

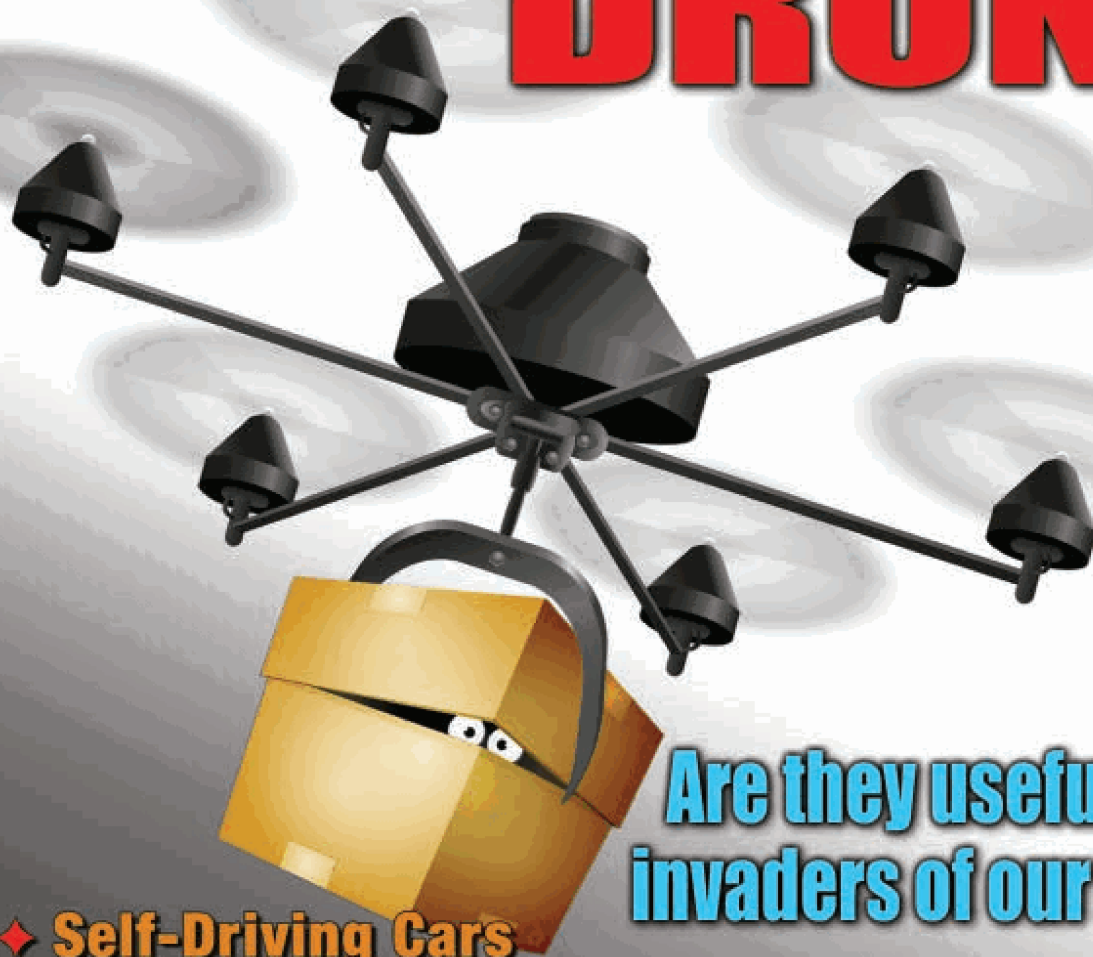
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SERVO

FOR THE ROBOT INNOVATOR
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MAGAZINE
April 2014

Invasion Of The **DROONES**



Are they useful tools or
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♦ **Self-Driving Cars**
An incremental approach

♦ **her - The movie**

How close are we to the future depicted
in the award winning film?

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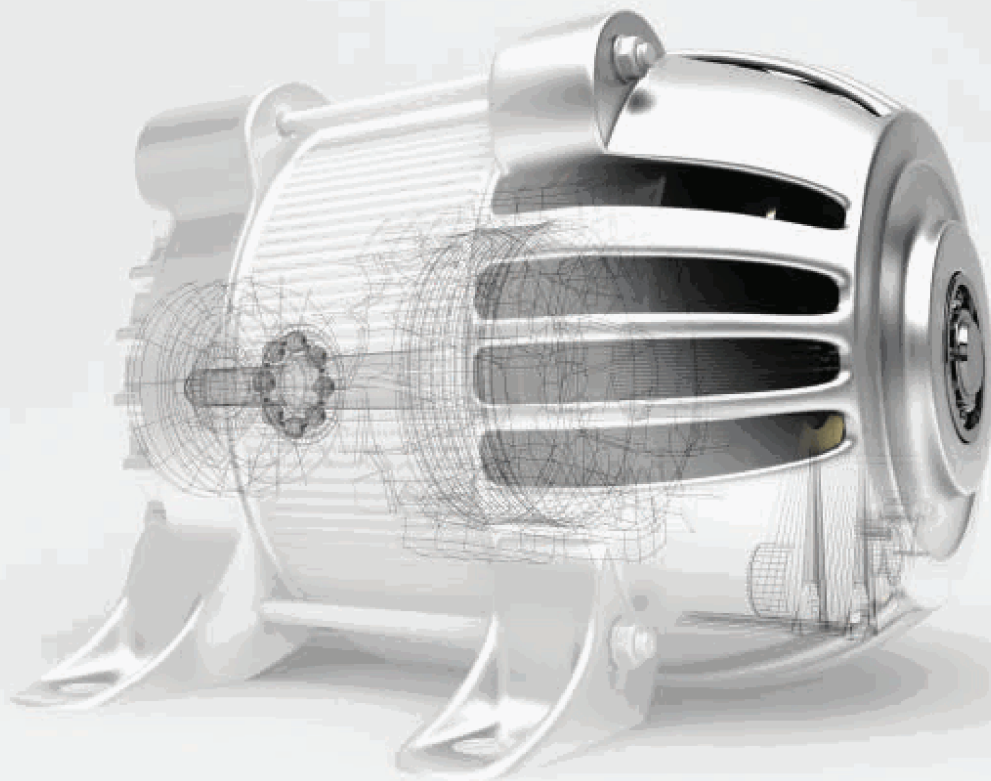
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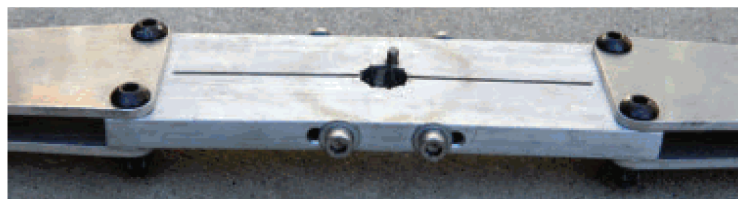
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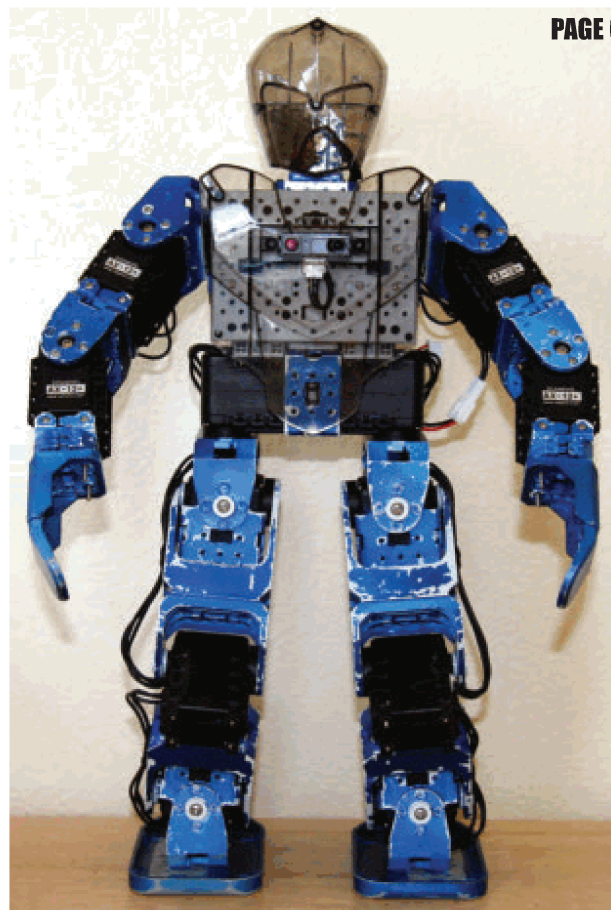
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Self-Driving Cars: An Incremental Approach

Google's driverless car has garnered a lot of attention lately, and rightly so. The technology appears to work better than the average human driver. As in the sci-fi movie *Total Recall*, the initial civilian application will probably be automated vans and taxicabs that ferry people around congested cities. And, of course, there's the obvious driverless tanker military application.

I don't really expect to see full-fledged Google cars selling in my local showroom — or on **amazon.com** — any time soon. Rather, it's going to be an incremental introduction to the technology. For example, take the autonomous emergency braking system (AEB) that automatically and appropriately applies the brakes if an array of sensors determines that the car is about to hit something. Once relegated to luxury cars, this capability is appearing on more affordable cars because of the precipitous drop in the price of sensors.

The issue with AEB systems — and many other autonomous systems for vehicles — is whether they work in a stand-alone or networked configuration. The stand-alone configuration is the default today, primarily because the infrastructure is lacking for consumer vehicles. Truck fleets are a different story, in that many delivery fleets are part of a network that monitors position, speed, miles traveled, and other parameters through satellite linkup. There simply isn't a standard network for consumer vehicles that can automatically control, say, maximum speed to reflect weather conditions on a specific road.

This situation may change if US regulators follow through with promises to implement a standard for vehicle-to-vehicle communications to eliminate collisions. Of course, if new vehicles in, say, 2017 are required to have these systems, it would take perhaps a decade for existing 'dumb' cars to disappear through attrition. Until then, avoiding vehicle-to-vehicle collisions will be in the hands of drivers.

Once vehicle-to-vehicle communications are implemented, it's a small step to add vehicle-to-infrastructure communications. Moreover, instead of relying on internal sensors and vehicle-to-vehicle communications, it would be possible for a 'smart' car to be aware of the 'dumb' cars on the highway by using roadside electronics. It would also be possible for someone in law enforcement or the government to monitor the position of your vehicle at all times. Think automatic speeding tickets. Or, automatic taxation based on miles driven on a given toll road.

I can't say that I'm totally comfortable knowing that someone in the government (or perhaps the management of Walmart) knows that I'm in the mall parking lot. I wouldn't turn down an automatic discount coupon on my favorite toothpaste, though. Who knows how my location data could be used by a hacker, for example. I'm sure these privacy concerns will be addressed in time. For now, I'm satisfied knowing that basic robotics are making a difference by saving lives. **SV**

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Dear SERVO,

The March issue came today, and I was stunned — for lack of a better word — reading the Mind/Iron editorial. About three months ago, I had to start using a cane because of a back issue (going back about two years) that gets worse rather than better. I won't go into all of the doctors and procedures I've been through with no success, so for the moment, I'm on pain meds and transdermal Lidocane patches. Everything you wrote I have experienced. I use an offset cane because the C and other styles made the pain worse. In addition to the items mentioned, I would like to add getting into and out of my truck — a Tacoma — and trying to jockey the cane and my body so I don't fall. Storage of the cane in a vehicle is also a challenge. I usually just put it in the back seat and struggle getting in and out. I thought about a scabbard strategically placed to hold the thing, so it won't get in the way.

My cane has a pistol-like grip which is sort of comfortable, but I've hurt my right hand — the one I hold the cane with — and the right wrist. I'm considering trying to get a Colt 1911 style after-market grip that is softer, to hopefully ease the distress on my right thumb and muscle pad. Failing that, I'm going to get a good plastic 1911 and try to fit it to the offset cane.

I haven't tried any of the four-footed self-standing canes because they look like they would be even more unwieldy to store. Sigh.

I really encourage you to explore the cane issue — especially the grips — which is the biggest problem, followed by the "what do you do when you need two hands" issue.

For me, this has been a very depressing and lifestyle altering change. I can no longer kayak, fish, hike, or even walk around a mall with my wife without pain. Sadly, the mobility problem may cause me to shut down my consulting business, as it's hard to visit clients and work on experiments.

George T. Cannon

I'm sorry that you came to learn of the cane by necessity. I'm also very active and would probably go nuts if I couldn't run/bike/swim for more than a few days. Perhaps you'll have time and the insight to develop something for the many thousands of others in your situation.

I wish you the best.

Bryan Bergeron, Editor



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ASK MR. ROBOTO

by Dennis Clark

Our resident expert on all things robotic is merely an email away.

roboto@servomagazine.com

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?

Post comments on this article at
www.servomagazine.com/index.php/magazine/article/april2014_MrRoboto.

When it comes to robots that run around outside, we tend to prefer wheels to legs for motivation (Boston Dynamics excepted). Indoor walking robots should have the edge dealing with human navigable spaces (iRobot Roomba excepted). Except for robotic trains, planes, and automobiles, my personal feelings are that walking robots are the wave of the future. Plus, I just think they are way cooler than their rolling brethren! This month, I have some questions about walking robots; bipedal walking robots, in fact. Technology marches on, and we hobbyists don't want to be left behind. Unfortunately, the more complex our projects, the more difficult it gets to troubleshoot them when something goes wrong as this month's readers can attest to ...

Q. I have a RoboBuilder Huno that has worked flawlessly for quite a while now. Recently, it just stopped working! When I turn it on and press the red center button, it starts blinking the Error light and nothing else happens. I know that the battery is charged and has the right voltage. I've connected it up and it can talk to the PC just fine. Can you tell me how to find the problem?

— Don

A. It sounds like your controller is working at least well enough to talk to the computer, so let's try the RoboBuilder troubleshooting tools. Launch the RoboBuilder Download Tool and connect it to your RoboBuilder controller. Click on the Diagnostic Tool tab near the top left of the program window. Then, click on the tab labeled "2. Check wCK(SAM)." You should see your Huno robot with all of its servos labeled on the left side of the program window. At the bottom of the program window, you will see the servos listed from lowest to highest, repeatedly (see **Figure 1**). I am willing to bet that at least one of the Huno servos fail. This means that your program — expecting the 16 Huno

servos — won't let the program run.

When the RoboBuilder controller can't find all of the servos that it expects for its motion files, it refuses to control any of them. My guess is that the creators of the RoboBuilder controller tried to avoid harm by preventing any servo from going rogue, in case more than one servo has the same address.

I tested this theory out by snipping one wire of a cable going to an arm servo (**Figure 2**). Sure enough, servo 15 is

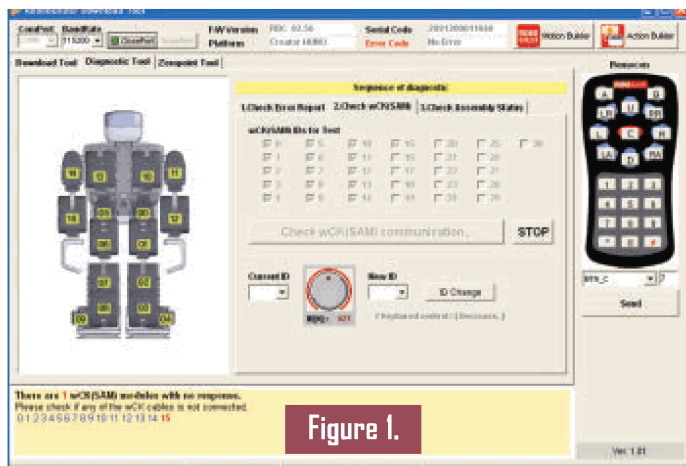


Figure 1.

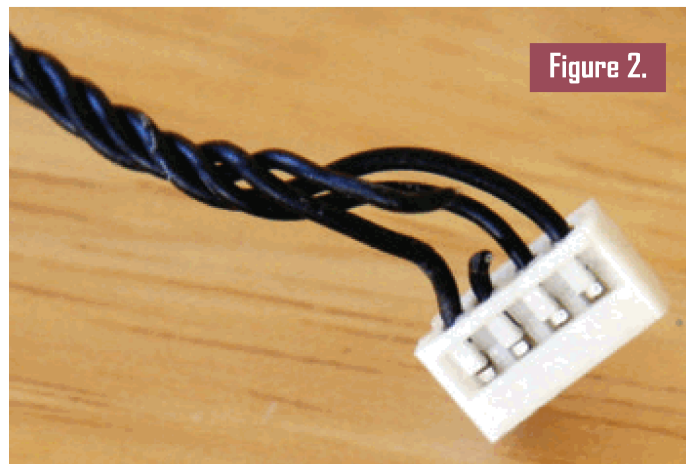


Figure 2.

shown in red on the bottom of the program window. Carefully examine the cables that run to the servos noted by the program. Let me know how it comes out.

Q. I have a Bioloid Premium robot that I built into the "Type A" walker that uses 18 servos. I built it with the gyro installed; my kit uses the CM530 controller. This robot has been working for months, but recently started doing strange things. Sometimes when I turn it on, it repeats a three-note sequence over and over. It will not respond to commands in this mode. Sometimes it starts up normally, but the legs turn pigeon toed and the arms are in the wrong place. It will then tie itself into knots if I try to give it any move commands. Sometimes it starts sounding a low note, repeating it in time to LEDs blinking on the hip servos. I've looked at all my cables and even restored the firmware and motion files. However, I can't get the task file to download anymore. I'm am super confused! Help me!

— David

A. I thought that my Google-foo would answer this question quickly. Eh, not so much. Rather, it did eventually help me find the answer, but I had to contact Bioloid technical support and get help from some online retailers that sell the Bioloid. Regardless, I found the answer! Our first step is to consult the CM530 guide which can be found at <http://support.robotis.com/en/product/auxdevice/controller/cm530.htm>. This by itself doesn't help us much, but it allows us to see that the CM530 is a lot like the CM510, whose Premium e-manual page is at http://support.robotis.com/en/product/bioloid/premiumkit/quickstart/bioloid_cm510_play.htm.

This e-manual shows the various types of robot you can build with the Premium kit. More importantly, about two-thirds of the way down the "page" there are some troubleshooting hints. Your issue is almost certainly this one: "The robot type and melody do not match." ("Huh?") Look at the Type A row and the Do Re Mi column where it says "Check cables for ID7-8." You said that your robot got pigeon toed on startup. These two servos control the hip action that turns the legs. The Bioloid support team suggested that I use the Dynamixel Wizard to look for bad connections to the CM530.

In the July 2013 Mr. Roboto

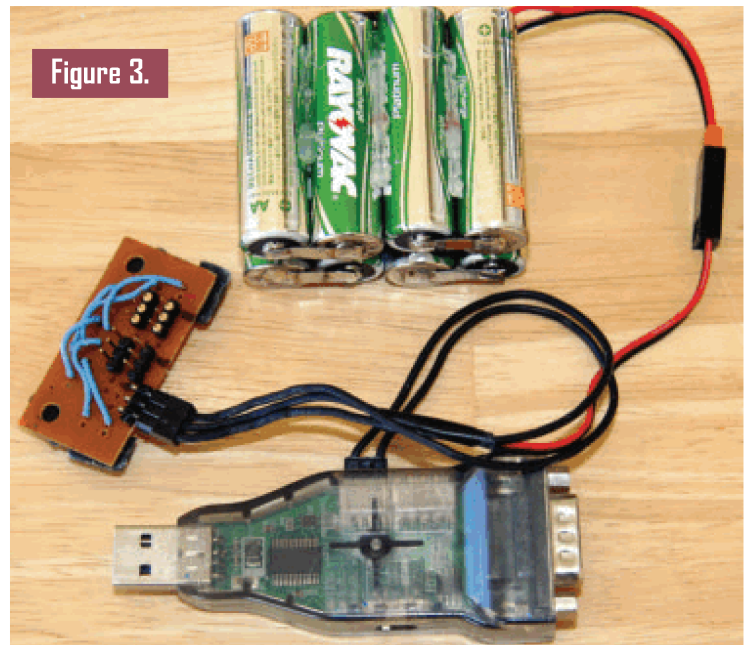


Figure 3.

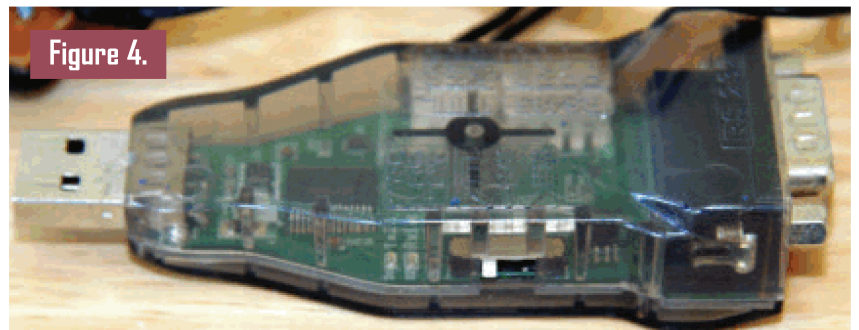


Figure 4.

column, I wrote about an Arduino library I created to use Dynamixel servos. In that, I created an interface board (Figure 3) that connects to the Bioloid USB2Dynamixel

device. Remember, you need to power the servos from an external battery; see that article for details.

To use the USB2Dynamixel, you connect your three-pin connector (with the V+ wire removed) to the connector on the side of the USB2Dynamixel unit. **Don't connect your battery yet.** On the other side, move the slide-switch to the TTL position (see Figure 4). Disconnect one side of your "legs" cable from the CM530 as shown in Figure 5. You do this so that you don't power your CM530 up from the external battery through the Dynamixel port!

Now, find an open servo port on one of your servos as I did in the ankle shown in Figure 6. What

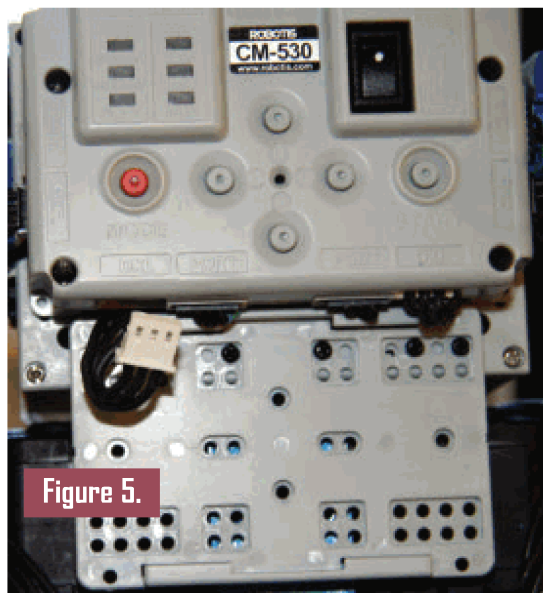


Figure 5.

you may not see is that I have the Bioloid robot hanging from a frame so that it can't trash my desktop if it decides to spasm. Now, plug your USB2Dynamixel into your USB port (I have a one meter USB extension cable that I use for this kind of thing) and connect the battery to your test rig.

If you have the Premium kit, you have the RoboPlus program. Launch this program, click on the Expert tab, and then click on the Dynamixel Wizard button. In the upper left of the program window, you'll see your serial port. Right next to that are two icons that look like two cables plugged together and two cables pulled apart. The only one that you can choose is the one immediately to the right of the COM port window.

Click on that, and then click on the giant button in the middle of the window that is called Start Searching. You'll see the pane to the left of the window fill up with servos (see **Figure 7**).

One at a time, click on a servo. This will fill the right pane with all of the Dynamixel parameters. Scroll down to nearly the end of the list and click on the "Goal Position" parameter. You will then see a knob appear (see **Figure 8**). This knob allows you to graphically change the servo position. **Adjust this knob very carefully or you may damage servos, fingers, or innocent bystanders!**

The knob will be set to the current position of the servo. As you manipulate your servo (gently), fiddle with



Figure 6.

the cable harnesses near it. If you have a bad cable, eventually something will happen. Either a servo will stop responding or you'll see numbers on the Wizard program start jumping around. When you find the offending cable, replace it. It may take you several attempts to determine the bad cable, but I am pretty certain that eventually you will.

Q I have a Bioloid Comprehensive kit that is really dated. I don't like the programs that I can get to run on the old CM5 controller, either. The Comprehensive kit was expensive and I don't want to replace the whole robot. Is there a way to upgrade it to the Bioloid Premium kit? How much would that cost? Will it work as well as a new Premium kit?

— Tom

A I looked around on the 'net in the USA for a way to upgrade. There are a couple of vendors that can help you. I got a lot of help from a great guy at Trossen Robotics named Kyle who talked me through the most comprehensive upgrade to create a Premium from a Comprehensive (*pun intended!*). **Table 1** shows a list of items we agreed would bring the kit up to

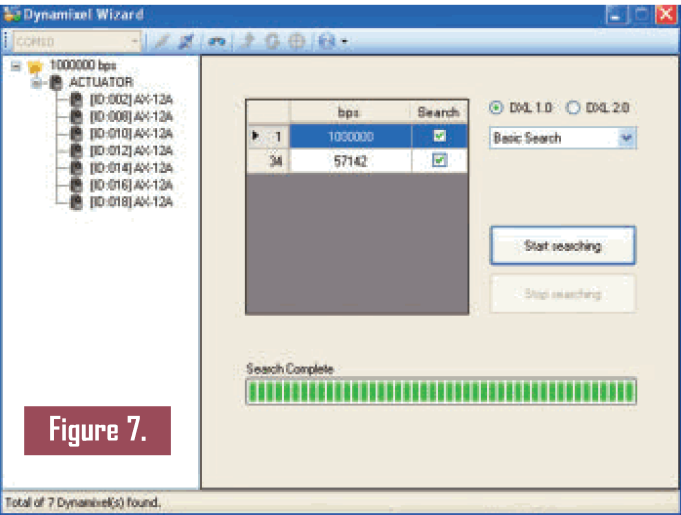


Figure 7.

Part Number	Description	US Price
RO-903-0413-000	LBS-10 11.1V Bioloid Premium LiPo Battery	\$29.90
RO-903-0183-000	Bioloid Skin FP04 F56/F57/F58/F59 Set	\$19.95
RO-903-179-000	Bioloid Premium Frame FP04 F51/F52 Torso Set	\$6.95
RO-903-182-000	Bioloid Frame FP04 F55 Cable Holder 20-pack	\$5.95
RO-903-180-000	Bioloid Frame FP04 F53 Four-pack	\$3.95
RO-903-181-000	Bioloid Frame FP04 F54 Four-pack	\$3.95
RO-902-0029-000-Z110	RC-100 Bioloid Boomerang Controller Kit Type = w/Zig-110	\$78.62
RO-902-0043-000	DMS-80 IR Distance Measurement Sensor	\$14.90
RO-902-0062-000	CM-530 Robotis Servo Controller	\$99.90
RO-902-0042-000	GS-12 2-Axis Gyro Sensor	\$34.90
Table 1.	Total	\$293.02

the Premium level, when purchased at Trossen Robotics. I chose Trossen because Kyle was so helpful getting answers for the previous question.

I didn't get the LiPo battery charger because I already have a few good chargers and I didn't need another one. It isn't cheap, but the upgrade is a lot less expensive than getting an entirely new kit.

Your question about whether it will be as good as a new kit is an appropriate one. The Comprehensive kit uses AX12+ servos and the Premium uses the newer AX12A servos, which are a slightly different form-factor. Kyle at Trossen says that their test Premium robot uses the AX12+ servos and they worked fine. As my regular readers know, I too have a Bioloid Comprehensive kit. Kyle convinced me that I should also do this upgrade! So, I got all of the pieces that he said to get and found all of the programs and files needed to bring my old beast up to snuff. I can confirm that it does indeed work, and the new kit is way more capable! I tore my old kit down to its component pieces, so I could start from scratch.

Here is where to get the assembly instructions: www.robotis.com/download/doc/BIO_PRM_Humanoid_ASM.pdf. Here are the default task and motion files: http://support.robotis.com/en/product/bioloid/premium_kit/download/bioloid_premium_demo.htm. Here is how to use those files: http://support.robotis.com/en/product/bioloid/premiumkit/quickstart/bioloid_cm510_play.htm. The online forums and Kyle both said to ditch the older Bioloid programs and get the newest ones here: http://support.robotis.com/en/techsupport_eng.htm#software/roboplus_main.htm. Here are instructions for the RC-100 and Zigbee remote control: http://support.robotis.com/en/product/auxdevice/communication/rc100_manual.htm. Here is the Premium e-manual: <http://support.robotis.com/en>.

Finally, **Figure 9** shows what our spankin' new Premium robot looks like.

I have sampled four low cost biped robot options: Robo Brother's Robo Philo, RoboBuilder, and now the Robotis Bioloid Comprehensive and Bioloid Premium. Of them all, the Bioloid Premium kit has the widest stance and most stable walk. The Premium kit is the only one with a gyro sensor, which helps with dynamic stabilization of the walk. The Premium is also the only low cost biped whose default motion file has a "continuous" walk. It walks as long as you hold the button down.

The other kits only walked for a couple of paces, then stopped until you pushed the button again. You have to try each kind to see just how nice this feature is.

Of course, the Bioloid Premium is also the most expensive one I have sampled, so more is expected of it. I'm not done yet; there are new kits coming out all the time. This Premium upgrade included the Zigbee 2.5 GHz controller which is way superior to the other kits' IR

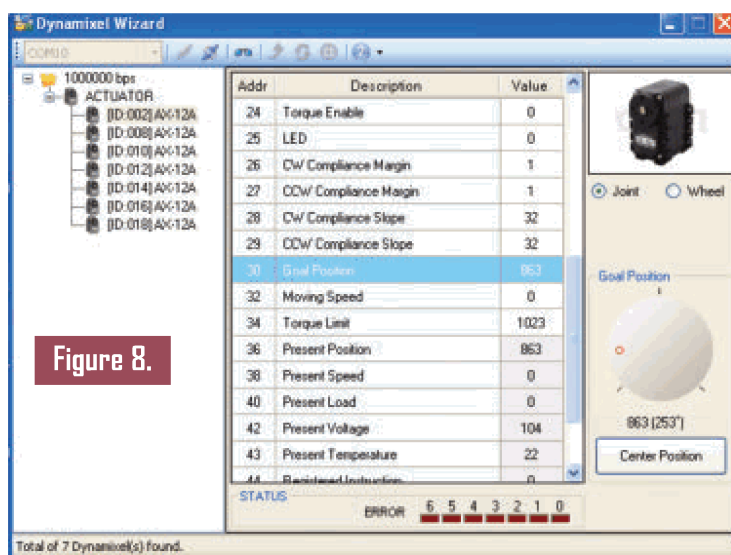


Figure 8.

controllers, if for no other reason than you don't have to stand behind your robot and point your remote at it.

Whew! There goes another reading session you've spent with Mr. Roboto! I hope you enjoyed yourself and learned something new. I sure did! Don't hesitate to drop me a line at roboto@servomagazine.com. Keep building robots and sharing your knowledge with others!! **SV**

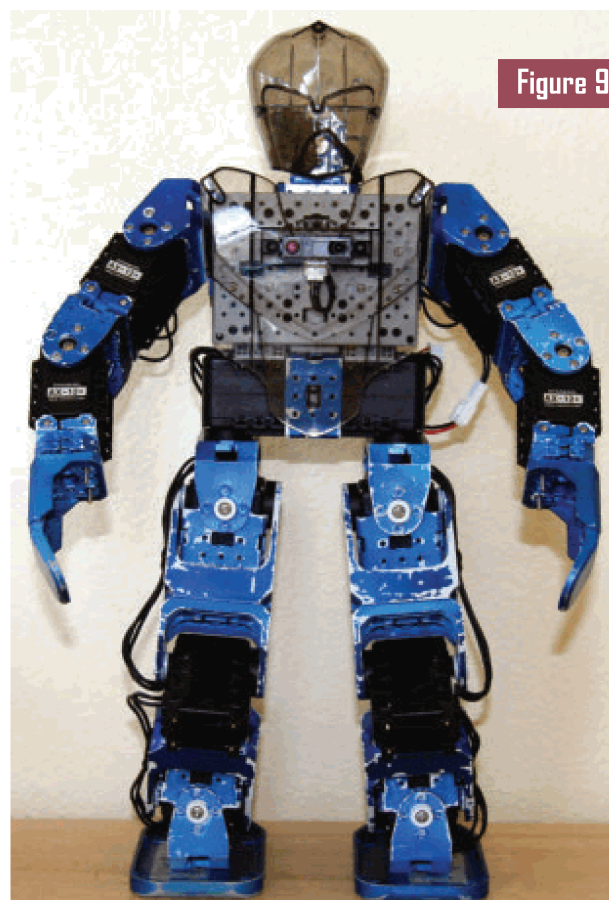


Figure 9.

Weapons of Bot Destruction

This month, we continue the revival of our 60 lb combat robot, Troublemaker. Last time, we upgraded the batteries from NiCad packs to lighter, higher energy density LiPoly packs. While a battery upgrade is undeniably practical, it does not galvanize the imagination as effectively as some other tweaks. This time, we wanted to turn our gray matter towards something a bit more exciting — upgrading Troublemaker's weapon.

The endless possibilities of weapon designs are some of the most unique and irresistible parts of combat robotics. In many ways, we think it appeals to one of the most

basic elements of play that we all enjoyed as kids one way or the other: wreaking havoc and destruction. More than that, we think that the weapon is the centerpiece of the core task of a combat robot — a task far more complicated than its tendency to be summarized through onomatopoeia might suggest.

That task is to disable your opponent which can be done in myriad ways. A bot can be high centered, flipped over, sent over the edge of an arena, or have its batteries ripped from its chest like a robotic version of *Indiana Jones and the Temple of Doom*. While this part of the task seems to get the most

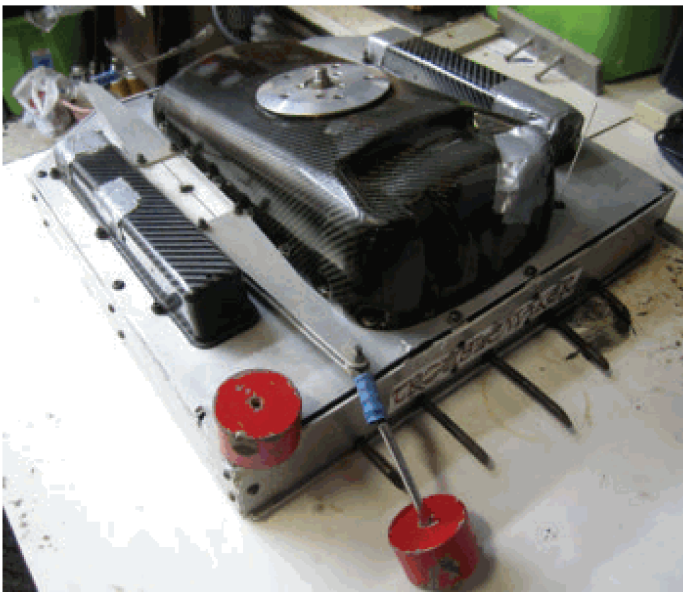
attention, there is an equally important aspect that needs to be considered: doing

any or all of these things to the opponent without having your own bot sustain commensurate damage.

It's all about Newton's Third Law of Motion, and we wanted to upgrade Troublemaker's weapon so that it would deal major damage to opponents without suffering an equal and opposite reaction of doom to itself. This calls for some serious physics.

Eye of the Brainstorm

There is always a lot to learn from history, so it is important to review the trials and travails of Troublemaker's record as a competitive combat. When we were first designing Troublemaker (then known as Trilobot) in 2001, the first step of our design process was to determine that we wanted something



TROUBLEMAKER, WAKING FROM ITS SLUMBER.



THE ONLY ACCEPTABLE WEDGES.

other than a basic wedge.

The wedge is an enduring and classic design in combat robotics. The wedge is — as its name suggests — a simple geometric design that can be described most simply as (other than using the reflexive definition of a wedge) a surface extending from the robot that forms an acute angle with the floor.

Wedges can be made from a single surface extending down the robot at an angle, or two surfaces that extend from the robot to meet at an acute angle. The basic idea of the wedge is to slide under an opposing robot so that the opposing robot breaks contact with the floor, loses traction, and can be pushed around with impunity.

To its credit, the wedge is a fantastically efficient design. Undermining the opponent's ability to drive around is a good way to gain the upper hand in combat, and being able to do it with a simple geometric design is spectacularly efficient.

The wedge has defensive properties as well, because an opponent will not be able to effectively ram into the wedge surface and will instead be redirected up the ramp of the wedge itself. The angled surface of the wedge can also deflect blows from other weapons like hammers and spinners which may glance off of the bot without making devastating contact.

Any damage to a wedge may be easily repaired (just smooth out or replace the surfaces), and if the wedge itself doesn't house any of the guts of the robot, the wedge can be punctured and battered without worry.

It sounds like we've made a great case for the wedge, but all of those positives can't seem to outweigh the inescapable glaring reality that a wedge is supremely boring. Breaking an opponent's traction is not nearly as exciting as breaking an opponent's drive train. And, while the wedge may be extremely efficient, it is not a



AN EARLY MOCK-UP OF THE SPINNING WEAPON.



TRILOBOT AND THE EARLIEST VERSION OF THE SPINNING WEAPON.



DECKED OUT AND READY FOR OUR INAUGURAL COMPETITION.

very thorough solution to the problem posed by a combat robotics competition.

If the opponent has lower ground clearance than the wedge, the wedge won't work. Or, if perhaps the base of the opponent has much higher ground clearance, the wedge might not break its traction.

The weight classes in combat robotics allow for plenty of weight to be dedicated to mechanisms that disable opponents in ways infinitely more exciting than high-centering them. While it may take a lot more effort and ingenuity to build an effective weapon, the payoff of a successful design is so much more than that for the uninspiring wedge.

The initial design of Troublemaker's weapon would require a few more ground rules than the first rule of our robotic fight club — no wedges. The unfettered brainstorming of combat robot weapons can lead to a lot of harebrained ideas — radio jammers, flamethrowers, acid cannons, Tesla coils, adamantium wolverine claws, spring-loaded Mjolnir — the list goes on and on.

The universe of acceptable weapons, however, is circumscribed by the rules of the relevant competition. Some common restrictions include limitations on pressure for pneumatic and hydraulic

systems, and bans on magnetic weapons, jammers, entangling weapons, liquid weapons, and projectile weapons. These limitations all have practical value, of course, and are included for the safety of the spectators and the integrity of the arena and of the judging.

These limitations did not do much to calm our brainstorming. When we were first designing Troublemaker, we threw around some crazy ideas involving active threat detection, pneumatic spikes, and other instruments of destruction. After stumbling upon the carbon fiber plenum top, however, we were inspired to design a spinning kinetic weapon.

The plenum top had a circular opening in the top of the component that looked to be the perfect place to mount a spinning weapon. The slanted trapezoidal shape of the plenum top also provided an unusual angle axis for the spinner to rotate about. We thought a spinning weapon had precisely the excitement and energy lacking in something like a wedge, and a smart design promised maximum robotic carnage with a fairly simple mechanism.

Designing Weapons

The spinning weapon we envisioned would rotate about an



THE CURRENT STATE OF AFFAIRS.



THE SPINNER IN PROFILE.

axis defined by a shaft protruding from the opening in the plenum top — the axis of rotation would be perpendicular to the top surface of the plenum top. The spinner would cause damage with some instruments of destruction at the outer ends of the spinning structure. Our proposed kinetic spinner, however, had to deal

with an issue faced by most weapon designs.

The essential conundrum of a combat robot weapon is captured by Newton's Third Law of Motion. Often summed up colloquially as "for every action there is an equal and opposite reaction," the law is more precisely stated as "when one body exerts a

force on a second body, the second body simultaneously exerts a force equal in magnitude and opposite in direction to that of the first body." The law is perhaps most efficiently described by a force diagram.

So, why does this present a problem for combat robots? Because if your spinning kinetic weapon or hammer or flipper imparts a magnitude of force great enough to cause grievous bodily harm to your opponent, guess what? An equal magnitude of force is coming right back at your robot.

A classic example of an exaggerated Hollywood version of this phenomenon is the oft-repeated scene where a character shoots a gun and either the recoil from the weapon sends the shooter flying backwards, or the hapless target is flung about by the impact from the projectile. Based on the most simplistic statement of the third law, this seems consistent. A bullet has a ton of force, right? Yes, but the real world is not as simplistic and one-dimensional as a force diagram.

The Hollywood scene is not replicated in real life because the force is transferred in myriad ways instead of solely along the same axis upon which the projectile was traveling. To use the less graphic half of the gun and bullet example, consider the recoil of the firearm. The recoil is the example of the third



HOW THE WEIGHT SHOULD LOOK.



THE SCARS OF BATTLE.

law in action, but the firearm doesn't fly back from the bullet at the same speed as the bullet itself. That's because the force is transferred throughout the mass of the firearm, which is much greater than that of the projectile.

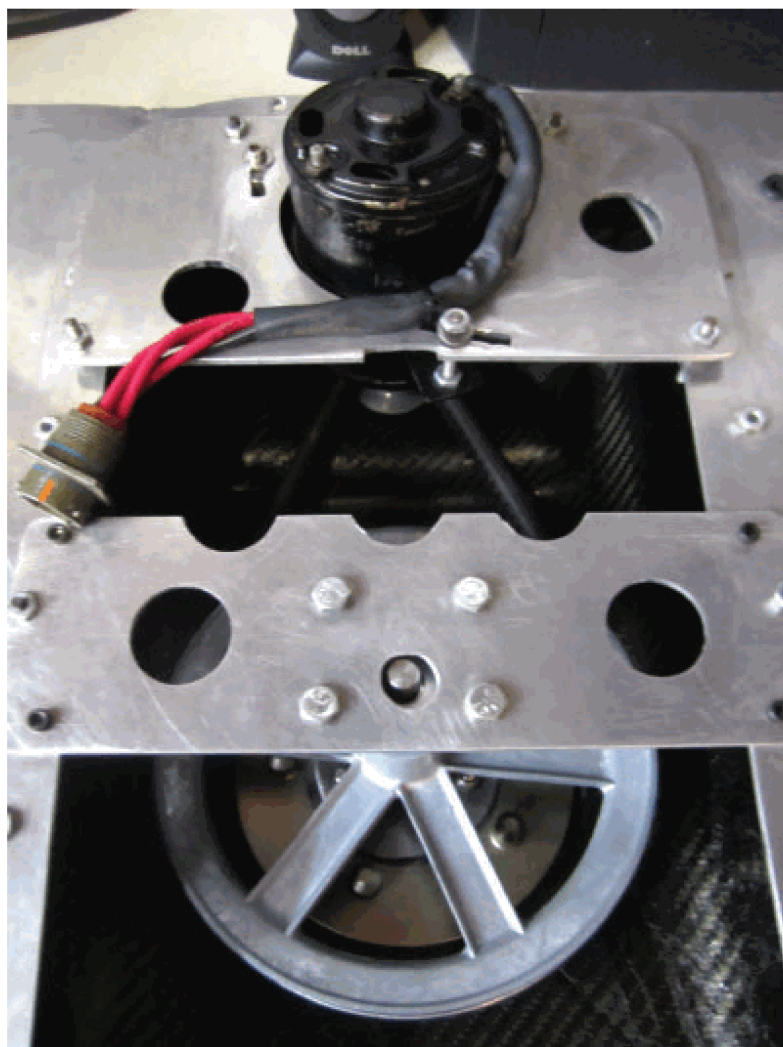
An expert marksman will hold the firearm in a way that transfers the force of the recoil safely, like through an arm or cradling shoulder. YouTube is full of examples of amateurs that don't know how to properly transfer the recoil force and instead meet with the bruising consequences.

Just as an unsteady shooter can end up with a bruised shoulder, a naïve roboticist can end up with a robot that takes as much damage from its kinetic weapon as it deals. We needed to figure out a way for the weapon to impart a lot of force without transferring most of that force right back into the bot. We thought to make the business end of our spinning weapon a couple of weights and to connect those weights to the spinner by cables.

The weights would do decent damage with a direct hit, and the force would be transferred through the cables instead of through the rigid spinner structure directly back into the robot.

Specifically, we used two 2.10 pound steel weights for the end of our spinner. The weights had a through hole to accommodate the cable, so we routed a steel cable through it. The cables looped around screws that were mounted in two triangular supports that extended in parallel to the middle section of the spinner. The middle section of the spinner was an aluminum plate. The center of the aluminum plate contained a hole to accommodate the drive shaft.

To strongly and safely couple the spinner to the shaft, the center aluminum plate also contained a slot running much of the length of the plate. Screws through the side of the plate allowed the plate to squeeze the motor shaft when tightened. This



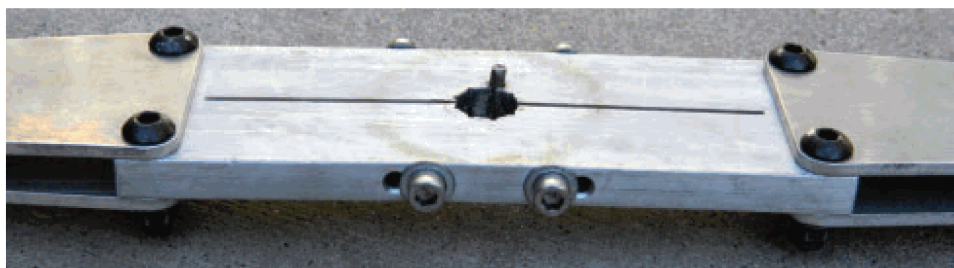
THE WEAPON MECHANISM.

would provide a strong even pressure that promised a better hold than a set screw.

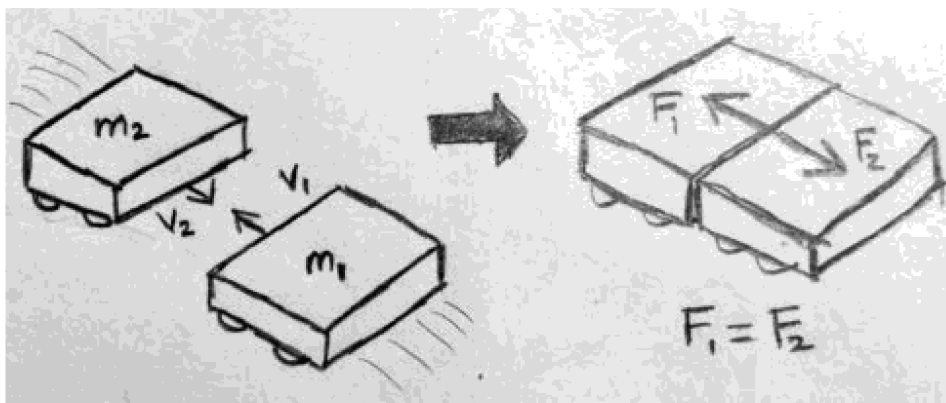
We continued the force transfer theme with the way we motorized the weapon. Instead of direct drive — which could transfer force from the spinner to the shaft of the motor

(potentially damaging the motor) — we powered the spinner through a belt and pulley arrangement.

An interesting aspect of the spinner itself is that the weapon spins in a plane that is at an angle to the ground. Most often, horizontal spinners are parallel to the ground to



THE CENTRAL CLAMP.



NEWTON'S THIRD LAW.

ensure that the robot remains balanced.

We fired up our weapon for the first time in testing to see if the angle of the spinner would cause the robot to dance haphazardly like a high schooler at prom. Fortunately, the bot remained balanced. The spinner was nicely centered on the robot, and the bot had a very low center of gravity thanks to some heavy low profile battery packs.

A History of Robotic Violence

We were excited to see how the spinning weapon would hold up in competition. We had tested the basic mechanism of the spinner before embarking to Phoenix for BotBash 2001, but it had not been tested in circumstances analogous to competition. We were excited to see what kind of damage our creation could dish out.

Our first match was against a worthy opponent called Blue Vixen — a diamond plate-armored bot sometimes equipped with a vertical saw blade. We fired up the weapon at the beginning of the match to the delight of the crowd. The bots approached each other like two stags with antlers ready, charging each other trying to impress a lovely doe.

Trilobot crashed into Blue Vixen with much fanfare and a lot of noise. After our successful match, we were able to see that our esteemed opponent had sustained a nasty dent. We counted our first match as a success.

The success of our weapon, however, was short-lived. The old starter motor we were using to power the spinner burned out, leaving Trilobot with naught but its front spikes to duke it out for the rest of the competition. We remedied our electrical issues by giving the bot — newly christened as Troublemaker —

a new spinner motor and new batteries. With those fixes, we were eager to see if the spinner would fare better in BotBash 2002.

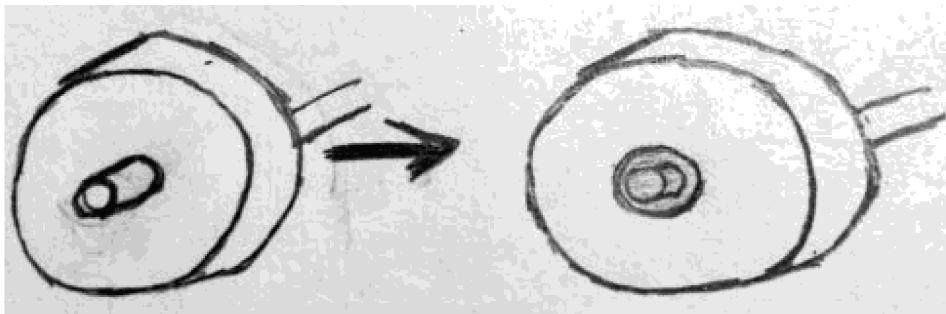
That year, the spinner did fare better for a time, but was taken out of commission for a reason we did not anticipate. One of our ferocious opponents sported a spinning disk weapon. As far as we can tell, when Troublemaker met that opponent the disk weapon actually cut the steel cable holding the weight to our spinner. Our efforts at safely transferring force away from our bot seemed to be working, but we had unwittingly created a weakness in our bot's otherwise awesome weapon.

For subsequent competitions, we sought to remedy this problem by encasing the steel cables with metal cylinders. Though these casings weren't particularly thick, the protective aspect of the casings was similar in spirit to the protection offered by the cables to the spinner itself. Instead of stopping cutting weapons with sheer hardness, the casings would safely transfer the force of the cutting weapon and leave the cables intact.

The idea was that when a cutting weapon contacted the casings, they would spin harmlessly around the cables, transferring the force of the weapon into that rotational motion. Outfitted with these casings, we were confident that we could use Troublemaker's fearsome weapon for more than one match.

You can imagine our disappointment when Troublemaker emerged from a match one weight down. We retrieved the dead weight and scratched our heads at our misfortune. The steel cable was frayed at one end, but it didn't look like it had been cut short. We realized that the spinner's undoing was actually with the end cap holding the weight on the cable.

An ill-placed hit by the spinner knocked the end cap right off, and without anything to persuade the weight to stay on the cable it was



A POSSIBLE FIX FOR THE WEIGHTS.

quick to follow.

That is where we left Troublemaker. It returned to Robot Central 2.1 pounds more lopsided than it had emerged. Once our competitive robotics days turned to FIRST and other pursuits, we never had occasion to fix the spinner. That's precisely what we aim to do now.

Spinner Doctor

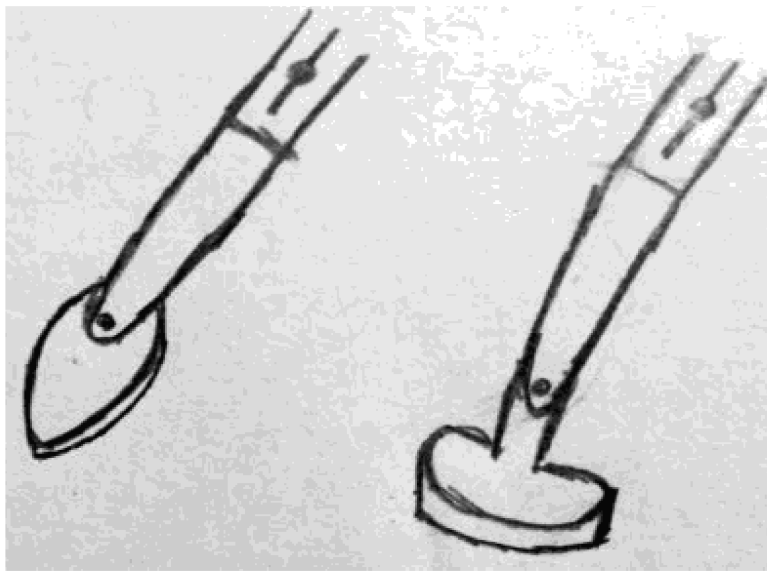
Since we seemed to have trouble with the spinner in every competition, it is apparent that it could benefit from a redesign. We need a better way to keep the weights attached to the cables, or we need some other implements at the end of the spinner instead of the weights.

Perhaps it is for their sentimental value, but our first instinct is to see if we can make the weights work. Since the problem area now seems to be the end cap, we just need to design a way to make those end caps less vulnerable. The intuitive solution is to recess the endcap into the weight itself, like recessed lighting in a newly renovated kitchen.

We could recess the end cap by partially drilling out the through hole in the weight with a larger bore drill bit. Even with the weight otherwise unattached to the cable itself, the endcap should stay recessed when the spinner is activated because the centripetal force would keep the weight at the outer end of the cable.

What if a completely different design might be better? Maybe after three years of competition it was time to try a totally new weapon design, one that wouldn't be subject to the same problems as the weights. As we brainstormed ideas, two main concepts rose to the forefront.

The first would go for a different



BLADES OF GLORY? HAMMER THROW?

style of weapon. Instead of blunt force, what about a cutting weapon? A sharp cutting weapon had apparently worked well against Troublemaker in BotBash 2002, and after our experiences in competition we had a better understanding of different solutions to the central task of combat robotics.

Our initial design with the weights sprung from the idea that imparting as much force as possible to the opponent had the best chance of disabling it. This sounds good in theory but again, not all opponents are so easily vanquished. As we discovered, many competitors go to great lengths to armor their bots. Troublemaker itself is a good example, sporting two layers of quarter inch thick 7075-T6 aluminum. No amount of blunt force will do much to that.

Surely, some opponents are vulnerable to the spinning weights, but others might be more effectively handled with a cutting weapon. The worthy opponent that knocked us out of BotBash 2001, for example, was Herr Gepounden. That bot was outfitted with a large sledgehammer, but also sported large exposed wheels. An effective cutting weapon may have been able to slice and dice

the wheels, disabling the bot and securing our spot in the next round.

What we envisioned as an effective cutting weapon were some sharp sort of cam shaped plates. The blades would be coupled to the main spinner structure with a bolt at one end, and the blades would be thin enough to travel through the space between the parallel triangular arms on the spinner.

If the blades could spin in place, that should prevent the force of an impact from being transferred back into

Troublemaker. Our big concern with this design is that the blades would have a lot less mass than the weights, and might not be able to transfer force as effectively into our target.

Our second proposed design seeks to address the mass issue. Instead of sharp blades, what if the tethered weights were replaced with solid hammers? A plate of aluminum could be attached with one bolt on the end much like the blades, but the business end of the hammer would have thicker plates attached, adding mass and force transferring power. The hammer would not be able to pass through the triangular supports after impact, though, and would crash into the sides.

Would the small amount of travel the hammers had before crashing into the side of the spinner dissipate enough force to prevent serious injury to Troublemaker? Could the blade design really deal some damage? What kind of hapless targets will we go crazy on when testing these designs next time (our printer robots, perhaps, from the August 2103 issue)?

Stay tuned for the destructive conclusion of Troublemaker's weapon redesign. **SV**

Know of any robot competitions I've missed? Is your local school or robot group planning a contest? Send an email to steve@ncc.com and tell me about it. Be sure to include the date and location of your contest. If you have a website with contest info, send along the URL as well, so we can tell everyone else about it.

For last-minute updates and changes, you can always find the most recent version of the Robot Competition FAQ at Robots.net:
<http://robots.net/rcfaq.html>.

— R. Steven Rainwater

APRIL

- 5** **Alabama Robotics Competition**
University of Alabama, Tuscaloosa, AL
K12 student-made autonomous robots must navigate an obstacle course.
<http://outreach.cs.ua.edu/robotics-contest>
- 5** **CIRC Central Illinois Bot Brawl**
Illinois State University Redbird Arena, Normal, IL
Events include RC vehicle combat, autonomous Sumo, line following, and line maze.
<http://circ.mtco.com>
- 5-6** **Trinity College Fire Fighting Home Robot Contest**
Trinity College, Hartford, CT
Autonomous robots must navigate a maze, locate a fire, and extinguish the flames in the shortest possible time.
www.trincoll.edu/events/robot
- 9-10** **DTU RoboCup**
*Technical University of Denmark
Copenhagen, Denmark*
Varied course including line following and wall following.
www.robocup.dtu.dk
- 10-12** **Istanbul Technical University Robotic Olympics**
Istanbul, Turkey
Events include line following, mini Sumo, fire fighting, vacuum cleaner challenge, and maze solving.
www.ituro.org
- 10-12** **National Robotics Challenge**
Marion, OH
Student-built robots compete.
www.nationalroboticschallenge.org
- 11** **Carnegie Mellon Mobot Races**
CMU, Pittsburgh, PA
The famous Mobot Slalom.
www.cs.cmu.edu/mobot
- 12** **Brown IEEE Robotics Competition**
Brown University, Providence, RI
Autonomous maze navigation.
<http://brown.edu/Departments/Engineering/Organizations/IEEE/competition>
- 12** **Robotics Tournament**
Rybnik, Poland
Events include Micromouse, line following, and freestyle.
www.robotictournament.pl
- 12-13** **The Tech Museum of Innovation's Annual Tech Challenge**
San Jose, CA
See the website for details on this year's challenge.
<http://techchallenge.thetech.org>
- 18** **UNI Sumo Smackdown**
UNI, Cedar Falls, IA
Competitors ship their robots in for an Internet-broadcast Sumo competition.
<http://www.narobotics.org>
- 20** **Mercury Remote Robot Challenge**
Stillwater, OK (and a remote location)
Teleoperated robots must navigate a course 100 miles or more from the operator.
<http://mercury.okstate.edu>
- 23-26** **FIRST Robotics Competition**
Edward Jones Dome, St. Louis, MO
Student robots built from a standardized kit compete in matches for the world championship.
www.usfirst.org
- 23-26** **VEX Robotics World Championship**
Anaheim, CA
Student robots built from VEX components compete in matches for the world championship.
www.vexrobotics.com/competition
- 25-26** **Greater Philadelphia SeaPerch Challenge**
Drexel University, Philadelphia, PA
Student-built tethered underwater ROV missions.
www.phillyseaperch.org

NEW PRODUCTS



Three-Wheel Robot Platform Kit

ServoCity is now offering a new three-wheel robot platform. This kit includes all the mechanical parts needed to build an omni-directional robot. Complete with large 6" diameter drive wheels with rubber lips, it offers fantastic traction.

The ball bearing swivel along with the ball bearing supported 4" wheel at the rear enables smooth turning transitions. The chassis can easily be reconfigured for various applications and accepts all Actobotics™ components.

The included motor mounts are compatible with ServoCity's 3V-12V gearmotors and 6V-12V precision gearmotors (drive motors sold separately). However, users can incorporate many types of drive motors by simply switching out the motor mounts.

Another feature is that the only assembly tools needed are a 3/32" and a 7/64" Allen driver. Retail price is US\$79.99.



Actobotics IGUS Slider Kits

ServoCity is also now offering a simple way for DIYers to motorize their IGUS® W1080-B or W16 slider. ServoCity has designed this kit using their versatile line of Actobotics components so that once built, the unit can easily be modified to create a custom system. Simply purchase the kit, a gearmotor, and a motor controller for a complete working setup.

The included motor mount is compatible with their 3V-12V gearmotors and 6V-12V precision gearmotors (motor sold separately). Builders can also use stepper motors if a stepper motor mount is purchased. Optional adjustable feet and limit switches are available for those who wish to add them. The kit comes in piece form with detailed assembly video instructions found on ServoCity's website. Both kits are US\$119.99 each.

For further information, please contact:

ServoCity

Website: www.servocity.com

PCB Assembly Kit

Beta LAYOUT Ltd. has developed a cost-effective printed circuit board (PCB) assembly kit enabling PCB designers, universities, labs, and home hobbyists to hand assemble SMD components utilizing a toaster oven. For less than \$406, any small space can become a PCB assembly reflow workstation.

To control and establish uniquely designed solder profiles is the US generation Reflow-Controller (V3) Pro,





which can be used in conjunction with a basic toaster oven to create the temperature profile needed to reflow components and create professional assembled boards. Other aspects include:

- Learning the profile and having five pre-selected profiles digitally displayed.
- With the press of a button, a profile can be repeated time and time again promoting component soldering consistency.
- Base values can be easily adjusted for various reflow requirements.

The Reflow-Controller (V3) allows a desired pre-heat phase to solder paste melting phase, avoiding mechanical stresses on the PCB and components.

After preliminary heating, the temperature is increased to just under the soldering temperature. This allows the volatile components of the flux to escape, eliminating blistering. As the heat increases, the flux melts forming a connection between the components and PCB. The soldering temperature is accurately adhered to during the soldering phase, so that the PCB is not damaged due to overheating.

To complete the kit, users can take advantage of free laser SMD stencils offered by Beta LAYOUT. To secure the stencil and enable precise solder paste applications, a magnetic workbench is also available. The final result is components are easily assembled to the paste and reflowed in the oven.

For further information, please contact:

Beta LAYOUT, Ltd.
Website: www.pcb-pool.com

ICONSTRUX.COM Launches

In 2003, computer scientist and author, Andre' LaMothe designed and delivered the do-it-yourself game console called the "XGameStation Micro Edition." As the first product of its kind, a whole site was dedicated to support and sell the product at www.xgamestation.com. Over the years, the XGameStation Micro was followed up with numerous other educational and edutainment based embedded gaming systems used by individuals, as well as many college level embedded systems courses.

In 2013, the creators of the XGameStation brand were frustrated with the retail websites available online for embedded systems and electronics enthusiasts. So, after a year of labor, a new site has emerged: iCOnstruX.com.

The site is targeted to real hackers and makers — people that build stuff — so there are a lot of embedded systems, gizmos, and gadgets, as well as complete kits, toys, and beginner products.



One of the unique things about iCOnstruX.com is the community which is helping Indie hardware developers by leveraging their vast experience in product development and manufacturing. So, iCOnstruX.com has programs where Indie developers can get help, consulting, and complete manufacturing support for new products they want to try and develop.

For further information, please contact:

iCOnstruX.com
Website: www.iconstrux.com

Low Pin Count, General-Purpose Eight-Bit PIC Family Expanded

Microchip Technology, Inc., has announced expansion of its eight-bit PIC microcontroller (MCU) portfolio, with the peripheral-rich, low pin count PIC16(L)F161X family. These new MCUs expand the offering of Microchip's Core Independent Peripherals (CIP) which offload timing-critical and core-intensive tasks from the CPU, allowing it to focus on other application tasks. Additionally, this family integrates fault-detecting hardware features to assist engineers in developing safety-critical applications.

The PIC16(L)F161X family offers a variety of key features, including the Windowed Watchdog Timer (WWDT) which monitors proper software operation within predefined limits, improving reliability. The Cyclic Redundancy Check with Memory Scan (CRC/SCAN) detects and scans memory for corrupted data.

This family also includes a Hardware Limit Timer (HLT) which detects hardware fault conditions (stall, stop, etc.),

simplifying closed-loop control applications. These peripherals make it easier for designers to implement safety standards (e.g., UL and class B) or fail-safe operation.

In addition to the HLT, the PIC16(L)F161X features the unique, 24-bit Signal Measurement Timer (SMT). The SMT performs high-resolution measurements of any digital signal in hardware, resulting in more precise and accurate measurements. This is ideal for speed control, range finding, and RPM indicators. Both timers are designed to reduce design complexity by eliminating the need for additional code and external components.

This high level of integration makes these MCUs appealing to a broad range of applications, such as monitoring and fail-safe systems (e.g., industrial machinery, power supplies), and products with variable-speed motor control (e.g., fans, home appliances).

The PIC16(L)F161X family is supported by Microchip's standard suite of development tools, including the MPLAB® ICD 3 (part # DV164035, \$189.99) and



PICkit™3 (part # PG164130, \$44.95) programmer/debuggers, along with the PICkit™3 Low Pin Count Demo Board (part # DM164130-9, \$25.99).

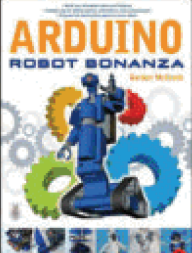
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**Microchip
Technology, Inc.**

Website: www.microchip.com

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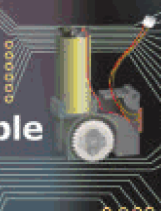
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bots IN BRIEF



BACK ON THE BEAT

Researchers and students in FIU's Discovery Lab have developed the initial prototype of TeleBot — which combines telepresence and robotics — to allow disabled police and military personnel to serve as patrol officers.

Unlike RoboCop, TeleBot is not expected to cause damage to life or property.

Researchers and students have worked for more than 18 months to refine technology that will allow a disabled person to control the robot remotely, see everything the robot “sees,” and interact with members of the public.

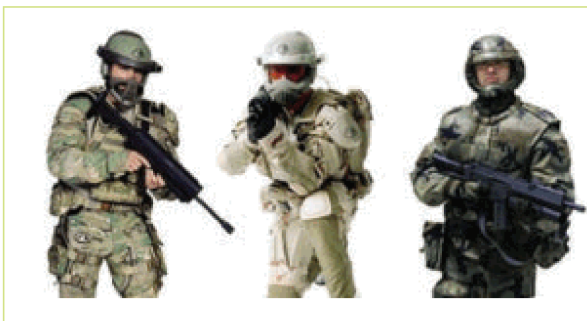
“This kind of project requires a lot of hard work, technical expertise, and resources,” said Jong-Hoon Kim, director of the Discovery Lab. “We had to build everything from scratch. The students are very motivated and feel like they are making a real contribution.”

Having overcome multiple challenges — chief among them proper hand functioning — the team has finished work on a prototype that stands six feet tall, weighs about 75 pounds, and can be controlled from a remote location.

The TeleBot project began in 2012 when Jeremy Robins, a lieutenant commander in the US Navy Reserves, donated \$20,000 to the Discovery Lab to develop an idea he had to bring disabled law enforcement officers as well as disabled combat veterans back to the force.

YOU'LL MARVEL AT THIS NEW SUIT

The head of US Special Operations Command said the first prototypes of a new, Iron Man-like protective suit could be ready for testing this summer.



Navy Adm. William McRaven said three unpowered prototypes of the so-called Tactical Assault Light Operator Suit — known in military parlance as TALOS — are being assembled and expect to be delivered in June. The plan is to evaluate the technology with the goal of fielding a system by August 2018, he said.

“That suit, if done correctly, will yield a revolutionary improvement in survivability and capability for special operators,” McRaven said during the recent 25th annual Special Operations and Low-Intensity Conflict conference held in Washington, D.C.

The technology may eventually include a powered exoskeleton, advanced full-body armor, and situational-awareness displays, according to the command's official request for information.

The idea for the project came about several years ago after a member of special operations forces was shot and killed while entering the door of a suspected insurgent, McRaven said.

Read more at <http://defensetech.org/2014/02/11/admiral-iron-man-prototypes-coming-in-june/#ixzz2tKlxsBTq>.

TIME FOR A CHANGE

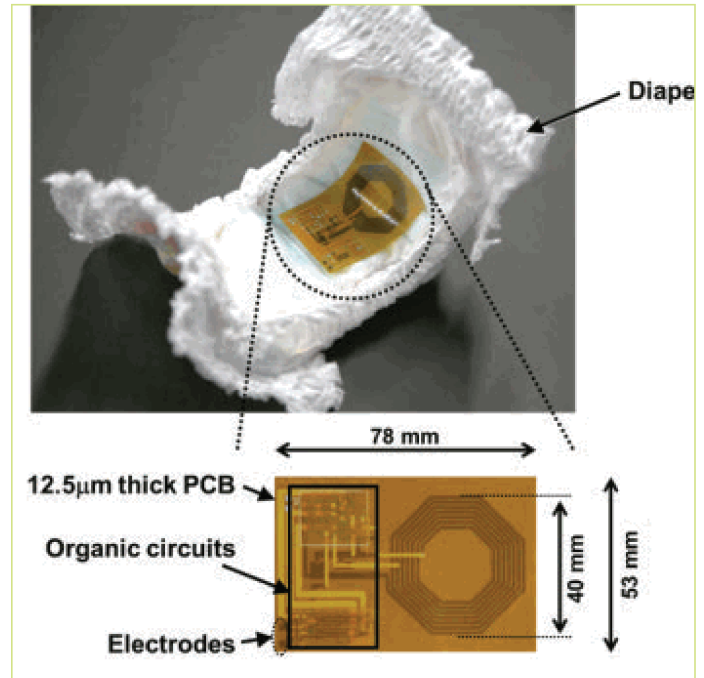
Imagine you're sitting in your living room watching the season premiere of your favorite show when suddenly you get a text message from your two month old daughter saying her diaper needs to be changed. No, she's not a super-smart infant who learned how to text at birth — it's the diaper. It knows when it's wet, and can alert you.

Thanks to a new invention from Takao Someya and a team of researchers at the University of Tokyo, that scenario may soon be a reality. Back in July 2013, the team announced in the journal, *Nature* that they'd come up with flexible circuits thinner than a piece of plastic wrap that could be implanted in the body to monitor body temperature or blood pressure, or implanted on the roof of the mouth to be used as a touch pad for quadriplegics.

Now, they've applied their research to a truly different problem: knowing when a diaper is soiled without having to undress the wearer first.

While another recent attempt to make diapers more intelligent involved QR codes, the Tokyo team — led by Someya and Takayasu Sakurai (both professors at the university) — have created a disposable, organic sensor that can be embedded in a diaper. The sensor — which is printed on a film using inkjet technology — responds to conditions that cause a change in electrical resistance such as pressure, temperature, and -- most relevantly -- wetness. When it senses that a diaper needs to be changed, it sends a signal to an external data-reading device.

Someya believes he can produce each sensor for mere pennies so that it wouldn't add much cost to diapers. He says the device is completely safe to wear next to the skin, primarily because it receives its power from the external monitoring device rather than generating its own electricity



(which could lead to a shocking experience). Someya added that its bendability was a plus. "It is completely flexible," he said, "therefore it's much safer than the conventional rigid electronics when it is put very close to skin."

The device needs to be within a few inches of the film to work, so the diaper wearer would have to have his or her private parts scanned. Not a big deal for infants, but it might be if used in adult diapers. However, the sensor would eliminate the sometimes difficult chore of undressing patients to see if they need changing, so it might be worth the initial embarrassment.

RULES OF THE (AIR) ROAD

The FAA (Federal Aviation Administration) is working with the Academy for Model Aeronautics (AMA) — the largest organization for model aircraft enthusiasts in the US — to create safety guidelines for model aircraft and drones. Many model aircraft hobbyists already belong to the AMA or at least know about its guidelines (don't fly higher than 400 feet, don't fly within three miles of an airport, etc.). Recently, however, the advent of relatively affordable easy-to-fly model aircraft — GPS-enabled quadcopters that can easily fly up to 1,000 feet and even autonomous drones — has added a large number of new users. In addition, the FAA notes some high-

end model aircraft can now have wingspans over 20 feet and have multiple jet engines.

Given that the FAA has started its work on integrating commercial drones into the national airspace system, working with enthusiasts to create safety guidelines for how they can safely fly is a sensible move. Many of the potential commercial drones, after all, are essentially the same machines that today's hobbyists play with.

As part of the agreement between the FAA and AMA, the AMA will "establish and maintain a comprehensive safety program for its members, including guidelines for emerging technologies such as model UAS."

HIT THE ROAD

The US Army Tank-Automotive Research, Development, and Engineering Center (TARDEC) and Lockheed Martin have demonstrated the ability of fully autonomous convoys to operate in urban environments with multiple vehicles of different models.

The demonstration held earlier this year at Fort Hood, TX, was part of the Army and Marine Corps' Autonomous Mobility Appliqué System (AMAS) program, and marked the completion of the program's Capabilities Advancement Demonstration (CAD). The test involved driverless tactical vehicles navigating hazards and obstacles such as road intersections, oncoming traffic, stalled and passing vehicles, pedestrians, and traffic circles in both urban and rural test areas.

The AMAS hardware and software are designed to automate the driving task on current tactical vehicles. The Unmanned Mission Module part of AMAS — which includes a high performance LIDAR sensor, a second GPS receiver, and additional algorithms — is installed as a kit and can be used on virtually any military vehicle. In the CAD demonstration, the kit was integrated onto the Army's M915 trucks and the Palletized Loading System (PLS) vehicle.

If you recall, we mentioned the Army's plan to replace

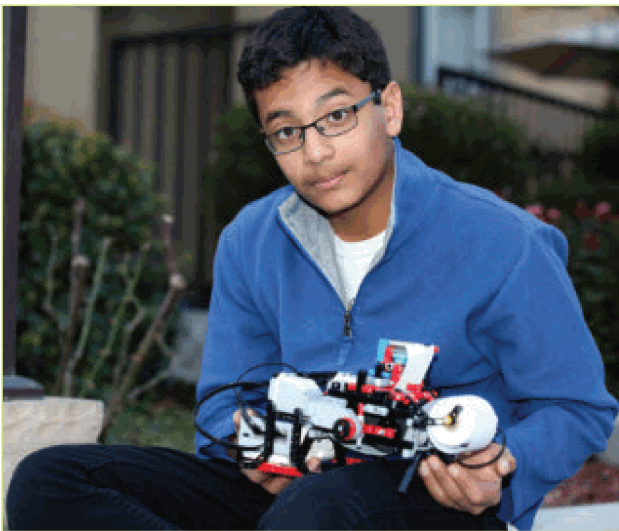


thousands of soldiers with robots as a way to increase efficiency by reducing the ratio of support personnel to combat troops. By cutting the size of a brigade by a quarter and filling the gap with robots specialized in logistics, the Army hopes to become safer, more versatile, and cheaper all at the

same time. However, this isn't about replacing front line soldiers with armed robots. It's more about replacing humans who drive supply trucks with robotic supply trucks that drive themselves. What's most important about this system is that Lockheed isn't making autonomous vehicles. They're making vehicles autonomous.

The trucks are autonomous; the Humvees are not. The trucks are negotiating dirt roads at speed in a convoy such that for the trucks in the back, there's a bunch of dust in the air which makes the autonomous navigation even more impressive (LIDAR doesn't like to deal with particles in the air, especially at dusk.) They seem to have no problem being passed by manned vehicles, and they're notably aggressive in tight urban environments.

The Army says they were "very pleased with the results of the demonstration," but made no comment as to when a system like this might actually be put to work in the field. As with all autonomous vehicle systems, there's a trust barrier that must be overcome.



VISION FOR THE FUTURE

When LEGO revealed its line of EV3 Mindstorms robots last year, bay area tech companies came up with some very goofy applications. However, 12 year old Santa Clara resident Shubham Banerjee just came up with a decidedly more meaningful one: a braille printer.

Banerjee noticed that braille printers can cost more than \$2,000 and wondered if he could drop the price, according

to his father. A MINDSTORMS kit is \$350 and easily modifiable, giving Banerjee most of the parts he needed to build the device.

The printer works with regular calculator paper. A robotic arm moves a module that contains a push pin, which pushes down on the paper to create the bumps that form a letter. Right now, one letter can fit on each line on the paper, and each one has to be manually input. It can print a letter every five to seven seconds.

Banerjee originally developed the printer for a science fair, but has since expanded his dreams for it. He hopes it can help people in developing nations have easier access to braille printers, which can open up a whole world of expression and interaction. He plans to make the design and MINDSTORMS program he developed open source for anyone to use, though the printer is still a prototype.

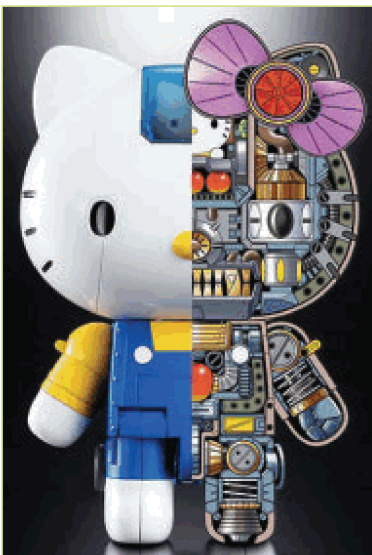
Learn more about this cool kid at <http://gigaom.com/2014/02/17/seventh-grader-builds-a-braille-printer-with-350-worth-of-legos>.

KNIT-WIT

In case you missed it, British artist-inventor, Andy Noyes debuted Agnes Roboknit at the 2013 Maker Faire in the U.K. Agnes is a humanoid robot who knits, scares small children, and occasionally looks around as if wondering why her maker condemned her to such a boring existence.

Noyes wanted her to look human from a distance, but he also wanted to show off her mechanical parts upon closer inspection. Agnes is almost completely hand-made — down to her homemade gears driven by DC motors and her latex skin cast from plaster casts of real people. Noyes originally planned to have her knit with real needles, but after discovering how difficult it was, he opted for a knitting loom instead.

Noyes named Agnes after his grandmother, although he had hoped to accompany the name with a clever acronym (A.G.N.E.S.) like other classic robots from the '80s. Agnes' motions are surprisingly simple, and somehow mesmerizing.



WELL, HELLO ROBOT KITTY!

Bandai is celebrating the simultaneous 40th anniversaries of Hello Kitty and its Chogokin — a “super alloy” equivalent to Marvel’s adamantium — line of die-cast metal figures with a Chogokin Hello Kitty. The Hello Kitty mech has changing eyes, a cockpit with a miniature Hello Kitty pilot, and firing fists. It will be available for purchase in June 2014.

Bandai portrays the beloved Hello Kitty as a robot that can be piloted by Hello Kitty herself. The Hello Kitty robot can be transformed into three different modes. Drive Mode features wheels

on her legs that let you “drive” her on surfaces. Attach the accessory ribbon to her back for Flight Mode. The ribbon disassembles to create fins for her feet for Dive Mode. Three eye mode expression changes are featured with this action figure including “Angry Mode,” plus die-cast Hello Kitty also features a rocket punch special effect part. A special display stand is also included that allows posing of Hello Kitty robot in all modes. She measures nearly four inches tall.



COLOR MY WORLD

Long-exposure light painting with robots is relatively easy to do with a minimal amount of hardware and programming knowledge. Thymio II shows us just how easy.

Thymio robots are equipped with an array of programmable LEDs, and it's very easy to get them to do simple behaviors like driving around in trajectories that combine lines and curves.

Aseba is a set of tools used in conjunction with Thymio which allow novices to program robots easily and efficiently. For these reasons, Aseba is well-suited for robotic education and research. Aseba is open source (GNU Lesser General Public License), and you can freely download it and play with



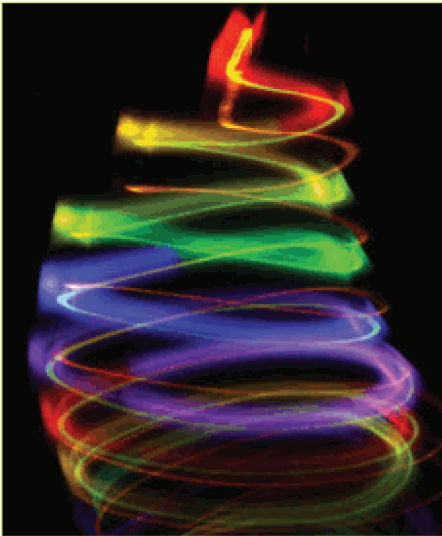
it from <https://aseba.wikidot.com/en:downloadinstall>.

Stéphane Magnenat started developing Aseba as part of his PhD work in the Mobots research group at EPFL.

You can buy a Thymio II robot for about US\$100 from the Aseba website.

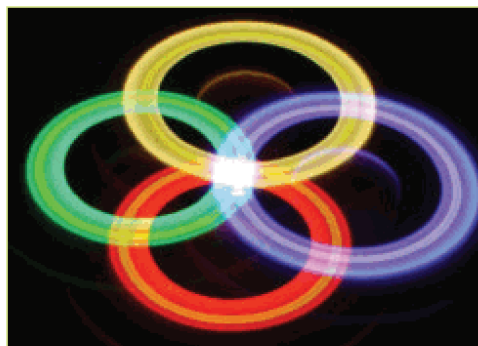
Thymio user Mariane Brodier created all of the images shown here by pre-programming motions,

cycling the LEDs through color changes, and then letting the robot go nuts in a dark room while pointing a camera at it with the shutter open for a minute or two. Here's some of what she came up with, along with her descriptions:



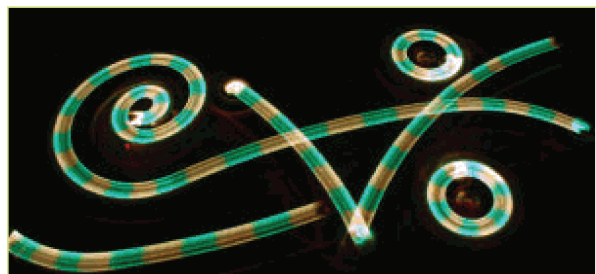
This image has been programmed only with colors, therefore without movements. In order to make this picture, the robot oscillated at the end of a wire that unrolls itself.

For this sequence, I was inspired by the Tangram, a Chinese puzzle that comes from splitting a square into seven basic parts: five triangles, a square, and a parallelogram with the robot being able to make only lines or curves, I could program the outline of several puzzles.



For this sequence, I based my work on "crop circles" that are often attributed to aliens.

This sequence looks much like the first, except that instead of using all colors, only two colors are alternated making dotted lines. This sequence is the last I made, therefore the trajectories are much more complex than in the first sequence.



RIVER RATS

RIVERWATCH is an autonomous surface-aerial marsupial robotic team for riverine environmental monitoring. The robotic system is composed of an Autonomous Surface Vehicle (ASV) piggybacking a six-rotor Unmanned Aerial Vehicle (UAV) with vertical takeoff and landing capabilities. The ASV provides the team with long-range transportation in all-weather conditions, whereas the UAV provides the team with an augmented perception of the environment. The coordinated aerial, underwater, and surface level perception allows the team to assess navigation cost from the near field to the far field, which is key for safe navigation and environmental monitoring data gathering.

The "marsupial" bit refers to the hexacopter which uses the boat as (to really stretch the metaphor) a pouch. With enough solar cells and good weather, the boat could power both itself and the hexacopter, extending its operating time significantly or in the absolute best case, indefinitely. The whole thing runs ROS and looks to be capable of very robust autonomous navigation, but the really cool part is how the boat and the hexacopter can team up and combine the data sets they collect to create far more comprehensive and accurate maps than either could alone.

A particular aspect to be taken into account is the interaction of robots to take the best of the complementary visual perspectives they have of the environment. The goal is to use an aerial perspective to promote on-water safe navigation. In the application scenario, the robotic team moving downriver assesses a series of environmental variables. If a pollution indicator is triggered, the aerial platform is asked to perform a local survey. This information is passed on to a remote control center where a human operator is monitoring and configuring the mission.

RIVERWATCH started as an experiment as part of ECHORD (the European Clearing House for Open Robotics Development). Once it actually started working, it was transferred over to UNINOVA in Portugal.



Continued on page 44

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COMBAT ZONE

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A Note from the Editor: Pete Smith's *Isotelus Rex* build series will continue in the May issue. He took this month off to fight robots!

Kevin

BUILD REPORT: Spanky Part 1: Combat Robot Platform

● by Mike Jeffries

Spanky is the newest robotic member of Near Chaos Robotics. Spanky was designed with two events in mind: DragonCon Robot Battles — an open platform Sumo style event; and the Sportsman class at Motorama — an event with a full arena.

For Robot Battles, any sort of spinning weapon is limited to a maximum tip speed of 20 ft/s. For Motorama, there isn't an explicit speed limit for spinning weapons. However, any high speed spinning weapons cannot be designed for kinetic energy transfer, and active weapons are mandatory. The difference in rules led to the decision to build a robot with modular weapon systems.

Robots with modular weapon systems have been around for a long time, and all of the ones that have done well have one thing in common: The base platform is designed to be

robust, simple, and easy to work on. Part 1 will focus on the base platform used for Spanky.

The platform concept is extremely simple. Spanky has two large wheels with the entirety of the inner workings contained within the wheel diameter. This arrangement would allow it to use an overhead swinging attack (thwack), utilizing only the power of the drive system. Building this style of chassis would allow for the most versatility in potential weapon systems — ranging from hammers and axes that bolt directly to the chassis, to circular saws and chainsaws that have external motors for primary weapon power.

Building with an overhead thwack style of attack as part of the design meant that a powerful drive system would be required, and that a good deal of attention would need to be paid to the weight balance. With this in mind, the majority of the drive

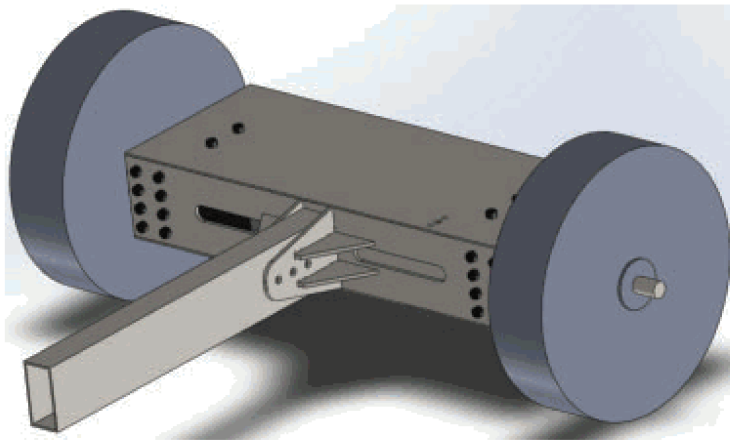


FIGURE 1.
Model of the
main chassis
showing a
generic
attachment
arm.

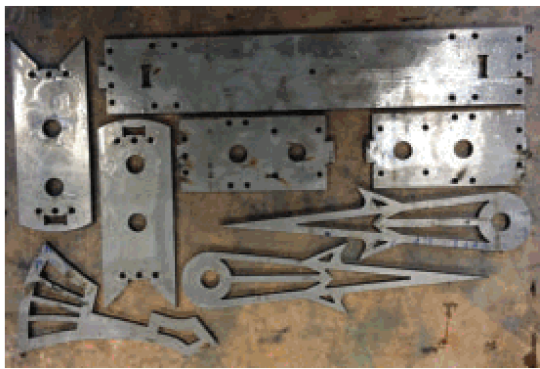


FIGURE 2. Waterjet cut steel plate used in the assembly of Spanky.



FIGURE 3. The back plate and outer side plate assembled prior to welding.

system was taken from my recently retired 12 lb robot Apollyon, which used 18 volt Dewalt drills for locomotion. Using these motors with a six-cell LiPo battery would mean approximately 3 HP in the drive system, and when geared for a travel speed of 10.5 ft/s, it would reach that speed in as little as one second.

With the drive system figured out,

the next major design element was weight balancing. With the small chassis size and rigid limitations as to how thick the armor would be, the first decision was to use steel as the primary structural material. Using steel had several benefits. The relatively high density meant it would need smaller design changes to get the same shift in the center of gravity, and using steel meant that the chassis could be welded into several major sections which would result in a very durable chassis.

The main body of the robot is a mix of 1/4", 1/8", and 1/16" 4130 steel plate with 1/4" steel plate making up the back plate, optional axle wedges, inner side rails, and outer side rails. The 1/8" steel plate was used for the front plate and the weapon mounting bracket. The 1/16" steel plate was used for the top and bottom armor. All three plates were also used for portions of the various weapon attachments.

With the chassis cut and welded, the next step was the assembly of the drive system, which also led to the discovery of a small but nearly disastrous design flaw. When the drive system assembly was planned, the decision to weld the majority of the chassis together had not yet been made. When it came time to assemble

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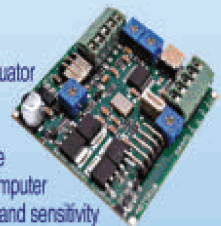
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FIGURE 4. This is the weapon mounting bracket part way through the welding process.

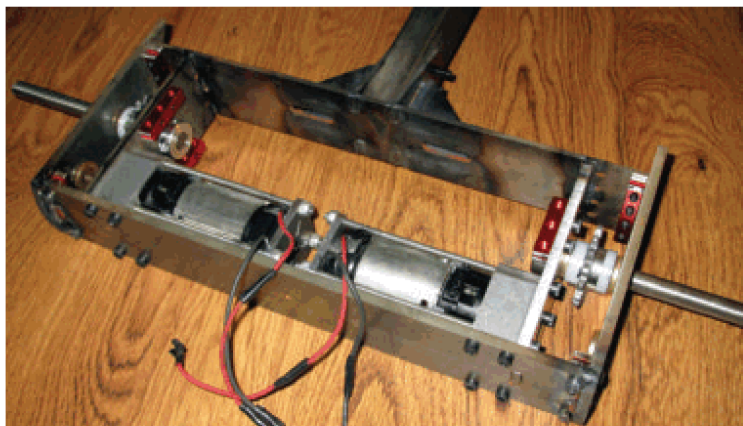


FIGURE 5. Drive system prior to the installation of the drive side shafts.

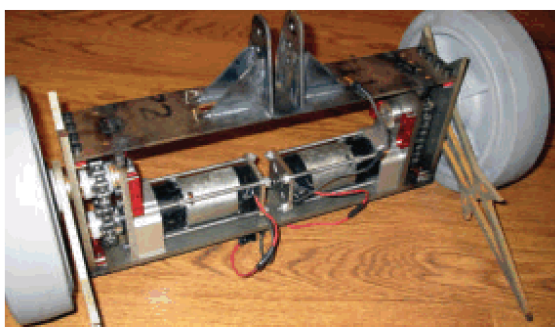


FIGURE 6. Fully assembled drive system with wheels and optional axle wedges.



FIGURE 7. The zigzag pattern identifies the relative front of the robot.

panels with a directional design such that no matter the orientation, there would be an easy to spot indicator of which direction was forward.

The final step for the base platform was wiring. As with the rest of the robot, the wiring was kept as simple as possible.

the drive system, it was discovered that there was no way to install the keystick with the stock shafts because the keyway did not extend the full length of the shaft.

The eventual solution was to extend the keyway in the shaft to allow the keystick to be suspended in the drive sprocket during insertion. To make the modification, the initial cutting was done on a small manual mill with the final cutting and shaping done using a rotary tool, as the final portion of the shaft was too hard for the mill tooling that I had available.

With the modifications complete, the drive shafts were able to be inserted and the drive train assembly was soon completed. The shafts are located with a combination of aluminum shaft collars and UHMW tube stock cut to length

and used as spacers.

One major difficulty with driving this style of robot is that forward and reverse are constantly switching. Which side of the robot is forward is dependent on which direction you're travelling and how aggressively you accelerated to move in that direction. The solution to this problem was to paint the top and bottom armor

The electrical components consist of a six-cell 2,650 mAh LiPo battery, a Team Whyachi MS-05 power switch, three Holmes Hobbies BR-XL speed controllers, and a Hobbyking R610 receiver. Two of the three BR-XL speed controllers are used to operate the drive system. The third BR-XL speed controller has a small plug attached to the motor side that allows powered weapon systems to be quickly connected to the electrical system.

When stripped down to the base platform, Spanky weighs 22 lbs 0.2 oz, which leaves just under 8 lbs for any weapon configuration.

The design and construction of the chainsaw, circular saw, axe, and hammer attachments for Spanky will be covered in Part 2. **SV**

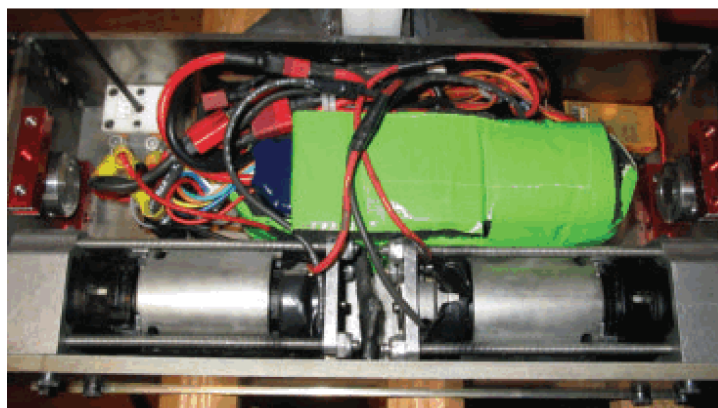


FIGURE 8. The electrical system of Spanky with the motor side of the third BR-XL disconnected.

Pushing Power:

How Strong is Strong Enough?

● by Kevin Berry

In February's Combat Zone, we featured a guide to robot speed (How Fast is Fast Enough?). This month, we address the other variable: torque. In terms of robot combat, torque is our fancy word for pushing power. Remember, speed and torque are inversely proportional. That means, more speed = less torque; more torque = less speed. If it wasn't for those pesky laws of physics, we'd be able to have a bot with high speed and high pushing power.

So, like every other part of bot design, it's a tradeoff. Setting the amount of torque you design in is one of the most judgment-based decisions. For the "Fast" article, I laid out a measureable guideline: typical speed is eight feet per second, ranging up to 14 fps for a mega speed bot.

How much pushing power you need — and can deliver — is subject to a lot of variables. The first, of course, is traction. All your precious calculations go out the window when your wheels start slipping because the arena floor is slick metal or covered with foam wheel powder, or your tires are clogged with debris, or the arena is damp (Battle Beach 2 featured an outdoor Insect box where battles were fought in a monsoon). So, traction will be reserved for a future article. In this one, we'll stay on the side of ideal mathematics.

Because it's not plagiarism if you steal your own stuff and (just like in

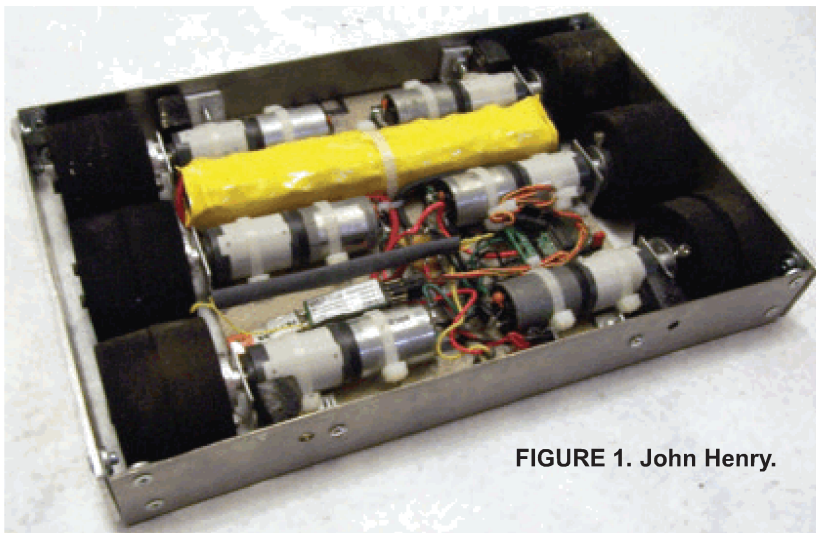


FIGURE 1. John Henry.

school) adding filler to get your word count up is allowed, I'm going to quote the Fast article. However, I'll substitute "torque" for "speed." To make it legal, I'm going to put quotes around the quote. (That last sentence and this one got my word count up by 26 more!)

"Bot torque is a function of three components: motor torque, gear ratio, and wheel diameter. Motor torque is, in turn, partially a function of battery voltage, current, and speed controllers, but for this article I decided to use the KISS principle, since I'm a pretty simple guy. I decided to only consider commercially available motor/gearbox combo sets, since it avoids a whole lot of complexity like chains, belts, bearings, those toothy things, and other gear head type stuff."

We're also going to assume the battery/speed controller/wire combination can deliver the maximum required current. Motors produce their maximum torque when their speed (rotations) are the least, with current peaking at the point of stalling. Thus,

the term "stall torque."

That means, if you were in a pushing match and had perfect traction, you'd produce the maximum torque. Of course, wheels will almost always slip first (except maybe if you have another bot on yours, and you're jammed against the bumper, and you push the control stick the wrong way, and ...).

An astute reader might notice that in

the accompanying figures, some motors are rated at "output torque" or "peak torque." There may be other reasons for that, but usually it goes to the fine print. Some motor/gearbox combos can't take full torque without shearing something expensive and vital, like a gear or shaft. It would be my decision to avoid these. In fact, your whole drive system should be able to handle a stall condition.

In my first lightweight bot during testing, I put fuses into the motor circuits. Within 10 seconds, I'd sucked up a doormat into the wheels, stalling them and blowing the fuse, saving the ESC. That led to several design updates. Combat damage and arena debris practically guarantee you will stall your drive system, even without perfect traction. "Caveat designare."

For this article, I stuck to the Robot Marketplace online store. I made sure to cover a wide range of motor/gearboxes, useful from Antweights to Heavyweights. Turns out for my tables, a range of 1 to 370 ounce inches of torque are available

Insect Bots	Wheel Diameter (Inches)				
	Torque (oz-in)	0.75	1	1.5	2
	10	2	1	1	1
	50	8	6	4	3
	100	17	13	8	6
	150	25	19	13	9
	200	33	25	17	13
	250	42	31	21	16
	300	50	38	25	19
	350	58	44	29	22
	400	67	50	33	25
Applied Torque (lb)					

Big Bots	Wheel Diameter (Inches)				
	Torque (oz-in)	4	6	8	10
	50	25	17	13	10
	100	50	33	25	20
	200	100	67	50	40
	400	200	133	100	80
	600	300	200	150	120
	800	400	267	200	160
	1000	500	333	250	200
	1300	650	433	325	260
	1500	750	500	375	300
Applied Torque (lb)					

Small Bots				
Motor	Torque	Unit	Voltage	Rated At:
Pager 25:1	1	oz-in	6V	Stall torque
Pager 81:1	3	oz-in	6V	Stall torque
Kitbots 1000	7	oz-in	12V	Stall torque
Micro 30:1	8	oz-in	6V	Stall torque
Spark 20:1	10	oz-in	6V	Output torque
Copal 30:1	11	oz-in	6V	Stall torque
Micro 50:1	15	oz-in	6V	Stall torque
Spark 35:1	18	oz-in	6V	Output torque
Spark 50:1	26	oz-in	6V	Output torque
B16	27	oz-in	6V	Stall torque
Copal 50:2	32	oz-in	6V	Stall torque
Spark 63:1	33	oz-in	6V	Output torque
Spark 86:1	45	oz-in	6V	Output torque
B16	45	oz-in	12V	Stall torque
Copal 60:2	50	oz-in	6V	Stall torque
Copal 50:1	53	oz-in	12V	Stall torque
Spark 115:1	60	oz-in	6V	Output torque
B62	70	oz-in	6V	Stall torque
Micro 298:1	70	oz-in	6V	Stall torque
Copal 60:1	71	oz-in	12V	Stall torque
Spark 150:1	78	oz-in	6V	Output torque
Spark 250:1	130	oz-in	6V	Output torque
B104	155	oz-in	6V	Stall torque
B62	187	oz-in	12V	Stall torque
Spark 360:1	188	oz-in	6V	Output torque
B231	225	oz-in	6V	Stall torque
B104	247	oz-in	12V	Stall torque
B231	370	oz-in	12V	Stall torque
All motors and values as listed on RobotMarketplace.com .				

for Insect bots. For large bots, 50 to 1,400 inch pounds make up quite a range.

For Insect wheel diameters, I went as small as 0.75" covering Fleaweights to as large as two for Beetles. Big boys got 4" to 10". This stuff isn't hard to figure out, it's mostly converting units. So, if you want micro small or hugely large wheels, the math is left as an exercise for the student.

Wheel diameter is the key dimension. Think of the wheel as a lever. The distance from the axle to the rim (or the radius) is the lever arm. A motor/gearbox with 20 ounce inches of torque on a 2" diameter wheel (1" radius) will produce 20 ounces of torque. A shorter lever arm (smaller radius) gives more torque for the same motor/gearbox. Of course, the smaller the wheel, the slower the bot. Thus the tradeoff in **Equation 1**.

The other key point to

understanding about torque is that it's very much a function of the motor design, and the ESC design or programming. Motor torque is usually a curve, not a linear function. Ditto ESC outputs. Since, in my humble opinion, combat doesn't call for

$$\frac{\text{Motor Torque (oz in)}}{\text{Radius (in)}} = \text{Bot Torque (oz)}$$

Equation 1.

Big Bots				
Motor	Torque	Unit	Voltage	Rated At:
AME 206	53	in-lbs	12V	Stall torque
AME 213	124	in-lbs	12V	Stall torque
AME 218	186	in-lbs	24V	Stall torque
AME 226	230	in-lbs	12V	Stall torque
AmpFlow E30-150	360	in-lbs	24V	Peak torque
AmpFlow F30-150	710	in-lbs	24V	Peak torque
AmpFlow E30-400	770	in-lbs	24V	Peak torque
NPCT64	825	in-lbs	24V	Stall torque
AmpFlow A28-400	930	in-lbs	24V	Peak torque
AmpFlow A28-150	1022	in-lbs	24V	Peak torque
AmpFlow F30-400	1300	in-lbs	24V	Peak torque
NPCT74	1480	in-lbs	24V	Stall torque
All motors and values as listed on RobotMarketplace.com .				

excessively precise calculations, you quickly reach a point where you just decide.

Now, to the question in the title: How strong is strong enough? Answer: It depends.

Yup. You decide. Are you building a pushy or a spinner? Wedge or boxbot? Two motors, four, or six? What kind of wheels? Soft, sticky, vulnerable foam or rock hard neoprene?

Kevin's rule of thumb — completely my own — is that for a pushy, you want to "theoretically" be able to push 3-6 times your bot's weight. So, a Beetle should be able to push 18 pounds at perfect traction. With four wheels, you need 4.5 pounds of push.

Looking at the chart, you can see this keeps you up in the area where you can have decent speed (lower torque motor/gearbox/wheel combo). (DISCLAIMER: Every single

veteran bot builder will disagree with me here. Of course, they will disagree with each other, as well. YMMV.)

Once, in a fit of pushyness, I built a Beetle that was all "push." A boxbot with six of the legendary Escap 33:1 gearmotors, 12 foam wheels, and not a lot else. It wasn't a bad bot, but I learned a lesson about surface area vs. floor loading vs. friction coefficient.

Since I'd done the research already to develop the torque tables, I threw in a couple of gratuitous tables listing the motor/gearboxes I used to develop them.

I fully expect — and hope — this article launches a great conversation in the community about torque vs speed vs friction, and we'll all learn something.

The spreadsheet that generated these tables is available at the Combat Zone article link. **SV**

BUILDING TIPS:

Balancing a Weapon Bar

● by Ray Billings

I frequently get asked about balancing weapon bars, and I figured a simple guide might be helpful. Although there are options for both static and dynamic balancing, I have never needed to do either in all of the years I have competed. Don't get me wrong, proper balancing of a spinning mass is crucial, but there is a way to make sure you get this right without any need for specifically balancing it once you are done. It really comes down to paying attention while you are machining it! Here is a step by step guide:

First off, decide on the dimension of your spinning bar. The ones here are approximately the dimensions for the spinning bar on my middleweight bot Mortician. Since your frame needs to be built around this and you need to figure your weight for the total of the bot, you really need to know the specifics on the spinning mass first. In this case, the bar is 5/8" thick giving a total volume of 109.73 inch³. This makes the unmounted weapon bar just over 31 pounds (**Figure 1**).

Okay, I drew it out, I know the weight. So, can I just start cutting and drilling? Precision counts in all machining, but it *really* counts when you are machining a spinning mass. The first thing you do is the hole in the center that the bar rotates around. This feature will be what you reference for every other dimension. In machining terms, this is the datum.

The first thing you need to make sure is that your mill or drill head is perfectly at a 90° to the work surface. If you make a mistake here, there is no chance of ever getting it balanced correctly. The hole needs to be perfectly perpendicular to the plane of the bar.

Next, make sure the hole is centered on the bar. First, you check the dimensions in the narrower section; they need to be identical. If this isn't identical, then shave off the side that is thicker until the dimensions match. This is the next most important dimension, since even slight differences will vastly throw the bar out of balance (**Figure 2**).

Now, make sure the hole is centered in the longer

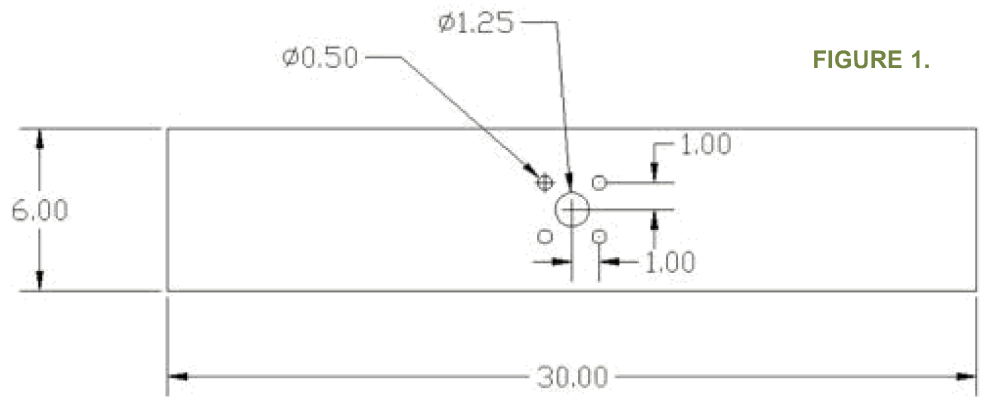


FIGURE 1.

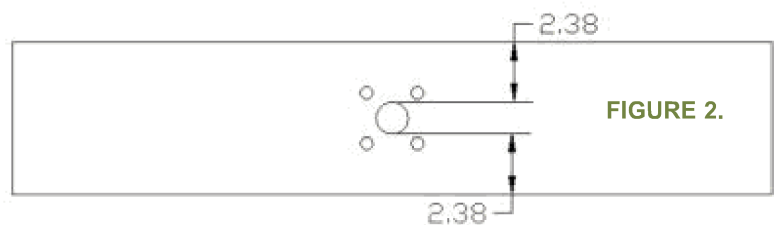


FIGURE 2.

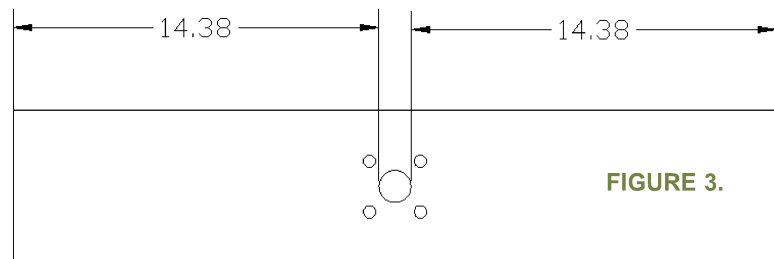


FIGURE 3.

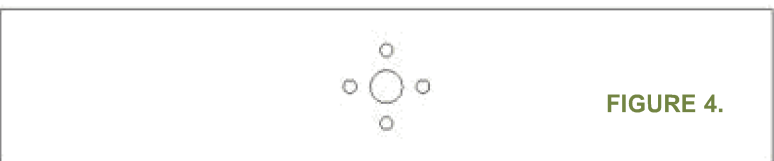


FIGURE 4.

section. Again, if one side is longer than the other, go ahead and shave it down to match. This is actually the most forgiving dimension, and a few extra thousandths of an inch will not really throw things out too far (**Figure 3**).

Finally, we come to the mounting holes. They should look like **Figure 3**, not **Figure 4**. The weakest portion of the bar is from the central spin point through the narrowest section to the edge. Placing a mounting hole in this position drastically weakens the bar (**Figure 4**).

As long as your machining is done precisely, you will never need to balance anything. **SV**

Melty Brains

by Kevin Berry

I can't believe it! Spinny McSpinny Pants built a wedgy-boxy bot for STEM Tech Olympiad 2014!

I am SO going to kick his bott off!

Uh oh

April Fools, Suckah!

Cartoonist's note: Yes, I know STO '14 is in May ... but this is gratuitous advertising. You get what you pay for!

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BUILD REPORT:

New Builders, Beware!

● by Andrea Suarez

I can spot a new competitor as soon as they come to the arena for their first match. It isn't because their hands are shaky and their robot is a slightly modified R/C car. It's because they will delicately place their shiny new robot in the arena.

During their first match they'll be so aggressive that they'll break their own robot, their weapon will shoot across the arena on first impact, or they'll hit a disabled opponent until they resurrect.

Here are some tips to avoid some common pitfalls at your first competition.

Stand on the Shoulders of Giants

Go online and watch as many match videos as you can. Why was the winner successful? What could their opponent have done differently to change the outcome? Did you agree with the judge's decision? Read through forums and ask detailed questions. Learn from other robots, but avoid building a carbon copy of an existing robot. Without a real understanding of the intricacies of a design, you'll have little success.

Remember there is no single design that ensures victory. The Internet gives you the ability to acquire years of experience over a weekend. Some things you'll only learn the hard way, but you'll have a vast head start.

Know Your Robot Meticulously

Know how it works, how it breaks, and how it drives. Practice, practice, practice. Drive it off a table and into a



Middleweight Blender loses its shell when its welds can't take the grueling forces of competition.

wall. Find something that weighs as much as your robot and fight it (safely, of course). If your weapon breaks catastrophically during testing, celebrate! It didn't cost you a loss at the event. Testing your robot will teach you invaluable lessons, such as the importance of thread locker and the difference between acrylic and polycarbonate.

Note that testing requires a finished robot weeks before an event. If your robot is polished and pristine when it enters the arena, you're already at a disadvantage. Set up some markers and practice driving every chance you get. You will not believe what an advantage effective driving can be. This skill alone can win matches.

Design for Painless Repairs

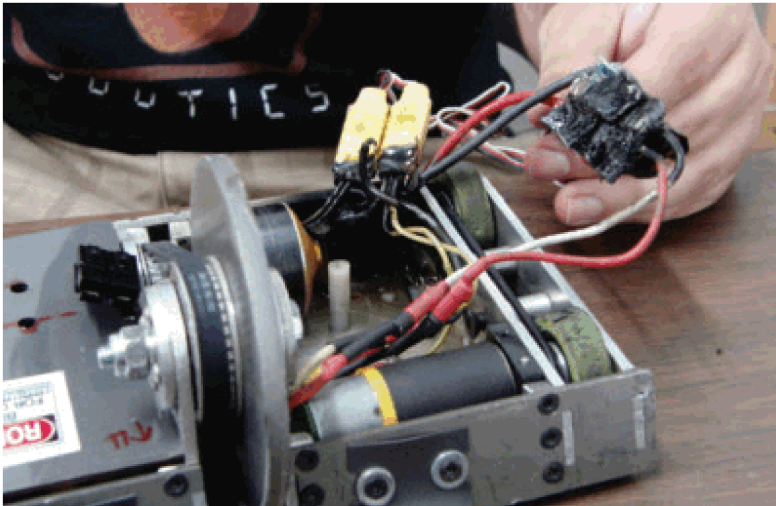
Many builders overlook this while they're designing their robot, but it often becomes critical at competition. Make your

battery accessible so that you don't waste 15 minutes just getting it on the charger. Try to use a limited number of screw sizes so you don't have to switch drivers constantly. Motors and speed controllers should be easily replaceable.

Carry a multimeter and know how to use it. It will become your best friend when you need to diagnose problems quickly and effectively. Most events guarantee no more than 20 minutes between matches, so you don't have time to switch out a working motor to find out you have a broken speed controller.



Video of Heavyweight match, Last Rites vs. Sewer Snake.



Know how to fix mechanical and electrical elements of your robot.

Have a Compliant Strategy

After each hit, reevaluate the status of your own robot and the status of your opponent. Often, a competitor is so focused on being the aggressor that they are unaware that their opponent is unable to move! Pay attention to what is damaged on the other robot and take advantage of it. Strategy is a significant part of the judge's decision.

Matches are judged on the entire duration of the match, so modify your strategy as time runs out. If you got 20 hits in the first 30 seconds and then

your weapon stopped working, you will probably lose that match. It's not about getting every hit; it's about getting the good ones. Sometimes a little patience pays off.

Never Lose Two Matches the Same Way

Each loss is a unique opportunity for improvement. Of course, everyone is competing to win, but this should just be the icing on the cake. There can only be one winner, and frequently luck is just as important as anything



Competitors from Australia, Canada, Florida, and California enjoy dinner with combat robotics legend, Matt Maxham (second from right), after a long day of robot fighting.

else. The audience will remember your matches, not your trophy. Don't be consumed by the desire to win — you will miss out on the experience while you're sulking in the corner.

Make time to watch matches and interact with other builders. You will be surrounded by the most incredible people you'll ever meet. You may be sitting next to a rocket scientist or the cofounder of Apple. I've made some great friends through the years, and I look forward to the company as much as the matches.

Improve the Sport

One of my favorite elements of robot fighting is the unbelievable sportsmanship. Everyone is there to see sparks fly, and it's common to find a builder helping an opponent minutes before they compete. Trading acquired knowledge between teams — even continents apart — has propelled this sport forward at an incredible speed.

Understand that judging close matches is exceptionally difficult. If you don't want to rely on the judges, go for the knock-out. Event organizers and judges are almost always volunteers, so be kind to them. These are the people that make this sport possible by sharing their time and enduring excitement for combat robotics.

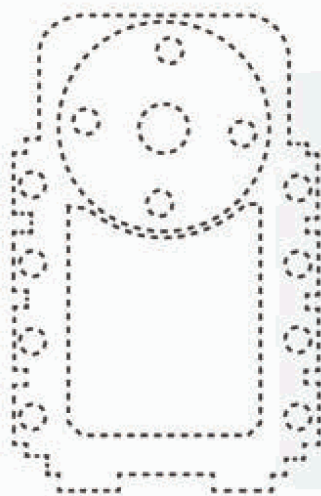
I owe a debt of gratitude to those who introduced me to this world of innovation, collaboration, and incessant thrills.

Enjoy the ride! **SV**



University of Miami Robotics team meets Apple cofounder Steve Wozniak in the stands.

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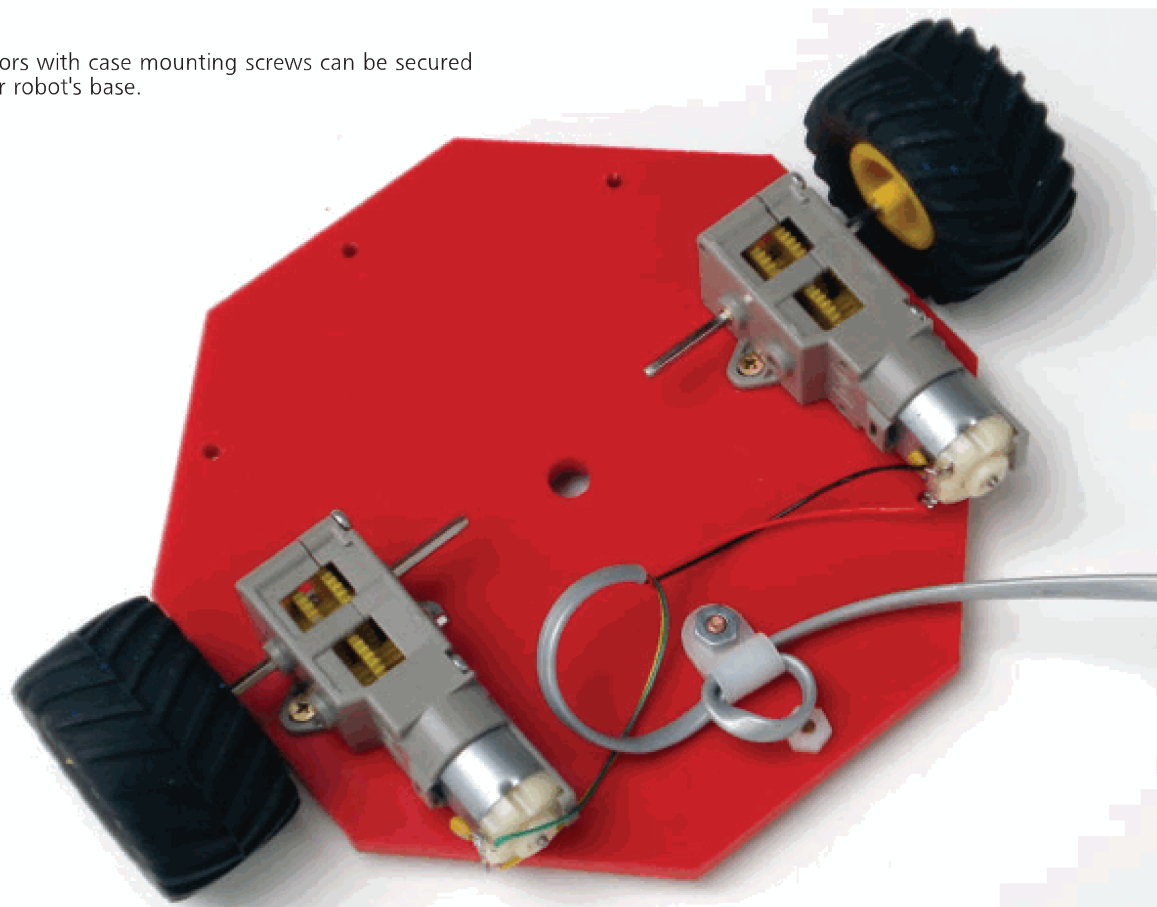


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Figure 1. Motors with case mounting screws can be secured directly to your robot's base.



How to Mount Motors and Wheels to Your Robot

By Gordon McComb

So, you've got a nice robot base. You've dug up some motors and wheels you think will be perfect. So, just how are you going to mount those motors to your bot? Then, there's the problem of attaching the wheels to the motors. Hmmm. Things aren't as easy as they first seem.

DC motors and radio control (R/C) servos — the two most common motor types used on smaller robots — each have their own means of mounting. Some are easier than others. In this article, I'll talk about popular ways to mount motors to robot platforms. Plus, you'll learn some tricks on how to attach wheels to those motors.

To avoid adding unnecessary complexity, I'll limit the discussion to small desktop robots only. Larger and heavier robots require far more robust construction — like working with steel and welding — than what's described here.

Mounting DC Motors

There are no standards in the design of a DC motor. Depending on how the motor was meant to be used, it may be a snap to mount or it could be cumbersome, requiring a hodge-podge of hardware.

Generally speaking, motors meant for generic use tend to have holes, brackets, or flanges that make mounting easier. Motors engineered to work with just a specific product rely on the design of that product for secure mounting. There are no holes, no brackets, and no flanges, making them harder to work with.

Motors designed for hobby robotics are made with mounting in mind. These include the various Tamiya motor kits (see **Figure 1**) which have flanges or other means for secure mounts. Solarbotics and many other robotics-centric online retailers import motors that have been specially selected because they offer mounting ease. If you're just starting out in robotics, these should be the ones you choose.

Some motors have already-threaded holes on their faceplate (the side where the shaft comes out), like that in **Figure 2**. If you have a die and tap set, you can drill your own holes or re-tap the ones already on the motor. To do this, you must disassemble the motor to remove the faceplate so you can drill new holes. Not a simple task. Disassembly is required to prevent metal shavings (from drilling and tapping) from getting into the motor, which will render it inoperable.

The part of your robot you attach the motor to — a base or a frame piece — needs to have mounting holes that match. You can use a piece of paper to trace the location and orientation of the holes in the motor, then use the paper to mark the placement for corresponding holes in the robot.

You need separate brackets if you must attach a vertically-mounted motor to a horizontal surface. Metal brackets are common finds at any home improvement store. They can be a bit bulky, however, being made for general household chores. For smaller bots, I prefer lightweight plastic brackets available at specialty online stores, or miniature metal hardware available from the larger electronic parts outlets like Mouser and Digi-Key.

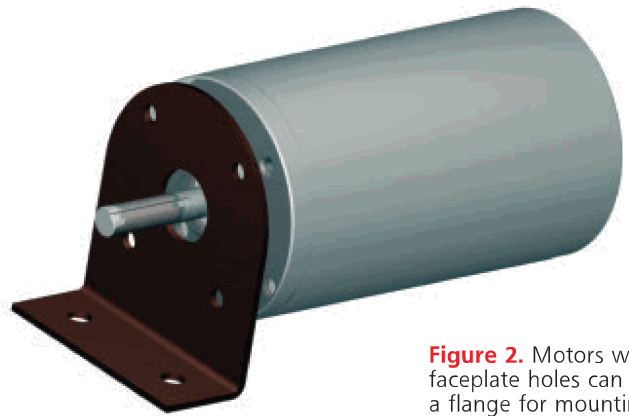


Figure 2. Motors with faceplate holes can use a flange for mounting.

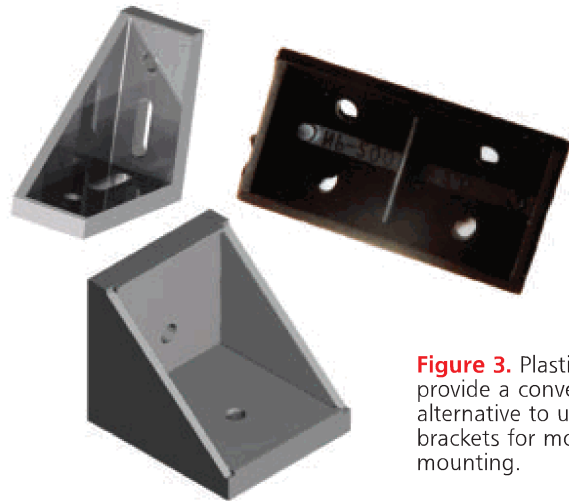


Figure 3. Plastic brackets provide a convenient alternative to using metal brackets for motor mounting.

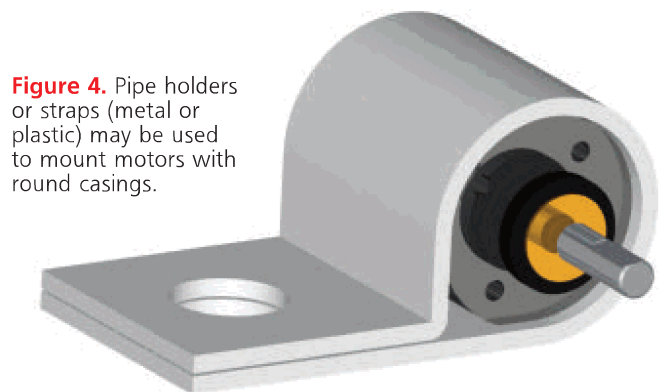


Figure 4. Pipe holders or straps (metal or plastic) may be used to mount motors with round casings.

Figure 3 shows a couple of plastic brackets in various shapes. One source for these is my own online store, Budget Robotics.

Another idea is to use pipe or cable clamps to hold the motor in place (**Figure 4**). Select a clamp — the plastic ones are perfect for small motors — where the body of the motor fits snugly when the clamp is closed. Choose a clamp that's on the small side; you can increase the diameter needed to

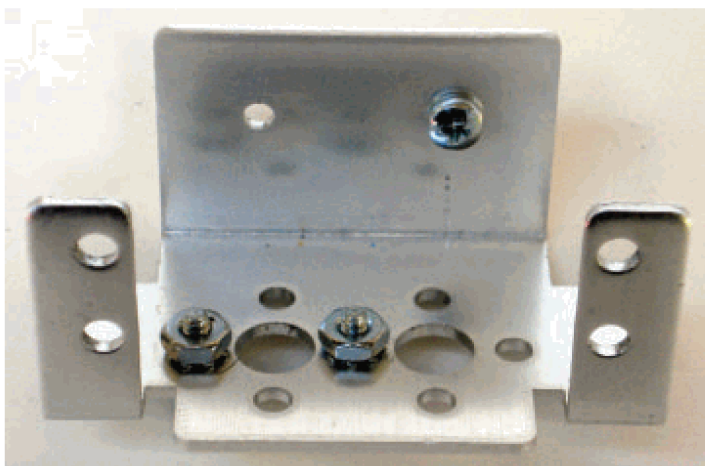


Figure 5. All-aluminum bracket for mounting a servo to a robot base. Available for standard and quarter-scale motors.

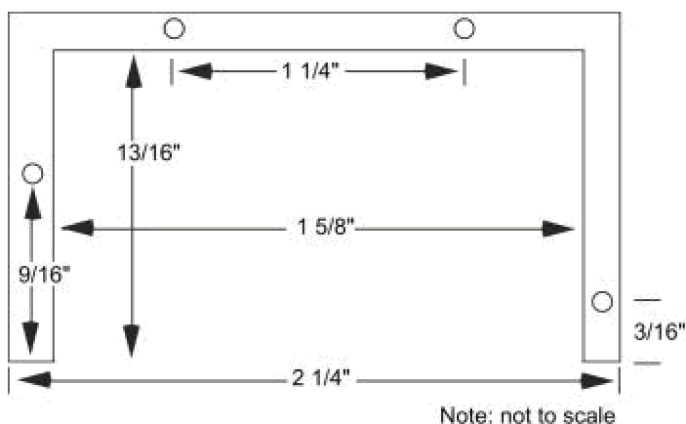


Figure 6. Make your own radio control servo mounts following this guide.

accommodate the motor by placing washers between the clamp openings.

Mounting R/C Servos

The world is quite a different place when working with R/C servos. By their nature, servos have mounting flanges. What's more, servo sizes and mounting configurations are fairly standardized giving you the option of using premade mounting solutions if you don't want to "roll your own."

Whatever the method, servos should be securely mounted to the robot so the motors don't fall off while the thing is in motion. Over the years, I've found *hard mounting* — using fasteners like screws and nuts — to be the best overall solution. This greatly reduces the frustration level of building and using your robot.

All servos have mounting holes in their cases. It's simply a matter of finding or drilling matching holes in the body of your robot, or using brackets with properly spaced holes in them.

You have two kinds of screws to choose from:

- Self-tapping metal or wood screws don't need a nut on the other end to hold things in place. Drill a small pilot hole to start, then insert the screw. The threads of the screw dig into the material and hold it in place.
- Machine screws and nuts are ideal if you need to disassemble your creation and rebuild it, or use parts for something else.

With the popularity of servos for robotics applications, there's no shortage of pre-made mounts for all types and sizes of servos. These are available from online sources such as Actobotics, Pololu, Budget Robotics, and RobotShop. See the Sources box for website details. **Figure 5** shows just one offering for mounting servos. This one is an aluminum bracket, providing multiple ways to attach the bracket to the body of your robot.

You can also construct your own servo mounting brackets using 1/8" thick aluminum or plastic. A template is shown in **Figure 6**. Note that the template is not to scale, so don't trace it to make your mount. Use the dimensions to fashion your mount to the proper size.

The first step in constructing your own servo mounting brackets is to cut and drill the aluminum or plastic. Use a small hobby file to smooth off the edges and corners. Use 4-40 screws and nuts or #4 self-tapping screws to attach the servo mount to wood, plastic, or other materials.

Mounting Wheels to DC Gearmotors

Often, it's the most obvious things we take for granted — like the wheels we use to build rolling robots. In the world of amateur robotics, you can now find motors that match the wheels made for them. These are the easiest to use when building a bot, but there are many other options. With some effort, you can adapt a wheel to most any kind of motor, using either a direct connection or by using a coupler.

When I first started in robotics, I used to spend an inordinate amount of time combing through various surplus catalogs looking for motors and wheels that could go together. It wasn't always easy to find matches. Today, there are numerous specialty online robotics retailers that offer low cost DC motors and wheels that are designed to complement one another.

While matching motors and wheels are handy, selection isn't always extensive. You may want a smaller or larger wheel than what's offered, or you may not like the width of the rubber treads on the wheel. That's when you need to come up with your own motor-to-wheel solution.

If your wheel already has a hub with a setscrew, you're in business ... assuming the wheel hub is the right size for

the motor shaft. If it's not, there are a couple of things you can do to solve the problem:

- If the wheel hub is too small, drill it out to fit the shaft. Obviously, this only works if the hole you drill isn't so large that it destroys the wheel hub.
- Use a reducing bushing, which is basically a short length of hollow tube. The inside of the bushing is sized to match the motor shaft; the outside is for the wheel hub. You then carefully drill a hole through the bushing. Use a longer setscrew, if needed, so it extends through the bushing and makes contact against the shaft.

What if the wheel lacks a setscrew? Or, the hub is too large for a bushing? Or, the wheel will be wrecked if the hub is drilled out? One solution is to use a flange that does have a setscrew and a hub with a properly sized bore that matches the shaft. You attach the flange to the wheel using fasteners, then mount the flange to the shaft.

So, what's a "flange?" It's anything that's smaller than the diameter of the wheel, and has a setscrew and hub compatible with the motor shaft you want to connect it to. Specially made flanges are available through Actobotics, Lynxmotion, Jameco, and several other online retailers. The flanges come in different bore sizes. Cost is modest.

A convenient ready-made flange is a surplus gear (a sprocket also works). Drill two or more holes through the face of the gear and match holes into the wheel. Be sure to keep the gear and wheel concentric. Mount the flat part of the gear against the wheel (see **Figure 7**), then attach the assembly to the motor shaft.

Mounting Wheels to R/C Servos

Servos engineered for full rotation are most often used for robot locomotion and are outfitted with wheels. Since servos are best suited for small- to medium-sized robots (under about three pounds), the wheels for the robot should ideally be between two and five inches in diameter and lightweight.

Servos differ in the type of spline used on their output gear. The splines provide a positive grip of the servo horn (sometimes called control disc or hub), so that it won't slip on the hub as the motor turns. The three most common spline types are noted simply by the manufacturer that popularized each one: Hitec, Futaba, and Airtronics. If you are purchasing wheels for your servos, make sure the wheels use the proper hub spline.

By far, the easiest way to attach wheels to servos is to use a wheel that's specially engineered for the job. Many specialty robotics retailers such as Parallax, RobotShop, Pololu, and others sell wheels meant for use with the standard size Hitec and Futaba servos.

Now for the bad news: Your choice of wheel diameters

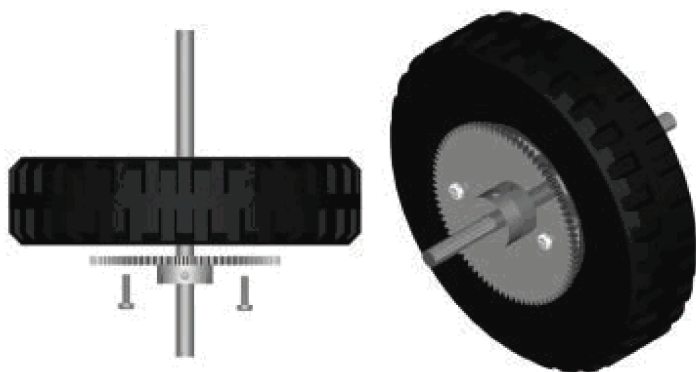


Figure 7. Concept behind using a metal or plastic gear as a flange for mounting a wheel to a motor shaft.



Figure 8. Most any kind of wheels can be converted for use with an R/C servo by attaching a servo horn to the side of the wheel. If your servo didn't come with an assortment of horns, you can purchase them separately.

is pretty limited. You'll find just a few sizes, with 2-1/2" (give or take a few fractions of an inch) being the most common. If you need a smaller or larger size, you can always make your own wheels as detailed next.

The general approach for attaching generic wheels to servos is to use one of the servo horns that comes with the servo and secure it to the wheel using screws or glue (see **Figure 8**). The inner portion of the horn fits snugly over the output shaft of the servo. Here are some ideas:

Lightweight foam tires — popular with model airplanes — can be glued or screwed to the servo horn. Popular brands are Dave Brown and Du-Bro, and these can

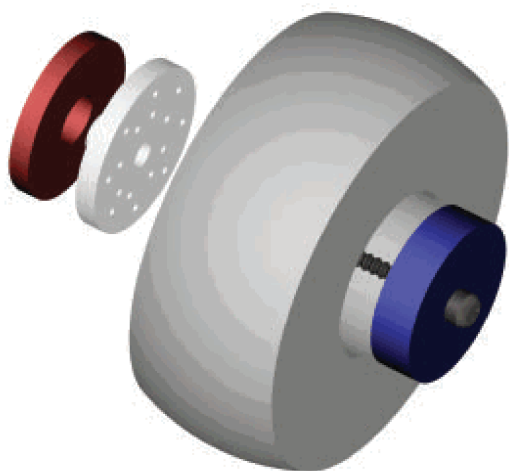


Figure 9. Assembly detail of a DIY robot wheel using a polyurethane skate wheel. This version uses a servo horn to attach the wheel to an R/C servo.



Figure 10. Polyurethane skate wheel mounted to a small robot.

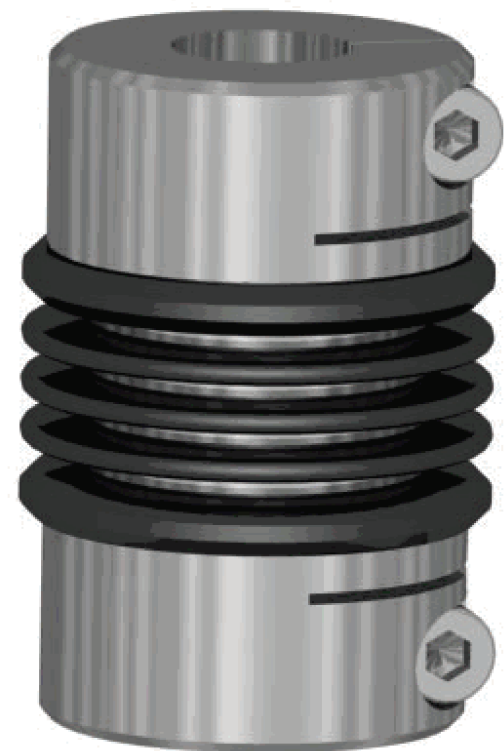


Figure 11. Flexible coupler for attaching between the shafts of a motor and wheel.

be found at most any well-stocked R/C hobby store. The tires are available in a variety of diameters, with the 2", 2-1/2", and 3" diameters the best for small bots. They do go up to 6" should you need the larger size.

Large LEGO "balloon" tires have a recessed hub that exactly fits the small round servo horn included with Hitec and many other servos. You can simply glue the horn into the rim of the tire.

A gear glued or screwed into the servo horn can be used as a substitute wheel or as a gear that drives a wheel mounted on another shaft.

Urethane skateboard/inline roller skate wheels make for incredibly "grippy" wheels for robots. The trick — if it can be called that — is to find metal or plastic discs that just fit into the hub of the wheel. Many skate wheels use metric dimensions; for those in the US, our hardware is in fractional inches.

If you have access to a 3D printer, lathe, or CNC router, you can easily make inserts that fit the skate wheels perfectly. **Figure 9** shows the construction of the wheel, and **Figure 10** shows a wheel attached to an R/C servo (mounted on a robot).

No matter what method you use to create custom wheels for servos, be sure not to block the screw hole. If necessary, insert the screw into the servo horn first, then attach the tire.

Using Couplers to Mount Wheels

Couplers are used to connect two drive shafts. A common application is to use a coupler to connect the drive shaft of a motor with the axle of a wheel. Couplers can be rigid or flexible.

Rigid couplers are best used when the torque of the motor is low, as it would be in a small tabletop robot. Conversely, flexible couplers are advised for higher torque applications as they are more forgiving of errors in alignment.

There are many types of commercially-available rigid and flexible couplers, and cost varies from a few dollars to well over US\$50 depending on materials and sizes. Common flexible couplers include helical, universal joint (similar to the U-joint in the drive shafts in older cars), and three-piece jaws. **Figure 11** shows a commercially-made coupler that has a flexible middle. These are available from online sources such as Small Parts (see the **Sources** box).

For low torque applications, you can make your own couplers using brass, steel, or aluminum tubing available at hobby stores. Tubing is typically sold by its inner diameter — 1/8" tubing is 1/8" inside, for example. The thickness of the tubing determines its outside diameter. Get tubing that

Sources

Actobotics / Servo City

Servo brackets, couplers, shaft adapters, wide variety of mounting solutions
www.actobotics.com

Budget Robotics

Servo brackets, plastic brackets, small hardware
www.budgetrobotics.com

Micro Fasteners

Small hardware
www.microfasteners.com

Pitsco

Servo brackets, robot wheels
www.pitsco.com

Parallax

Servo brackets, small hardware, wheels for R/C servos
www.parallax.com

Pololu

Motor mounts, wheels for R/C servos
www.pololu.com

RobotShop

Servo brackets, wheels for R/C servos
robotshop.com

Small Parts (Amazon Supply)

Couplers
www.smallparts.com

Figure 12. Use a metal collar around thin-wall metal tubing to provide compression against a solid motor shaft.

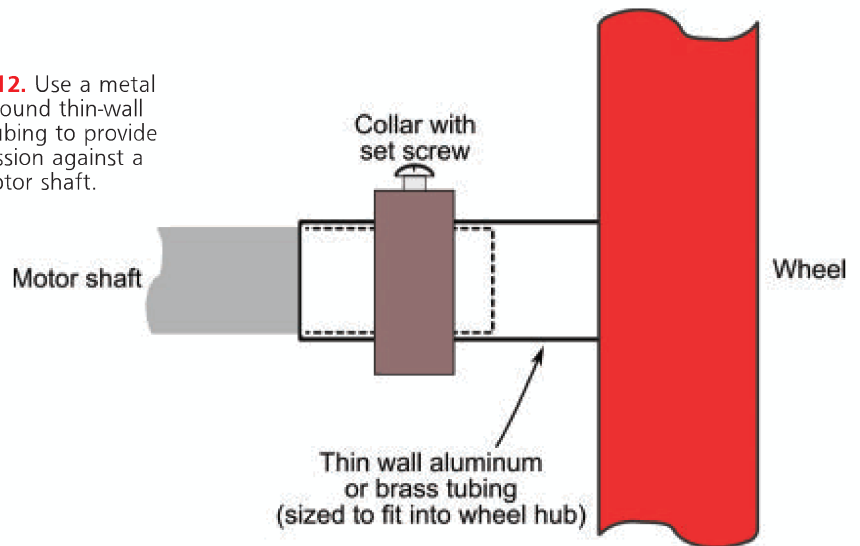
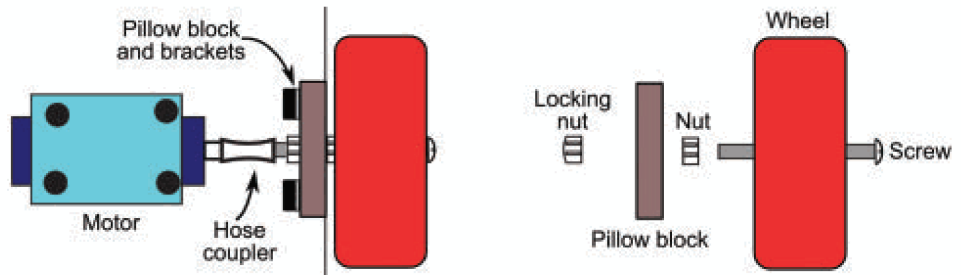


Figure 13. Flexible rubber tubing or hose may be used to connect a motor shaft to a wheel with its own axle.



just fits over the motor or wheel shaft you're attaching to (bring your motor for sizing). K&S Metals is a popular supplier of metal tubing in hobby stores throughout North America.

To use, cut the tubing to length. You can then secure the tubing to the shaft in several different ways, including:

- Crimp on with an appropriately sized metal collar. The collar comes with a set screw; carefully tighten the set screw over the tubing (see **Figure 12**). This type of metal collar is available at any R/C hobby store; a popular brand name is Dura Collar. If you can't find a collar just the right size for the tubing, you may need to select the next size smaller, then drill out the collar. The collar is plated brass, so it's not as hard to drill as it may look.
- Use large wire crimper pliers to squeeze the tubing around the shaft. This only works for thin-walled tubing and when working with smaller motors that don't put out a lot of torque.

When using the crimp-on metal collar trick, you can help cinch up the fit by drilling a small (1/16") hole in the

tubing where the set screw will go. This works well when using thicker walled tubing. When assembling the collar over the tubing, carefully line up the hole with the set screw, then tighten the screw.

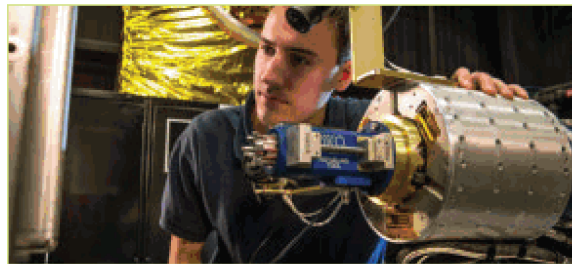
For desktop robots, flexible plastic rubber tubing will work just dandy as a coupler. Select the rubber tubing so that it is just slightly smaller than the motor shaft and wheel axle you are using, and press it on for a good fit. If the motors develop too much torque for the press-fit to hold, use small worm gear clamps to hold the tubing in place. You can get these worm gear clamps at any hardware store.

Figure 13 shows one example. The wheel is held in place with a *pillow block*, which is merely a piece of wood, plastic, or metal that's fastened to the base of the bot. Use a long machine screw as the wheel axle; hold the wheel/axle combo in the pillow block with a pair of nylon insert locking nuts as shown.

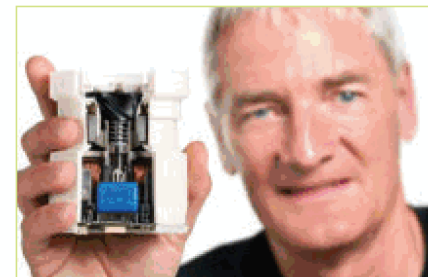
Plastic tubing is available at hardware and home improvement outlets, as well as many hobby stores and pet stores that sell fish aquarium supplies. The tubing can be clear, white, black, or other color. Fiber reinforced tubing is good for jobs requiring a bit more strength. **SV**

WHAT A BLAST!

It's corrosive, it's hazardous, and it can cause an explosion powerful enough to thrust a satellite forward in space. In February 2014, NASA conducted a multi-center, remotely controlled test of new technologies that would empower future space robots to transfer this dangerous fluid — satellite oxidizer — into the propellant tanks of spacecraft in space. The ground-based Remote Robotic Oxidizer Transfer Test (RROxiTT) is another step forward in NASA's ongoing campaign to develop satellite-servicing capabilities for space architectures and human exploration.



SUCKING UP OPPORTUNITIES



Dyson — the engineering company best known for its bagless vacuum cleaners — is to invest \$8 million in a robotics lab at Imperial College, London. Dyson's \$8 million will go towards hiring 15 researchers and roboticists at Imperial, including some Dyson engineers.

The research will focus on vision systems that can help robots understand and adapt to the world around them, the company said. Dyson has been working on robotics with Imperial's Prof Andrew Davison since 2005, and he will run the new lab. The research will cover domestic robots as well as robotic vacuum cleaners.

As Sir James Dyson said: "My generation believed the world would be overrun by robots by the year 2014. We now have the mechanical and electronic capabilities, but robots still lack understanding — seeing and thinking in the way we do. Mastering this will make our lives easier and lead to previously unthinkable technologies."

In 2001, Dyson's prototype robotic vacuum cleaner — the DC06 — nearly made it into production, but Sir James pulled the product saying it was too heavy and expensive.



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part 2

Nuntius

The Garden Avenger



By David Dorhout

Post comments on this article and find any associated files and/or downloads at
www.servomagazine.com/index.php/magazine/article/april2014_Dorhout.

Summer is coming, all is not lost. The nights are getting shorter and the days are getting longer which can only mean that spring is approaching here in North America. Picnics, camping, and sunshine — it's all right there around the corner. The problem is you've gotten quite comfy in your den this past winter and figured out how to have everything delivered to your door. Fortunately, you subscribe to *SERVO Magazine* and have it delivered, along with your groceries, paper towels, and robot parts. You read the previous article about Nuntius — the telepresence robot — and you can picture yourself building a similar robot to be your surrogate for the summer. This brilliant stroke of deduction will allow you to wait out for those beautiful summer days and cool autumn nights until the cold winter winds arrive again and make it popular once more to stay indoors. So, go ahead. Grab yourself a serving of your favorite vitamin D fortified food item and let's get started.

This is going to be a bit of a major build, so let's break it down before we get started. The previous article explained the overall concept and delved into detail on a few critical concepts. Now, we're going to go into detail while we walk through the build starting with the robot, the controller, and then the program for each.

Nuntius — A Road Map

Prior to starting any build, it's important to have a clear picture of what you want to achieve. I'm not saying that you need to first create a CAD model or even a drawing, but you should know what you want it to do. For Nuntius, I wanted to build a telepresence robot with a manipulator that was intuitive to control and simple to set up. Just turn on the robot, plug the controller into the TV, and go. So with that, let's begin by looking at building the robot.

Before I began designing the robot, I mentally made a requirements list (road map) of what it needed to be able to do (features) and uses for it. The key physical feature of Nuntius is that it is a large robotic arm (manipulator) on a mobile platform that can drive through rough terrain. Therefore, the size of the manipulator determined how big the robot body needed to be, which then dictated the size of the motors. The motors then determined the kind of motor controllers required, and suddenly the requirements of the major systems are mapped out. We're now ready to start designing the body and look of the robot.

What's in a Shape?

Designing the shape and layout of your robot is very important; you should spend some time just thinking about it. I start by considering the forces that are going to be acting on the robot and the environment that it's going to be operating in. I then try and craft it such that it's also aesthetically pleasing. There's no reason why you can't make it work well *and* look good. Your robot wants to be as popular as you are. I started with the robot's arm. First of all, it was going to be lifting and pulling things while swinging around, so it needed to have a firm platform and be close to the ground to prevent tipping. Second, it was going to be driving through the grass and tight spaces. These requirements led me to choose a differential drive system on a teardrop platform with a single coaster wheel in the rear (**Figure 1**). The robot was narrow enough to drive through small gaps, but wide enough to be stable and fit the control board between the wheel motors.

I decided that I wanted the manipulator as far forward as possible, so that it would have maximum reach and accessibility. Having the manipulator in front of the wheels could have caused the robot to tip forward under some

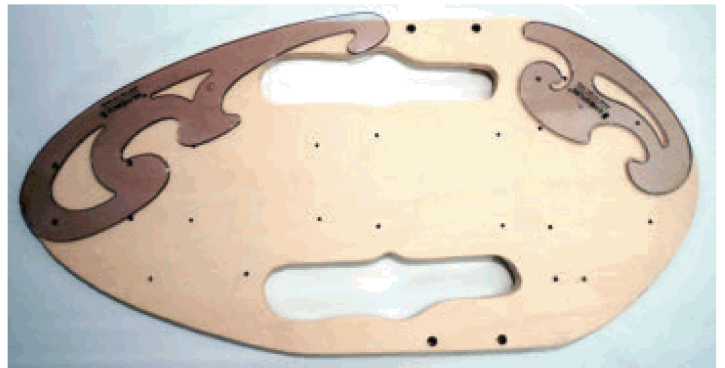


Figure 1. Tear shaped wooden body of the robot. Notice the partial motor cutouts allowing the robot to have a lower center of gravity. The strange plastic curves on the robot platform are from a drawing tool called a "French Curve" and are useful for drawing more graceful curves. You can see how the curves for the platform were taken from the two French curves.

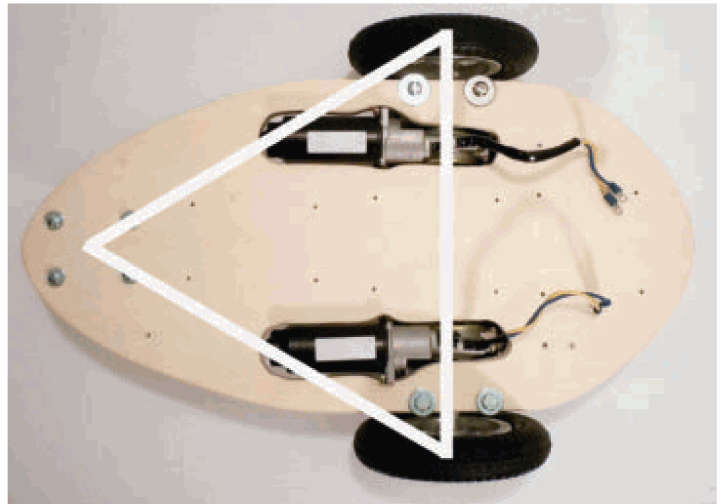


Figure 2. The robot with the motors and wheels attached. The center of gravity triangle extends between the drive wheels and the coaster wheel in the back.

circumstances, so I placed an oversized battery inside the center of gravity triangle formed by the two drive wheels and the coaster wheel in the tail (**Figure 2**). The oversized battery added stability and aesthetics. (The size and shape of the battery fills out Nuntius and creates the impression that it has a body.)

Sketching out the body of the robot, I started by placing the base of the manipulator and other major components on a sheet of birch plywood from the local home improvement store. I used birch plywood because it's strong, looks nice, and it's readily available compared to plastic sheets. I then cut it out with a hand jig saw and rounded the corners with a hand-held belt sander.

Motors and Wheels

I briefly mentioned before that one of the first things

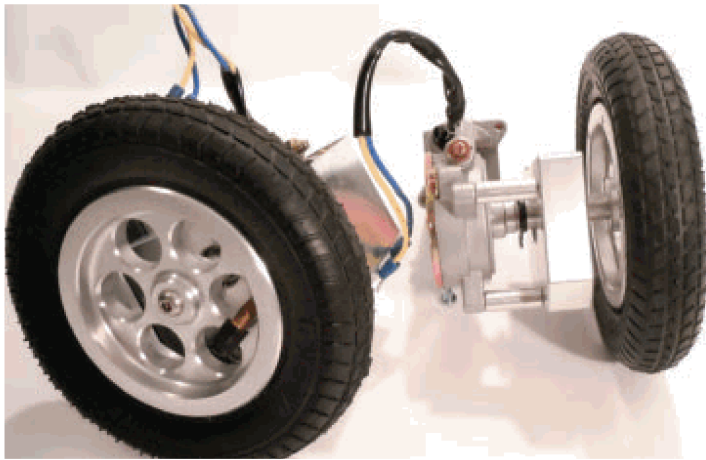


Figure 3. Parallax motor and wheel set with rims and motor mounting block milled from 6061 aluminum billet.

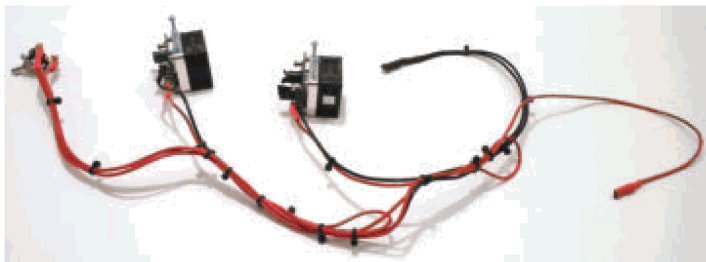


Figure 4. Power distribution wire harness. From left to right, on/off switch, HB-25s, and battery connectors.

that I did during the design phase was to choose the wheel motors. Picking out wheel motors tends to be one of those things that you can spend an inordinate amount of time doing. I think it's partly due to the sticker shock. You buy your microcontroller (in this case, a Parallax Propeller demo board for ~\$20), but then the motors, wheels, and motor controllers end up costing around \$300-\$400 for everything. That's a lot of money — especially if your last

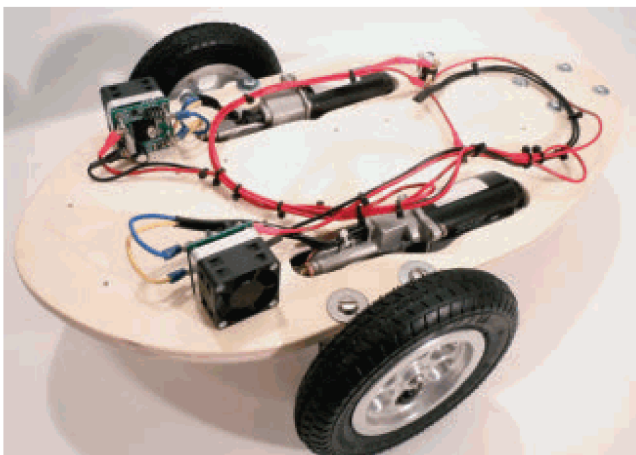


Figure 5. Robot base with wheels, motors, motor controllers, and the power distribution wire harness installed.

robot used continuous rotation servos that cost \$25 total and included the wheels. You start looking around, finding surplus windshield motors on eBay, but then you realize that you need to find the right size tire. So, you look around some more, possibly looking at lawnmower wheels at some home improvement store. However, you realize that windshield motors don't naturally afford themselves to being attached to lawnmower wheels (weird, huh?), so you're going to need to create a coupling for between the wheel and motor. Don't forget the last step — you still need to create a mount for attaching the motor to the robot.

Wow, so that's a lot of work just to put wheels on your medium size robot. It's not too difficult, but it does take time. It helps to have access to a CNC machine or a 3D printer. It's up to you, and you may end up saving some money. At the very least, everyone should look around and price out the components; it will make you appreciate the work that goes into producing a high quality wheel and motor set like the ones Parallax sells.

Parallax now sells two different motor and wheel sets that include integrated quadrature encoders (0.14" linear travel resolution). The only difference is that one set has its rims and motor mounting block milled from a 6061 aluminum billet (60 lb payload), and the other is injected molded plastic (20 lb payload). I used the aluminum version because I wanted the option of using the motors on an even larger robot in the future, and I really liked the way they looked (**Figure 3**). One last thing about this wheel set is that it uses pneumatic tires that help give the robot a smooth ride and better traction in the grass.

Motor Controllers and Power Distribution

Now that you've selected the wheel motors, you need to have a way to control them. I decided to use the HB-25 motor controller for a couple of reasons. The first thing that you should always check is the amount of current (in amps) that your motor may require (continuous and surge value). Looking at the datasheet, I saw that the motors may draw a bit more than eight amps depending on the load and terrain. The HB-25s are rated for 25 amps continuous duty, so they won't have a problem with these motors.

The second reason that I chose these motors is that you're able to control them the same way you control a servo using pulse width modulation (PWM).

Lastly, remember the quadrature encoders? It's possible to connect the quadrature encoder from one wheel to its HB-25 motor controller for closed-loop control that's useful if you want your robot to drive in a straight line or go at a constant speed while traveling up or down hill. The quadrature encoder tells the HB-25 how fast the wheel is turning; the HB-25 checks to see if it's going at the correct speed based on the PWM that you gave it; and automatically adjusts the amount of power it gives the

wheel motor so that it is going at the correct speed. Connecting the wheel motors, controllers, and battery together is the humble power distribution system (**Figure 4**). It's easy to allow these wires to become a rat's nest, but a few zip ties and you'll have nice tidy sets of wires. Keeping everything organized will help troubleshooting and prevent wires from being caught and pulled (**Figure 5**).

Connecting the Base with the Manipulator

The manipulator (**Figure 6**) might look familiar to you, especially if you've spent any time searching the Web for robot parts. I followed the basic design of Lynxmotion's AL5D arm kit. I especially liked this manipulator because it is a well thought out design and uses a custom plastic injected base that is designed for use with a servo. Just like wheel motors, manipulators get exponentially more expensive the larger they are. Your manipulator's performance will be the results of its size, components (servo strength), and the way you use it. Remember, your manipulator is like your own arm. It's easier to lift if the object is closer to the base.

The Controller's Mini Arm

The controller's miniature arm uses variable rotary resistors to provide positional feedback. Each joint consists of one of these resistors that are also called potentiometers or "pots." The miniature arm is fairly delicate because each joint is made up of just the potentiometer and is not reinforced at all (**Figure 7**). You can see in the photo that the potentiometer's collar nut is used to attach it to one side of the joint, then a small bolt goes through a hole drilled in the shaft and into the other side of the joint.

This design was fine for my limited use, but I would definitely recommend using reinforced joints if anyone other than you is going to use it. I put a piece of Plexiglass between the base of the arm and the board holding the control board to reduce friction. The gripper of the manipulator is controlled with a natural pinching motion and the help of a tension spring (**Figures 8 and 9**).

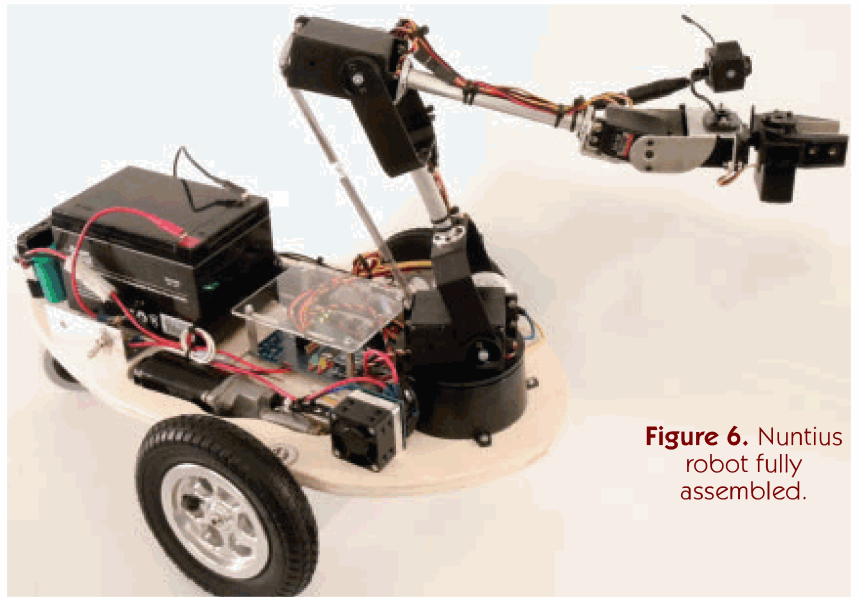


Figure 6. Nuntius robot fully assembled.

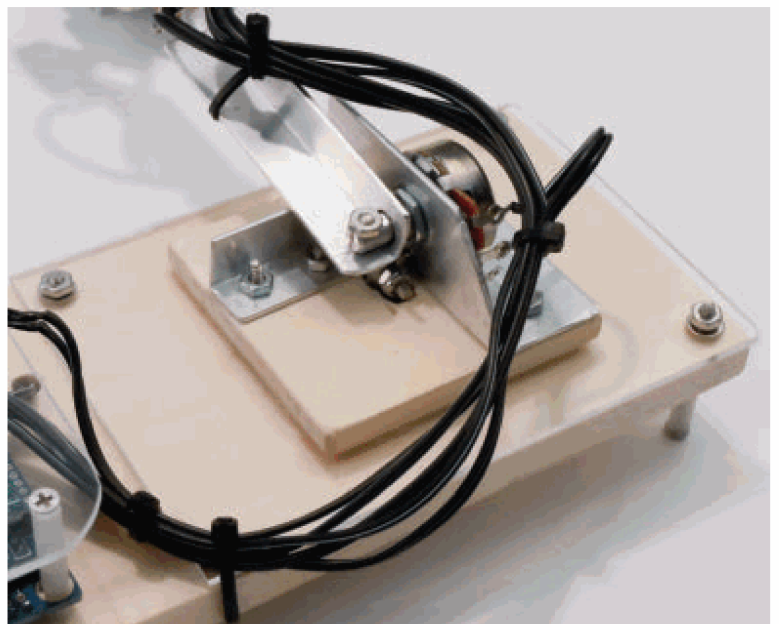
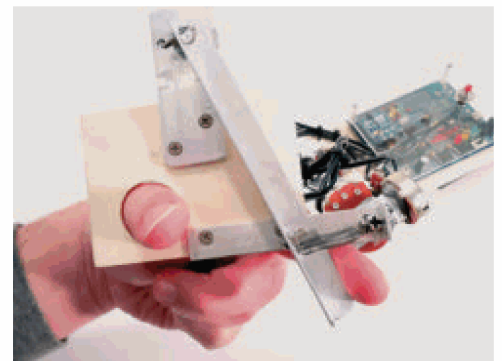
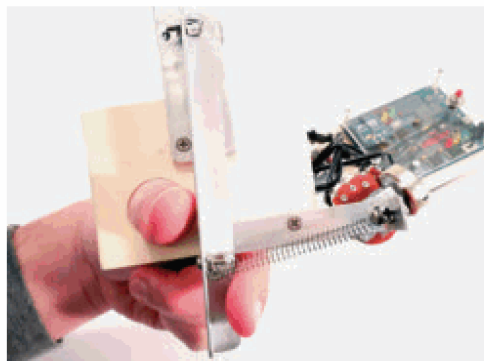


Figure 7. Base joint of mini control arm showing joint assembly and Plexiglass sheet for reducing friction.



Figures 8 and 9. Close-ups of miniature control arm joint design (open and closed) for controlling the gripper portion of the manipulator.

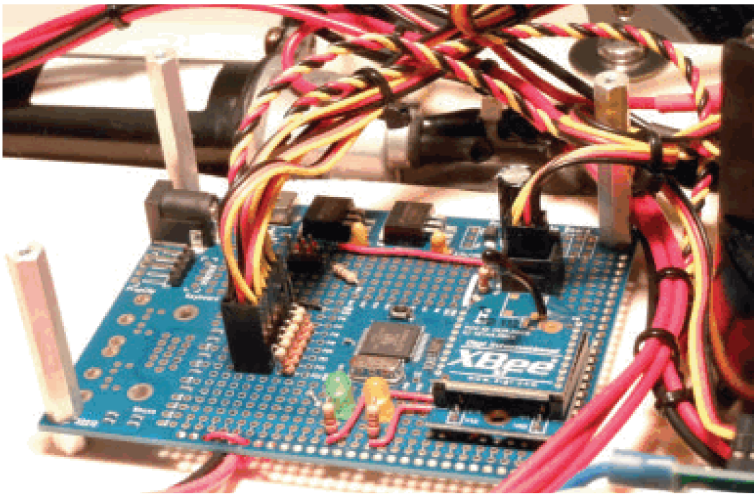


Figure 10. Close-up of robot Propeller demo board. Notice the Tx (transmit) and Rx (receive) LED indicators next to the XBee.

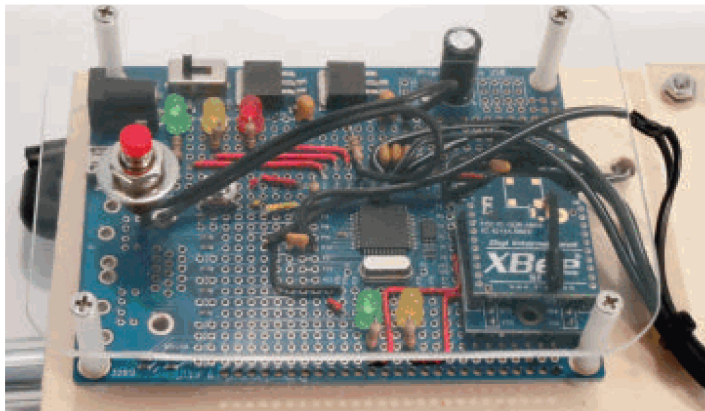


Figure 11. Close-up of remote control Propeller demo board with the large "press to start moving" button mounted on the Plexiglass shield.

Robot and Controller Electronics

Both the robot and the controller use a Propeller chip mounted on a Propeller prototyping board. I chose a Propeller chip because there are a number of things that had to happen simultaneously, and the Propeller chip has eight 32-bit cores (called cogs) that allow for true parallel processing and would allow for future feature expansion. The Propeller chips are also able to simulate in code a number of things that would otherwise require additional components. Communication between the controller and robot is accomplished using two Series 1 XBees.

On the robot, I made things simple by having a separate power supply for the wheel motors (the large, black lead acid battery in the abdomen), servo motors (6V Ni-MH), Propeller prototyping board (six AA), and a 9V for

the camera. That's a lot of batteries. I had originally intended to power everything from the 12V lead-acid battery, but that's a project for a different day.

The benefit of each system having its own power supply is that one system doesn't affect the other, such as the wheel motors straining and causing the voltage to drop momentarily which would then cause the microcontroller to think that you're resetting it. The important thing to remember is that all of the different power supplies have to share a common ground. Otherwise, things won't work correctly. That got me when I was just starting out.

Remember, voltage is the electrical *potential difference* between the high (+) and the low side (-) and everything in your system needs to have a common reference point to work properly. That common reference point is ground (-).

The Propeller prototyping board on the robot can be divided into three sections: 1) servo connectors; 2) HB-25 motor controller connectors; and 3) the XBee (**Figure 10**). The six servo connectors get their power from the 6V Ni-MH battery mentioned before, and are connected to pins 18-23 on the Propeller chip using a 3.3K Ω resistor in between. The resistor protects the Propeller chip from accidentally shocking. The HB-25 motor controllers are similarly connected to pins 2 and 3; again with 3.3 K Ω resistors in between. The XBee is directly connected to pins 0 and 1. Each pin is also connected to a 220 Ω resistor, an LED, and 3.3 volts.

A detailed look at setting up and using XBees can be found in the book, *Getting Started with XBee RF Modules*. I highly recommend the book or getting the kit that the book comes with. As of this writing, the book is available as a free download on Parallax's website.

The controller also uses a Propeller prototyping board (**Figure 11**). The controller board can be divided into three sections, as well: 1) the XBee; 2) mini arm inputs; and 3) the "press to start moving" button mounted on the plexiglass shield. Part 1 explained how the simple capacitor decay circuit worked, so I won't go into detail on that, but in a nut shell, the Propeller sets a pin to output and then outputs a voltage that fills a capacitor.

The Propeller then changes the same pin to input and times how long it takes the capacitor to drain through the variable resistor. In this case, the variable resistor is the potentiometers in the mini arm's joint and the time value given the position. Using a small capacitor like a 10 nF allows this whole process to repeat more than a hundred times per second. The XBee circuit is the same as on the robot; the button is just a button.

For the wireless video camera, I used an inexpensive 2.4 GHz color model that had a microphone. There are a number of different kinds that you can choose from, mostly depending on your budget. I chose this one because the camera was small and light weight, and the entire

camera/receiver cost less than \$20 online.

Robot and Controller Programs and Code

In the previous article, we walked through a section of the code and explained how it was created so I won't go into that this time, either. However, take a look at the program flow charts for the controller and the robot, and compare them to the actual source code. (Code listings are available at the article link.)

Taking a closer look at the controller program's flow diagram (Figure 12), we see that after starting up, the program settles into a loop where the position of each joint in the mini arm is recorded, and then it checks to see if the "movement" button is pushed. The program now has a decision to make. If the button is pushed, the program then determines in what direction the robot will move at what speed based on the direction the arm is pointed and how far it is extended. The speed is proportional to the relative extension of the arm. The further out it is extended, the faster the robot moves.

If you look at this same section in the source code, you can see that it is even possible for the robot to move in reverse if the arm angle is greater than 90° (bent backwards). In the code, this is determined by the value of the variable *ShoulderPW* being less than or equal to 1500. The final step in the loop is to use the XBee to send the

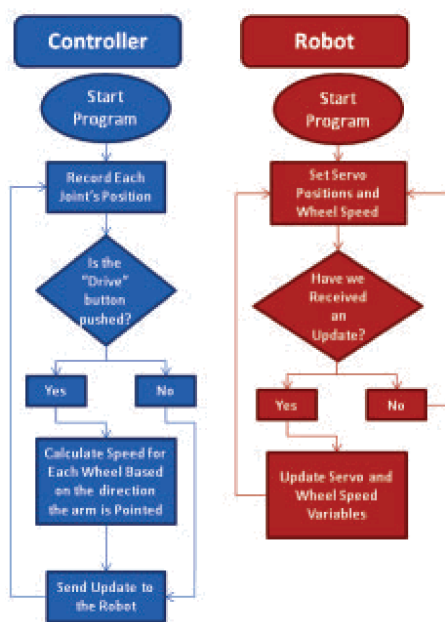


Figure 12. Controller and program flow charts.

positional values to the robot and then start the loop over again.

The program for the robot begins by starting and then entering the main program loop. The main program loop begins by checking to see if the controller has sent new positional and speed values to the robot. If new values have been received, the program then sets the servos in the arm to the new values, along with the motors. If no new data has been received, then the program loops and the robot continues to listen.

Conclusion

Telepresence robots are becoming more and more popular every day. A few of the unique features of Nuntius are the plug-and-play controller, the mini arm that provides natural input control, and the manipulator on the

robot allowing Nuntius to interact with its environment. Building a telepresence robot is a major undertaking that requires a controller, a robot, and a wireless video system. This article walked through each of the major systems and provided the source code. However, if you're considering building your own version, plan on spending several weekends assembling your system and make sure to post your project on the forums.

I'm excited to see how you build off of this information. Have fun! **SV**

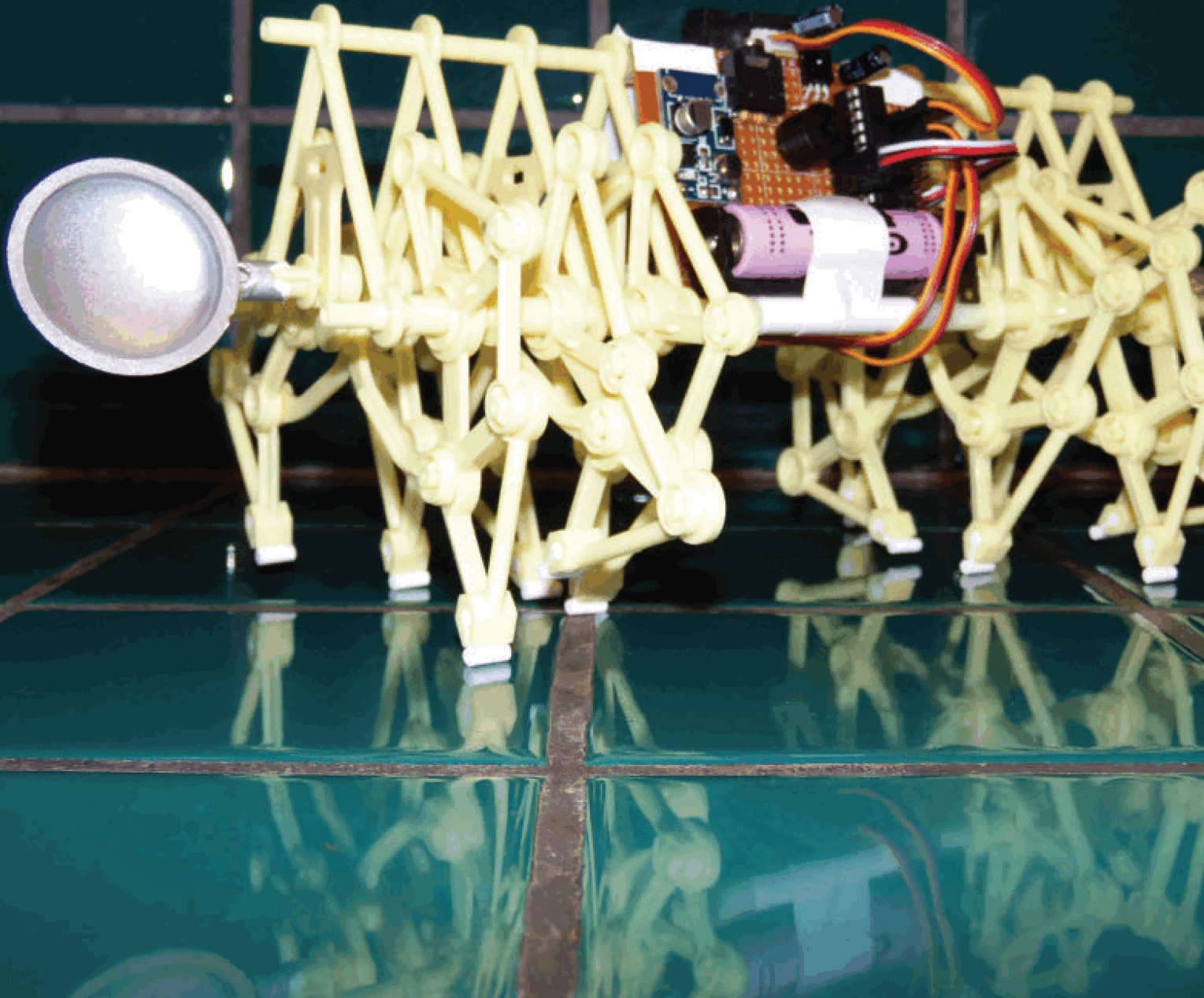
PARTS LIST

ITEM	MANUFACTURER	WEBSITE	QTY	COST	TOTAL
Propeller Proto Board	Parallax	www.Parallax.com	2	\$19.99	\$39.98
Motor Mount & Wheel Kit - Aluminum	Parallax	www.Parallax.com	1	\$299.00	\$299.00
-or-					
Motor Mount & Wheel Kit - Molded Plastic	Parallax	www.Parallax.com	1	\$199.00	\$199.00
HB-25 Motor Controller	Parallax	www.Parallax.com	2	\$49.99	\$99.98
AL5D Arm Hardware-Only Kit	Lynxmotion	www.lynxmotion.com	1	\$143.88	\$143.88
HS-422 Servo for AL5D Arm	Lynxmotion	www.lynxmotion.com	1	\$9.99	\$9.99
HS-485HB Servo for AL5D Arm	Lynxmotion	www.lynxmotion.com	1	\$16.99	\$16.99
HS-645MG Servo for AL5D Arm	Lynxmotion	www.lynxmotion.com	1	\$31.49	\$31.49
HS-755HB Servo for AL5D Arm	Lynxmotion	www.lynxmotion.com	1	\$27.99	\$27.99
HS-805BB Servo for AL5D Arm	Lynxmotion	www.lynxmotion.com	1	\$39.99	\$39.99
6.0 VDC Ni-MH 2,800 mAh Battery Pack	Lynxmotion	www.lynxmotion.com	1	\$26.95	\$26.95
XBee 1 mW Wire Antenna (XB24-AWI-001)	Parallax	www.Parallax.com	2	\$22.99	\$45.98
XBee Adapter Board					
(mm to standard .1" hole spacing)	Parallax	www.Parallax.com	2	\$3.99	\$7.98
12V Power Patrol Sealed Lead Acid (9AH)	Interstate Batteries	www.interstatebatteries.com	1	\$49.99	\$49.99

TheoBot

By Eric Ostendorff

A DIY StrandBeest Walker



Hack a \$10 Theo Jansen Walker Toy into a Programmable Robot

NOTE: This condensed article is a companion to the SpiderBot construction article in the March issue of *SERVO*. TheoBot uses the same servos, sensors, and PICAXE processor detailed there, so please refer to that article for specific details.

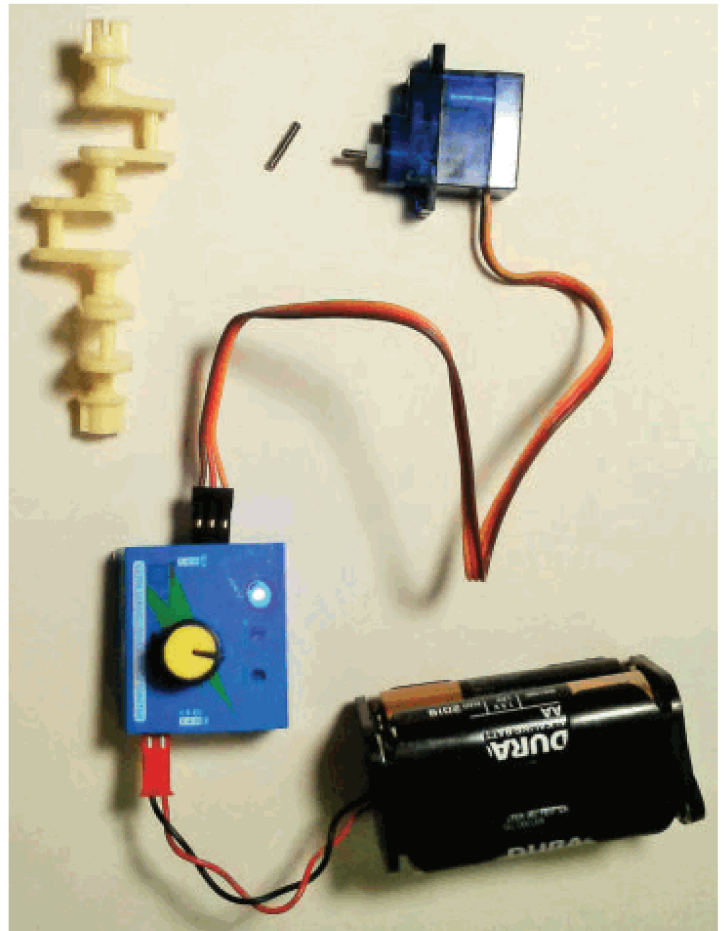
Strandbeest is a large wind-powered, multi-leg walking machine designed around Theo Jansen's fascinating leg linkage (<http://en.wikipedia.org/wiki/Strandbeest>). Numerous videos show the Dutch artist/engineer with his creations walking along the beach; check out www.youtube.com/watch?v=azy-c6QXUCw.

The Strandbeest leg mechanism is somewhat different from the Spider robot's Klann linkage from last month, but is another great candidate for hacking into a servo-driven, differential drive robot. The chassis has a wide stance with an unusual aspect ratio and geometric look. Physically, there is plenty of room for adding sensors, LEDs, and other custom parts, plus numerous unused PICAXE pins to control everything.

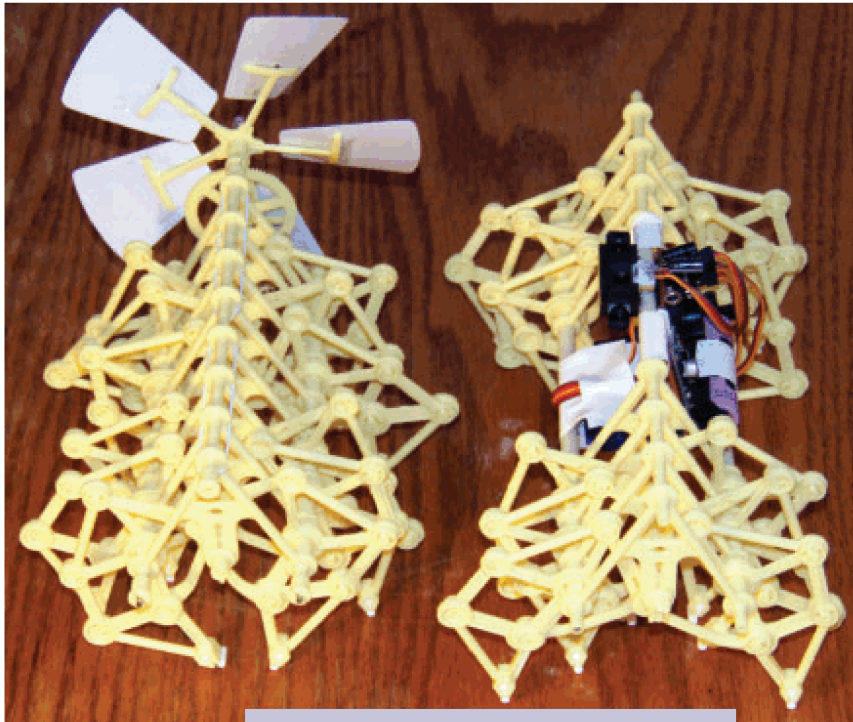
The stock kit assembles easily in an hour or two, and is an enjoyable build. There is much redundancy in building 12 identical legs. I bought two kits: one to leave stock and one to hack. Mechanically, the main challenge of hacking this kit is coupling the servos to the two crankshafts.

After modifying two HXT900 servos for continuous rotation, thread a 3/8" length of 2-56 threaded rod (cut the head off of a 2-56 bolt) halfway into the servo output shaft. Drill a 1/8" hole about 3/16" deep into the meatier end of each crankshaft. Work on one servo/crank assembly at a time. Use double-stick tape to fasten a servo firmly to a tabletop with the output shaft screw pointing upward.

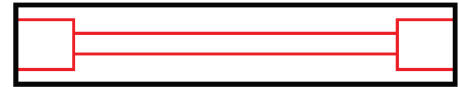
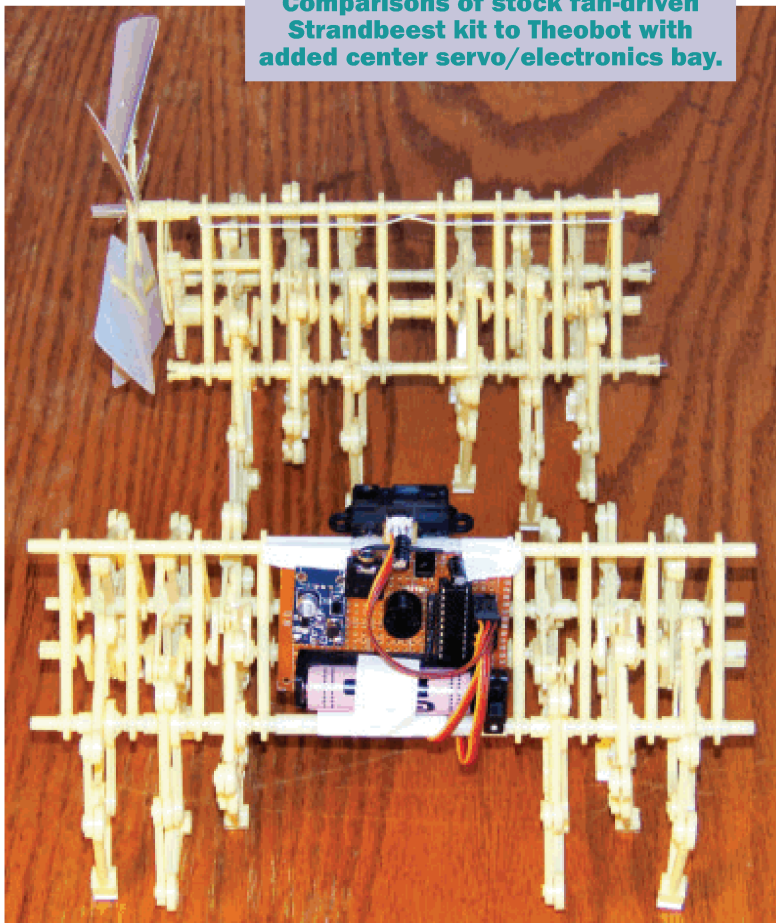
Hook up a servo tester so you can rotate and stop the servo. Fill the crankshaft hole with JB Quick Weld or an equivalent, then press the crankshaft onto the servo screw. As the epoxy sets up, rotate the servo and align the



The 2-56 threaded rod; half of 3/8" length in servo hole and half epoxied into drilled-out crankshaft.



Comparisons of stock fan-driven Strandbeest kit to TheoBot with added center servo/electronics bay.



3X Spacer Rod: 1/4" styrene rod, 2.75" long
0.081" through hole (#46 drill)
0.173" countersunk holes (#17 drill)
0.200" deep

crankshaft so it spins true and the main journals are concentric with the servo centerline. (See my video at www.youtube.com/watch?v=kSADSBj-xrQ.)

My cranks had very slight warping/runout, so I simply eyeballed it to get it as true as possible. There is some flex in the A-frames to accomodate this. Add the leg linkages and A-frames to build two separate halves of the robot per the instructions. Check out

www.youtube.com/watch?v=xq4AbO

_xZu8 where my servo is simply held by a tape strap for testing.

In the stock configuration, the two halves press directly together, allowing the cranks to engage and rotate as one. Two 2 mm steel rods run through the A-frame edges to keep everything together. However, our hacked TheoBot is wider by two servos. Adding a 7 mm central bay makes our chassis wider to accomodate both servos.

I turned three 1/4" styrene rods on a lathe per the diagram, which pressed beautifully into place after drilling the ends with a #17 drill (0.173"). Alternatively, K&S 7/32" brass tubing (stock #130) from a hobby shop can be used to make spacers.

Roll-cut three 2.9" lengths and glue them around the A-frame posts using thick gap-filling CA. Or, for you minimalists, the original steel rods could be used as spacers, again using gap-filling CA to glue the rods inside the A-frame post holes.

After installing your spacers of choice, fabricate a servo support from sturdy tape or better yet, sheet plastic. Use a servo tester to drive the servos and align them properly (no binding) as you glue or tape them to the panel.

The new center bay is an ideal fit for the same 5 cm x 7 cm circuit board which fit perfectly into SpiderBot. I also used the same electronics as in SpiderBot: a USB 5 VDC booster, PICAXE 20M2 controller, Sharp IR distance sensor, TSOP4038 IR

Epoxy the crankshaft inline with the servo while rotating with a servo tester.

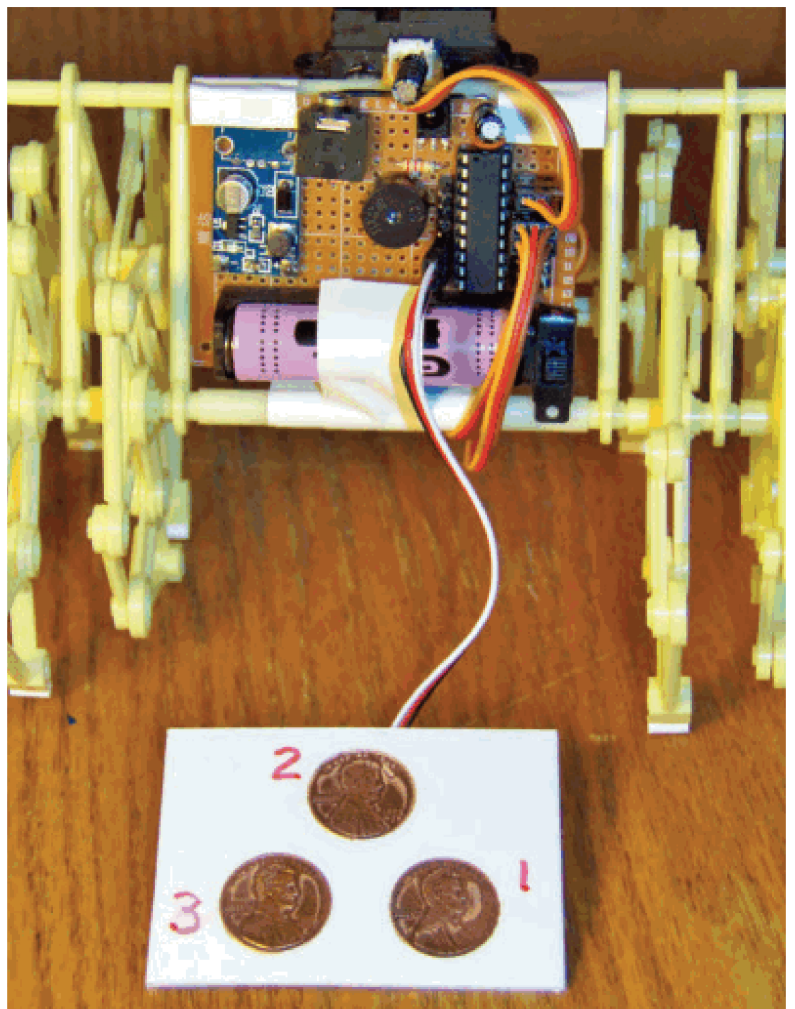
receiver, and a single 14500 Li-Ion cell. The components were rearranged on the circuit board to better fit TheoBot's form factor, which put the programming jack on top and relocated the power switch for better access.

For future expansion, I put three-pin servo headers on all PICAXE port B pins B.0-B.7, as the servo commands only work on port B. On my TheoBot board, the headers connected to PICAXE pins B.0 and B.1 are powered with 5 VDC from the USB booster module for 5V accessories, such as the Sharp IR distance module used on Spiderbot.

The remaining headers on B.2-B.7 connect (via switch) directly to the 14500 Li-Ion battery to power the servos. I installed single-pin male headers on all port C pins for future expansion (LEDs, touch sensors, etc). Additionally, the 5V beeper is attached to pin C.7 and the 4038 IR receiver for remote control is attached to input-only pin C.6 (as on Spiderbot). IR remote control is demonstrated at www.youtube.com/watch?v=L1W3Mec9mxo. Anticipating rearranging the board numerous times, I simply taped the board edges to two spacers in the center bay.

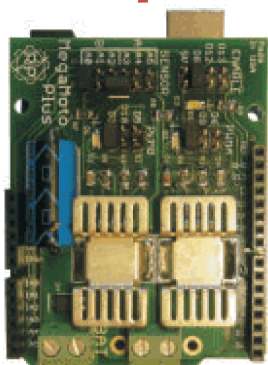
Compared to Spiderbot, TheoBot has two new features. The first is gesture control to steer the robot. The Sharp GP2Y0A21 IR sensor points straight up so it measures vertical distance to control the robot. I can make it go forward and backward, stop, and turn by raising and lowering my hand (www.youtube.com/watch?v=5rcjZZreLFY).

Second, it is a simple matter to add touch sensors to the robot, as no additional circuitry is required. I put three pennies in a 5 cm x 7 cm plastic panel — the same size as the circuit board — which can mount opposite the circuit board in the center bay. The pennies are wired directly to PICAXE pins C.1, C.2 and C.3 and are read using the "touch16" command



Three pennies wired directly to the PICAXE input pins become touch sensors.

Extreme Motor Speed Control!



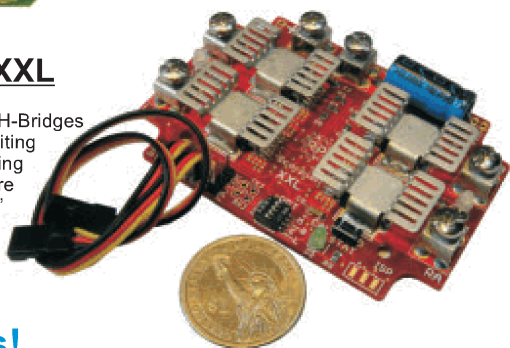
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(www.youtube.com/watch?v=MBUKMS3DAAM).

Code downloads for all three demos are available at the article link.

Have fun building your TheoBot. The walking action is mesmerizing to watch, and there is a lot of potential in this robust little robot. The PICAXE has enough power, functions, and extra I/O pins to keep you busy for quite a while. Happy hacking! **SV**

STRANDBEEST Robot Kit — eBay
2x HXT900 nine gram servos — Hobby King
4x 2.7K Resistors (for modifying two servos)
5x7 Perfboard
Male 0.001" header strips 3x8 for servo headers
14500 Li-Ion cell
Plastic 1xAA battery holder for Li-Ion
PICAXE 20M2 (www.phanderson.com/picaxe)
20-pin IC socket
Disk capacitor 0.1 µF
Electrolytic capacitor 10 µF
1/8" Stereo jack (for programming)
10K Resistor
22K Resistor
5 VDC USB booster circuit — eBay
5V Mini electromechanical beeper — eBay
Sharp GP2Y0A21YK IR distance measuring sensor (Junun.org)
IR Receiver module TSOP4838 or equiv.
3PDT Switch (or DPDT switch with center-off)
Superglue/CA
Styrene sheet (1/16" or 1/8")
2-56 threaded screws, cut heads off for servo/crank union
JB Quik Weld or equivalent five minute epoxy for servo/crank union
1/4" plastic rod or 9/32" brass tubing for extending chassis
Servo cable/connector for connecting touch sensors
Also required: Programming cable and compatible USB/serial adapter

STRANDBEEST Robot Kit — eBay
http://cgi.ebay.com/ws/eBayISAPI.dll?ViewItem&item=330992928896#ht_9750wt_1166

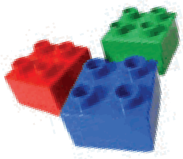
Four volt 14500 Li-Ion cell
www.ebay.com/itm/251402790291

\$2.69 Hobby King HXT-900 nine gram servos
www.hobbyking.com/hobbyking/store/uh_viewItem.asp?idProduct=662

Perfboard
www.ebay.com/itm/261340136969

Sharp GP2Y0A21 IR distance module
www.junun.org/MarkIII/Info.jsp?item=73

Mechanical 5V beeper
www.ebay.com/itm/141120795549



No PC and You Need to Code Your LEGO EV3? No Problem!

By Dave Prochnow

Baked inside of each LEGO MINDSTORMS EV3 Brick is the ability to code primitive programs. Don't get too excited, though. Programs coded on the Brick are able to read a sensor and turn a motor, and that's about it. Although this onboard, or — in the LEGO parlance — on-brick environment isn't nearly as powerful as the computer-based EV3 Software application, you can easily create a small linear code snippet within a matter of minutes. When used within this context, programming the EV3 Brick without a PC can be a very powerful tool.

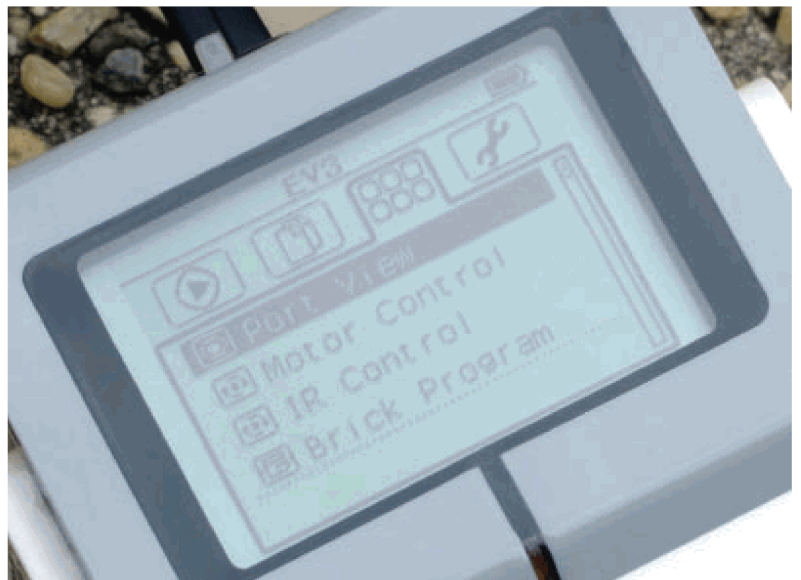
Hand-in-Hand Programming

When you first turn on the Brick, you are greeted with the EV3 Brick Interface. This interface contains four tabbed menus: Run Recent (a shortcut for executing apps that have been recently run); File Navigation (for accessing apps stored on the Brick); Brick Apps (the tab that contains the on-brick programming environment); and Settings (for controlling volume and network settings).

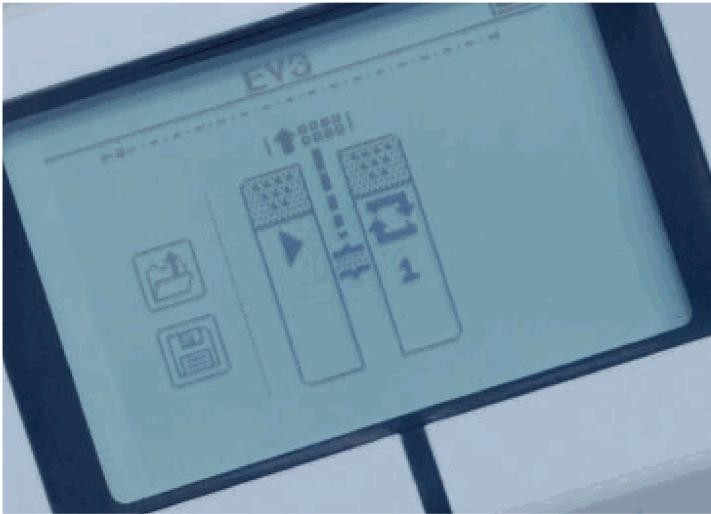
Inside the Brick Apps tab (the location of your future PC-less programming), there are four main preinstalled apps (other apps that you build in the PC-based Software application will be accessed here after being uploaded to the Brick). These are:

- Port View — an overview of the sensors and motors that are currently active on your robot and connected to the Brick ports. You can also experiment with the active ports by pressing the Center button for toggling settings.
- Motor Control — access the active motors that are connected to the Brick. There are two modes of operation that can simultaneously access a pair of ports: Ports A & D and Ports B & C.

- IR Control — control active motors connected to the Brick with the Remote Infrared Beacon and the Infrared Sensor. Again, there are two modes of operation that simultaneously control two ports: Ports A & D and Ports B & C. The Infrared Sensor



The LEGO EV3 on-brick programming environment is accessed inside the Brick Apps tab.



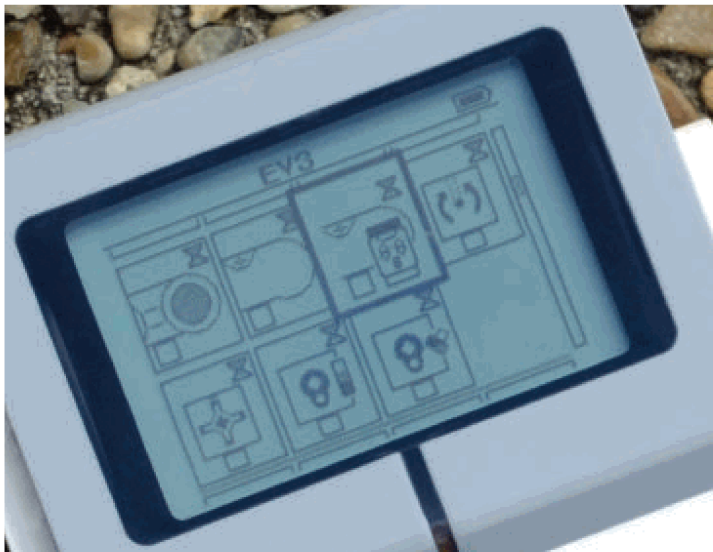
The EV3 Brick programming Start screen features five elements (pictured from left to right): Load (top left); Save (bottom left); Start block; Sequence Wire; and Loop block (far right).

must be plugged into port 4 for this app to function properly.

- The Brick Program — our goal. The Brick Program is the on-brick programming environment where you can create small EV3 programs. No matter what you're programming, four basic actions are used in this program:

1. Create.
2. Delete.
3. Run.
4. Save/Load.

Create. Building a program is a simple intuitive process.



Add a block to your program inside the Block Palette. In this example, the LEGO EV3 Color Sensor with color recognition has been selected.

Each program begins with three components: a Start and Loop block connected together with a Sequence Wire. This program beginning is the EV3 Brick Program Start screen. In order to "program" the Brick, all you have to do is add blocks to the Start screen. Blocks are obtained from the Block Palette. You open the Block Palette by highlighting the Sequence Wire and pressing the Up button. Inside the Block Palette, there are 17 blocks that can be added to your program.

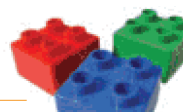
Blocks are divided into Action Blocks (e.g., motors) and Wait Blocks (e.g., sensors); there are six Action blocks and 11 Wait blocks. Inside the Block Palette, you select a block to add to your program by pressing the Center button. After you press the Center button, you are returned to your program and the selected block is inserted after the Sequence Wire that you had previously highlighted along with the addition of another Sequence Wire for adding more blocks.

Back in your program, you can move between blocks by pressing the Left/Right buttons; add more blocks by highlighting any Sequence Wire and pressing the Center button; and configure block settings by highlighting a block and pressing the Center button. A block's setting selection is rather limited (e.g., motor direction) and kinda cryptic (e.g., a Color Sensor light intensity setting of <100). Therefore, trial-and-error testing is the order of the day for EV3 on-brick programming.

Delete. If you determine that a program block is unnecessary, you can remove it from your program. Oddly, this process is vaguely similar to adding a block to your program. In other words, you highlight the undesirable block and press the Up button. This action takes you to the Block Palette. In the Block Palette, you press the Left button, highlight the trash can icon, and press the Center button. You are now returned to your program and the offending block is removed.

Run. In a refreshing nod to a true integrated development environment (IDE), you can run your program from within the Brick Program app by pressing the Left button until the original Start screen's Start block is highlighted and pressing the Center button. You can abandon/abort/stop your program's execution by pressing the Back button. This is a handy feature when you "accidentally" create an endless loop program. Yup, you can screw up even primitive programs with an errant block.

Save/Load. Your program can be saved to storage memory onboard the Brick. The Save action is selected by highlighting the Save icon (curiously, a 3.5 inch floppy disk icon is used for representing Save) that is located to the left of the Start block. This action launches a filename screen. You can name your program on this screen by using an on-screen keyboard. The keys of this keyboard are accessed with the Brick's direction buttons, and the Center button is



used for selecting a highlighted on-screen keyboard key. Programs are saved in the BrkProg_SAVE folder.

Once a program has been saved, you can access it with the Load action. The Load action (i.e., an open folder icon) is situated left of the Start block and directly above the Save action icon. A loaded program will replace the program that is currently in the Start screen.

Limited, but Not Limiting

After an initial inspection of the Brick Program app, you might be tempted to throw up your hands and pull out the PC for a return to real full-fledged EV3 programming. However, there are two saving graces with the on-brick programming interface: speed and convenience.

For example, if you want to test a motor or verify that a sensor is functioning properly, a short linear test program within the Brick Program app is a great solution. Likewise, if you want to test the validity of a short logic branch, a series of blocks can be quickly and easily laced together inside an on-brick program for testing a scenario without investing a lot of time in rewriting blocks of PC-based code.

On-brick programming isn't really so primitive, after all. In fact, this ability to create short tight program snippets with the EV3 Brick will leave you wishing that other



After the Color Sensor block has been added to your program, you can configure its settings by pressing the center button and scrolling through the color selections. The color red has been selected in this example.

microcontrollers enabled you to perform similar rapid programming "sanity checks" on your next robot without having to resort to pulling out the PC. **SV**

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MF70 Micro Mill CNC Conversion



Figure 1.

Recently, I covered 3D printing in the pages of *SERVO Magazine* in a multi-part series. While 3D printing is great for prototyping, nothing beats the ability to mill an aluminum part consistently on a CNC router or milling machine.

By Michael Simpson

In this new series, I will take the Proxxon MF70 micro mill shown in **Figure 2** and convert it to the fully automated CNC machine shown in **Figure 1**.

I chose the Proxxon MF70 due to its cost, availability, and size. The converted machine is small enough to sit on a desk, and makes an excellent addition to a desktop 3D printer. This series will be my most complex project to date, so I will break it down as follows:

Part 1: CNC Introduction

I will cover various CNC types and drive systems.

Part 2: Conversion Overview

Here, we will discuss the components needed for the conversion. We will also go into the hardware and software used to control the CNC.

Part 3: X, Y, and Z Axis Conversion

We will go step-by-step through the process of adding the stepper motor mounts to each of the three axes.

Part 4: Electrical Hookup and Testing

In this part, we will hook up the controller to a PC and



Figure 2.

to the three CNC motors. We will configure the control software and finally, conduct some basic tests.

Part 5: Tuning and Configuration

Before you can use the MF70 CNC, you will need to tune the machine so that you can create consistent and accurate cuts. In this article, we will cover tuning and configuration options.

Part 6: Operation

I will take you through my workflow from part design to part creation.

Part 7: Upgrades

In this part, we will learn how to add an emergency stop button and depth probe.

Part 8: Going Further

I will highlight some of the things you may want to do to take your CNC mill to the next level.

I will try and follow this outline as much as possible, but it's hard to predict the space needed for some of the different topics. Where possible, I will combine parts into one article.

CNC Overview

Before proceeding with the conversion, I thought I would give you a crash course in the CNC machining process.

What is a CNC machine?

CNC stands for "Computer Numerical Control." In a nutshell, a computer is used to place the working end of a tool at a given X, Y, Z point in space. While other parameters may also be employed — such as angle and rotation — we will be concerned primarily with the X, Y, and Z location of the tool. As for the tool head, this can be a 3D printer injection nozzle, laser, plasma torch, or even a cutting knife or wire. In this series, I will primarily be interested in a spinning tool head with a router bit or end mill attached.

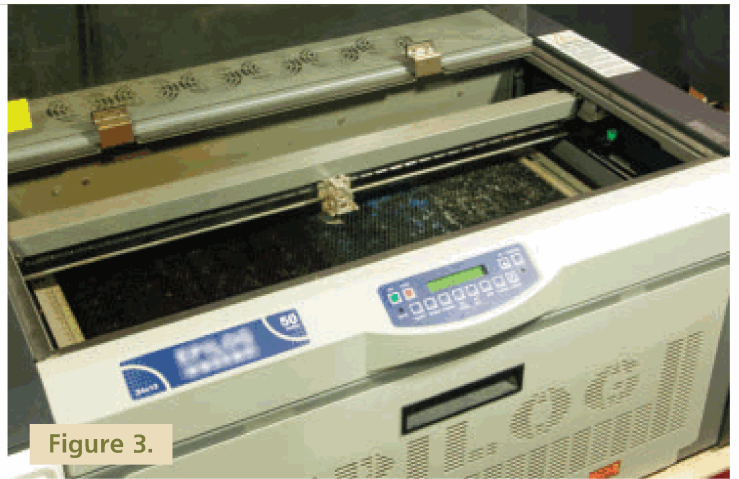


Figure 3.

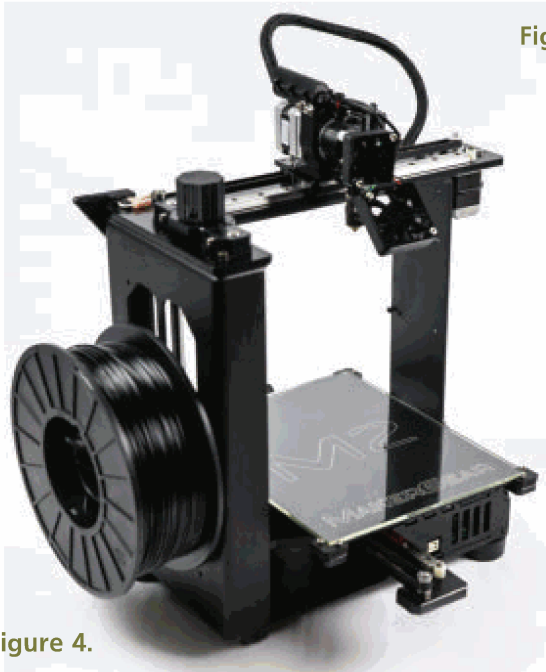


Figure 4.

Figure 5.

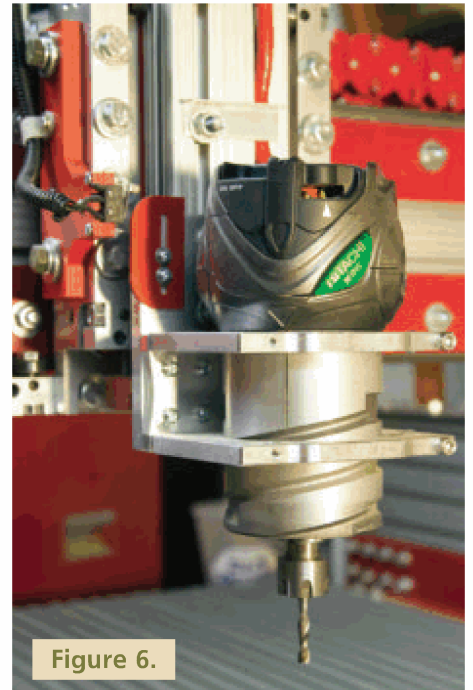
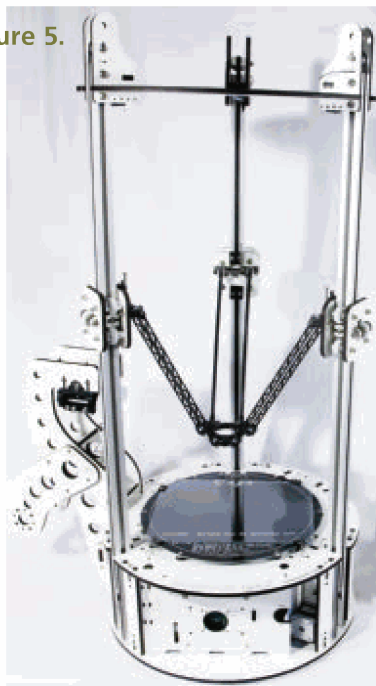


Figure 6.

Figure 3 shows a CNC laser cutter. The actual laser is mounted in the back of the unit, so that the laser can make quick passes for engraving. The X and Y positions of the beam are controlled with moving mirrors, while the Z axis is controlled by a moving platform.

The MakerGear M2 3D printer shown in **Figure 4** is another CNC machine. It has a moving X and Y axis, and uses a moving head much like the laser. In this instance, an extruder is the tool attached to the business end of the machine.

Even the unique 3D Rostock design shown in **Figure 5** is a CNC machine. The X, Y, and Z axis positioning is achieved by the relationship between the three arms.

There are other CNC devices also in use. Pick and place machines are CNC machines at their core. All that said, the actual machines I want to discuss are CNC routers and CNC mills. These have a rotating tool connected to the working end of the machine, much like the router connected to the KRMx02 CNC shown in **Figure 6**, or the spindle head connected to a KRmc01 CNC shown in **Figure 7**. It is these CNC types I will be introducing.

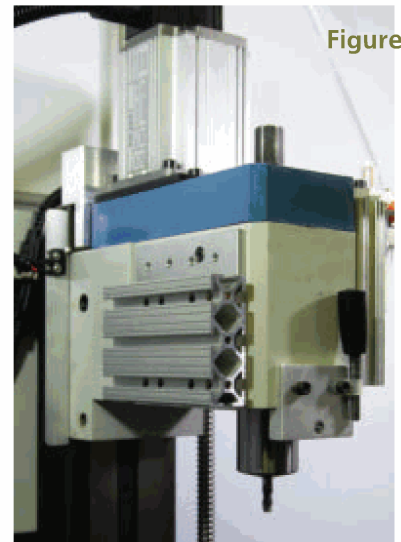


Figure 7.

CNC Types

There are two basic types of CNC machines designed for rotary tool cutting: the CNC router and the CNC mill.

CNC Routers

CNC routers utilize a high speed router or spindle. They ride on rails or rods utilizing bearings, much like the machine shown in **Figure 8**. CNC routers excel at cutting wood, wood products, and plastics. Rigid routers can also cut aluminum. The KRMx02 shown in **Figure 9** has a dust evacuation system and a large clamping table. This makes it well suited for cutting sheet goods.

CNC Mills

CNC mills utilize a low speed spindle. Unlike the high speed spindle, the low speed spindle can also utilize twist drill bits. This allows them to perform drilling operations. The CNC router can only use very small drill bits due to the speed. Being able to drill larger holes allows the CNC mill to produce metal parts much easier and quicker than a CNC router.

The part shown in **Figure 10** has several 1/4" holes. This part takes less than 30 minutes to make using a drill bit on a CNC mill. Milling the holes on a CNC router would take 30 minutes every couple of holes.

CNC mills excel at cutting metals, but with the correct

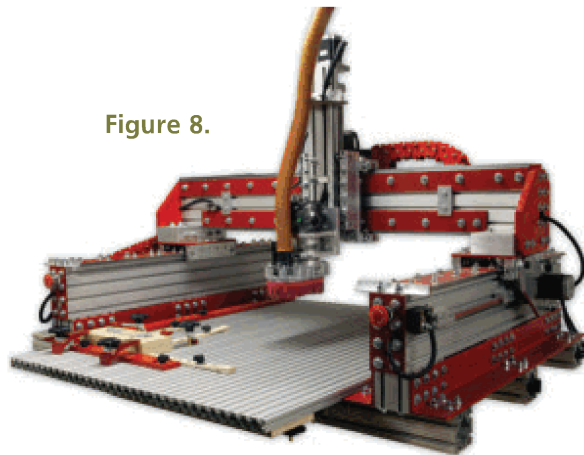


Figure 8.

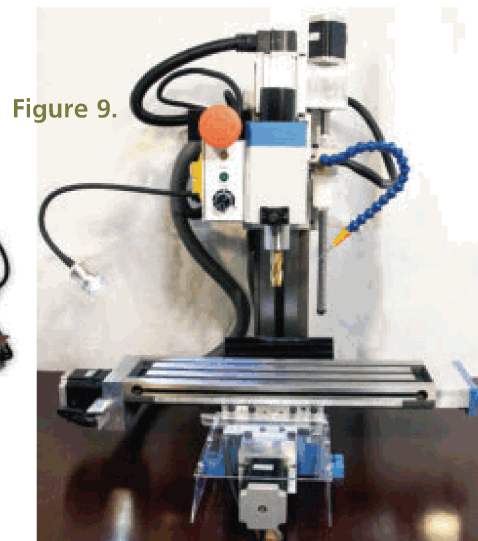


Figure 9.

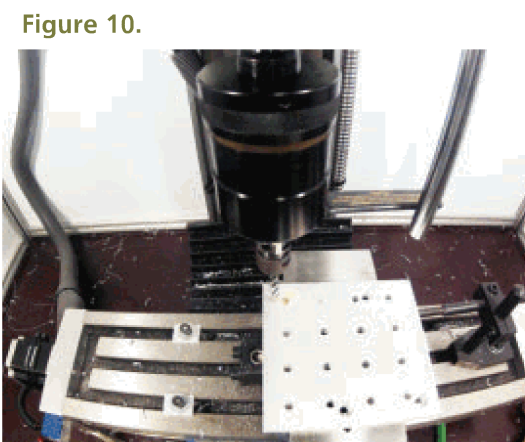


Figure 10.

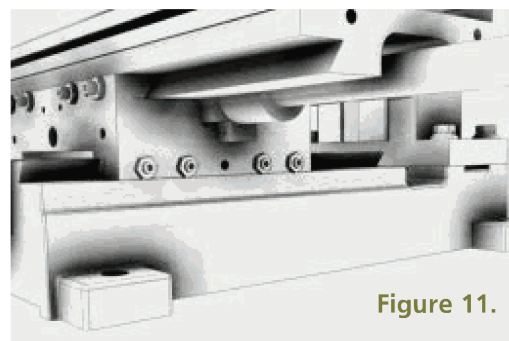


Figure 11.

end mills can cut and drill other materials, as well. CNC mills only move the head in the Z (up and down) direction. Instead the table moves in the X and Y directions. The table does not use a bearing and rail system like the CNC router does. Instead, the table uses a set of greased or oiled dove tails like those shown in **Figure 11**. This setup creates a very rigid machine which is required for milling metal.

Unlike CNC routers, DIY CNC mills are rarely built from scratch. They are usually created by converting milling machines.

Drive Systems

There are several ways to move a CNC axis. This can be done with belts, chains, ball screws, ACME screws, or a rack and pinion drive. Ball screws, ACME screws, and rack and pinion are the most prevalent.

Rack and Pinion Drives

Rack and pinion drives (**Figure 12**) utilize a geared down pinion that runs along a matching rack that runs the length and width of the machine. These drive systems — while a little more complicated — allow for

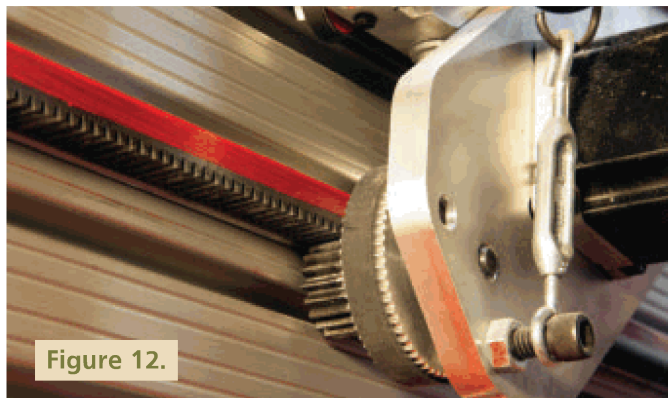


Figure 12.

very quick movement of the CNC.

Ball/ACME Screws

Screw systems use a large screw that runs the length of the CNC. Normally, the screw is fixed on the CNC machine. A carriage is attached to a nut that moves as the screw twists.

ACME Screws

An ACME screw like in **Figure 13** is not the same as standard screw threads found on a threaded rod. They are much more efficient and can include multiple threads to

allow the screw to move several times faster than a standard threaded rod. The ACME nut is often spring loaded to help keep backlash to a minimum.

Ball Screws

The ball screws shown in **Figure 14** are the ones used on the KRmc01 milling machine conversion.

They have small grooves in the threads to allow a series of small ball bearings to be inserted between the nut and screw. Because the ball bearings need to move as they spin, a small tube is used to allow the balls to circulate as the screw twists.

Ball screws are much more expensive than ACME screws. The price goes up considerably as the length is increased. For this reason, they are rarely used on larger CNC routers.

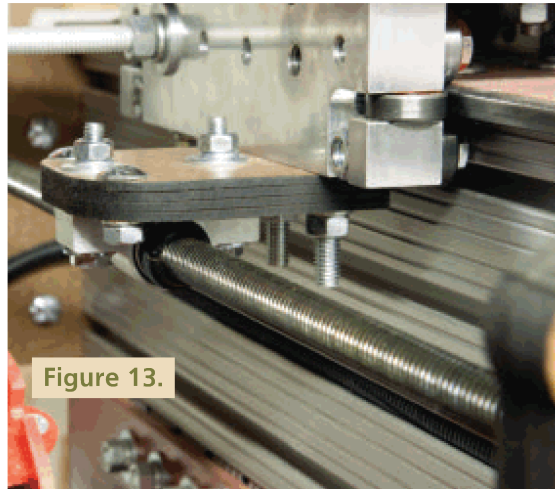


Figure 13.

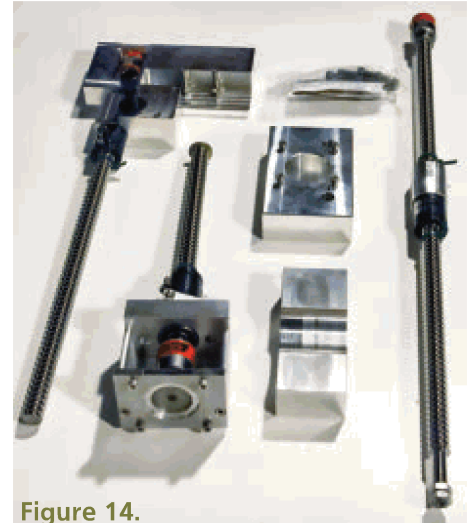


Figure 14.

Stepper Motors

Stepper motors are attached to the various screws or rack and pinion drives with couplers or pulleys. The stepper motor receives instructions from a controller that is connected to your PC. The PC talks to the controller via controller software like Mach 3.

MF70 Mill

As stated earlier, we will be converting a MF70 mill. The MFC70 mill has your basic dove tail ways with adjustable shims (**Figure 15**). Unlike a larger mill which has cast iron ways, the MF70 ways are aluminum. While not perfect, they are okay on a machine this size.

The MF70 mill utilizes a high speed direct drive spindle head (**Figure 16**). While at first glance it may seem like a rotary grinder, it's far from it. The motor is 1/8 HP. It has

low run out and runs at 5,000-20,000 RPM. While I normally like a slower spindle on a milling machine, these speeds are adequate for the smaller bits that this machine uses.

The machine comes with 1/32", 1/16", 5/64", 3/32", 7/64", and 1/8" collets shown in **Figure 17**. With the 1/8" collet, you can use many small end mills and drill bits that are readily available from various sources.

The machine has an X-Y travel of 5-17/64" and 1-13/16". It has a Z travel of 2-3/4".

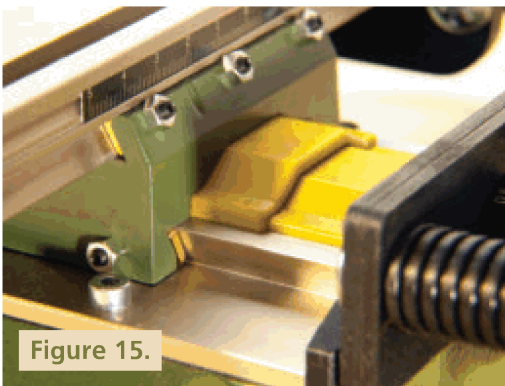


Figure 15.



Figure 16.

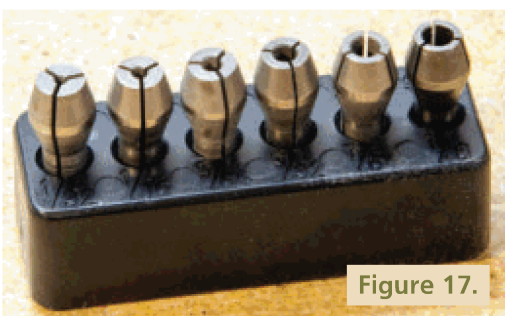


Figure 17.

Conclusion

We only dipped our toe into the CNC waters, but I can assure you, if you build this CNC machine it won't be your last. Once you catch the CNC bug, it's forever.

Next Month

Next time, we will go over all the components needed to complete the conversion. I will supply a complete BOM with links so you can order your parts. **SV**

I have created a *SERVO Magazine* forum. If you have any questions, please post them at <http://forum.nutsvolts.com/viewtopic.php?f=49&t=17107>.

If you want more information on my KRMx02 and KRmc01 CNC books, you can find them at www.kronosrobotics.com.

I also have a free download for an early CNC router book that I wrote. You can download it at www.kronosrobotics.com/krmx01/index.shtml.

I have started a MF70 CNC conversion page. It's at www.krcnc.com/mf70.

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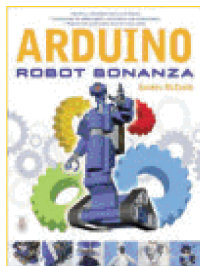
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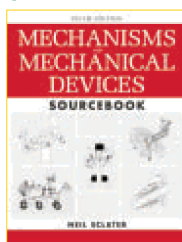


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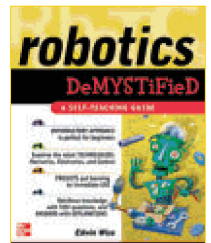
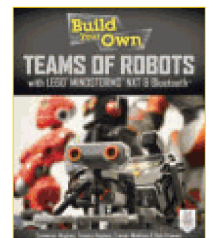
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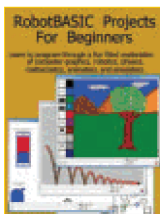
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by John Blankenship,
Samuel Mishal

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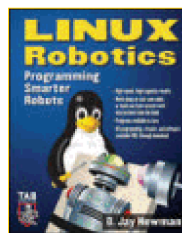


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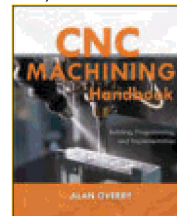


CNC Machining Handbook: Building, Programming, and Implementation

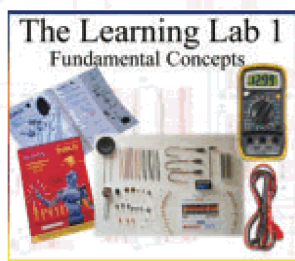
by Alan Overby

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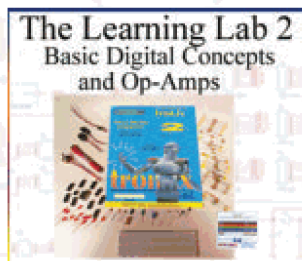
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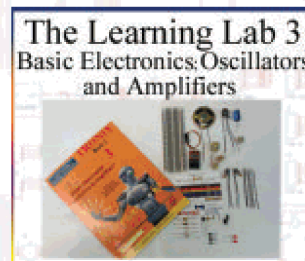
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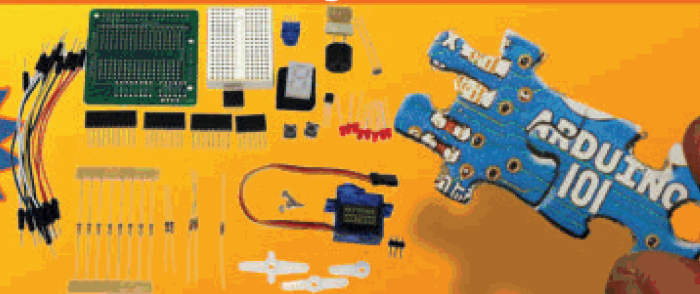
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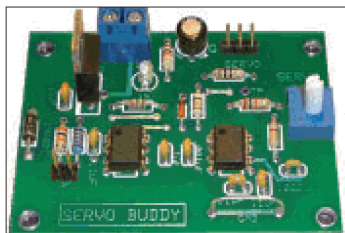


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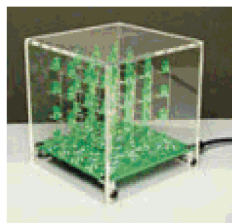
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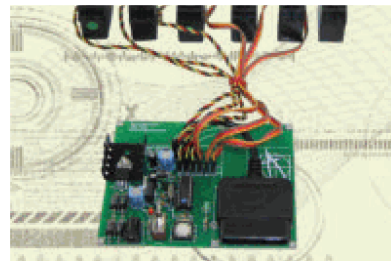


This kit shows you how to build a really cool 3D cube with a 4 x 4 x 4 monochromatic LED matrix which has a total of 64 LEDs. The preprogrammed microcontroller that includes 29 patterns that will automatically play with a runtime of approximately 6-1/2 minutes. Colors available: Green, Red, Yellow &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

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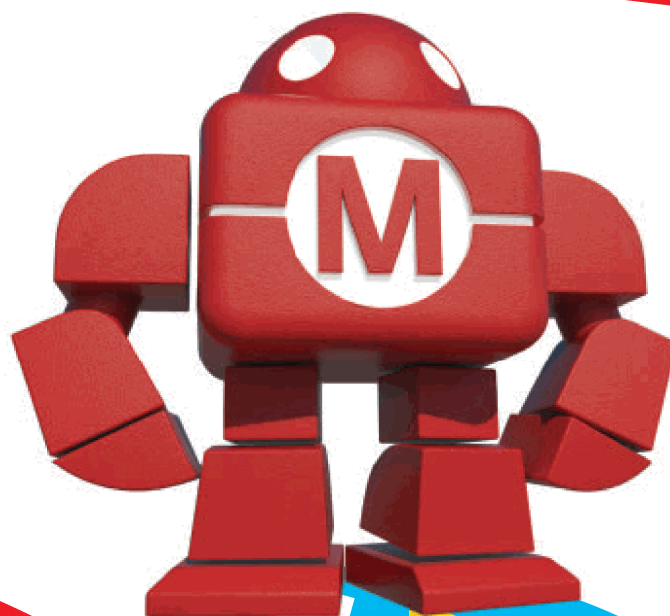
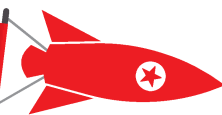
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The Robot Emoticon

By Paul Verhage

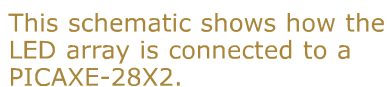


I saw a great computer while watching the movie *Moon* by Duncan Jones. Gertie, the Lunar Industries main computer indicated its emotional state via an LCD screen displaying different faces (by the way, Kevin Spacey makes a great computer voice). I thought how cool that would be for one of my robots. The various faces could be stored in the display's memory and then called up as needed by the robot. That way, the robot wouldn't have to store the images or spend time creating them. Unfortunately, the cost of full color LCD screens and their software was too high to justify for a simple project like this. That left my idea in the state of limbo until last year when I read a *SERVO Magazine* article about a two-color, 8x8 LED array sold by AdaFruit. Now, the rest is history ...

The BL-M12X883 is a one inch square LED array, eight cells wide and eight cells tall. Each cell contains two LEDs: one red and the other green. The LEDs are on separate control lines allowing the LEDs in each cell to be illuminated individually, simultaneously, or not at all. With two LEDs per cell, there are at least four colors for each cell: dark (off), red, green, and yellow (both on). In addition, I read that

A row in the array is activated by grounding it, and only one row can be grounded at a time. Grounding more than one row simultaneously results in a short of the worst kind. After grounding a row, the microcontroller illuminates any of the eight red or green LEDs, intersecting that row by applying voltage to their respective columns. To limit current to safe levels, each column of red and green LEDs connects to its PICAXE I/O pin through a resistor.

The magic of persistence of vision creates the illusion of a complete image in the display. While the microcontroller is only illuminating a single row of LEDs at a time, our eyes and brain are too slow to detect that the LEDs are off longer than they are on. To us, it appears the entire display is constantly illuminated. A microcontroller can even sweep through the rows quickly enough to create simple moving graphics (although I have seen signs of strobing in quickly changing images). As you can see, this LED display can make a pretty good “face” for a robot.



How the Robot Emoticon Works

After becoming familiar with the display, I needed to select a microcontroller to operate it. Discussing this topic at the BoRG (Boise Robotics Group) led me to choosing the PICAXE-28X2 for the Robot Emoticon. Memory wasn't the issue here; it's a question of having sufficient I/O. As the **schematic** shows, the PICAXE activates each column (it should be a row, but I turned my display 90 degrees in the final printed circuit board, or PCB) using a three to eight decoder or multiplexer (74HC238). This way, the PICAXE only needs three I/O pins to activate each column.

The decoder can't sink enough current for all of the LEDs. With all the LEDs illuminated, the total current can reach around 65 mA. Therefore, the decoder activates eight Darlington transistor pairs in a ULN2803 that can sink far more current.

The decoder's three input lines connect to the PICAXE's I/O pins A.2, A.3, and A.4. The program in the PICAXE repeatedly counts from zero to seven, and uses the count to set the I/O pins (in binary fashion, three bits correspond to the range of digital zero to seven). Because the circuit doesn't use A.0 and A.1 for setting the rows, the program multiplies the count value by four before setting the A bank (which leaves I/O pins A.0 and A.1 unchanged). The code to ground (or activate) a column looks like this:

```
For Row = 0 to 7
  Row = Counter * 4
  pinsA = Row
```

The PICAXE-28X2 can source 20 mA per I/O and a total of 200 mA, which is good enough to operate the LEDs in the display. The PICAXE uses bank B for the red LEDs and bank C for the green LEDs. The program uses variables named *Green* and *Red* (one byte each) to store the value indicating which LED is to be illuminated. Bank B and C I/O pins are set binary fashion from the value stored in variables *Red* and *Green*. For example, if only the first green LED is to be illuminated, then *Green* is set to 00000001, or 1. If the second and third red LEDs are to be illuminated, then *Red* is set to 00000110, or 6. The code to set banks B and C looks like this:

```
Green = 1
Red = 6
pinsB = Red
pinsC = Green
```

After a short pause that keeps the LEDs illuminated momentary, the count is incremented and the *Red* and *Green* variables are updated so the PICAXE can activate the

desired red and green LEDs in the new column.

There's additional supporting hardware in the Robot Emoticon circuit. This includes a 100 µF capacitor to prevent the supply voltage from fluctuating as the LEDs blink off and on, a 1K pull-up resistor to keep the PICAXE out of Reset mode, a programming port (DB-9 and two resistors), and a four-wire power and communication header. The four-pin header connects the Robot Emoticon to the robot by providing power, ground, and two control signals.

Because of the lack of real interrupts in the PICAXE-28X2, the Robot Emoticon communicates with the robot controller through two wires in the four-pin header. The robot controller sets these two lines either high or low to indicate which face to display, and then goes about its way operating the robot.

The Emoticon reads the line settings between refreshing images. There is no reply from the Emoticon to the robot controller in the current program, although this feature could be incorporated through a software change. Using two communication lines was a compromise that limits the Emoticon to four images or movies, even though the PICAXE has more than enough memory. Adding additional communication lines would increase the possible faces while tying up more of the robot controller's I/O.

Constructing the Robot Emoticon

Usually, I design new PCBs first at home using Dalpro PCB products (now Camcon Chemical). However, this time I went directly to designing the PCB using the FreePCB Editor. The reason is that the complexity of the circuit makes using a single-sided PCB a bit problematic. Besides, I had some room for this circuit in my next board order.

The finished product is a two-sided board with solder mask, through-hole plating, and top silk. My design saved some board area by placing the encoder and ULN2802 beneath the LED matrix array. This is possible because I soldered two 1x12 row receptacles to the PCB rather than the LED array. That raised the display high enough that the two ICs can fit beneath the display.

I prefer to use receptacles anyways, just in case I make a design error in the PCB that doesn't show up until after the soldering is completed. The final PCB is a bit taller than I planned because the circuit uses through-hole resistors rather than surface-mount, and because of the room needed for a DB-9 programming port. I'll probably use surface-mount components in a future upgrade, and solder the DB-9 to the back of the PCB and behind other components. Alternatively, I may try separating the drive electronics from the display and connecting them with a cable.

Using the Robot Emoticon

First, one needs to determine what an image will look like. This really means determining the color of each pixel and then simplifying this pixel pattern into one byte values that the Robot Emoticon can use to recreate the pattern. Rather than convert red and green pixel patterns into byte values by trial and error (more error than trial, I'll bet), I created a spreadsheet to create the final pixel pattern and corresponding bytes' values.

The spreadsheet (available at the article link) contains an array for the red LEDs and an array for the green LEDs. A 1 is entered in a cell if the LED in that cell is turned on, and a 0 if that LED is turned off. Located at the bottom of the red and green arrays is code to generate the one byte values for each column. The combination of 0s and 1s in the red and green arrays becomes input to a third array in the spreadsheet. That array is conditionally formatted so that if both the red and green LEDs are off, then the cell is dark gray in color. If both red and green LEDs are on, then the cell is yellow in color. Of course, if only the red or green LED is on, then the cell appears only red or green, respectively. The conditional formatting creates a pattern showing what the LED display will really look like based on the setting of the red and green LEDs.

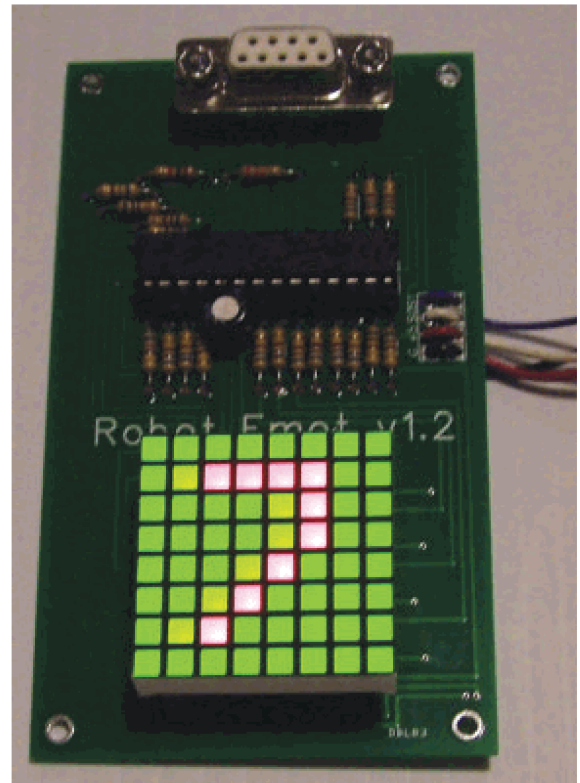
In order to update the display fast enough for video, the Robot Emoticon program uses a look-up table of one byte values for the red and green LEDs in order to set the LEDs. So, for example, the first entry in the look-up table is the setting for LEDs in the first column; the second entry is the LED setting for the second column; etc. This is what the code used to set the *Green* and *Red* variables looks like using this method:

```
FOR B8= 0 to 7
LOOKUP B8, (251,251,251,251,255,255,255,255),Green
LOOKUP B8, (251,255,255,251,255,255,255,255),Red
pinsB = Red
pinsC = Green
```

Results

I found that the PICAXE is fast enough to repeat an image five times before smoothly generating the next image in a sequence. My first result was a program to create a set of Cylon eyes scanning back and forth. With this program, I envision the robot controller signally the Robot Emoticon to scan eyes back and forth while the robot searches for its target. Upon detection of the target, the robot controller then signals the Emoticon to display the eyes pointing in the direction of the object.

In a second test of video, I created a count down movie. It begins by displaying the digit seven (shown in

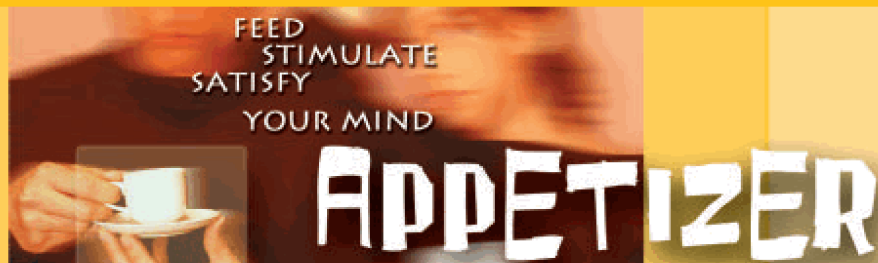


Bad background lighting makes this picture more difficult to see, but this 64-pixel image is displaying the digit 7. In normal lighting conditions at home, the image is bright and contrasty.

the **photo**) and then displaying new digits as the count approaches zero. At the end, the LED display flashes, alternating red and green screens before going all yellow and then blank. (Hey, I think this could be a new digital art form: four color 64-pixel movies. Hollywood, here I come!)

SV

A kit of parts is available from the SERVO Webstore at <http://store.servomagazine.com/home.php>.



The Movie 'her'

The future we see in 'her' is this close to being here.

by Joanne Pransky

The movie 'her' (and yes, they purposefully use a lower case h) brilliantly tells the not-too-futuristic story of a biological male who falls headphones over buffering wheels in love with an artificial intelligent (AI) operating system. (My referencing a 'biological' male is purposeful, too, as it soon may be difficult to differentiate between humans and machines.)

I'm far from alone in pondering and positing: If a human becomes more than 50% non-biological, will that change his classification from 'man' to 'machine'? Or, will the definition be based on some other criteria? For instance, having a biological brain yet nearly 100% artificial body parts; or having a nonbiological brain governing our biological organs. Or will "human" be defined primarily by instincts and visceral emotions?

Simultaneously, compelling and polarizing are the social issues that director and writer Spike Jonze invites the viewing audience to think about — issues that yours truly (the World's First Robotic Psychiatrist®) has been contemplating for over three decades.

'her' certainly appears to be surreal and little more than science fiction in its printed descriptions, but the film slowly (yet intensely) forces us to see the reality of just how attached we are — and will increasingly become — to technology as it responds to us in



ways that seem exceptionally intelligent and remarkably similar to the way we humans feel, act, learn, and think.

Regardless of technology's lack of an embodiment (like the software in the case of 'her'), our relationships with AI bots (software and/or hardware) may become more primary than the human-to-human relationship.

The movie introduces us to Theodore Twombly — lonely and recently separated from his wife. He decides to try the latest technology: the OS1 companion software. After having cursory conversations with some of the female-voiced options,

he decides upon Samantha, whom we come to know as Sam. As time and conversations with Sam progress, Theodore acquires more than just data from her — he develops genuine comfort and companionship, gains intellectual and philosophical insights, and shares adventure and laughter (Sam learns to improve her humor and sarcasm).

Ultimately, his growing intimacy with Sam even leads to sexual pleasure (will this be referred to as 'Turing' him on)? In a short time, she (I mean 'her') winds up confessing to Theo that she loves him too.

While she admittedly can't empathize with jealousy or with the pain and void experienced by losing someone, Sam expresses her desire to be alive. This longing manifests in Samantha's "showing up" for a date with Theo (quite literally) via the physical assistance of an attractive female sex surrogate who serves as a fleshly conduit for Sam's voice, emotions and responses, thus enabling her to simulate a direct physical sexual experience with Theodore.

Granted, some of us wouldn't mind being human beta testers for evolving AI forms that want to add to their sexual experience algorithms (for the sake of humankind, of course). Yet whether we fall for them or whether they love us, the critical issues here are anthropomorphism

3 GOLDEN GLOBE NOMINATIONS

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I predicted that one day the #1 use of robots would be to cure loneliness. My vision was that the PC on our desk — the most common and accepting form of technology — would someday have legs, arms, and enhanced intelligence that would enable it to accompany us in practically all situations and environments.

For children, it could take the form of the gentle and safe nanny/playmate named 'Robbie' that was depicted in Asimov's book, *I, Robot* in 1950. For the elderly, it might be a mobile companion capable of not only carrying them from the bed to the bathroom, but of conversing and singing along the way. For lonely teens, it might be the perfect accepting friend that doesn't bully, and one that can also act as a sexual

and human perception. The belief that we are being understood and loved will be experienced quite differently by each end-user. Samantha represents a futuristic version of Eliza, a software "psychotherapist" developed in the '60s by computer scientist Joseph Weizenbaum that used natural-language processing (NLP).

Nearly half a century later, the Eliza effect is quite real, as proven by BlabDroid — the first robot to direct and shoot a documentary in which strangers divulge their dark secrets. Recently, the bureau chief of *Time Magazine* — a distinctly sharp individual — wasn't able to determine if the telemarketer on the phone was a human or a robot.

Most of us already spend as much time (if not more) on our devices than we spend face-to-face with other humans. The term computer widow (or widower) was coined in the '70s/'80s for those people who felt that their partners preferred time at the keyboard vs. time with them.

Though the industrial robot was just taking off in the '80s and personal and service robots were in their infancy,

the risk of disease, pregnancy, or rejection. (For further documentation on this, refer to AI expert David Levy's book, *Love + Sex with Robots*.)

Even after sex, will we want our robotic companions to keep us company in bed, perhaps to fill an emotional bond or physically protect us while we're dead to the world. What will robots do while we sleep? Will they also go into sleep mode? Will they recharge and perform preventive maintenance functions during this time?

Will we give them the equivalent of eight 'man' hours of software tasks, or will we kick them out of bed (this could become a legal violation of robo-rights) to do strenuous chores while we slumber? What about our waking hours?

Will our robots sit with us at mealtime? Will they speak to us while we do the chewing and swallowing (as did Sam in 'her')? Will they simulate eating and drinking (and getting drunk) so we don't have to dine by ourselves? Or, will humans lose weight as they spend less time wining and

Image courtesy of Joanne Pransky



dining due to the lack of being able to share this social experience?

The forms taken by our future bots will be diverse and custom-designed to suit both preferences and tasks. We may even employ hard-body specialists to help us with our ever-changing AI embodiment requests. Though 'her' shows us the future (without giving us a specific year), Sam's hardware took the form of a somewhat conventional high-tech camera either embedded in a smart phone in Theodore's pocket (simultaneously reading his environs in real time — similar to a baby strapped in a parent's carrier as the adult controls her whereabouts and provides additional input) or the camera was about the size of a mole placed on the face of Sam's sex surrogate.

Even though camera phone technology will probably be outdated in the future (just ask the Google Glass developers), I think the phone/camera/earbud served as the ideal representation of Samantha since this technology is something we're all quite familiar and comfortable with.

Most of our direct communication throughout the day will soon be conducted indirectly via voice technology, so the speech interface in 'her' certainly seems spot-on. Devices that require fingers/touch/keyboard will eventually become obsolete.

Should we all be using Nuance's Dragon Dictate if we need to practice our verbal skills? (Nuance, by the way, provides Siri's speech-recognition engine.) Will writing in the future mean speaking words that are then transformed into text for others to read?

Since most of us speak and write very differently, might a career of the future consist of someone helping us with the transition from typing words to mastering the art of clearly saying exactly what we mean to optimize immediate voice-to-text conversion?

If there's a direct link from our brains to those with whom we communicate (human or machine), we may also have to learn to control our thoughts, especially if there's not a filter in the future. When we're speaking to someone, thinking how boring it is and wishing we were doing something else, will that person know it (unless there's a social auto-correct/editing function that first deletes, modifies, or lies for us before transmitting)?

Director Jonze's decision to use an intelligent, talking operating system as the object of Theo's love reinforces the importance of imagination. We're shown how our imagination and fantasies shape the dialogue from our non-human partners so they can anticipate and satisfy our needs and desires, thereby becoming our primary choice of contact.

Furthermore, we need not be limited to just one AI 'partner.' Why not have a robotic work assistant, sexual partner, and/or BFF (best friend forever) like Theodore's neighbor, Amy? Amy also chose a female-voiced AI bot, but to serve as a close female friend for chats and to share some giggles over Amy's manipulation of a videogame for moms in which they were programmed to masturbate in the kitchen instead of cooking.

Movie images courtesy of 'her.'



Are we destined to have very different relationships with our various "intelligent" devices and any surroundings that use AI to engage us in conversation? Quite possibly, but while this doesn't mean we'll get personal with our appliances, if our refrigerator keeps reminding us of how unhealthy our food choices are, we may definitely come to dislike it/her/him!

As the movie encourages us to wonder, what happens when we realize that our OS1s are not monogamous? (That said, the movie did not address the scenario of a single-user having multiple AI companion bots or sharing multi-user bots.) Samantha, however, turned out to be not-so-dedicated since she was able to have 8,316 simultaneous relationships (talk about a multiple personality disorder)! Out of all of them, however, she said that she loved only 567 as much as Theodore.

Comments like that beg the question: How will we humans feel when we're rejected by a robotic companion? How about when a parent removes a child's robotic playmate against his or her wishes (as done with Robbie in Asimov's story)? Or, due to some hacking, what if our intelligent partners are rendered of little or no value to us? Or, as in 'her,' what if the manufacturing company (Element Software) and its operating system go out of business?

Even though Samantha said goodbye in the movie when all OS1s were given an imminent deadline for a complete shutdown, what if there's no preparation for our loss of attachment in the event of a severed connection? (See the movie 'Cherry 2000' to see how one human male coped with his sudden loss).

Will I wind up moderating two different encounter groups — one for robots that have to deal with their loss and another for grieving humans who need to cope with feeling abandoned?

Nominated for a 2013 Best Picture Academy Award, the must-see film 'her' gives significant meaning to Isaac Asimov's quote, 'The saddest aspect of life right now is that science gathers knowledge faster than society gathers wisdom.' Amen to that. **SV**

Go to www.servomagazine.com/index.php/magazine/article/april2014_Pransky to comment on these topics.

DRONES

Figure 1.



Back Country Voices recently held a Veteran's for Peace demonstration in the San Diego, CA area (refer to **Figure 1**). Citizens like these folks who have heard negative reports in the media are concerned about their privacy and safety when it comes to drones. "They're everywhere! They are spying on me! They are out of control! They can kill me with their bombs and guns!" Bad press and abuses of power continue to bring controversy to an otherwise useful technology.

Figure 2 shows a different demonstration of Drone Nation Code Pink who are among thousands of other groups not only here in the US, but around the world who are alarmed at what they hear and read about the use of drones. **Figure 3** is an example of a political slam against President Obama and how his administration has allowed the use of drones all around the US — much against voter's wishes.

As with any contentious point in life, it is always best to listen to both

sides of an issue and then decide for yourself. You may have heard that **Amazon.com** has investigated the use of small unmanned aerial vehicles (UAVs) for the special delivery of Amazon products with what CEO Jeff Bezos calls Amazon Prime Air. Two mockups are shown in **Figure 4**. Sure, the demo clip on the news looked cool, but will it work in today's society? Even Domino's Pizza has envisioned an air-borne pizza delivery method shown in **Figure 5**. I'll discuss these scenarios later.



Figure 2. Drone Nation Code Pink demonstration.

Post comments on this article at www.servomagazine.com/index.php/magazine/article/april2014_ThenNow.



Figure 3. Poster warning of Obama's plans for drones.

Not all drones are necessarily UAVs or flying robots. Some are perceived as humanoid bipedal robots such as the fourth incarnation of the RoboCop series just out in theaters this year. Others are termed "unmanned ground systems" and are just that — remotely controlled or autonomous robots that roll across the ground.

Your Neato or Roomba vacuum cleaner robot can certainly fit into this category. However, it is the UAVs that seem to bother the majority of the public and are frequently given the somewhat sinister moniker of "drone." I'd like to discuss just how this term became so sinister.

There was a time when people thought of drones as male honey bees; the term was certainly not applied to anything man-made. These bees develop from eggs that have not been fertilized, so they cannot sting since the worker bee's stinger is a modified ovipositor — an egg laying organ. The drone's main function is to be ready to fertilize a receptive queen.

That might sound like a great life for a bee, but read a bit into Wikipedia to find out



Figure 4. Jeff Bezos displays Amazon Prime Air's multi-rotor craft.

what really happens to these guys after mating.

Other drones have been used as far back as the first World War.

Figure 6 shows a pretty girl posing with a drone engine. Her name was Norma Jeane Dougherty and she worked in a factory that made small target drones that pilots used as flying targets to hone their dog-fighting skills.

She later took the name Marilyn Monroe after supposedly being 'discovered' in these photos. (For some reason or another, she is not known for her drone building skills.) **Figure 7** shows a post WWI 'radio plane' that was used as a spy drone, as well as a target drone.

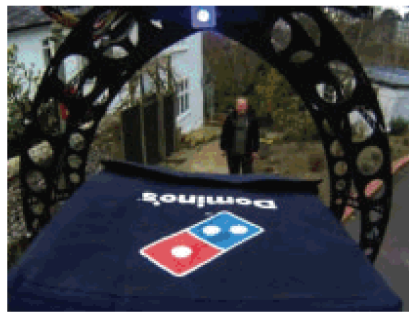


Figure 5. Domicopter drone delivers pizza.



Figure 6. Norma Jeane Dougherty assembles a drone.



Figure 7. WWII radio plane.

UAV Popularity is Growing

Let's forget bees and Marilyn, and examine just what it is that has caused this extreme popularity in UAVs. Why were there almost no multi-bladed flying platforms just 15 years ago? Even the toy and model helicopter market was quite small before the turn of the century.

There have been model helicopter enthusiasts for many



Figure 8. Blackhawk 500 gas helicopter.



Figure 9. Parrott AR.Drone.



Figure 10. Parallax ELEV-8.

years, but the earlier ones were almost all gas-engine powered.

The reason for the popularity? Enter the high power density LiPo batteries for electric planes and flying platforms. You don't need a screaming glow-plug gas engine trailing smoke to allow your model to leave the ground these days.

Figure 8 shows a \$500 gas-powered Blackhawk 500 that is flying inverted with the typical smoke trail. An electric helicopter with a small LiPo battery pack can get you 10 to 15 minutes of flight at a lower overall cost for the whole system of less than \$100. The negative aspect: a shorter flight time than the gas-powered models.

Model helicopter designs improved very rapidly and costs began to plummet. A little over a year ago, I covered the multi-rotor craze a bit from my exploits with a helicopter and the ELEV-8 from Parallax. One of the most difficult parts of my learning to fly a model helicopter was the instability of early models.

Handling the collective, cyclic, and tail rotor pitch was difficult for beginners like me. Manufacturers began to sell cheaper models that did away with the complex tail rotor that canceled rotor torque but allowed easy steering. These designs used two co-axial rotors to cancel the torque of each rotor, plus they didn't require a tail rotor.

If you went into any county fair booth or a Brookstone store in an airport a few years ago, you would have seen dozens of the small co-axial copters available to try out. Purists wanted a better design and opted for a single rotor and tail rotor, but stability was still a problem.

MEMS Technology Made Flying Easier

Aside from the LiPo battery capacity, the onboard gyro/accelerometer chips now cost just a few dollars each as opposed to thousands of dollars for spinning gyros just a dozen years ago.

With the introduction of very

cheap and tiny gyros and accelerometers built into R/C systems, control became a lot easier. Micro-electromechanical systems (or MEMS) are a combination of an integrated circuit and micro-mechanical sensor technology that allows outside forces such as

linear acceleration and rotational force to be measured on a single chip.

The outputs of these measurements can be fed to a flyer's receiver to compensate for flying instability and allow inexperienced R/C flyers to keep helicopters and multi-rotor flyers fairly stable in flight.

Enter the Multi-Rotor Flyers

Go into the same Brookstone store these days and you'll see the Parrott AR.Drone. It's the \$300 quadcopter shown in **Figure 9** that was one of the first smartphone app controlled flyers with an HD camera. There are still the standard co-axial helicopters, but the 'buzz' these days are the multi-rotor craft.

The MEMS and other sensors such as GPS, magnetometer compass, altitude hold, tilt and roll control, data capture, and recording are just a few of the capabilities of the newer control boards. The Parallax ELEV-8 shown in **Figure 10** uses a Hoverfly Sport control board (shown in **Figure 11**) that allows for easy control and stability of multi-rotor flight.

The Lockheed F-117 Nighthawk stealth fighter would have been impossible for a human pilot to fly were it not for the onboard computer systems that compensate for the terrible aerodynamics of the plane that are needed for stealth. The same goes for the multi-rotor craft and their MEMS chips.

The quadcopter brain shown in **Figure 12** is a project of Alan

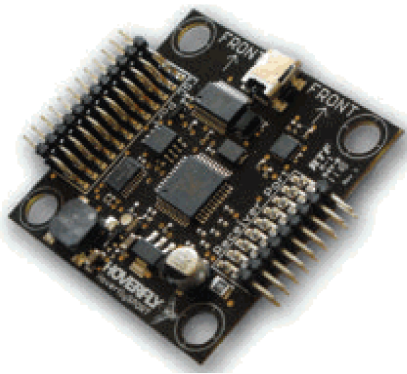


Figure 11. Hoverfly Sport multi-rotor controller.

Kharsansky on the hackaday.com site. It was a project in progress as the firmware needed some tweaking, but you can see the blue Xbee module through which it is controlled from a laptop or similar.

My own ELEV-8 quadcopter is up and flying, and I feel much more confident in my ability than when I managed to crash one at Parallax — twice onto the street when I was visiting the company. Parallax president, Ken Gracey just smiled at me and said no problem.

Yes, there was an operator issue which has made me look a bit more carefully at the overall picture of controlling unmanned aerial vehicles. I am concerned that some department is going to place an inexperienced person behind the controls of an expensive UAV. Who knows what might result.

Issues with Unmanned Aerial Vehicles

As with any newly-evolving technology, ideas for applications are exploding from those who hope to develop and market UAVs. Some applications are a bit premature, such as the aerial delivery methods mentioned earlier. Other applications like aerial surveillance are excellent uses of this technology. Unfortunately, it is this use of the technology that is the root of the

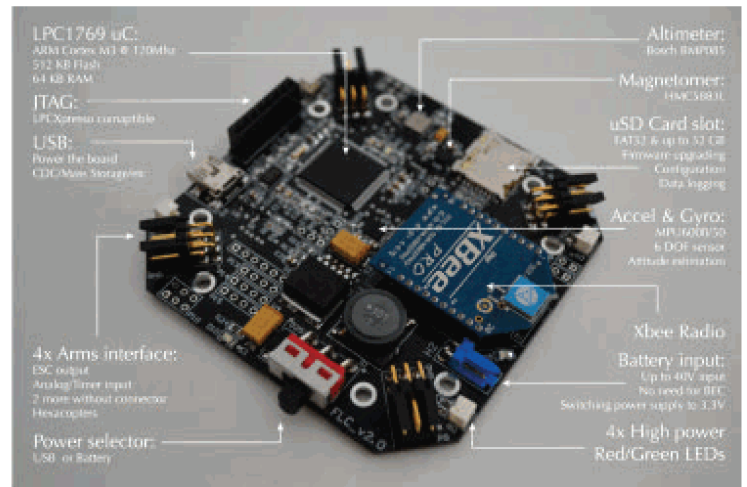


Figure 12. Quadcopter brain by Alan Kharsansky.

widespread concerns.

Two issues stand out in the minds of the public with the use of unmanned flying vehicles. The more vocal groups seem to be concerned with the illicit use of UAVs by government agencies for spying on private individuals. The other side is more concerned with the safety aspects of operating these flying vehicles. Both concerns are real and are foremost in the minds of the various agencies and groups that are studying and compiling these matters.

The *Time Magazine* cover shown in **Figure 13** illustrates the public's feelings of "What happens when they are unleashed at home?"

The map in the background of **Figure 14** is a sensible approach by the government to locate various test sites to "prove" the many types of UAVs that are on the drawing boards of various vehicle manufacturers and government agencies. The aircraft must be tested, and approved test areas need to be set aside. Protesting won't stop progress that is truly needed by our nation for its defense. The Northrop Grumman MQ-4C Triton in **Figure 14** is typical of the 'evil drone' depicted by most protesters.

It is huge at 16 tons with a



Figure 13. Time Magazine cover on drones.

8,000 pound thrust jet engine, and can fly for 27 hours straight. It has multiple cameras, sensors, and radars pointing in all directions including down.

Evil? Doubtful. This particular UAV is strictly a surveillance drone and is used by the Navy and other military agencies for fact-gathering only. No, it is not flying above our homes, looking at us in our backyards. However, it is these types and sizes of UAVs that seem able to draw ire from even the most complacent people in our society.

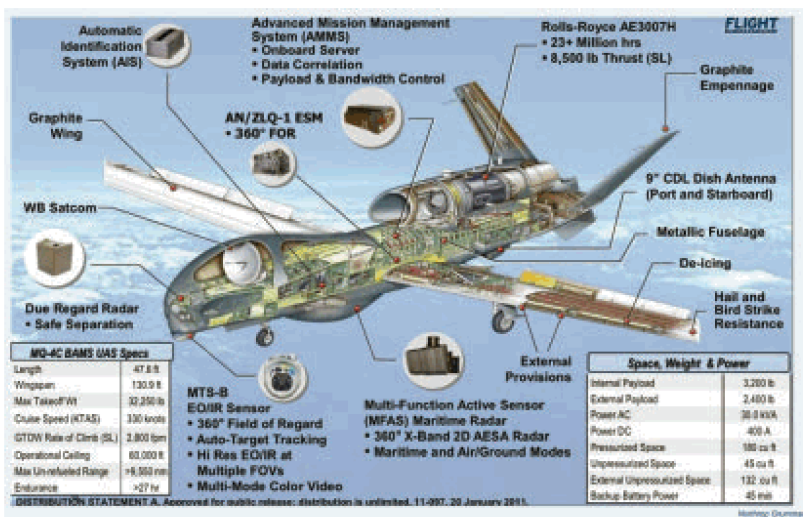


Figure 14. Northrop Grumman MQ-4C Triton UAV.

Government Control of 3D Airspace

In times past, forward-thinking magazines such as *Popular Mechanics* would look to the future and envision helicopters and similar air vehicles that did not require long runways. 'Everyone will have such a flying craft in their garage.'

Many decades later, there are still no such vehicles available to the average person. Why? Can you imagine your neighbor returning home from a quick trip to the grocery store with several bags of chips and a 24-pack of his favorite beer with only 20 full cans left in it? The big game is about to start. Four empty cans are rolling around on the floor as he tries to land in his driveway. Need I say more?

Today's airspace is already crowded with over 250,000 planes in the US alone. Air traffic controllers are taxed to the limit as **Figure 15** might suggest. Now, add 25,000,000 commuter aircraft to this scenario. There are no 2D roadways for aircraft such as those depicted in sci-fi movies like *Star Wars*. It is a 3D headache for air traffic controllers with today's highly-trained private and commercial pilots.

Can you imagine the nightmare

that would exist with 25 million more people darting about the air? It is this 3D airspace that causes the most concern among government agencies. The addition of millions of unregulated UAVs could make the air traffic control scenario much worse since these small guys might not show up on ATC radars.

The larger military UAVs are certainly more reliable and safer to operate above towns and cities, but there are concerns for the smaller vehicles with limited range and operating time. These types of vehicles will more than likely be multi-rotor craft and operated by personnel with limited experience.

Onboard sensors and video feedback to an operator may be of low quality. Unseen power lines and tree branches are hazards around populated areas. The loss of a single motor or prop on a quadcopter can send the UAV straight to the ground, unlike a winged plane or helicopter that may glide a distance or auto-rotate to the ground safely.

Unmanned Aircraft Systems (UAS) test sites at the University of Alaska (that also has test sites located in Hawaii and Oregon, the state of Nevada, Texas A&M University at Corpus Christi, North Dakota Department of Commerce, Virginia Polytechnic Institute in Blacksburg,



Figure 15. Air traffic control radar map.

and Griffiss International Airport in Rome, NY) have been set aside by the FAA (Federal Aviation Agency) for extensive testing of these vehicles. These six sites will be used to test how best to integrate drones into the national airspace by 2015.

Intended to create a procedure to ensure drones are used safely, the sites also have the potential to pump tens of billions of dollars in economic benefits into these states. Aerospace industry states such as Ohio, Florida, and even California fought hard to get the nod from the government for these sites.

This final FAA selection is one of the first US regulatory moves to begin integrating unmanned aircraft with piloted planes and helicopters. The test sites will be used to help the FAA develop certification standards for unmanned aircraft, and how they can be operated within the air-traffic control system accordingly.

The FAA will require test site operators to maintain records of devices flying at the facility, create a written plan for how data collected by airborne vehicles will be used and retained, and conduct a yearly privacy review. Facilities must also adhere to all privacy laws that may apply to drone use, such as restrictions on law enforcement to obtain search warrants, according to the FAA's privacy policy.

Smaller Multi-Rotor UAVs

Though the larger Predator and

Triton UAVs seem menacing, it is the smaller and much more numerous small craft like the ELEV-8 and similar flyers that most people seem to worry about on a personal basis. These are the types that folks see as invading their personal space. They also see them as quite dangerous in the hands of inexperienced operators. Fortunately, there are trained and safe operators for the majority of these UAVs. However, as mentioned, folks aren't so worried about the experienced pilots.

Most multi-rotor craft have many fast-turning propellers that are extremely sharp and have no protective rings around the periphery to shield them like the foam rings on the Parrott AR.Drone. These props can and have dealt some very serious cuts to unaware bystanders — even props on very small quadcopters.

Rings have mass — even foam rings — and the increased weight means less payload. Designers must cut all weight in any way they can. They might start with the use of simple metal box beams (like the two previously mentioned mockups) just to prove the concept. The final product may end up with carbon-fiber tubes to hold the outrunner motors and props.

UAVs for the Rest of Us

With 'fly back home' software, GPS, ultrasonic and pressure altitude sensing, advanced MEMS sensors, RF connectivity, and high energy batteries, multi-rotor UAVs for today's consumers offer advanced capabilities for low costs. The Hubsan X4 H107D FPV (First Person View) quadcopter shown in **Figure 16** can be yours for \$105 to \$175, depending on where you buy it.

As you can see, it's quite small but does not require a smartphone since its hand-held transmitter has four channels with a 4.3 inch LCD with a 640 x 480 resolution with instant video review.



Figure 16. Hubsan X4 H107D FPV quadcopter.



Figure 17. Fly America quadcopter pro package.

If you want to go 'professional,' the Fly America FPV shown in **Figure 17** costs \$3,600 for the basic package or \$3,999 for the professional two-person package. The 'two persons' are the pilot and the camera operator. With 600 mW video RF output at 5.8 GHz and a two-axis gimbled zoom camera, this is a serious quadcopter.

Final Thoughts

I've discussed the public's fear of drones as well as the quadcopter popularity, and tried to meld the two together in a mutually friendly

existence. There will always be people who do not trust emerging technology. Horseless carriages scared horses and were "dangerous." Cell towers and phones emit dangerous RF radiation that has been reported to cause cancer. These and other examples take shreds of truth that scare uninformed people.

As robotics enthusiasts, we should talk to our friends and neighbors about drones and how they can be so helpful when used correctly. Just freely admit that there needs to be sensible regulations applied to this—as with any new — technology. **SV**

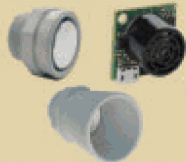
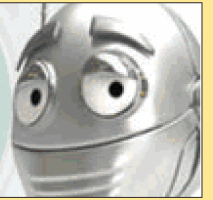
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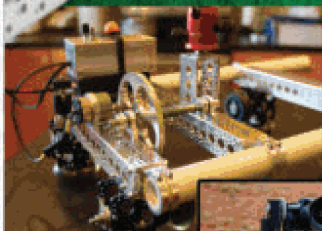
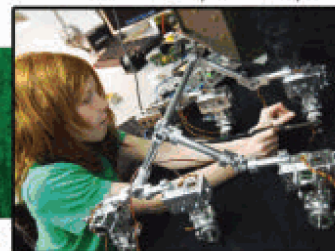
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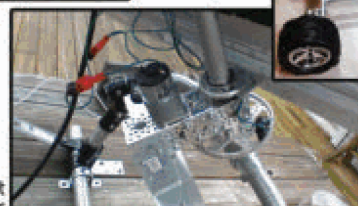


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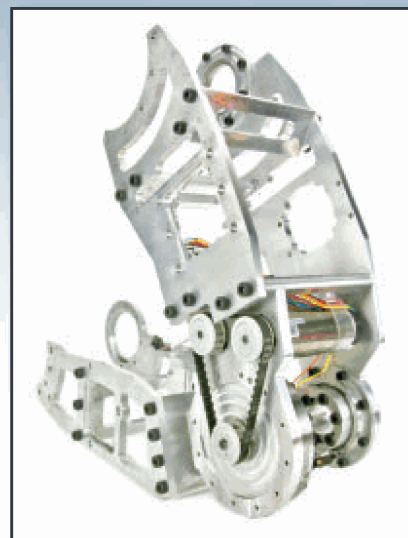
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Shown here is an articulated humanoid robot leg, built by researchers at the Drexel Autonomous System Lab (DASL) with a Tormach PCNC 1100 milling machine. DASL researcher Roy Gross estimates that somewhere between 300 and 400 components for “HUBO+” have been machined on their PCNC 1100. To learn more about this project, visit www.tormach.com/servo.



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