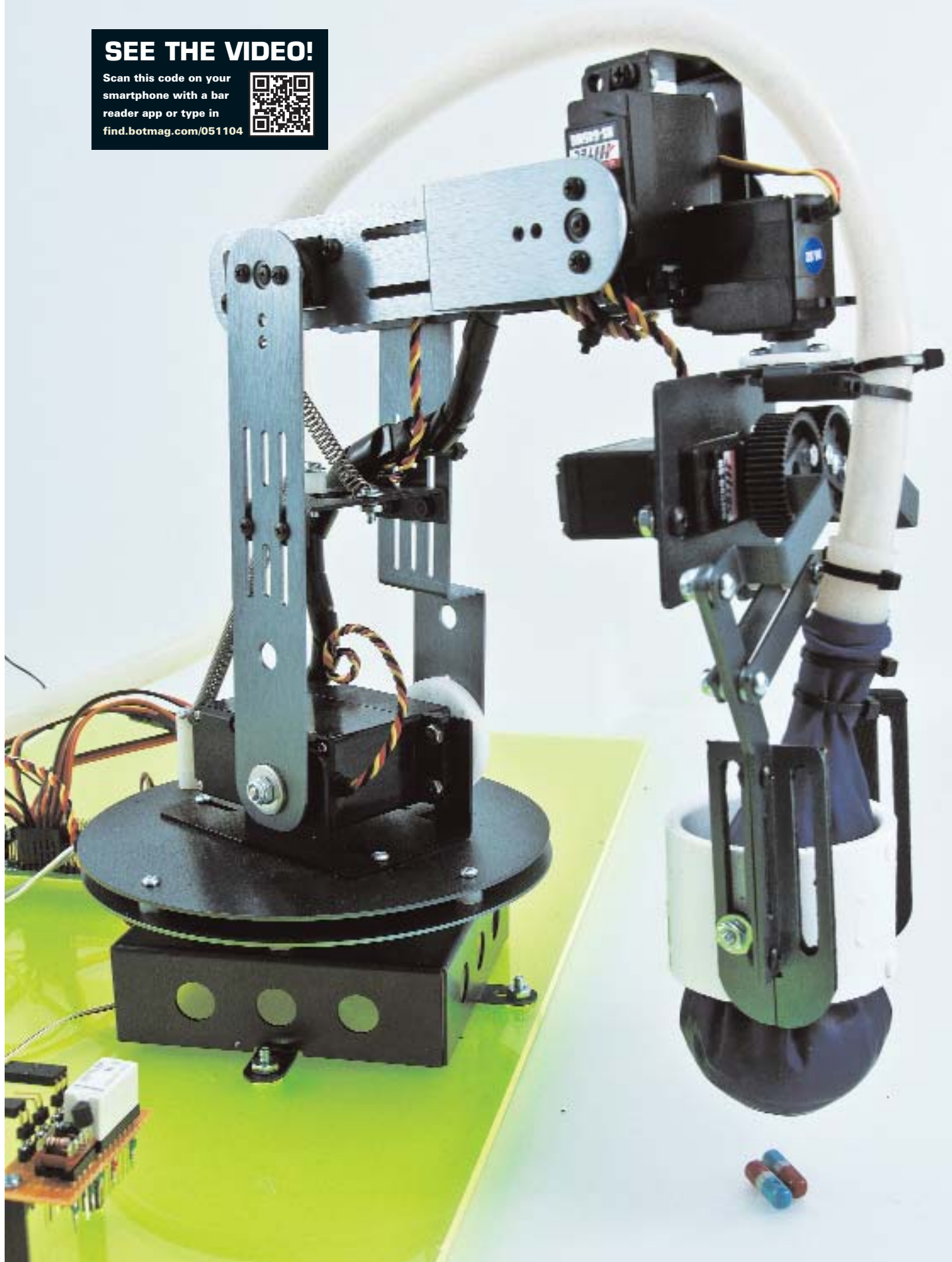


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by Steve Norris

Balloon Bot

A Gripper that Never takes a Coffee Break

As I have learned from my own projects, the major challenge in creating a successful robotic arm is the gripper. A robotic arm's capability and usefulness is directly related to its ability to manipulate its environment. So when I read about a new gripper invented at Cornell University based on something as simple as a balloon filled with coffee grounds I was, to say the least, intrigued. After studying their novel design I was sure I could implement my own (cheaper) version and apply it to my next project.

THE UNIVERSAL GRIPPER

Working with funds from DARPA, researchers at Cornell University, the University of Chicago and iRobot came up with a robotic gripping device using a latex party balloon filled with ground coffee. They call it a "universal gripper" and it takes advantage of a physical phenomenon called jamming transition. When particles like coffee grounds are densely packed they can no longer slide past each other and behave like a solid. When the grounds are loosely packed, they behave like a liquid. You have probably seen this effect if you have ever bought one of those vacuum-packed bags of ground coffee. Because all the air has been removed, the coffee is tightly packed and forms a hard brick. When you open the bag and let the air back in, they return back into loose coffee grounds.

Using this principle the Universal Gripper will conform to just about any shape when pressed against an object. A pump then removes the air creating a vacuum that in turn causes the coffee grounds to



Balloon and coffee "robot parts."



Close-up of the PVC coupling used to hold the coffee filled balloon. Note the short piece of PVC pipe at the bottom which forms a ridge that the balloon will grip when suction is applied.

"lock up" and grip the object. The object can now be manipulated or moved to a new location. To release the object the vacuum is removed and air is allowed to flow back into the balloon.

Using this elegant idea I constructed my own version mostly from parts that I had lying around my lab. So let's take a look at the components as well as the techniques I used to build my very own gripper which I appropriately called BalloonBot.

THE CRUSTCRAWLER SG6-UT ROBOTIC ARM

For the arm I used the CrustCrawler SG6-UT Arm. It is an all aluminum 5-axis robotic arm system constructed from anodized 0.063-gauge 5052 brushed finished aluminum components. The arm uses the CrustCrawler Retract System (CRS). The CRS system is a custom manufactured spring and tension plate that is used to cancel the forward weight of the robotic arm from the elbow to the gripper allowing the servo to use its entire torque curve for lifting objects. The CRS system also increases lifting capacity and servo life. Although this project will not take full advantage of the SG6's own gripper assembly it does contain an adjustable electronics stand located above the gripper assembly to accommodate an array of sensors and the ends of the gripper are rounded for an even gripping surface.



The Yost ServoCenter Mini controller board is used to control the 6 servos on the SG6-UT robotic arm as well as the power relay for the Handi-Vac suction pump. It connects to the PC using a standard USB mini cable.

PHOTOS BY STEVE NORRIS

THE YOST ENGINEERING SERVOCENTER MINI

To control the SG6-UT arm's six servos and the vacuum pump (more on the pump later) I used the powerful Yost Engineering ServoCenter Mini embedded servo controller. This controller allows RC servo motors to be controlled from any USB port. The ServoCenter can control the seek position and speed of up to sixteen connected servos — independently and simultaneously, with simple serial commands. You can also chain ServoCenters together to control up to 256 RC servos, with completely independent movement, from only one USB port. Independent control allows you to move one servo to a position slowly, while another is moving to a different position at a faster speed, and group moves allow you to synchronize multiple servos easily.

The ServoCenter controller provides a built-in Sequencer / BASIC Interpreter called SC-BASIC which allows the sequencer to run independently on the board itself. Sequencer programs are stored in non-volatile EEPROM memory that retains the program even when the unit is reset or powered off, eliminating the need for a PC or other external command device.

For advanced applications the ServoCenter can be programmed directly using a simple packet serial protocol or using the included ActiveX control or Win32 DLL. There is also a .NET wrapper class to make it easy for Microsoft's .NET family of languages (C#, Visual Basic, F#, etc) to interact with the controller. Sample programs illustrating all programming methods are included in the documentation and on the examples CD.

The ServoCenter also is equipped with sixteen digital I/O channels that have configurable internal pull-up resistors and power supply pins for connection to external digital I/O modules. There are also eight analog input channels that also provide power supply pins for connection to external analog input modules. They can be read in either 8-bit or 10-bit resolutions.

THE BALLOON AND THE COFFEE

To construct the gripper I first purchased a package of 100 10-in. party balloons from Amazon.com. They are manufactured by BSA and come in a rich assortment of colors (according to the package). I decided to go with Royal Blue for my gripper. For the coffee I chose Stop & Shop (a local food chain) Original Roast Ground Coffee that cost \$2.79 for 13 oz. It has a rich aroma and locks up like a dream when a vacuum is applied. And for what its



Picking up two gell caps is a piece of cake!

worth it does not produce a bad cup of coffee either.

The amount of coffee you place inside the balloon is somewhat critical. If you place too much coffee in the balloon it will become too rigid and the robotic arm will not have enough power to push down and envelop the object to be grasped. Too little coffee and the grounds will not lock up with enough force to hold the object. For my configuration, using the SG6-UT, I found that 1/2 cup of coffee worked well.

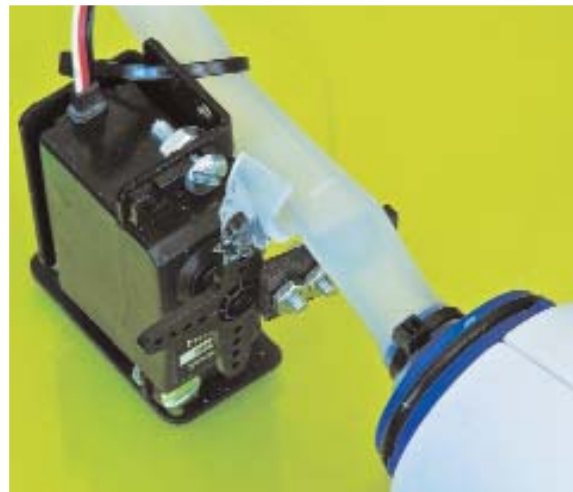
The easiest way to get the coffee into the balloon is with a small funnel. Place the end of the funnel in the balloon and spoon in the coffee a teaspoon at a time. Lightly tap the funnel and the coffee grounds will flow into the balloon with ease. But no matter how careful you are, expect to have coffee grounds spill all over the place.

To stretch the balloon and give it more room and flexibility I inflated/deflated it before loading the coffee.

GRIPPER MOUNTING

The mounting of the balloon gripper to the SG6-UT proved to be reasonably simple. I used a PVC 1 1/2-in. straight coupling. Inside the bottom of the coupling I glued a 1/8-in. length of 1 1/2-in. PVC pipe.

The balloon slips through the coupling with the bottom of the balloon protruding out the bottom about two inches. This leaves the rest of the balloon and some of the coffee still up inside the coupling. When suction is applied the coffee locks up and the gripper grips the object to be picked up and also the 1/8-in. piece of pipe inside the coupling. This secures the balloon and the object while it is being lifted. The whole assembly is attached to the arm's existing gripper using two 1/2-in. 4-40 machine screws that pass



Close-up view of the servo assembly that controls the release of suction. Note the small hole in the tubing that is used to allow air to pass back into the system.



The suction control system uses a Reynolds Handi-Vac, a relay board and the suction release servo.

through the coupling and then through the convenient parallel slots cut into each of the paddles of the gripper. Since the SG6's gripper is effectively locked in place I disconnected its servo from the controller.

THE VACUUM SYSTEM

To create the strong vacuum needed for the gripper I chose the Reynolds Handi-Vac for the source of suction. It is part of Reynolds Vacuum Food Storage System. Like the balloons, I bought it through Amazon.com and for under \$10. From the numerous negative comments on the Amazon page I would guess that as a Vacuum Food Storage System it could leave much to be desired. Fortunately as a suction source for my BalloonBot it worked flawlessly.

I made several modifications to the pump starting with the removal of the freezer bag attachment chamber to expose the suction input port. Over the port I placed a small piece of scotch tape with five tiny holes poked into it (using a sewing pin). This little homemade screen prevents any coffee grounds from being sucked into the delicate pump mechanism. Next I opened the pump housing and attached two wires across the built-in power switch. The pump is powered by 6 AA batteries. I drilled a hole in the case so that the wires could pass out of the pump and connect to my controller. Using one of the digital I/O ports on the ServoCenter and a 5 volt DPDT DIP relay I can turn on and off the pump under programmatic control. The optimal time for the suction pump to run and ensure a secure grasp is seven seconds.

The balloon is connected to the suction pump with a 24-in. length of White Silicone Tubing, with 1/2-in. ID, 5/8-in. OD, and a 1/16-in. wall. I also bought this on Amazon.com. This tubing is very flexible and can easily hold the vacuum generated by the pump. I used tie-wraps at strategic locations to connect the tubing to the pump and balloon as well as hold it in place along the spine of the SG6-UT arm.

The biggest challenge of the entire project was to come up with a mechanism that would release the suction when you wanted the gripper to release the object. To solve the problem I cut a small 1/16-in. hole in the tubing about an inch from the pump. I installed a Parallax Standard Servo next to and parallel to the hole. I glued a small "cap" (tube cross section, see photo) made from a piece of the tubing to one of the servo horns. I extended the adjacent servo horn by about an inch as well. When suction is being applied the servo holds the cap over the hole. To release the suction the servo spins counterclockwise which disengages the cap and pushes the tube up with the extended servo horn. The act of pushing the tube up elongates the small 1/16-in. hole



BalloonBot's grip is adaptive and strong. It has no problems picking up forceps.

and releases the suction.

All the components for BalloonBot including the SG6-UT, the Yost ServoCenter, and the vacuum system were all mounted to a 12 x 24in. sheet of florescent green Plexiglas. Why is the Plexiglas florescent green? It looks cool and I had a piece lying around saving a trip to Home Depot.

SOFTWARE

The Yost ServoCenter is connected to my PC via a USB cable. Like most serial interfaces the ServoCenter uses the FTDI chip and driver to create a virtual serial port. You can install the ServoCenter Control

Panel Utility to directly communicate with the ServoCenter controller board through the virtual serial port. The Control Utility has an easy to use user interface that allows you to control and configure each individual servo port, configure digital and analog ports, as well as program the built in Sequencer.

For my project I choose to communicate directly with the ServoCenter from a C# program using the Win32 DLL and .NET class wrapper. The application I wrote (called the BalloonBot Studio) allows the user to manually position the SG6-UT arm as well as move it to several preprogrammed positions for object pickup and release. I also implemented a complete pickup and release sequence to aid in testing the gripper with a variety of objects.

EXPERIMENTS

Once I had the gripper operational it was time to see what it could do. As I discovered the gripper is very adept at picking up and holding a variety of small objects. It easily picked up small tools like forceps and wire cutters. I tried a range of screws all the way down to a 1/2-in. 4-40 screw. It picked them all up with ease and in many case several at a time. Try that with any conventional gripper! Finally I tried it with two Tylenol caplets. Not only could it pick two at the same time placed in virtually any position, it never crushed or damaged them. Truly amazing!

My congratulations to Cornell University, the University of Chicago and iRobot for coming up with such an innovative and revolutionary gripper!

The source code and schematics for BalloonBot can be downloaded by typing in find.botmag.com/051104. ©

Links
BalloonBot YouTube video,
www.youtube.com/watch?v=quvRo9pvRdI

CrustCrawler, www.crustcrawler.com,
(480) 577-5557

Parallax, www.parallax.com, (888) 512-1024

Steve Norris website, www.norrislabs.com

Yost Engineering, www.yostengineering.com,
(888) 395-9029

For more information, please see our source guide on page 89.



"Yes, but can it grab a mouse?"