking the "Add Raster Layer" button (**Figure 9**) and navigating to the file. Other layers can be added as well.

Generally, we are mapping relatively small areas with our drones, but you can find shapefiles for rivers, roads,

**Figure 9: Click this icon to add a "raster" or gridded data layer to the GIS map.**

**Figure 10: Click this icon to add a "vector" layer such as a shape file to the GIS map.**

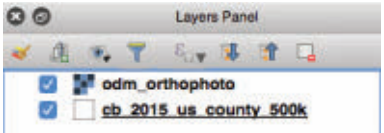



**Figure 11: In the layer window, you can turn various layers on and off, reorder layers, change their display properties, etc. With some fiddling of the settings, very professional and complicated maps can be made.**

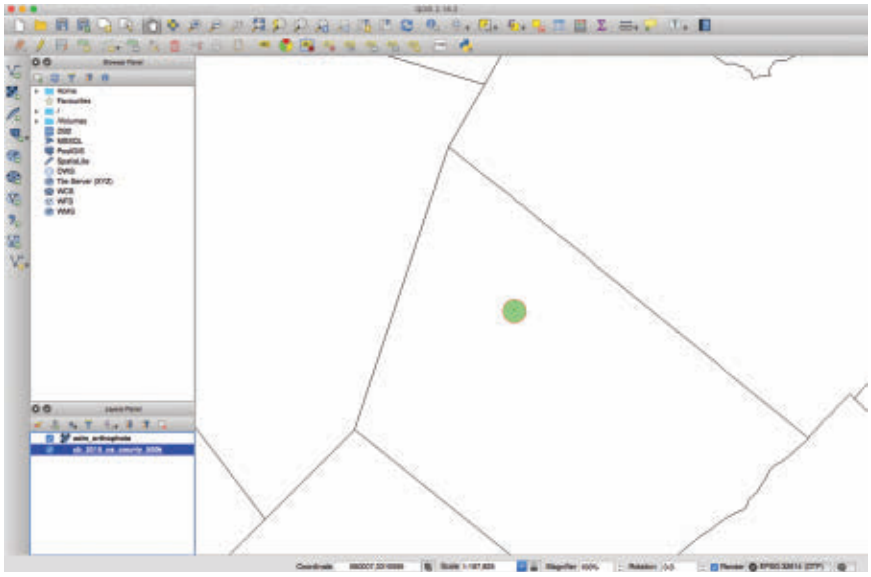


**Figure 12: You can barely see the mapped area (circled in green) in the county outline. Adding a shapefile of streets, property boundaries, or other important landmarks could help further tie the survey into other datasets.**

and other features all over the Internet. The United States Geological Survey (**https://water.usgs.gov/maps.html**) and Census Bureau (**www.census.gov/geo/maps-data/data/tiger-cart-boundary.html**) provide useful files.

I downloaded the county outlines file from the Census Bureau and added it by clicking the "Add Vector Layer" button (**Figure 10**). The layers can be reordered and their coloring changed in the layer window at the bottom left (**Figure 11**). As you can see, the mapped area really is very small compared to the county (**Figure 12**). A shapefile of the houses to be built could be set on the map though, as well as street placement and other important features.

The textured results are a little bit more difficult. MeshLab (**www.meshlab.net**) is a great tool to start with. In the *odm_texturing* directory, you will find the objects *odm_textured_model.obj* and *odm_textured_model_geo.obj*. These are the same except for georeferencing in the *_geo.obj* file. Open the textured meshes with MeshLab. There are three rings you can click on and use to rotate the mesh (**Figure 13**). The scroll wheel of the mouse zooms into and out of the image; command and drag pans the image.

Textured meshes are generally not perfect. If all of the photos are very nearly straight down, it is not really possible to get the structure of the sides of objects. Roofs and short objects seem to be rendered very well, but the sides of some taller objects were missing the side structure.

Taking photos from multiple angles would be a good solution, but only if that information is important for your application. I could imagine a camera on a pan/tilt head or multiple cameras being really useful here.

Lastly, you can open the *odm_georeferenced_model.ply* file with MeshLab as well. This is a dense point cloud file that should have the points of the 3D reconstruction available. These files can also be read into many common CAD tools such as SolidWorks and the AutoDesk products.

## Closing Thoughts

Now that we have ODM up and running, we're ready to collect some data of our own. Next time, we will talk about different cameras that can be used, affix one to our quad, and take some real world data. We'll process it with ODM and see if we can take some measurements.

Until next month, fly safely. **SV**

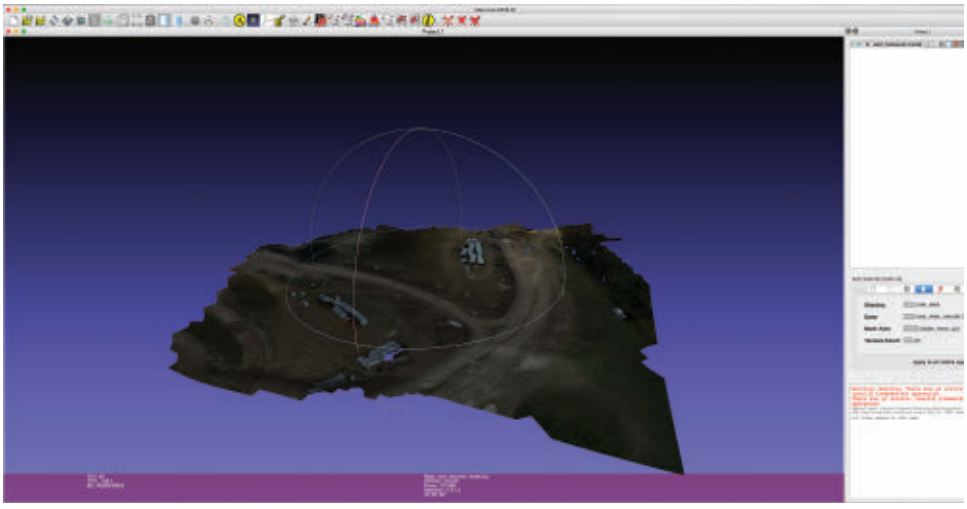


**Figure 13: The textured mesh shows the 3D shape of many of the objects on the ground. Grabbing the rings lets you pivot the image around. Zooming is accomplished with the mouse wheel and panning with command/control and drag.**

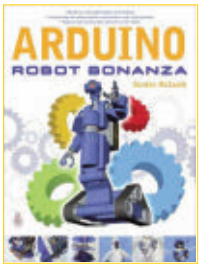
# The SERVO Webstore

## CD-ROM SPECIALS

## 04.2017 FEATURED

## ROBOTICS

### Arduino Robot Bonanza
by Gordon McComb




***Create high-tech walking, talking, and thinking robots. "McComb hasn't missed a beat. It's an absolute winner!"***

Breathe life into the robots of your dreams — without advanced electronics or programming skills. *Arduino Robot Bonanza* shows you how to build autonomous robots using ordinary tools and common parts. Learn how to wire things up, program your robot's brain, and add your own unique flair.
**$29.95**

### Robot Builder's Sourcebook

Fascinated by the world of robotics but don't know how to tap into the incredible amount of information available on the subject? Want the names, addresses, phone numbers, and web sites of companies that can supply the exact part, plan, kit, building material, programming language, operating system & computer system? Robot Buider's Sourcebook is just what you've been looking for!
**$36.00**

### Making Things Move: DIY Mechanisms for Inventors, Hobbyists, and Artists
by Dustyn Roberts

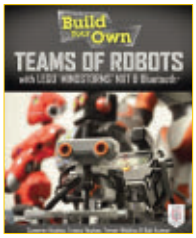
In *Making Things Move: DIY Mechanisms for Inventors, Hobbyists, and Artists*, you'll learn how to successfully build moving mechanisms through non-technical explanations, examples, and do-it-yourself projects — from kinetic art installations to creative toys to energy-harvesting devices. Photographs, illustrations, screenshots, and images of 3D models are included for each project.
**$29.95**

### Build Your Own Humanoid Robots
by Karl Williams

GREAT 'DROIDS, INDEED!

This unique guide to sophisticated robotics projects brings humanoid robot construction home to the hobbyist. Written by a well-known figure in the robotics community, *Build Your Own Humanoid Robots* provides step-by-step directions for six exciting projects, each costing less than $300. Together, they form the essential ingredients for making your own humanoid robot. **$24.95**

### Build Your Own Teams of Robots with LEGO® MINDSTORMS® NXT and Bluetooth®




Plan, design, assemble, and program robot squads that communicate and cooperate with each other to accomplish together what they can't do individually. Inside the authors show you how to construct a team capability matrix (TCM) and use the Bluetooth Robotic-Oriented Network (BRON) so your robot teams can share sensors, actuators, end effectors, motor power, and programs. **$30**

### Robotics Demystified
by Edwin Wise

YOU DON'T NEED ARTIFICIAL INTELLIGENCE TO LEARN ROBOTICS! Now anyone with an interest in robotics can gain a deeper understanding — without formal training, unlimited time, or a genius IQ. In *Robotics Demystified*, expert robot builder and author Edwin Wise provides an effective and totally painless way to learn about the technologies used to build robots! **$19.95**

**To Order Call 800 783-4624 or visit our webstore**

# Order online
# www.servomagazine.com

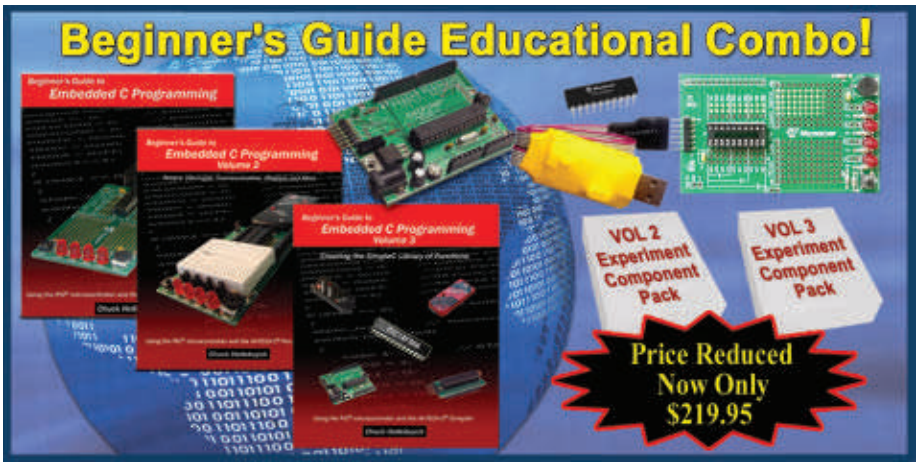
## SPECIAL OFFERS

### DIY Drones for the Evil Genius

by Ian Cinnamon, Romi Kadri, Fitz Tepper

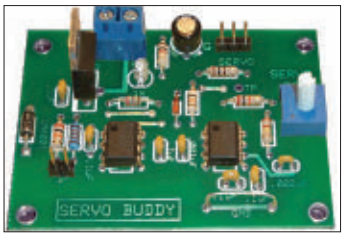
This fun guide shows step-by-step how to construct powerful drones from inexpensive parts, add personalized features, and become a full-fledged pilot. It not only covers safety, mechanics, drone design, and assembly, but also teaches the basics of Aerospace Engineering. You will discover how to add video transmitters, GPS, first-person view, and virtual reality goggles to your creations.

**Reg $25.00 Sale Price $19.95**



## PROJECTS

### The SERVO Buddy Kit




An inexpensive circuit you can build to control a servo without a microcontroller.

**For more information, please check out the May 2008 issue or go to the SERVO webstore.**

Includes an article reprint.

**$39.55**

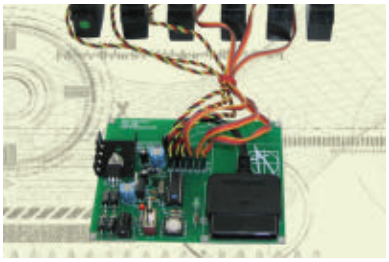
### 3D LED Cube Kit

**From the article "Build the 3D LED Matrix Cube" as seen in the August 2011 issue of *Nuts & Volts Magazine*.**

This kit shows you how to build a really cool 3D cube with a 4 x 4 x 4 monochromatic LED matrix which has a total of 64 LEDs. The preprogrammed microcontroller that includes 29 patterns that will automatically play with a runtime of approximately 6-1/2 minutes.
Colors available: Green, Red, Yellow & Blue.
Jig and plastic cases also available.

**$57.95**

### PS2 Servomotor Controller Kit



This kit accompanied with your own PlayStation controller will allow you to control up to six servomotors.
Includes all components and instruction manual.
For more information, please see the February 2011 edition of *SERVO Magazine*.
Assembled units available!

**$79.95**

by Bryce Woolley and Evan Woolley

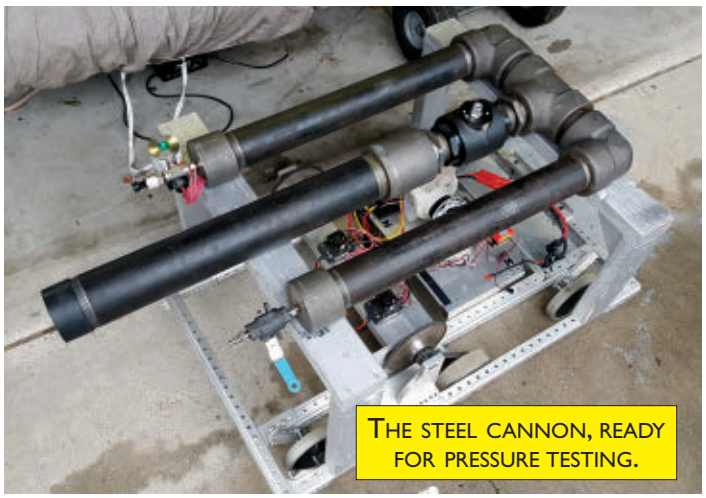
Go to **www.servomagazine.com/index.php/magazine/article/April2017_TwinTweaks_High-PSI-Cannon** to comment on this article.

# Full Metal Cannon

As all of you robotics innovators are likely acutely aware, one of the long term projects for the Twin Tweaks crew has been a high pressure robotic air cannon. We've extensively chronicled the initial design of the cannon and PVC prototyping (October 2015 and December 2015), experimentation with trigger designs (October 2016), the initial construction of our high pressure steel cannon (December 2016), and even building a mini version of the cannon with the Agent 390 tracked base from Actobotics (April 2016). What else could there possibly be to cover? As it turns out — a lot. Building a high pressure cannon is one thing, but testing it is a whole other ball game — literally. We couldn't even rely on just baseballs for testing anymore. We had to upgrade to a 10 pound chromoly slug. But that's getting a little ahead of ourselves.

As the December 2016 article went to print, the pipe sealant on the steel cannon was still curing. We didn't know if the cannon was even going to hold pressure, much less how it would handle firing a projectile over 20 times heavier at over 30 times the pressure than we had tested before. According to our calculations, we could potentially be shooting a 10 lb slug at over 300 mph. This would easily be the most dangerous project we've ever done for *SERVO Magazine* (or for anything, really).

So, we want to make this clear up front: High pressure pneumatics are dangerous. Don't try this at home! We took numerous safety precautions at every step of the way, overseen by Robot Central's resident safety guy (our dad), who is, in fact, a professional safety guy. So, slip on your gloves, don your safety glasses, and keep that hearing protection nearby because things are going to get loud.



The steel cannon, ready for pressure testing.

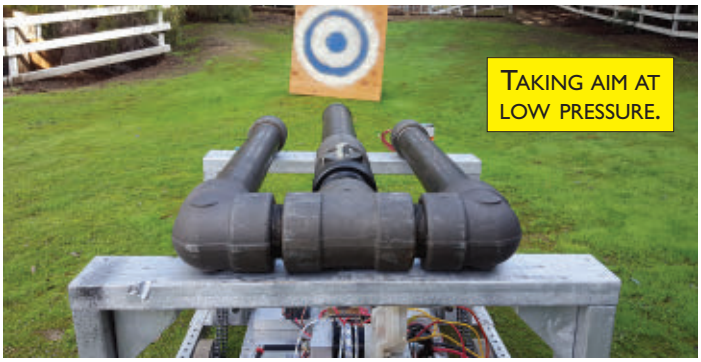
## How We Learned to Stop Worrying and Love the Tank

One of our Bot-mas gifts was a panel meter from Newport that would translate the voltage from the pressure transducer into a readout of the pressure in the cannon tank. We put the meter into a protective casing and wired it up to connect it to the transducer and to AC power. The panel meter was essential for our very first test of the steel cannon — making sure it held pressure.

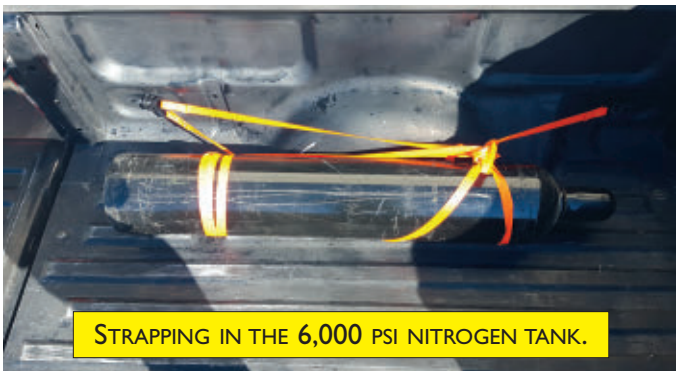
As we were out and about gathering some last minute things from the hardware store, we kept our eyes out for Snoop: a leak detector that would come in handy if filling the cannon tank was accompanied by an angry hissing sound. We couldn't find any Snoop, but figured we could make due with soapy water if need be. Once applied to all of the seams in the tank, the leak detection fluid would bubble at the site of any leaks.

Hopefully, we could avoid giving the tank a sponge bath. We hadn't yet acquired our high pressure nitrogen, but we still had our small shop compressor and thought that would be sufficient for our initial test. We hauled Protobot down from its ceiling hooks in Robot Central and planted the cannon on top of it. Filling the tank was a little tricky since the shop compressor didn't have the right Foster connectors to hook up with the tank input valve, but we made do. We filled the tank with about 60 psi, guided by the bright red readout on our panel meter. The only hissing sound that accompanied the inaugural pressuring of the cannon was our collective sigh of relief — the tank was

The wired up Newport panel meter.



TAKING AIM AT LOW PRESSURE.



STRAPPING IN THE 6,000 PSI NITROGEN TANK.

POTENTIAL STEEL SLUGS: 6" LONG 4140, AND 3" LONG 1018, 4140, 1045, AND 8620.

holding steady. No apparent leaks. Just to be sure, we left the 60 or so psi in the cannon overnight.

The next morning the pressure had dropped slightly, but only by about 3 psi. We figured that was actually because of the chilly temperatures overnight — the air in the tank would have compressed in response to the nighttime temperature drop. We deemed the first pressure test a success — there were no leaks.

We couldn't resist the opportunity to shoot something, even though we didn't yet have our high pressure nitrogen. We took Protobot and the shop compressor to the backyard, set up our trusty plywood target, and loaded the cannon with a baseball. We filled the cannon to about 70 psi, guided by the readout on the panel meter. We used a wrench to manually open the valve since we hadn't yet figured out the trigger mechanism for the steel cannon.

The valve opened easily, and the baseball careened into the target with an audible thwack. It was a solid hit and close to a bullseye — but it was also quite like the testing we had previously done with the PVC prototypes. The whole point of making the steel cannon was to crank things up to 11 and fire a way heavier projectile at way higher pressure, precipitating in (we hoped) way more destruction. To do that, we would need to get our hands on high pressure nitrogen.

## Parts of Glory

As amply demonstrated during the Twelve Days of Botmas, acquiring robot parts is most often simply a matter of placing an order online and waiting for the box from McMaster-Carr to show up at your doorstep mere hours later. Sometimes, though, you need to visit specialty suppliers, and sometimes you need to bring a big truck.

A 6,000 psi tank of nitrogen is one such specialized part. Even though the max pressure of the cannon would only be 3,000 psi, we wanted a 6,000 psi tank to give us more fills for testing. After lots of research, we found a promising supplier: Action Gas, a welding supply store based in Lake Elsinore, CA. They even had a store in Temecula — Robot Central's home base. We applied for an account as Team Double Trouble Robotics, and we hoped that we could pick up the canister from the Temecula location. On the weekend we planned to pick up some of our last materials needed for testing, we called Action Gas and discovered that unfortunately the Temecula store didn't have a 6,000 psi canister in-store. However, the Lake Elsinore location did. We took the truck.

The Lake Elsinore store was impressive — a bright and open warehouse with welding equipment galore. The back of the warehouse contained plenty of compressed gas canisters, dutifully lined up and ready to ship out to help weld some metal. We had other plans for our canister.

We were instructed to bring the truck to the back of the store, and by the time we finished paying the very reasonable rental fee, the canister was standing behind the truck, daring us to load it in. The canister was about four feet tall, and wide enough to promise a difficult time getting it into the truck bed. The Action Gas guy that guided the canister over to the truck looked at the canister, and then to us, and asked if we had ever loaded one of these before. We admitted that we had not. He gave us the scoop on tipping the canister to lean in on the tailgate, and then lifting the canister and sliding it in. He warned us that the 3,000 psi canisters tip the scales at about 100 lbs. This was a 6,000 psi canister. He wished us luck getting it loaded.

We eventually did. As we were strapping down the canister in the bed of the truck, the Action Gas guy wandered back and looked with approval at our efforts to strap down the canister. He said we would want to be sure to secure it really well — if something goes terribly awry and a 3,000 psi canister blows, it's like a bomb going off. But a 6,000 psi canister ... he speculated that would be more like a ballistic missile. We added an extra strap.

Shaping up the 10 lb slug.

Our 10 lb slug, ready for glory.

Ready to pressure up with the 6,000 psi canister (Evan for scale).

The yard guys at the feed store were a little incredulous. The quality of the straw bales, they warned us, was subpar. It was the last of their current stock, and had gotten a bit damp and muddy in the unusually wet weather Southern California had experienced in the last few weeks. The yard guys asked what we planned to use the bales for — maybe bedding or something like that. Our answer of "target practice" was truthful, though we think more likely conjured images of an archer with a bow and arrow rather than a high pressure robotic air cannon.

We hauled the straw bales back to Robot Central and stored them in a horse stable in the backyard. The bales were not nearly as heavy as the nitrogen canister, but were certainly over 100 pounds each. Everything about this project was turning out to be heavy.

Given the awesome dangerous power of the 6,000 psi canister, the Action Gas guy was curious about what we planned to use it for. So we told him, and he thought it was awesome. We hoped it would be — assuming we could get the ballistic missile of a canister back to Robot Central safely. It was a very cautious ride back from Lake Elsinore.

Back at Robot Central, we strapped the canister to the leg of the built-in workbench to keep it secure in case the "Big One" hit. If that ballistic missile hit the ground the wrong way, we would need more than The Rock in a helicopter to save us.

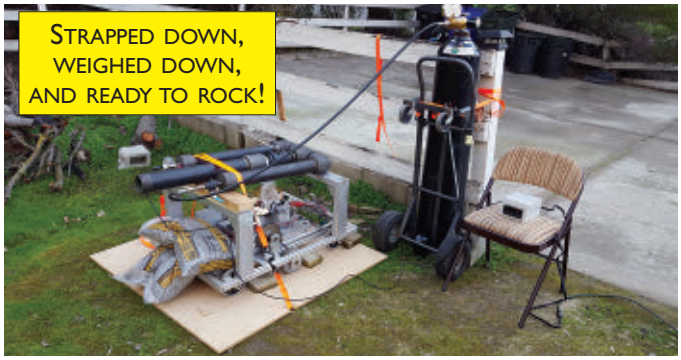
Once the canister was secure, we still had a few more errands to run. Specifically, we needed to find a solution to a problem we didn't have with low pressure testing. For the PVC prototypes and for the low pressure baseball tests, shooting at our plywood target was fine. It was starting to crack a bit, but the baseball would bounce fairly harmlessly off of the target and roll lazily down the hill in the backyard — our makeshift shooting range. This time, however, we were hoping to shoot a steel slug at up to 300 miles per hour. The plywood target wouldn't stand a chance, and we were worried that after ripping through the target that the slug would keep on going and either ricochet back off the hillside and hit a defenseless car sitting in the driveway or keep traveling up the hill and into the wild blue yonder.

We wanted something that could absorb the force of the projectile; something that our slug could burrow into instead of ricochet off of. So, we hopped back in the truck and headed to the local feed store for some bales of straw.

## A Clockwork Test with Orange Straps

With our nitrogen strapped down and our straw bale target set up, we were almost ready for testing. The last step was to prep our slugs. McMaster had a nice selection of large diameter steel rods, so we ordered some to have a few options for potential projectiles. One potential slug was a 2-7/8" diameter 6" long rod of chromoly (numerically known as 4140). We were concerned that diameter could be too small for our 3" diameter cannon barrel, so we also ordered a few 3" diameter rods (3" long), thinking that the tolerance on the diameter could end up giving us the perfect fit.

We had a few alloys to choose from among the 3" long slugs, too — 1018, 4140, 1045, and 8620. The softest alloy was the 1018, and that rod had a few dents from shipping. That wasn't ideal because it would probably deform so much upon impact that we wouldn't be able to reuse it. As it turned out, we didn't need to hem and haw about the virtues of different alloys because the 2-7/8" diameter chromoly rod ended up being a perfect fit for our cannon barrel. Plus, it weighed about 10 lbs, which had a nice round appeal.



Strapped down, weighed down, and ready to rock!

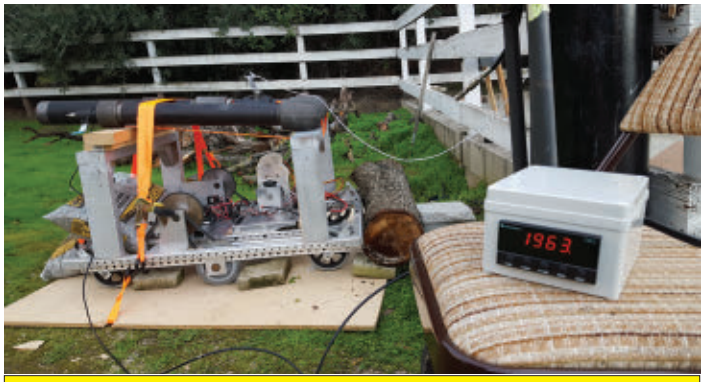
We could potentially use the chromoly slug without modification, but that would be a bit sloppy. Using a tabletop grinder, we chamfered the top and bottom edges a bit to ensure there wasn't any imperfection to hang up the slug on its speedy trip through the barrel of the cannon. We also drilled a shallow hole into the top of the slug and cut a few taps into it. We had a long rod of all-thread that we could use to screw into the slug in case it ever became stuck in the barrel. With our slug prepped, we were finally ready to start cooking with high pressure nitrogen. We wheeled out the nitrogen canister to the backyard and strapped it to a fencepost. We carefully removed the cap that covered the canister valve, working with the delicate care of a bomb diffuser. We attached our regulator to the canister valve with similar care.

Instead of setting Protobot up on the even ground of the backyard, we used a panel of particle board to hopefully provide some levelness and stability. We hooked a strap under the platform because we didn't intend to let Protobot free wheel about when it would be shooting a 10 lb slug at up to 3,000 psi. Cognizant of Newton's Third Law, we wanted to prepare for the equal and opposite reaction by strapping Protobot down and weighing it down for good measure. We wheeled Protobot onto the platform, then carried out the 120 lb cannon and placed it on Protobot's uprights. We strapped the cannon down to Protobot and the particle board, and used cinderblocks as wheel stops behind each of the bot's six wheels. As a final touch, we weighed down the front of the robot with two 50 lb bags of gravel. Everything about this project really was heavy.

We placed Protobot close enough to the nitrogen canister so that we could fill the cannon while the canister remained strapped to the fencepost like Hannibal Lecter. We put our panel meter on a chair next to the bot so we could keep an eye on the pressure. It was finally time to pressurize.

Safety, of course, was a chief concern. We weren't entirely sure how our stack of straw bales would handle our cannon's fastball from hell, so we started with only a few hundred psi and worked up from there.

Our process of pressurizing the cannon was detailed and methodical, and we would call out each step as we




That's 1,963 psi!

Making hay at 1,000 psi.

Measuring actuation torque.

Letting out a cloud of nitrogen.

Bullseye (almost) at 1,000 psi.

Our target is worse for wear.

completed it. First, we hooked up the pressure transducer to the panel meter, ensured the cannon valve was closed, and loaded the projectile. We wrapped the baseball in a single sheet of newspaper for wadding and loaded the ball with a long rod of all-thread topped with a tennis ball (our own custom ramrod). Once the cannon was loaded, we would go nowhere near the business end of the barrel until the projectile was evacuated.

Next, we connected the high pressure hose from the nitrogen canister to the cannon input valve using our locking Foster connector. We then opened the cannon input valve. We closed the regulator bleed valve and then opened the nitrogen canister, calling out and confirming every step along the way. Finally, to fill the tank, we opened the regulator valve. The knob on the regulator valve gave us fairly fine control over the fill rate, and one of us would call out the rising pressure as reflected on the panel meter. We quickly surpassed 90 psi — the highest pressure we ever tested the PVC prototypes at ... 100 psi, 200 psi, 300, 400, 500 ... eventually, we closed the regulator valve at 616 psi.

We called out every step of disconnecting the nitrogen canister too. We closed the nitrogen canister valve, closed the cannon fill valve, and then slowly opened the regulator bleed valve to let the pressure out of the high pressure hose. We opened the bleed valve slowly because it was actually pretty loud (though we were wearing hearing protection, which would be even more essential just a few moments later). We disconnected the locking Foster connector from the high pressure hose to the cannon input valve, and we were finally ready for testing.

Since we hadn't yet figured out our remote trigger mechanism, we had to do with the low-tech solution of a cable attached to a wrench so that we could open the valve manually. We fired.

The baseball was a complete blur as it crashed into the straw bales. The ball bounced off, but the bales worked as intended and absorbed most of the force. Now it was time for the chromoly slug.

## 2001 PSI: A Bot Odyssey

The chromoly slug was a snug fit with just one sheet of newspaper for wadding. We pressed it in with our ramrod and wondered what pressure we would be comfortable shooting it at for the first time. We settled on 1,000 psi, and went through the same call and response step-by-step to pressurize the cannon. Equipped with our hearing protection and safety glasses, we let it rip.

It sounded like a bomb going off, and the chromoly slug ripped straight through the straw bales and it was out of sight before the cloud of nitrogen at the mouth of the barrel dissipated. The recoil from the cannon blast was impressive. The entire assembly — with the 120 lb cannon, the extra 100 lbs of gravel, Protobot, the particle board platform, and various cinderblocks for wheel stops — must have weighed easily over 300 lbs. Yet, a shot at 1,000 psi caused the entire thing to buck noticeably — particle board and gravel and all.

We dashed up the hill, hoping that we wouldn't have to hop the fence to the neighbor's yard to retrieve the slug. We found the slug at the very top of the hill — well over 100 feet away from the cannon. Would we dare to increase the pressure even more?

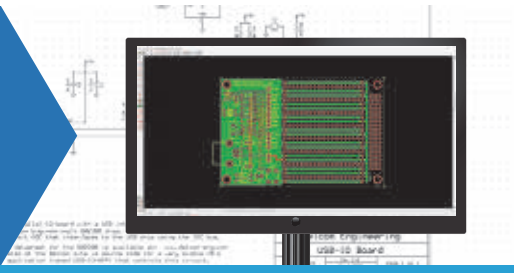
Of course we would. We pressurized the cannon to 2,000 psi, following our same step-by-step routine. This time, the slug obliterated one of the straw bales, but it didn't seem that much stronger than the 1,000 psi shot. That's because the actuation torque on the cannon valve had increased significantly with the higher pressure. We couldn't get a nice smooth release on the valve, and the cannon wasn't putting the full might of the 2,000 psi behind the slug. We tried again at 2,000 psi and had the same problem.

We dropped back to around 1,000 psi for our final tests — we wanted a nice clean release, and we wanted to see what the 10 lb slug would do to our plywood target at an estimated muzzle speed of about 180 miles per hour. We again followed the same step-by-step firing procedure, and the slug blasted right through the target as if it was paper.

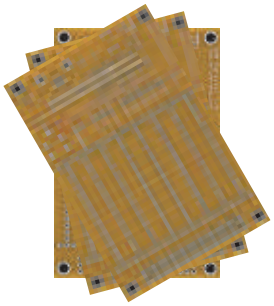
To ensure that our air cannon hijinks were science and not just screwing around, we wrote everything down. However, there was one more thing we wanted to write down: the actual actuation torque at different pressures, which we measured with a torque wrench. At ambient pressure, the actuation torque was 10 ft-lbs. At 1,000 psi, it was about 30 ft-lbs, and at 2,000 psi it was a whopping 80 ft-lbs. These numbers would be essential for designing our trigger mechanism, and once we had that fashioned, we could find out what the cannon could do at the max pressure of 3,000 psi.

We might need a new target, though. SV

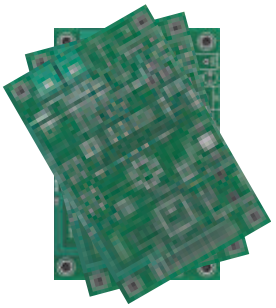

FREE
PCB Layout Software &
PCB Schematic Software



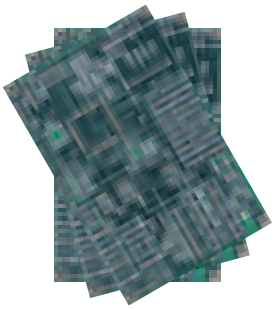
expresspcb.com



3 PCBs
$41 + shipping
2-layer
MiniBoard
(Shipped in 1 business day)



3 PCBs
$61 + shipping
2-layer
MiniBoardPro
(Shipped in 2 business days)



3 PCBs
$81 + shipping
4-layer
MiniBoardPro
(Shipped in 3 business days)

1 DOWNLOAD our free CAD software
2 DESIGN your 2 or 4-layer PCB
3 CHECK your design with xCHECK DRC
4 SEND us your design with just a click
5 RECEIVE top quality boards in just days

Now Offering
SMT STENCILS
– Nano Coating available–

MADE IN THE USA | www.expresspcb.com

by Tom Carroll
TWCarroll@aol.com

# What's New in Robotics

**At the beginning of each year, there is always a flurry of excitement in the electronics field as electronics manufacturers exhibit their new wares at the huge Consumer Electronics Show (CES) in Las Vegas in early January. In the early days of the show, robots were more of a curiosity than a 'must have' consumer product. New television sets, stereos, appliances, vacuum cleaners, and similar products were front and center at the first CES exhibition in 1967 in New York, with over 17,000 attendees. These days, all types of robots are front and center as major draws for viewing by over 170,000 attendees. For now, it is the place to exhibit your new consumer and home robots. Maybe in a couple dozen years, the show will be called The Consumer Robot and Electronics Show. Maybe I'm just dreaming of a possible continued robot evolution. Or, am I?**

## Early Educational Robots: the Boe-Bots

For the past 50 years, robotics has grown in leaps and bounds as new types of robots are constantly being introduced. Before I delve into the latest robot offerings introduced at the 2017 CES, I would like to discuss a series of earlier robots that made quite an impact on the experimental robot community. I'm talking about the Parallax Boe-Bot series.

Yes, there were the Androbot Topos, RB5X robots, and the Heath Hero series of the '80s, but these robots really did not furnish the robotics education and programming that the little Boe-Bots offered at an affordable price. The Heathkit Hero 1 and 2000 had an educational course included in the robot's construction, but the kits were quite pricey. Other robots of the '80s were in the thousands of dollars and beyond most experimenter's budgets.

Back in 1992, Chip Gracey took a 16C56A chip and made the first BASIC Stamp microcontroller board. Chip's brother, Ken joined him in founding Parallax, and experimenters soon snapped up 125,000 of these simple 'stamp-sized' boards to control almost everything. Ken was determined to show potential users just how easy it was to use the Stamp. One of Parallax's early customers was Chuck Schoeffler who recommended that the Gracey team use their successful Stamp's 1 and 2 as controllers for a robot as seen in **Figure 1** — a prototype built from an electrical junction box.

By 2002, Parallax had sold over three million of their BASIC Stamps. A later robot prototype in **Figure 2** uses an acrylic board to mount a smaller experimenter's board to, with the same rubber wheels driven by small servos. The robot in **Figure 3** has their Board of Education (BOE) mounted on an aluminum chassis; thus, the name Boe-Bot. Notice the small Stamp 2 on the robots in **Figures 2** and **3**. Today's ActivityBot — some 25 years later — uses their eight core Propeller chip (**Figure 4**). This powerful microcontroller is the heart of many devices — from educational robots to

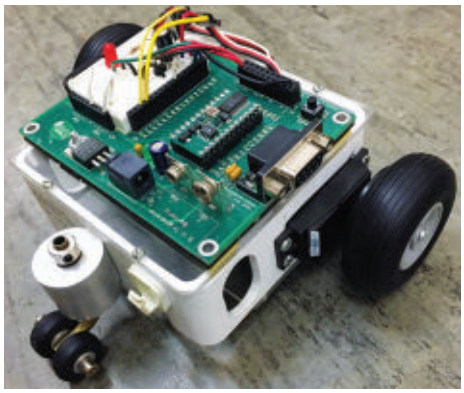


*Figure 1. Early Boe-Bot prototype made from an electrical junction box.*

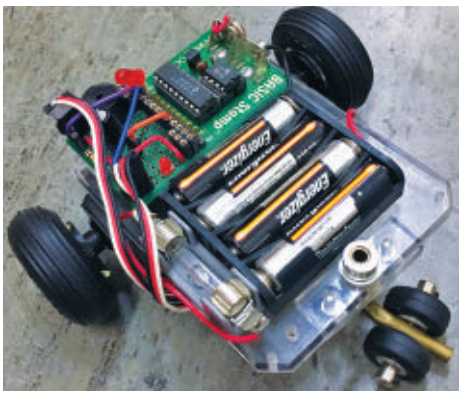


*Figure 2. BASIC Stamp proto circuit board on an early servo-driven robot.*

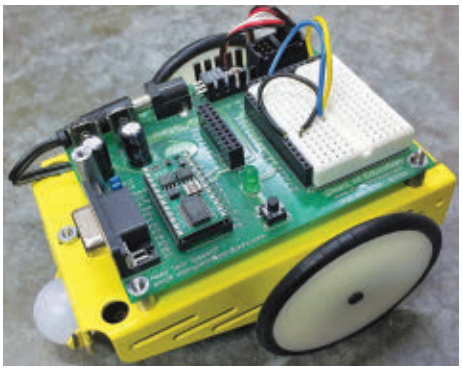


*Figure 3. The Parallax Boe-Bot is taking shape.*

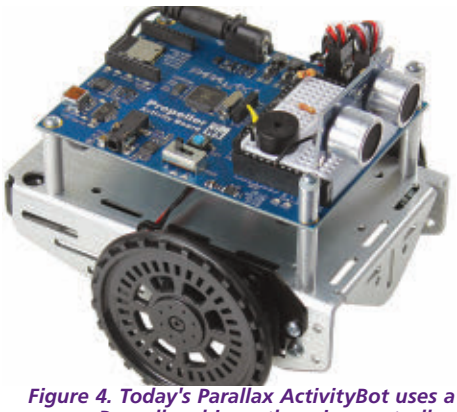


*Figure 4. Today's Parallax ActivityBot uses a Propeller chip as the microcontroller.*

Post comments on this article at **www.servomagazine.com/index.php/magazine/article/April2017_ThenandNow_Whats-New-in-Robotics.**

***Figure 5. The Parallax Scribbler 3 kit ready to use.***

advanced industrial controllers.

One feature that makes these robots such a value is the vast amount of course material available for both the Boe-Bots and Stamps. Their books are well written and are acclaimed by educators around the world. For those who don't enjoy assembling kits, Parallax offers their latest of the Scribbler series: the very affordable S3 (shown in **Figure 5**) that assists in teaching students everything from Blockly programming to Spin in a GUI environment. The hacker's port allows the addition of numerous interconnected devices.

## Robots at CES 2017

Outside of huge (and expensive) OLED televisions and various entertainment devices, robots and artificial intelligence seem to have created the most buzz within the show's thousands of vendor booths this year. Of all the new 'must have' gadgets on display, robots and other appliances (touted as robots) drew the most crowds. Many of these products would not have been called robots just a few years ago.

On the CNET site (**www.cnet.com**) and their excellent coverage of this year's CES, they made a very concise opinion of what so many attendees at the show were thinking. "*At CES 2017, you have to ask: What makes a robot a robot? An abundance of drones, driverless cars, and smart home devices equipped with voice assistants have blurred the definition of the word robot.*"

I asked that very question in last month's column when I discussed how robots have changed over the years — from the evil humanoid characters in Karel Capek's play, *RUR*, to Unimation's first industrial robot, to the myriad of all types of today's robots. It is that wide variety of robots designed for the home and personal use that make a trip to CES so memorable. These types of robots will only continue to grow as inventors and entrepreneurs keep enticing us with new robotic products that each of us just have to own.

## Amazon's Alexa and Robots

The Amazon Echo, Dot, and Tap have been available for two years now, and have made quite a showing with robots. Many of the robot and other technology exhibits at CES touted the use of the Amazon Echo and Alexa for control of their products. Amazon now has over 7,000 third-party integrations or skill sets available as apps.

In the beginning, the Echo and its siblings were a bit baffling to early users and were more of show-off pieces of technology than truly useful devices.

In recent times, the original Dot and its newest version have found themselves attached to mobile robots as control devices, utilizing many of those available apps. My article from last July discussed some of my (and other experimenters) early Alexa robot control attempts.

## The Future of Service and Personal Robots

On their website, TechRepublic (**www.techrepublic.com**) wrote about "CES 2017: Robots of the Future." They stated, "By 2018, the International Robotics Foundation predicts that 35 million service robots will be sold." These are not industrial and military robots sold to manufacturing businesses, hospitals, and governmental groups, but are 'service' robots that are intended for home, consumer, and commercial business use. The article continued, "And by 2020, $83 billion will be spent on these robots, according to a report by Intel." They asked three very important questions in the article: "So, who makes them? What can they do? And when will they be ready?"

Let's take a look at some of the robots at this year's CES.

## Ewaybot MoRo

The Chinese robotics company, Ewaybot showed off its new flagship robot, MoRo at CES. Founded by three Chinese students from Harvard and Carnegie Mellon University, it was a major draw at the show for many serious robotics experimenters and reporters from robotics journals. At an estimated cost of $30,000, their 'flagship' product seems to be more of a robot *yacht*. Their literature touts the robot being a member of your family, but it is more appropriate in a university or industrial laboratory environment as shown in **Figure 6**.

***Figure 6. Ewaybot's MoRo shown in a simulated laboratory environment.***

MoRo stands a bit under four feet

and weighs almost 80 pounds. Each of its two arms can lift a mass of 1.5 kg, though one website touted a lifting capacity of 5 kg, or 11 pounds. The robot is powered by a lithium-ion battery, giving it an eight hour battery life. It also has Wi-Fi connectivity. **Figure 7** shows a simplistic view of the robot's internal structure. The steel rods where the shoulder structure rides up and down in the Z axis can be seen in the right side slot of the robot in the drawing.

The MoRo is unique in several ways. The robot uses their own in-house designed servos for each of the robot's two 6-DOF arms, and one each for head and shoulder movements. These servos are fairly large at 2.9" x 2.7" x 1.7" and weigh 340 grams (or 12 ounces) each, draw 10.8 amps stall current, and have 42 Nm torque. That's 372 inch-pounds or 5,947 inch-ounces — a lot of torque. Compare that to a large Hitec quality servo like the D980TW that has 611 oz-in of torque and weighs 2.76 oz.

They have a 32-bit MPU driving a brushless motor through metal and nylon gears. Though certainly larger, these servo actuators seem to be in the same range and type as the Robotis Dynamixel and Dongbu HerkuleX rotary actuators, though I have not read any direct comparisons.

The arm's 'shoulder' mounts can be driven up and down together the length of the slots on the sides of the robot's body. Each arm can reach out to 70 cm from the body. You can see each arm's six axes of motion in **Figure 7**. There are two axes at each shoulder, two more at the elbow, and two at the wrist, with a Z axis to move both arms up and down together.

The head contains the Intel RealSense camera that can rotate horizontally 360° and pan up and down. The RealSense 3D camera series has been on the market for several years, and have found their way into several different laptops as web cameras, as well as motion sensing and facial/object recognition devices. In robot applications such as the MoRo, optical recognition of people and hand gestures are a key part of advanced robot control. The Intel series is positioned to take the place of the Microsoft Kinect in many mobile robot applications.

MoRo is capable of SLAM navigation, has a Nividia GPU, an Intel CPU, the RealSense 3D camera for facial recognition and object detection, real time voice control, and uses the popular differential drive base. MoRo has its RealSense 3D camera 'talking' to their own EwayOS operating system that supports and operates with ROS and Ubuntu.

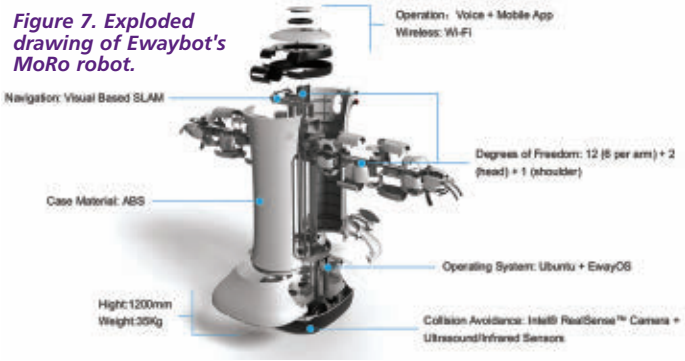



*Figure 7. Exploded drawing of Ewaybot's MoRo robot.*

According to the folks at Ewaybot, "MoRo is a robotic assistant that is designed to simplify your life. The robot is mobile and will work both indoors and outside. It can grasp and handle objects, listen to voice commands, and supports face detection through the built-in Intel RealSense camera."

MoRo is expected to be available to the public in mid 2017. Commercial butler and robot aide (for seniors) variations are actively being pursued.

## Kuri by Mayfield Robotics

Mayfield Robotics is based in Redwood City, CA and was formed in 2015 by Sarah Osentoski, Kaijen Hsiao, and Mike Beebe. Mayfield is entirely owned by the large German company, Bosch. Osentoski and Hsaio — now the chief operating officer and chief technology officer — had both previously worked on robotics in other Bosch divisions. Bosch had formed a Startup Program: an incubator within the company in which employees with an interesting idea could test different ideas for products to see if they had commercial potential. Thus, the successful startup was formed without the frightening period of crowd funding or pleading to prospective venture capitalists for money.

The 20 inch tall/14 pound Kuri shown in **Figure 8** was designed by a former Disney Pixar studio animator. The robot reminds me of a penguin with its flippers permanently fastened to its sides, possibly due to thoughts of the Disney Pixar animation characters. The photo in **Figure 9** shows an evolution of four of the many steps taken by the Mayfield team to

*Figure 8. Mayfield Robotics' Kuri is a member of the family.*

*Figure 9. An evolution of Mayfield Robotics home robot, Kuri.*

develop Kuri's final form.

The top of its head contains a capacitive touch sensor to allow a tap on the robot's head to cause it to look upwards. An HD camera behind one of its eyes allows Kuri to capture photos and videos when so programmed. The eyes can blink and represent a smile. The robot can move its head to look up or down and side to side. Four microphones in its body can locate the direction of voices or sounds and move to that location to investigate. To command the robot to perform a task, just say "Hey, Kuri" followed by the task's description. This is similar to the Google Home voice-activated speaker powered by the Google Assistant when you say "Okay, Google."

There is a soft blue light that can emanate from the robot's chest as an indication of its mood, such as happiness or just thinking. Two speakers in its base can play music, repeat what the owner says, or just talk in "robotese." Though it has speech recognition, the robot doesn't say anything other than playing back what the owner said. It responds to commands and situations with beeps and other sounds like R2D2. There is a mapping sensor in the rear to allow the robot to learn a floor plan and the locations of obstacles. Kuri also has Bluetooth and Wi-Fi connectivity, allowing remote operation. It will return to its charging base when it wants to take a 'power nap.'

"Kuri is earnest and helpful, and closer to an intelligent pet than a robot butler," according to Hsaio. "He's less about outright functionality, and more about adding to a family." Voice commands will be supported, though Mayfield is still deciding exactly what features Kuri will launch with.

Right now, the thinking is to include the ability to read stories (that's talking) and play music, follow you as it plays your favorite podcast, and act as a mobile camera — all to be launched with a "Hey, Kuri" command. Its niche in the modern household may be a bit like the table-top Jibo or mobile Pepper — not just a friend but a part of the family.

## New Robots from LG

Many people seem to believe that LG comes from their tag-line, 'Life's Good,' but it actually comes from its original name, Lucky Goldstar. It began as a Korean chemical company in 1952 after the Korean War and branched into electronics in 1958. In the early days, its electronics were not known for reliability and quality, and it had a 'not so good' reputation. They quickly strove to change this image, and became the Korean electronics and appliance manufacturing giant they are today. They have made many innovative products and have become an electronics leader in today's technology world.

LG's new Hub robot has been described as "adorable," but it is "essentially a digital assistant with a face." It uses the Amazon Echo Alexa voice-recognition cloud for control. That makes it similar to the Echo in that it answers questions, turns on music, and checks the weather. It has the ability to connect with other LG home appliances such as refrigerators, dishwashers, washing machines, and especially the number one home robot: a vacuum cleaner. It also has an interactive display, can share information, stream music, create reminders, and much more. The Hub and Mini Hub are shown in **Figure 10**.

Hub's facial recognition capability and its ability to greet each person that it 'sees' should be one of the most desirable features of the Hub. It can be programmed with a unique greeting for each individual rather than a boring "Hi, Tom." The robot's animated 'face' that can swivel to look at the person speaking reminds one of the long-awaited Jibo. The Hub robot can respond to its human counterparts by nodding its head when answering simple questions.

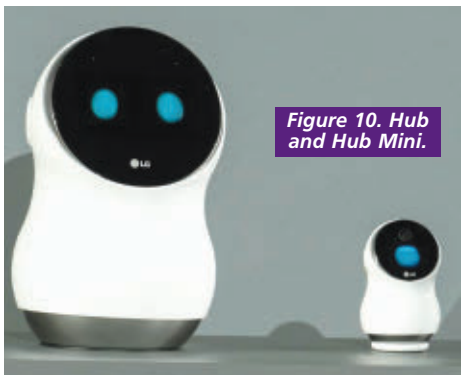


*Figure 10. Hub and Hub Mini.*

LG is also offering a mini version of the Hub that can be placed around a home for room to room control, just like Amazon did with the introduction of the Dot. LG was suggesting at CES that the final production models of the Hub robots will actually be able to recognize *who* is speaking, not just that a *person* is speaking. That is a quantum leap past Alexa and Siri. Pricing on this series of robots has yet to be announced, however.

LG also debuted two robots designed for public spaces. The more impressive of the two is the white AirBot Airport Guide Robot shown in **Figure 11** that has a curved LCD display screen on its front. LG has plans to have it in Seoul's Incheon International Airport this summer. It will answer questions in four languages: English, Chinese, Japanese, and Korean. After scanning a passenger's ticket, the Airport Robot Guide provides information about a flight's boarding time and gate location, and the weather of the traveler's destination.

The airport robot also offers directions to locations within the airport, along with estimated distances or walking times, and can even escort lost or late travelers to

*Figure 11. LG AirBot airport guide robot.*

their gates, or any other airport location. In a very busy airport environment, I would worry about an errant luggage cart or a wheeled piece of luggage accidentally slamming into the large LCD screen and damaging it.

The idea is good, but is the robot up to the task? Their airport cleaning robot shown in **Figure 12** can work in the late night hours when foot traffic is minimal and proximity to careless humans is at a minimum. It is equipped with LiDAR and SLAM navigation to detect obstacles, and always knows its location.

*Figure 12. LG airport cleaning robot.*

## UBTECH Robots

One of the most highly anticipated robots of 2017 is the 20 inch/50 cm tall Lynx biped humanoid from Chinese-based UBTECH Robotics. The company has gradually been expanding its presence outside of China with some innovative products. Their Jimu Robot series for children and bipedal humanoids such as the Alpha 1s have been on the market since 2016. It was the large wheeled humanoid Cruzr and amazing bipedal Lynx that seemed to create the most buzz at CES 2017.

## UBTECH Lynx

It is the Lynx that members of the Seattle Robotics Society are most excited about. This small biped humanoid (shown in **Figure 13**) has some amazing capabilities. At the beginning of this article, I mentioned just how many Alexa apps have been developed for so many uses, including appllications with robots. The Alexa app is not just connected to Lynx, it is *embedded* within the robot. You can dictate emails to Lynx and even have the robot read back your received emails. The robot can be used as a smart home controller and security monitor. As with the Amazon Echo and Dot series, you can use Lynx in conjunction with Amazon Music and Spotify.

*Figure 13. UBTECH Lynx bipedal robot — a winner for 2017.*

*Figure 14. UBTECH Cruzr with nice articulated arms.*

The robot was designed as a personal assistant as it has facial recognition with its built-in camera. If you have ever thought about learning yoga, your new Lynx can show you the correct poses and guide you through the steps of learning. Lynx was one of the most popular displays at CES, and it was not due to any verbal capabilities. Lynx seems to have mastered a few dance moves in addition to yoga positions.

People with whom I talked with about CES told me of the lines of people who wanted to see the Lynx dance, waving its articulated arms as it moved and grooved.

If you want to call a friend via video, Lynx can set up the connection through Wi-Fi and its camera. The same camera and its system can recognize family members and even pets, though it might take some time for Fluffy or Rover to accept the diminutive robot as a friend. The voice recognition features of Amazon's Alexa AI have made Lynx a winner. Though its facial features (especially the eyes) remind me of the Aldebaran Robotics Nao, its price tag is not in the Nao range of $8,000 (down from $16,000). It is reported to be in the $800 range — less expensive than the Robotis Bioloid and Hovis Lite. This robot should be a hit.

## UBTECH Cruzr

The Cruzr was another of UBTECH's must-see robots at CES 2017. Unlike the small Lynx, Cruzr (shown in **Figure 14**) was designed for commercial businesses. "Cruzr's mission is to improve your business, collaboration, and overall quality of life," said John Rhee, General Manager, North America, UBTECH. "With Cruzr, companies can better attend to their customer's needs, while allowing human teams to focus on more complex issues requiring human interaction. Ultimately, Cruzr enables companies to spend more time making smarter business decisions."

Cruzr is a cloud based intelligent humanoid robot that provides a new generation of service for a variety of industrial applications and domestic environments. Offering user-friendly humanlike interaction, it can be configured for a variety of specialized applications such as:

**Humanoid Design with Flexible Arms** — Cruzr moves like a human and can greet visitors, shake hands, move around, dance, and even hug.

**Voice Recognition and**

**Interaction** — Cruzr recognizes people by voice facing them when they speak, and can reply. Cruzr can also engage in casual conversation.

**Remote Centralized Control System** — With a cloud based operating system, Cruzr can set up multi-angle advertisements and real time video surveillance.

**SLAM Navigation** — Cruzr has a smart localization and mapping function to guide you.

**Intelligent Customer Service** — With a custom Q&A library, Cruzr can answer basic customer queries or transfer questions to offsite specialists.

**Video Conferencing** — Cruzr provides video conferencing with a built-in 13MP HD camera for video and audio, with the freedom to move about the meeting space.

**Facial Recognition** — Cruzr can recognize customers and respond accordingly.

**Video Surveillance** — Cruzr's video surveillance and autonomous security-patrolling skills can send out alert notices via APP, and records video for later review.

**Automatic Self-Recharging** — Cruzr's battery provides 5-8 hours of active use. When its battery is low, Cruzr will automatically return to its self-recharging dock.

*Figure 15. UBTECH's TankBot, the large Cruzr, and the Lynx biped robot.*

*Figure 16. Hanson Robotics' Albert Einstein robot.*

UBTECH's Jimu robot line debuted several new additions: the TankBot, Karbot, and LionBot. The TankBot joins the Cruzr and Lynx in **Figure 15**. I had the opportunity to make the TankBot kit available to the Seattle Robotics Society members at a recent meeting for them to examine, and see how it would fit within their various schools as part of a STEM program. Most schools use a more dedicated line of robot kits such as the LEGO MINDSTORMS. UBTECH is continually expanding their Jimu line to include build-your-own robots which give kids a basic introduction to coding.

The Karbot should appeal to young students, with UBTECH banking on the unique combination of robots and cars for "kids and teens on wheels." The Karbot can move along track lines, all while detecting and avoiding obstacles, as well as with in-app joystick controls and an Android smartphone app. The UBTECH line was among the CES 2017 Innovation Awards Honorees.

## Final Thoughts

There were many other robots shown at CES 2017 such as Hanson Robotics' Albert Einstein bot shown in **Figure 16** and the new LEGO Boost — a simpler version of their very popular MINDSTORMS that is geared for younger children. Pepper, the humanoid robot from the French company, Aldebaran and the Japanese conglomerate, SoftBank was present throughout the show floors.

Having been shown around the world for the past several years, this articulate wheeled humanoid shown in **Figure 17** has great promise in homes and businesses.

Robotics has long outgrown the 'industrial' moniker and is making its way into all aspects of everyone's daily lives. Mark Cuban, TV's 'Shark Tank' and owner of the Dallas Mavericks, recently Tweeted on Twitter, "We have to win the robotics race. We are not even close right now."

Referring to President Trump's trillion dollar investment in America's infrastructure, Cuban commented, "If it was me spending the money, I would take $100 billion of the proposed $1 trillion in infrastructure investment and invest it in robotics. I would invest it in the companies that do R&D, software, and design for robots and every other facet of the robotics industry." The Shark Tank star pointed out that China is investing much more heavily in robots than the US is.

I certainly hope that changes under President Trump's watch. SV

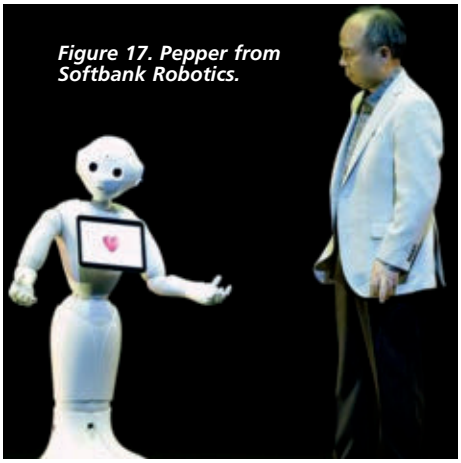


*Figure 17. Pepper from Softbank Robotics.*


Actuonix Motion Devices ....21
All Electronics Corp. ....23
Dobot ....3
EarthLCD ....23
ExpressPCB ....59
Front Panel Express ....59
Hitec ....2
IR Robot ....37
Maker Faire ....35
Maxbotix ....20
M.E. Labs ....45
PanaVise ....19
PCB Cart ....67
Pololu ....Back Cover
RoboGames ....66
Robot Power ....41
Super Bright LEDs ....20
The Robot MarketPlace ....19
Tormach ....13

# ROBOGAMES

**World's Largest Robot Competition**
***-Guinness Book of Records***

**North America's Top Ten Geek Fests**
***-Wired Magazine***

**SportCenter's Top Ten**
***-ESPN SportsCenter***

**"If you are a robot enthusiast, I would definitely encourage you to attend the RoboGames... Take a plane, train, space elevator, but definitely go!"**
***-Servo Magazine***

**"Impossible to Imagine, Impossible to Forget!"**
***-Robot Magazine***

**Compete at RoboGames!**
Last year, over 1000 builders from around the world brought over 800 robots to San Mateo, in the 11th annual international event. This year, we expect even more robots and engineers to compete. Be one! With 80 different events, there's a competition for everyone - combat, androids, sumo, soccer, Lego, art, micromouse, BEAM, or Tetsujin! More than half the events are autonomous. Even if you just come to watch, you'll be overwhelmed with the diversity.

Last year, RoboGames hosted teams with over 800 robots from Argentina, Australia, Austria, Brazil, Canada, China, Colombia, Czech Republic, Denmark, Germany, India, Indonesia, Iran, Japan, Korea, Mexico, Netherlands, Peru, Singapore, Slovenia, Sweden, Taiwan, UK, and the USA.

**Be a RoboGames Sponsor!**
RoboGames is the world's largest open robot competition - letting people of any age, gender, nationality, or affiliation compete. Sponsoring RoboGames not only helps more people to compete, but also gets your company unrivaled press coverage and visibility. The event has been covered by CNN, ESPN, Fox, CBS, ABC, NBC (live), EBS Korea, NHK Japan, BBC, and countless print and web companies. Your logo can be everywhere the cameras turn!

**Rent a Booth!**
Booth spaces are at the front of the venue, ensuring lots of traffic. With 3000-5000 people each day, you're company will get amazing traffic!

## Events:

**Combat:** 340 lbs, 220, 120, 60, 30, 3, & 1 lbs

**Androids:** Wrestling, Demonstration, Stair Climbing, The Eagle, Door Opening, The Toss, BasketBall, Lift and Carry, Marathon, Obstacle Run, Penalty Kick, Dash, 3:3 Soccer, Weight Lifting

**Open Events:** Fire-Fighting, Robomagellan, Maze/MicroMouse, Walker Challenge, Biped Race, Robot Triathlon, Line Slalom, Ribbon Climber, Vex Open, Lego Challenge, Lego Open, Aibo Performer, Balancer Race, Best of Show, Bot Hockey

**Sumo:** 3kg - Auto & R/C, 500g , 100g , 25g, Humanoid

**Robot Soccer:** Biped 3:3 & 5:5 , Mirosot 5:5 &11:11

**Junior League:** Lego Challenge, Lego Open, Lego Magellan, Woots & Snarks, Handy Board Ball, BotsketBall, 500 g Sumo, 120 lb combat, Best of Show, Vex Open

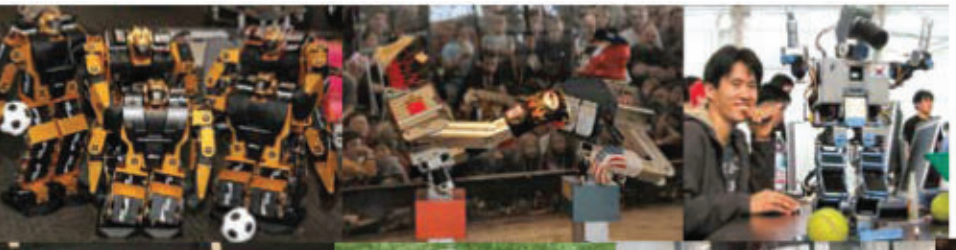
**Tetsujin (ExoSkeleton):** Lifting, Walking, Carrying

**Art Bots:** Static, Kinetic, Bartending, Musical, Drawing

**BEAM:** Speeder, Photovore, RoboSapien Hacker

**April 21-23, 2017**
**Alameda County Fairgrounds**
**Pleasanton, CA**

**http://RoboGames.Net**



PCBCART

# PCB Manufacturing Service
## for Robotics Companies of All Sizes

Over 10 years' experience in serving worldwide robotics companies with quickturn PCB prototyping & mass production services allows us to print custom circuit boards precisely with superior quality & performance while keep your options open & your costs down.

### Our advantages:

- Easiest online quoting & ordering system
- Free Design for Manufacturability Checking
- FR4 PCBs to Aluminum PCBs, Flex PCBs, etc.
- Custom electrical test including flying probe test, etc.
- Advanced capabilities including Gold fingers, Via in pad, etc.
- Flexible PCB Assembly & Components sourcing services

ISO 9001 SGCC · Pb LEAD FREE · UL

www.pcbcart.com

sales@pcbcart.com

# Romi

The new starting point for robotics

Pololu
Robotics & Electronics

Find out more at **www.pololu.com/romi**