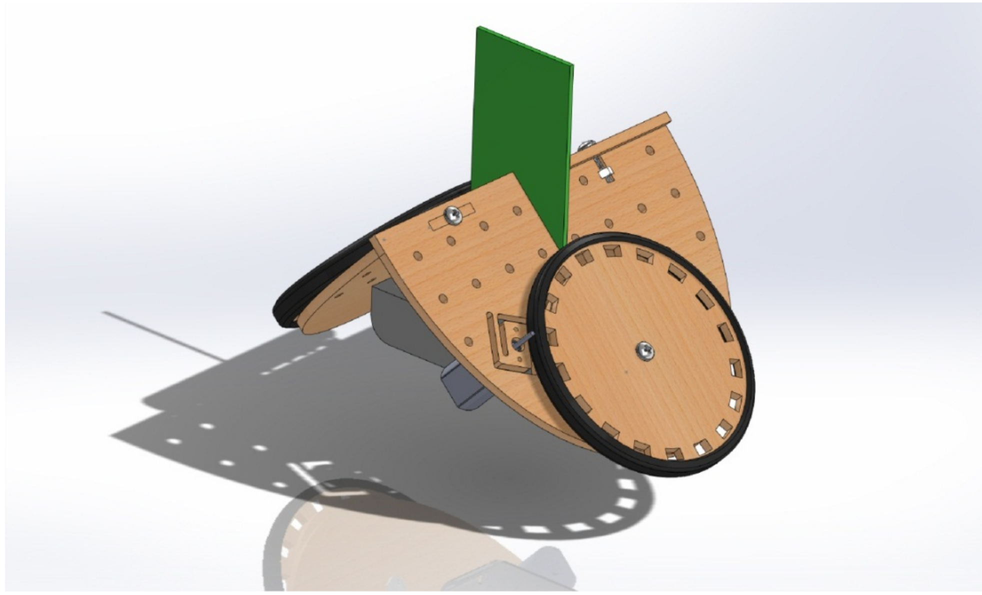
www.twilltech.com/DuckBot



1. The DuckBot is a compact robotic platform for STEM education. It balances on just two wheels eliminating the need for casters, or a steering mechanism. A simple rolling contact design eliminates all gears and the associated noise. Sensors may be used on the wheels for closed loop servo control of position. Although it does not require expensive sensors to balance, numerous sensors may be added. DuckBot offers this and a unique learning experience for a cost of about $10.

2. DuckBot is intentionally compact and inexpensive. Individuals and small teams can each make one from scratch, kit, or ready built.

- Standard Concepts:
  - Open loop motion via off board programming
  - Closed loop motion using wheel sensors
  - Blinking lights and sound
  - Response to light and sound
- Additional Concepts
  - Balancing by center of gravity placement (like a rocking chair)
  - Geometry concepts:
    - Projection of a circle is an ellipse
    - Projection of elliptical parts may be a circle (see top view)
  - Dynamic behavior
    - DuckBots wobble in response to sudden commands
    - Discovery: will a ramp up fix this?
    - Can it be exploited? Add other features to personalize your DuckBot
    - Introduction to digital filters.

DuckBots are the entry level robot in a family of robots developed by interns at Twill Tech. Each has a unique balancing technology. The DuckBot features a static balancing trick. A 1 meter tall “StickBot” walks while truly balancing on two feet is suitable for collegiate study. A 2 meter tall “TwillBot” balances on two in-line wheels. (Distinctly different from Segway robots which utilize two adjacent wheels.) TwillBot is intended for academic research in dynamics and control.

3. The DuckBot consists of just 6 basic parts that may be hand-cut, or preferably laser cut. In mass production parts could be injection molded utilizing simple tooling or die cut from heavy stock. A few standard 3mm screws, nuts, and balls are used to complete the mechanical assembly. The two motors are low cost Mabuchi DC motors from surplus stock but are readily available. Suitable substitutes are available in CD players, and toys of all descriptions.

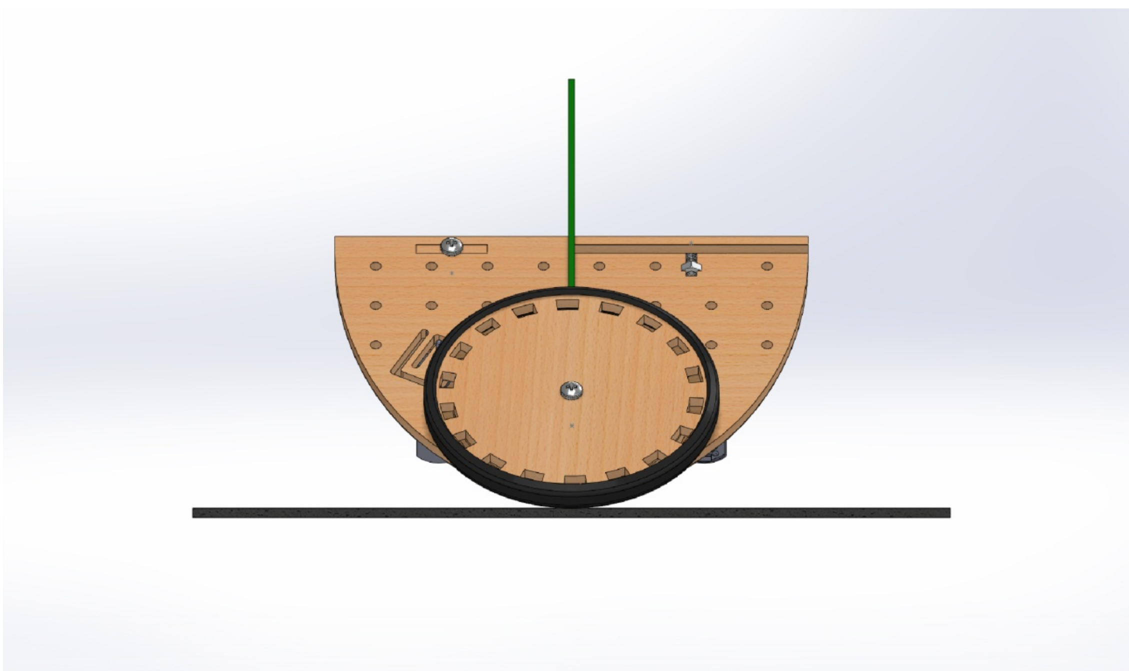
Previous revisions used "O-Rings" for the rolling drive. These always caused problems and are expensive. Instead tires may be formed from simple rings cut from bicycle inner tubes. The motors are mounted on flexures cut into the frame. This provides the small shaft loading required even if dimensions vary on the wheel and tire.

A complete parts list is included in appendix A below.

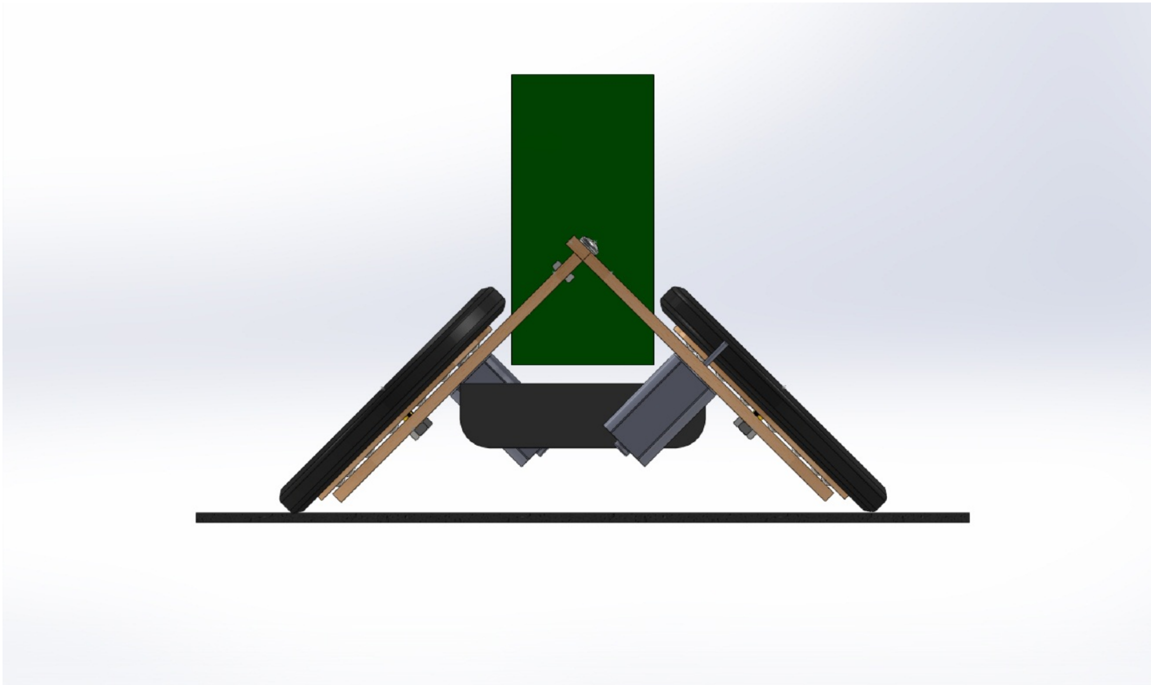
4. A number 2 Philips screwdriver is the main tool needed for assembly. Pliers, wire strippers, and a soldering iron will be desired by more advanced builders.

To minimize the cost of the printed circuit board assembly, a programming cord is needed. This may be shared by many students.

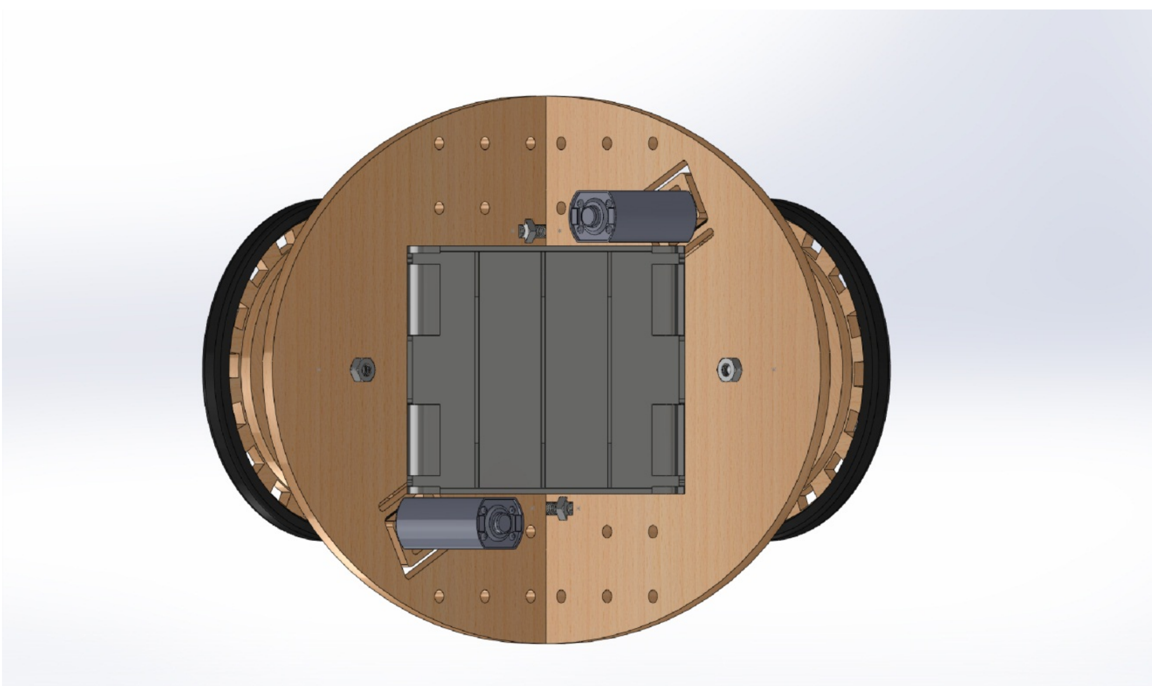
5.



From the side, the circular wheels appear to be ellipses. This gives the DuckBot its unusual balancing ability.



Front view shows the pair of wheels angled at 45 degrees to the floor. Even though the centers of the 80 mm wheels are just 28 mm from the floor, the center of gravity may be as high as 56 mm. A more advanced kit could use an adjustable angle to allow for a higher center of gravity.



This bottom view shows extra 3 mm holes that may be used for adding on extra features such as decorations and sensors. CAD files are available upon request in any format, including stl and dxf for fabrication.

6. DuckBots may be provided completely assembled or preferably in a kit for students to assemble. All parts assemble using a #2 Phillips screwdriver. No glue is required. Kits may include pre terminated features. For example, the motors could be provided with short wires and connectors that just plug into the mother board. Cost can be reduced by eliminating these connectors and other niceties. These will require some soldering. This is to be encouraged as students become more advanced adding sensors and indicators.

7. The bill of materials (BOM) provided shows an estimate of how the part cost could be reduced by mass production. Fabricating one or a few adds up quickly to about $100 each. But fabrication in just 1000 brings the price down to about $10.

The BOM contains just the bare minimum of components to minimize base cost. That said, extra pads on the PCB add no cost. So numerous extra devices will be supported and may be added later. These include, but are not limited to, light sensors, LEDs, wheel encoders, expansion ports and even room for a solid state accelerometer.

8. The Software will all be developed by students in the popular Arduino environment. This simple to use Integrated Development Environment gives students access to thousands of examples waiting to be found on the web. Courseware is readily constructed bringing students from blinking a light, through simple motions, to complex dynamic behavior.

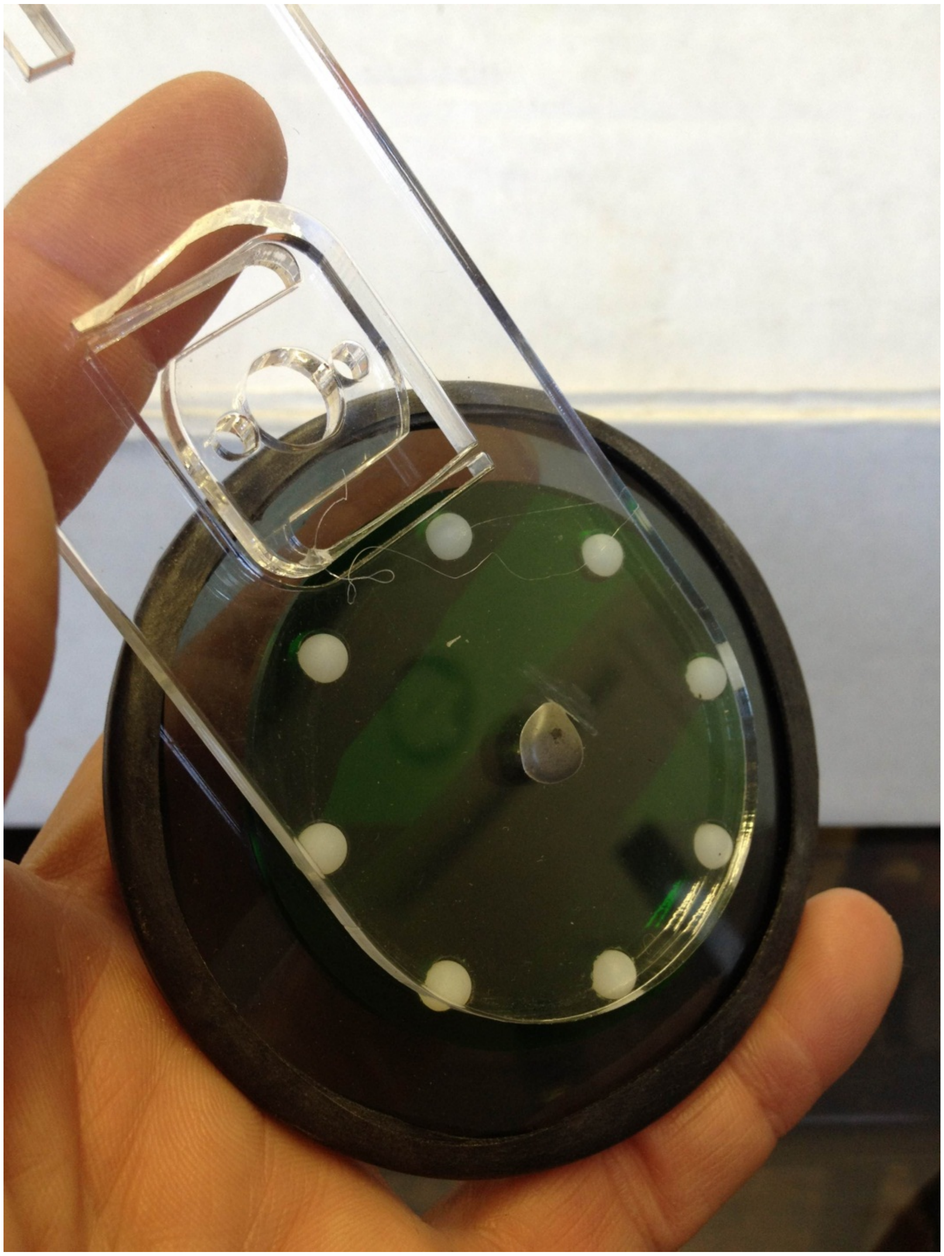
9. A few prototypes have been made over the last decade. Now that laser cutters and 3D printers are everywhere, this work is even easier. Alas, no complete DuckBot exists today. One could be fabricated quickly if needed.

A larger version standing 5 feet tall was fabricated and used extensively. Students immediately discovered the interesting dynamic behavior of this type of “Androbot” robot.

Androbot was an early personal robot commercialized in 1984. The interesting feature is the use of “canted wheels”. Normally, a two wheel robot would need to have the “center of gravity” well below the wheel center. This is the necessary requirement for it to balance. A costly alternative is to use a dynamically balancing scheme along the lines of a Segway personal transporter. As may be seen in the elevation illustration, when viewed from the side, the DuckBot wheels appear to be ellipses. The radius of curvature at the contact point may be arbitrarily large. So the center of mass may be considerably above the wheel center.

When a DuckBot accelerates, a for-aft oscillation is excited. Students quickly see that this oscillation can be controlled by tailoring the commands to the motor. This forms the motivation to learn about basic digital filters implemented in code. Extra resonant appendages may also be excited independently by dynamic control of the motion.

10. Below is a snap shot of a DuckBot wheel assembly. This prototype is realized in Plexiglas making the "Lazy Susan" bearings clearly visible. The motor mount with flexures is also evident. A strip of inner tube nicely conforms to the wheel forming a tire.



11. Videos will be posted at twilltech.com/DuckBot/videos as they become available.

Bill of materials

Group	component	Quatity/ Bot		price	at Quatity		price	at Quatity		Ext (Q1)	EXT (Q1000)		investment required
Electrical													
	ATMEGA 328	1		$2.77	1		$1.61	2000		$2.77	$1.61		$3,220
	PCB, bare	1		$2.00	1		$0.85	2000		$2.00	$0.85		$1,700
	LED	2		$0.43	1		$0.10	10000		$0.86	$0.20		$1,000
	Regulator, 5V	1		$0.97	1		$0.32	3000		$0.97	$0.32		$960
	resistors	6		$0.10	1		$0.00	5000		$0.60	$0.00		$0
	capacitors	6		$0.60	1		$0.19	5000		$3.60	$1.14		$950
	connector, 6 pin	1		$0.95	1		$0.20	1000		$0.95	$0.20		$200
Mechanical													
	bushing, brass	2		$ 0.20	1		$ 0.02	1000		$0.40	$0.04		$20
	motor	2		$ 2.00	1		$ 0.35	1000		$4.00	$0.70		$350
	balls, steel	16		$ 0.15	1		$ 0.01	1000		$2.40	$0.16		$10
	screws, M3x12	6		$ 0.03	1		$ 0.01	1000		$0.16	$0.06		$10
	nut, M3	6		$ 0.03	1		$ 0.01	1000		$0.16	$0.06		$10
	leg, laser Cut	2		$ 10.00	1		$ 0.75	1000		$20.00	$1.50		$750
	synchroniser, laser Cut	2		$ 10.00	1		$ 0.50	1000		$20.00	$1.00		$500
	wheel, laser Cut	2		$ 10.00	1		$ 0.50	1000		$20.00	$1.00		$500
	PCB Holder, laser Cut	1		$ 10.00	1		$ 0.25	1000		$10.00	$0.25		$250
Other													
	battery	4		$ 1.75	1		$ 0.25	100		$7.00	$1.00		$25
	battery case w/switch	1		$ 1.28	1		$ 0.50	1000		$1.28	$0.50		$500
	Packaging	1		$ 0.20	1		$ 0.05	1000		$0.20	$0.05		$50
										$97.14	**$10.64**		$11,005