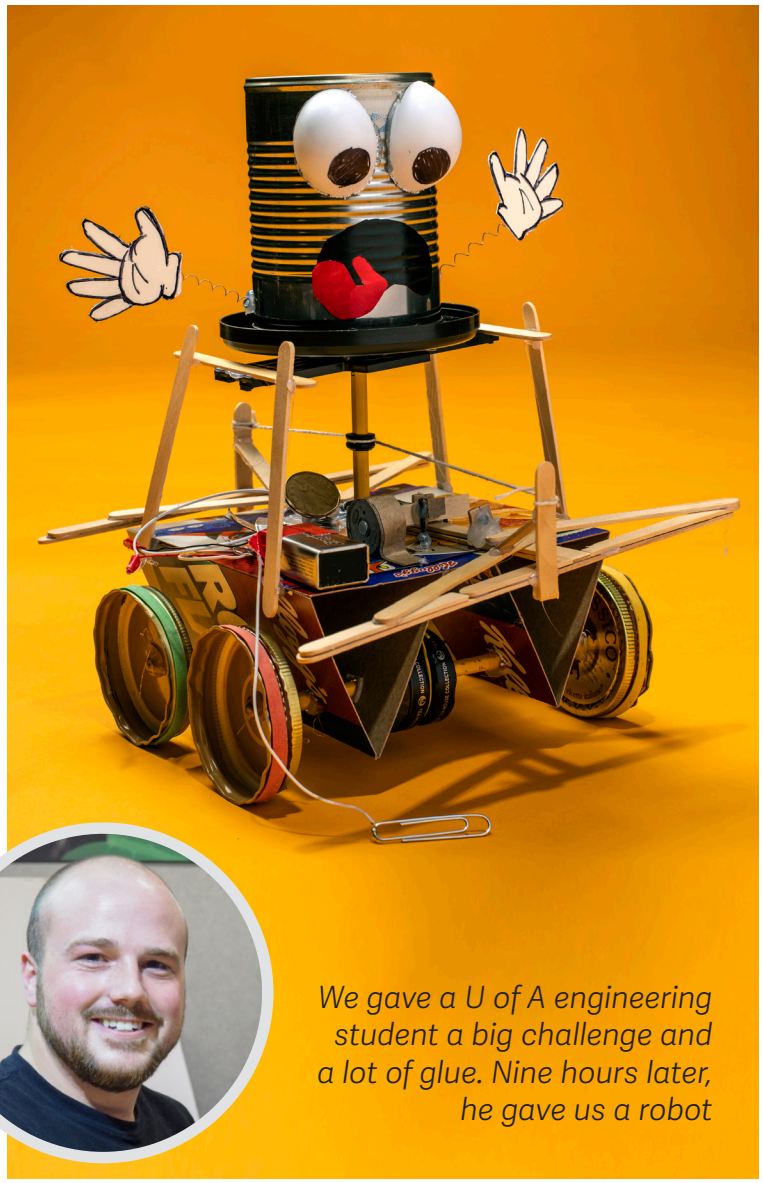
newtrail
UNIVERSITY OF ALBERTA
ALUMNI MAGAZINE

How to...

BUILD A ROBOT FROM HOUSEHOLD JUNK

(And it really works!) *Text and photos by Therese Kehler*



ROBOT PHOTO BY JOHN ULAN

We gave a U of A engineering student a big challenge and a lot of glue. Nine hours later, he gave us a robot

As office chatter goes, it was a typical day in the office of *New Trail* magazine. I wonder, one editor asked the room at large, if it's possible to build a robot from junk around the house?

And so it began. The magazine enlisted the talents of UAlberta engineering grad **Dylan Brenneis**, '16 BSc(MechEng), who came up with a robot that, unlike the average wheeled vehicle, could make a single decision (to turn and flee) based on a single input (bumping into something.)

"The robot is kind of your middle point between machine and intelligence," says Brenneis, who is doing his master's through the Alberta Machine Intelligence Institute and is a self-professed builder and tinkerer. (And he wears his hobbies on his sleeve: just check out his homemade watch with a built-in harmonica.)

Brenneis set aside a couple of hours to build the rudimentary robot out of household junk. Seven hours into the nine-hour build, Brenneis confessed he hadn't made this particular robot before. "Never," he said, laughing. "It's all uncertainty!"

Well, that plus a small motor, a big idea and a lot of glue.

Here's how Brenneis did it.

If you take the challenge, email clips or photos of your lil' robot in action to *newtrail@ualberta.ca* or tweet them to *@UAlbertaAlumni*.

PHOTO BY JOHN ULAN

MATERIALS

From DVD player (or similar)

- Disc support
- Motor with pulley
- Wires
- 3 screws
- 2 magnets
- AV port
- Circular rubber ring

22 Popsicle sticks (approximately)

Empty cereal box

Wire coat hanger

3 large paper clips

Aluminum foil

2 tacks

3 wooden pencils, unsharpened, eraser ends cut off

1 drinking straw (8 mm diameter)

2 small metal lids (such as from Snapple)

4 metal jar lids (such as from pasta sauce)

5 elastics (1 small, 4 large)

9V battery

Ping-Pong ball

2 springs from clickable ballpoint pens

Plastic lid (from 650 g yogurt tub or similar)

30-cm string

TOOLS

Screwdrivers (variety)

Tweezers

Glue gun (lots of glue!)

Ruler

Scissors

X-Acto knife (or similar)

Wire cutters

Pliers

Soldering iron

Duct tape

Electrical tape

Power drill and bits

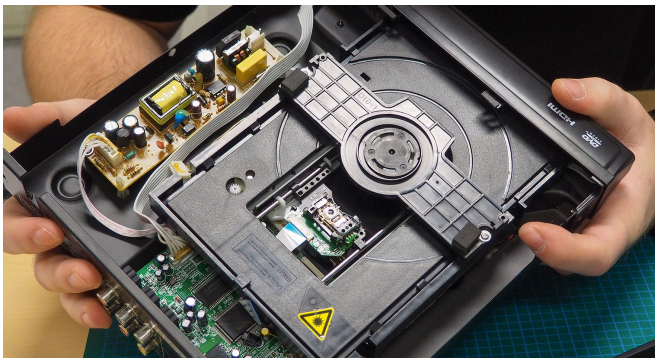
Hacksaw

Black permanent marker

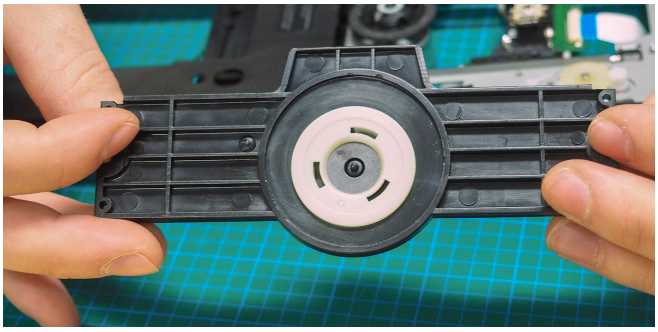
STEP 1:
STRIP A DVD PLAYER FOR PARTS

It's easy to buy parts at a hobby supply shop. But cannibalizing outdated electronics is more fun.

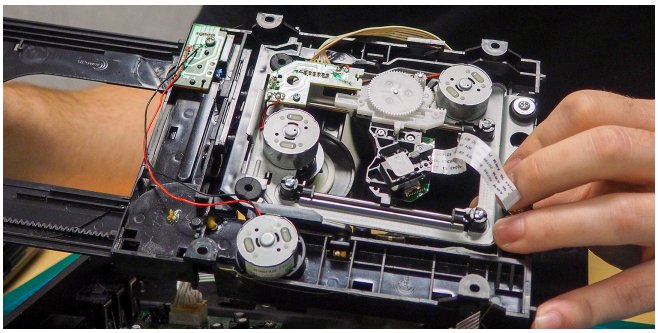
1. First, unscrew and remove the DVD cover. Inside is the plastic tray box where many pieces you'll need will come from.



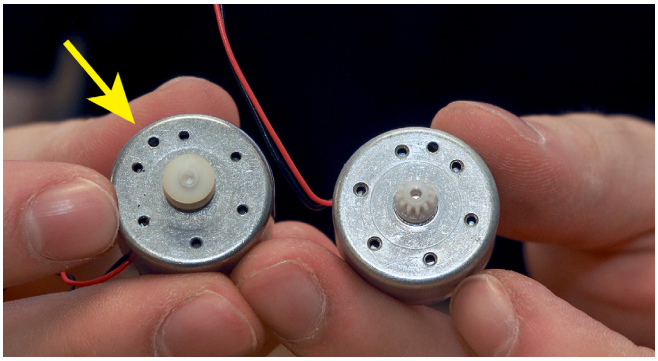
2. The **disc support** is a flat plastic piece with a spinning bearing in it. The shape will vary from one machine to the next. It will be attached to the top of tray box.

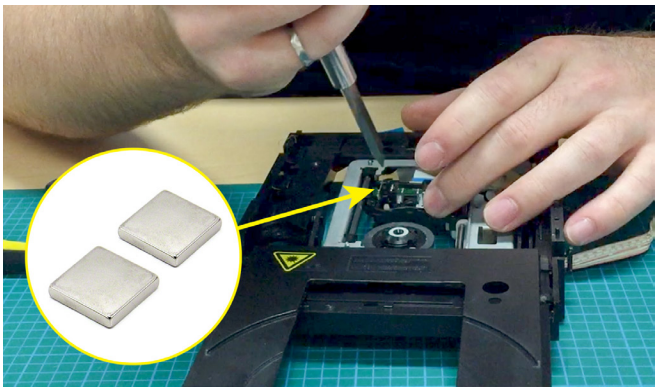


3. After removing the top of the tray box, the **motors**—silver, quarter-sized discs—will be visible.

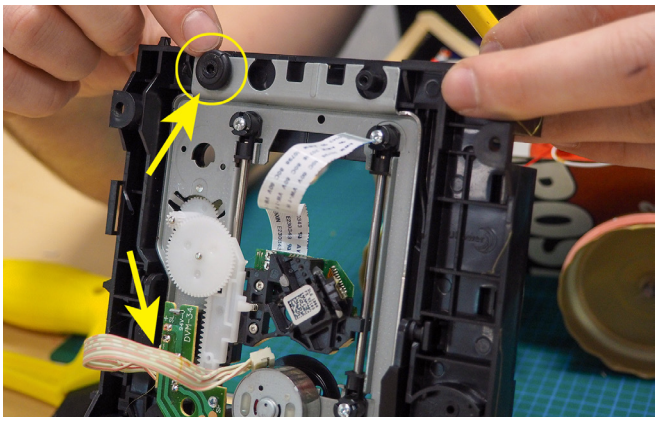


4. The plastic hub in the centre of the motors will either be a toothed gear or a pulley. This project uses the **pulley-style motor**, shown in photo on the left. Keep about 12 cm of wire attached.





5. Smaller than your pinky fingernail, two **neodymium magnets** are buried inside the optical lens.



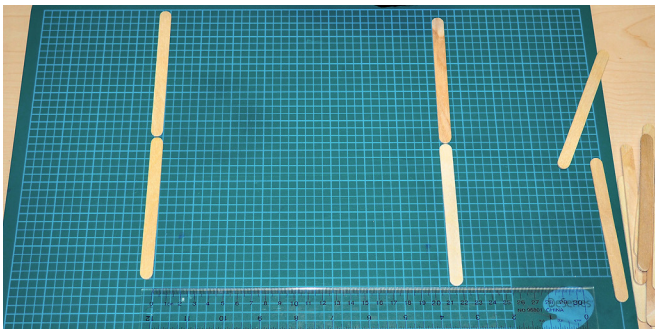
6. Pry a **circular rubber ring** from the foot of the disc drive and cut out a white plastic ribbon cable, which will provide wires.

7. Pry out an **AV port** (metal casing only) from the back of the player. Also keep **three screws** from anywhere on the machine.

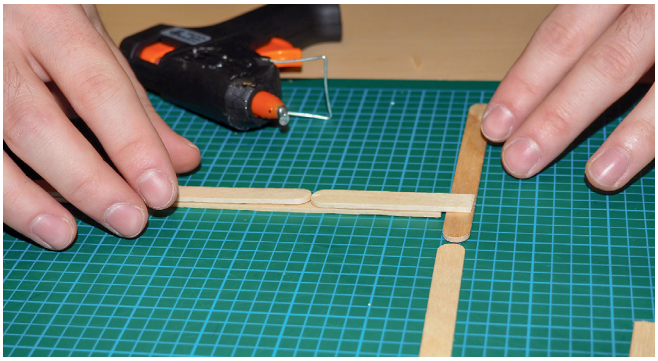
STEP 2:
BUILD A BUMPER

A robot needs a mechanism—a brain—to trigger an action based on input. This robot's mechanism is a bumper that slides to move a switch. The action it triggers is to reverse the spin of the motor based on the input: hitting a wall. The result? The robot changes direction.

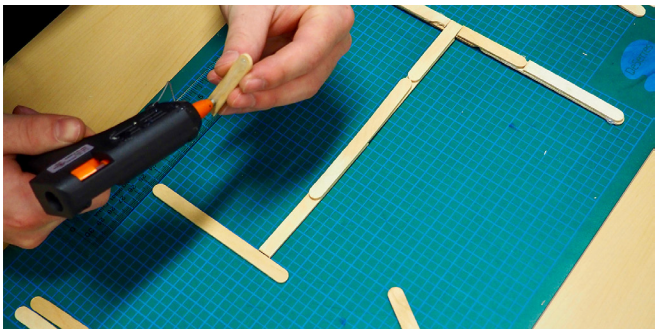
1. Lay two Popsicle sticks end-to-end. This will be the front bumper. Lay two more Popsicle sticks, 23 cm from (and parallel to) the first ones. Measure from the outside edges of the sticks. This will be the back bumper.



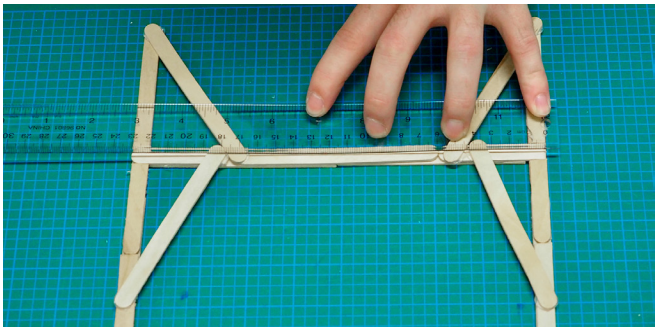
2. Lay a third line of sticks vertically joining the parallel, soon-to-be bumpers. Position this vertical line 2 cm off-centre of the parallel bumpers. The tips should almost touch the parallel sticks. This will be the **support bar**. Glue a second layer of sticks to the **support bar** in a running bond (a.k.a. bricklayer pattern). This layer will overlap onto the **bumpers** to secure them. For both layers, cut the sticks to fit as needed.



3. Glue a second layer of sticks to the **bumpers** in a bricklayer pattern. Cut the sticks as needed and fit them around the tips of the **support bar**.



4. Use four more Popsicle sticks to create angled braces that connect the **bumpers** to each side of the **support bar**. The braces will create a shallow triangle shape, with the apex about 6 cm from the **bumper**.

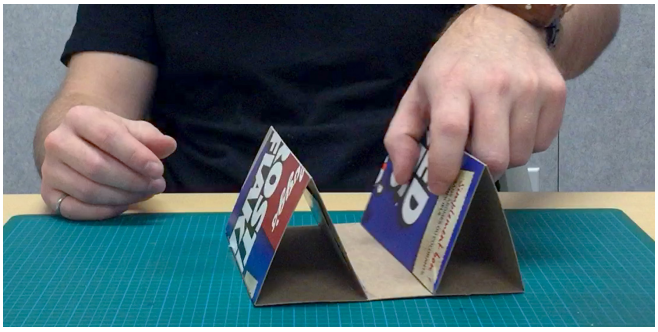


STEP 3:
CREATE THE CHASSIS

Frame material is a trade-off between weight and strength. Use lightweight cardboard from a cereal box and bolster it with a second layer to reinforce areas where the box was creased.

1. Cut cardboard into a rectangle measuring 16 cm x 48 cm. This is the **chassis base**. Mark four vertical lines on it: at 8 cm and 16 cm from each end.

2. Lightly score and then fold the cardboard along these lines, working from the outside edges inwards, to create two triangles, one at each end. Glue the edge of each triangle to the **chassis base**. These triangles are the **vehicle struts**.

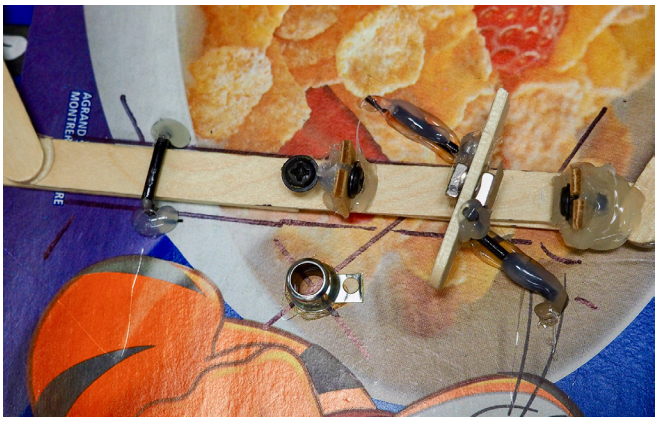


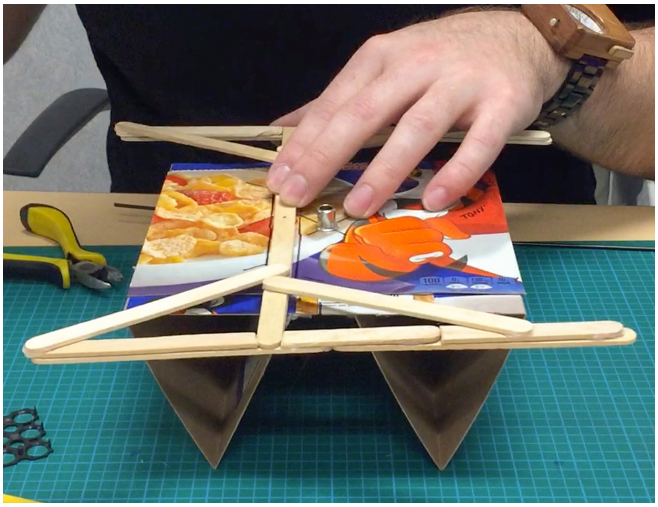
3. Once the glue is dry, flip it over, so the struts are pointing down, and glue another piece of cardboard to the flat part to make it stronger. This flat part is the **top of the chassis**.

4. Make an X from corner to corner on the **top of the chassis** to mark the centre and glue the metal **AV port** there.

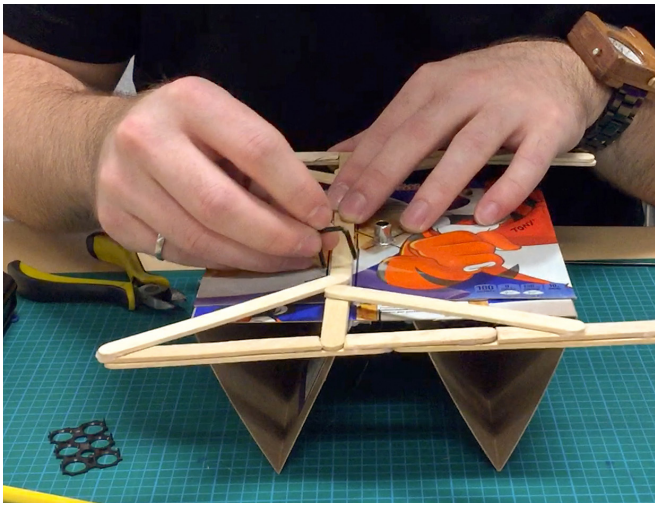
STEP 4:
MAKE THE MECHANICS

It took just a few screws, tiny magnets, bits of wire and a paper clip but the bumper mechanics were, by far, the trickiest to execute. This additional structure to the bumper, shown in this photo, ensures the bumper switch travels exactly as far as it needs to and stays in that position until it is intentionally changed. Without this, the robot would probably switch itself off or change direction just by jostling itself around.





1. Lay the **bumper** you built in Step 2 on the **chassis** so that the **front and back bumpers** and **vehicle struts** are at right angles. Trace lines along the length of the **support bar** on the **chassis top** to mark the position of the support bar.



2. Cut a 4-cm length of the wire coat hanger and use pliers to bend it into a squared U-shape **guide**, slightly wider than the **support bar** (i.e., slightly wider than a Popsicle stick). The **support bar** must be able to slide freely through the **guide**.

   Drill two small holes (a bit smaller than the diameter of the coat hanger wire) along the markings for the **support bar**. The width between them should equal the width of the **guide** you just made. Position these holes about 4.5 cm from one edge of the cardboard **chassis**.

3. Lay the **bumper** on the **chassis**, then press the **guide** into the holes. The **guide** should fit snugly and the **support bar** should slide easily. Once you are certain the **guide** is in the right place, secure it with glue underneath.

4. The **second guide** is different.

a. Cut two pieces of wire hanger, about 3 cm long, and bend them into L-shapes. The smaller leg of the L should be about the same width as a Popsicle stick.

b. Cut a 3.5-cm length of Popsicle stick. Find the middle of the stick and glue two magnets: one flat against each side.

c. Glue the short leg of one L-shaped wire flat against one side of the stick, slightly to the side of the magnet.

d. Glue the short leg of the other L-shaped wire flat against the other side of the stick, on the opposite side of the magnet.

e. *Note:* The longer legs of the L-shaped wires will be glued to the chassis, on either side of the **support bar**. Therefore, when gluing the legs onto the magnetic stick, be sure there is room—height and width—for the **support bar** to slide underneath it.

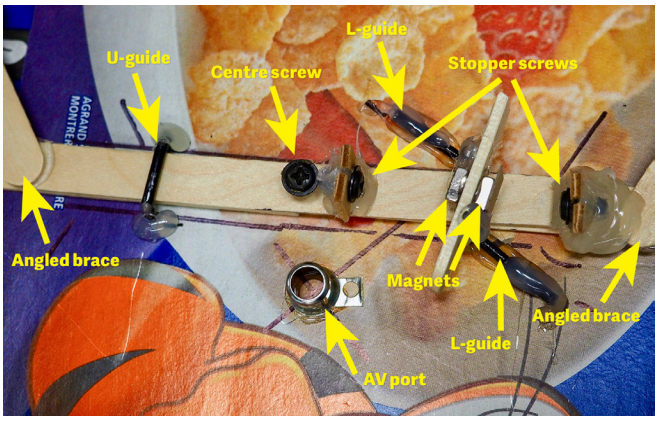
f. *Extra note:* Don't attach this piece to the **chassis** yet!

5. Drill a small hole into the **support bar**, near the middle. Partially insert a screw—don't tighten it all the way, it should not go all the way through the support bar. This is the **centre screw**.

6. Cut two squares of Popsicle stick. Put a screw through each square, tighten it and secure with glue on the pointed side. These are the **stopper screws**.

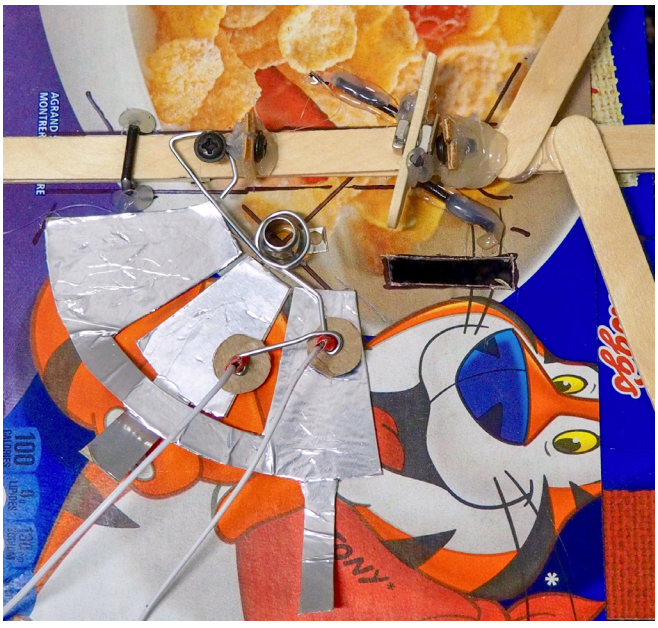
7. Glue the squares with the **stopper screw** vertically onto the support bar. Position the first about 1 cm inside of the angled brace furthest from the **U-guide**. The second will be glued about 4 cm away. The screw heads must face each other.

8. Set the bumper into a neutral position (i.e., centred) on the chassis. The L-shaped **guide** and magnet bar can now be glued to the **chassis**, positioned midway between the two **stopper screws**.

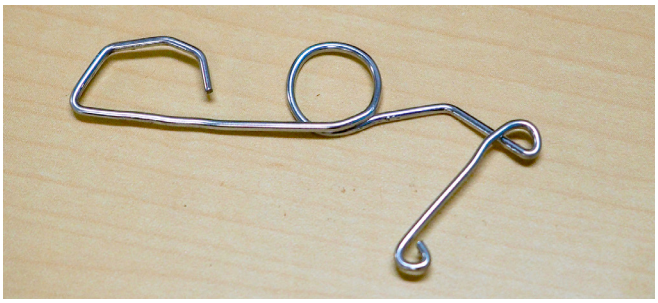


STEP 5:
ADD THE WIRES

This step creates an infrastructure of wires and metal surfaces to conduct electricity, as well as ingenious foil surfaces that work with the electrical switch. The end result will look like this photo.



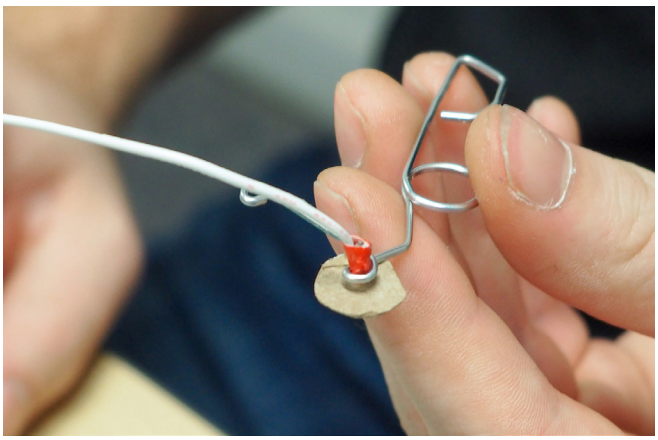
1. Straighten a heavy-duty paper clip. In the middle, form a loop that fits around the **AV plug**. On one end, form a big hook that will fit loosely around the **centre screw** in the **support bar**. Bend the other end will be bent into two small loops, with about 2 cm between them. Refer to photo for shape. This is the **electrical switch** that changes the flow of the current.



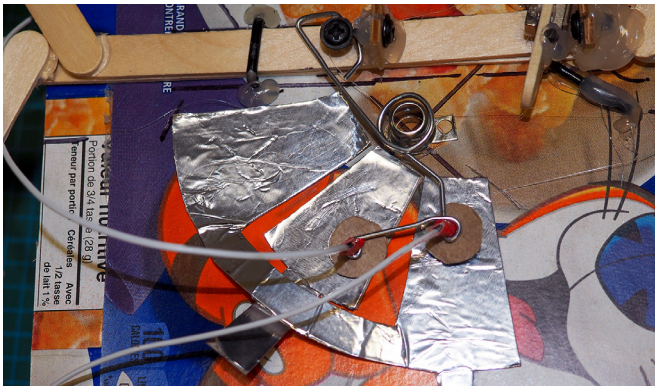
2. Cut two pieces of cardboard to be the same size as the head of a metal thumbtack. Take two tacks and push one through each piece of cardboard.

Pull two pieces of wire from the ribbon cable and expose the ends. Solder one wire end to the pin-end of a tack. Secure the wire to the pin with a tiny piece of duct tape. Repeat with the second tack and wire. The tape and cardboard serve to insulate the tack from the paper clip and avoid shorting out the battery.

Push the tape-wrapped pins through the small loops on the **electrical switch**. The metal tack head should be on the bottom.

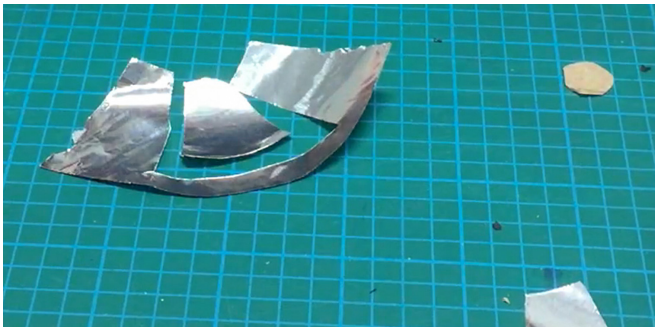


3. Set the **electrical switch** (with inserted thumbtacks) onto the **AV port** (on top of the **chassis**). The middle loop goes onto the **AV port**; the hook wraps around the **centre screw**; the end with the thumbtacks rests on the **chassis**. Slide the support bar back and forth to see how the thumbtacks change position. This photo shows how the switch is positioned onto the chassis, with the foil contacts to be made in the next steps.



Now, we'll make foil-covered cardboard surfaces that will contact the thumbtacks.

4. First: cut some aluminum foil shapes (isosceles rectangles, to be exact) that will guide the size and shape of the final version. In the photo, the small cardboard circle on the right is the size of the thumbtack head. Note that the angles allow it to form a fan-shape.



5. How do you know if they are the right size? Take a look at this photo. Note that two thumbtacks in the **electrical switch** simultaneously touch the middle plus one outside piece. When the switch moves, the other tack will touch the middle piece.

6. Now that you know what you are building, cut the shapes from cardboard, then glue aluminum foil to one side. Note the addition of **the tabs** protruding from the two pieces. These become part of the **on/off switch**.

7. Glue the two pieces onto the **chassis. The middle piece goes down first**.

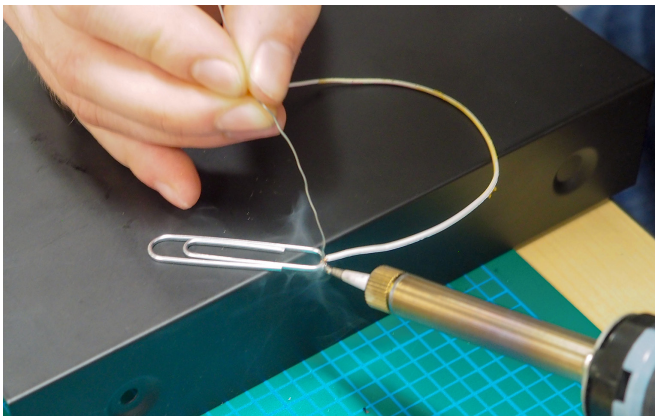
8. Pull two more pieces of wire from the ribbon cable and expose the ends. Solder a wire to each of the two remaining paper clips. (If you don't have a soldering iron, wrap the wire around the clip and secure with duct tape.)

   Here's what you just accomplished:

   The wires from the paper clips will be connected to the battery's two terminals. The paper clip running to the **positive terminal** is clipped onto the tab of the single template, charging this surface. The wire connected to the **negative terminal** is clipped to the tab of the doubled template, creating the grounded the surface.

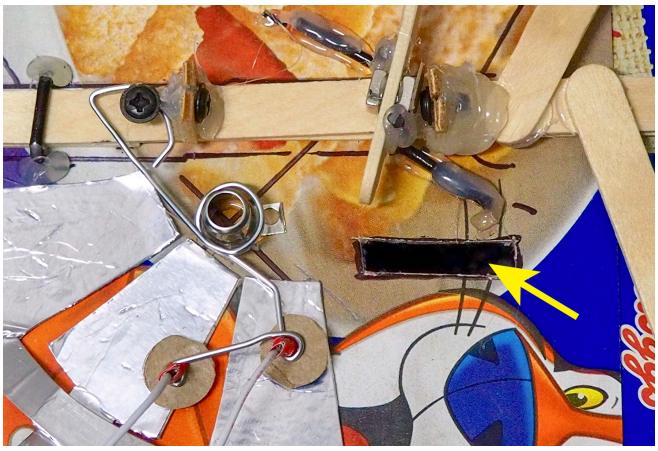
   The cardboard acts as insulation between the two charged foil surfaces.

   The thumbtack wires will eventually connect to the **motor**. When the thumbtacks change position, the electrical polarity changes and the **motor's direction** will reverse.

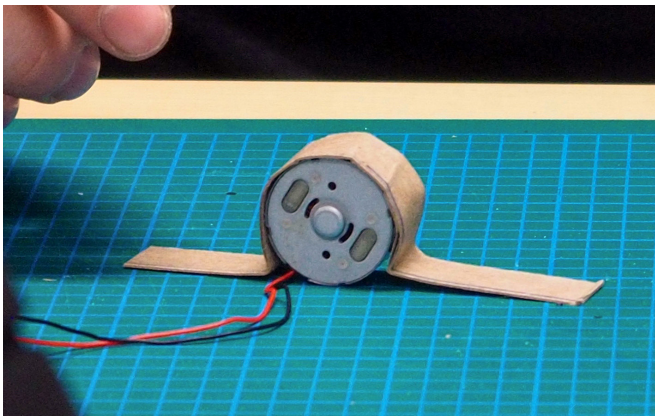


STEP 6:
INSTALL THE MOTOR

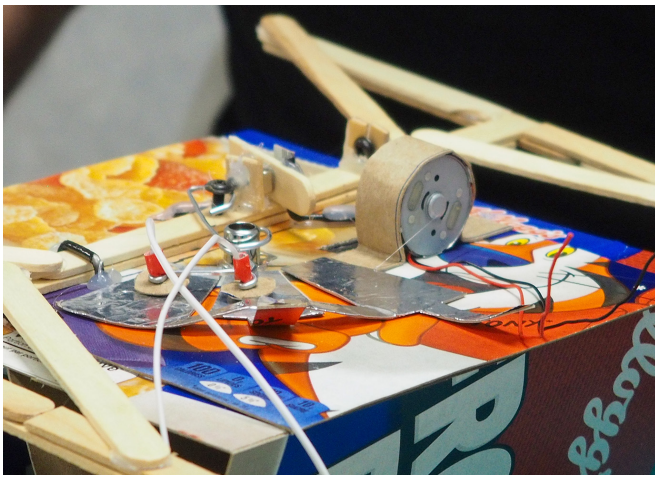
The **motor** is only useful if its spinning action is translated into robot action. In this section, we mount the **motor** and start preparing to build the **drive train**.



1. Cut a slit into the top of the **chassis**, kitty-corner between the magnetized **guide** and the **AV port**.



2. Cut a cardboard strip that is the width of the **motor**, long enough to wrap around its circumference plus a bit extra. Glue the cardboard to the **motor's**, not quite fully encircling it. There will be tabs extending on either side.



3. Glue the tabs to the **chassis top**. Make sure the **motor** is positioned with its pulley directly over the slot.

STEP 7:
MAKE THE WHEELS READY TO ROLL

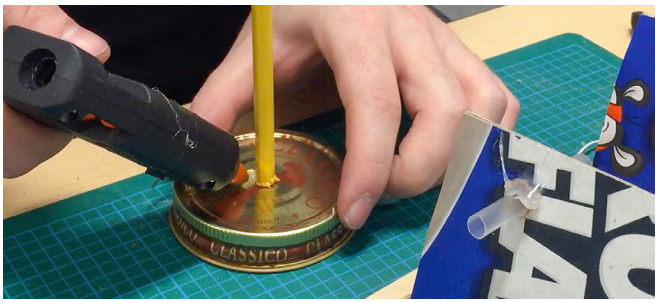
The undercarriage uses lots of glue, a drinking straw for the **bearings**, pencils for **axles**, jar lids for **wheels** and elastics for **treads**.

1. Push a pencil all the way into the straw to make sure it fits and can turn within it. Split the straw lengthwise if it's too tight to allow the pencil to move. Remove the pencil, then cut the straw into four pieces of equal length. These will be the **bearings**.

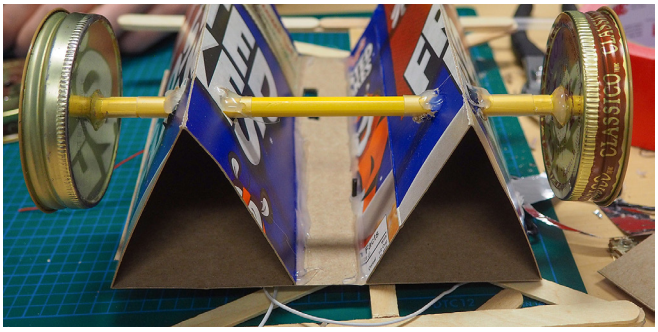
2. Drill holes through the struts for the **bearings** and pencil **axles**. Loosen them slightly by wiggling a pencil into them.

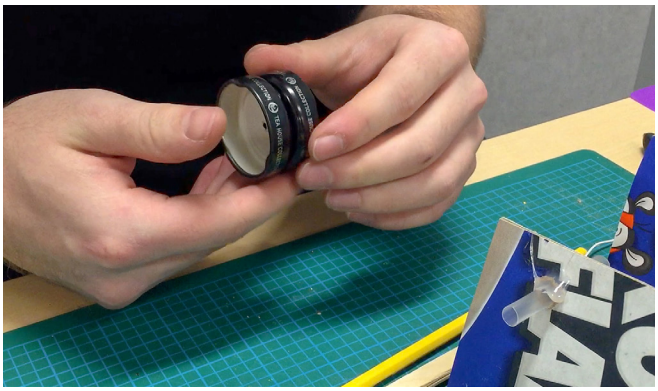
3. Push a straw **bearing** into each hole and glue into place. The **bearings** should stay put but the pencils **(axles)** pushed through them should turn freely.

4. Drill holes in the four large jar lids, which will be the **wheels**. The holes need to be slightly smaller than the pencil to hold tight. Push a pencil into one **wheel** and glue it on both sides.

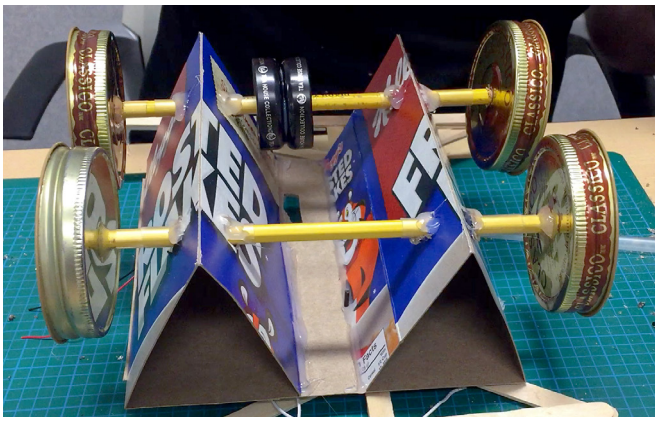


5. Push the pencil through the **bearings** of the **struts** that are furthest away from the **motor** on the chassis. Slide the second **wheel** onto the **axle** and glue it firmly.



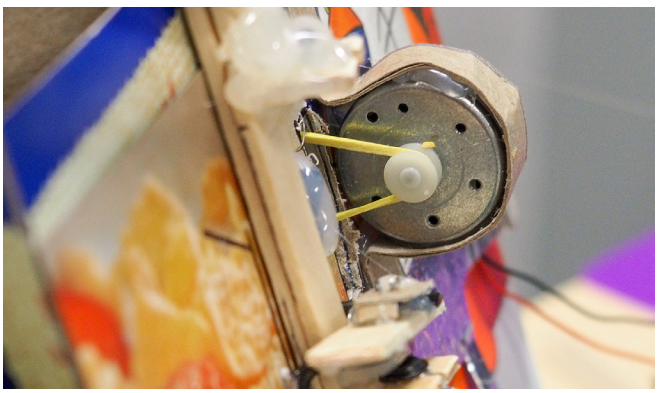


6. Build the **drive train** before installing the second **axle** and **wheels**. Glue the tops of the two small metal lids together. Drill a hole through the glued-together lids, big enough for a pencil to fit snugly.



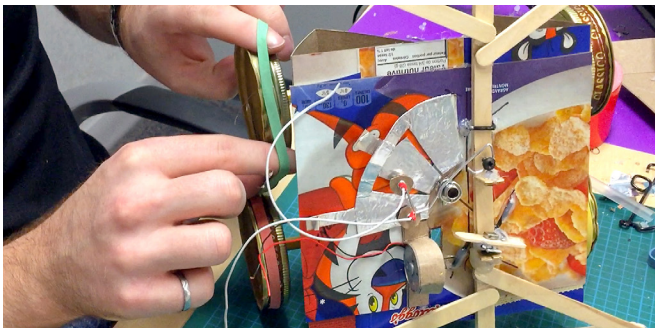
7. Now build the second **axle** and **wheels**, incorporating the **drive train**. Push a pencil into a **wheel** and glue it on both sides. Push the pencil through the bearing on a strut under the **motor**, then through the **drive train**. Slip the pencil through a small elastic (about 4 cm in diameter), then finally through the bearing on the other strut. Slide the second wheel onto the axle and glue it firmly.

8. Pull the elastic up so it encircles the **drive train**. Glue the **drive train** into place on the pencil.



9. Stretch the elastic through the slot in the **chassis** and loop it over the pulley on the **motor**.

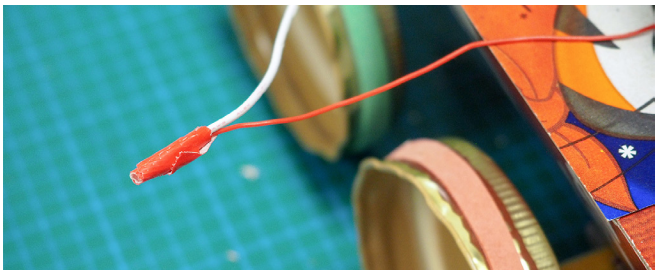
10. Wrap the large elastics around the tin lids to create **tire treads**.



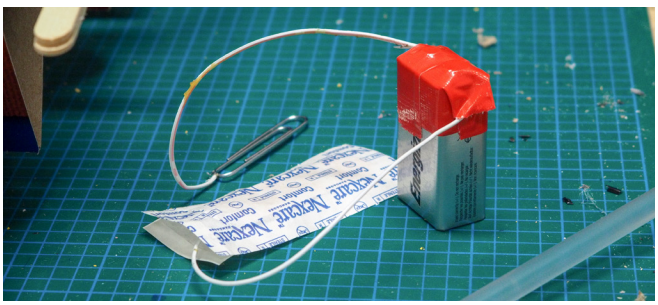
STEP 8:
ADD POWER

With a twist of wires and a bit of electrical tape comes the moment where you find out if you've hooked things up correctly.

1. Connect the thumbtack wires to the **motor** wires. Twist is OK; twist and solder is better. Tape to prevent short circuits.



2. Connect the paper clip wires to the battery terminals. Use duct tape to ensure they don't fall off. (We used an envelope from a bandage to cover one of the paper clips to prevent the clips from touching.)

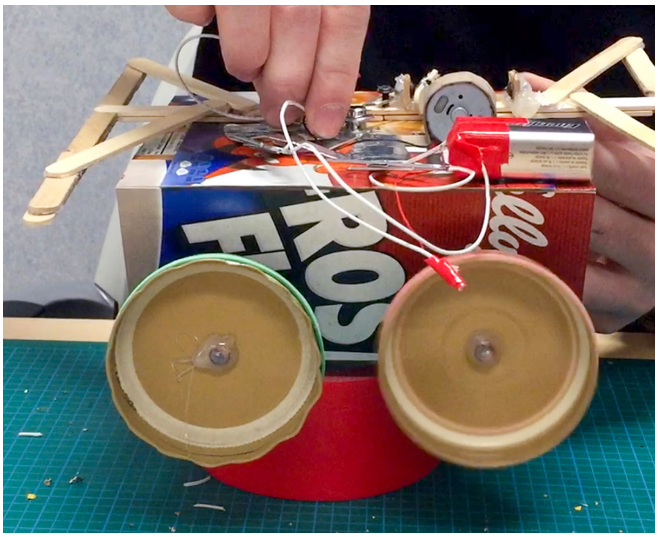


3. Glue the 9V battery onto the **chassis top**.

4. Test the connections: Lift the **chassis** so its wheels don't touch a surface, then connect one paper clip at a time to the tabs on the tinfoil contacts—positive terminal to the centre surface, negative terminal to the outside surface. When the second clip is connected, the wheels should spin.

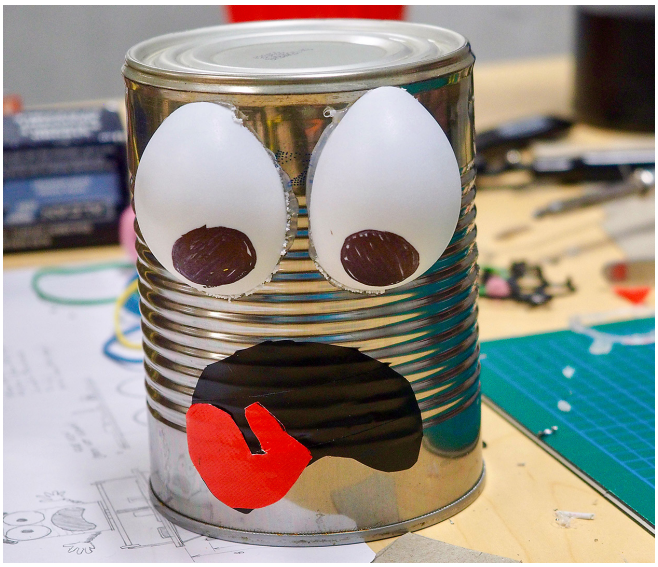
5. Test the switch by sliding the **bumper** back and forth, moving the thumbtacks from one set of tinfoil contacts to the other. When the tacks move, the **motor** should reverse direction.

6. If the tacks aren't making solid contact, you can weight them down. Brenneis glued a loonie and a quarter to one of the tacks as ballast.

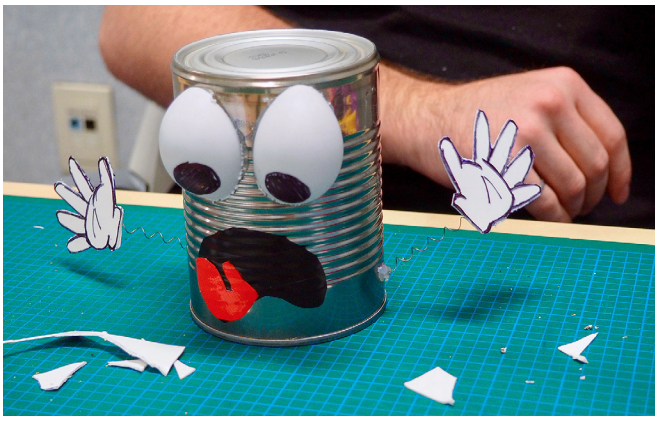


STEP 9:
ADD SOME PERSONALITY

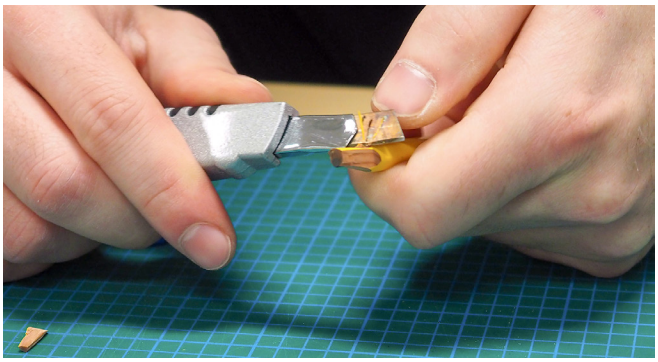
Once you have tested the connections to make sure the wheels spin, make your robot loveable. We used a tin can body, Ping-Pong eyeballs and springy arms. The body sits atop an elevated platform made from a plastic lid and the **disc support**. Brenneis added a twist—a piece of string stretched between bumpers that rotated the platform, ensuring our robot always looked where he was going.



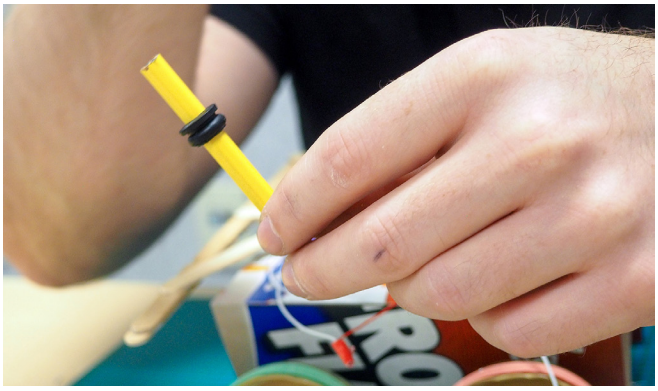
1. Carefully cut a Ping-Pong ball in half and use a black marker to draw **eyes**. Glue them to the can. We used black electrical tape and red duct tape to fashion a **mouth** and **tongue**.



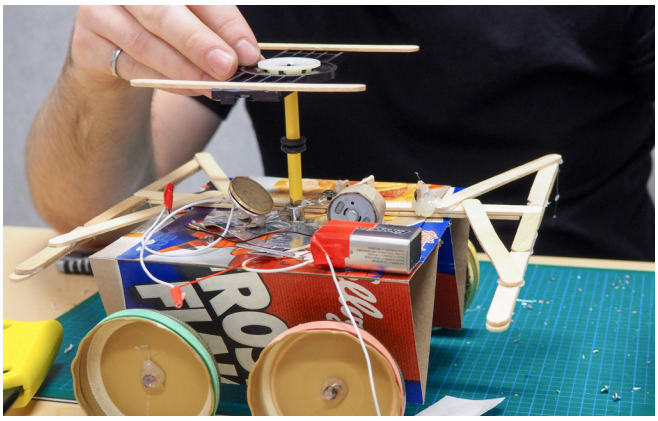
2. Stretch out the springs from the ballpoint pens. Make **hands** from white cardboard and glue to the springs. Glue the springy **arms** to the tin can **body**.



3. Cut a pencil to 8 cm and partially sharpen one end, just enough so it fits inside the **AV port** that is glued to the top of the **chassis**.



4. Slip the pencil into the circular rubber ring that you got out of the **disc drive**.

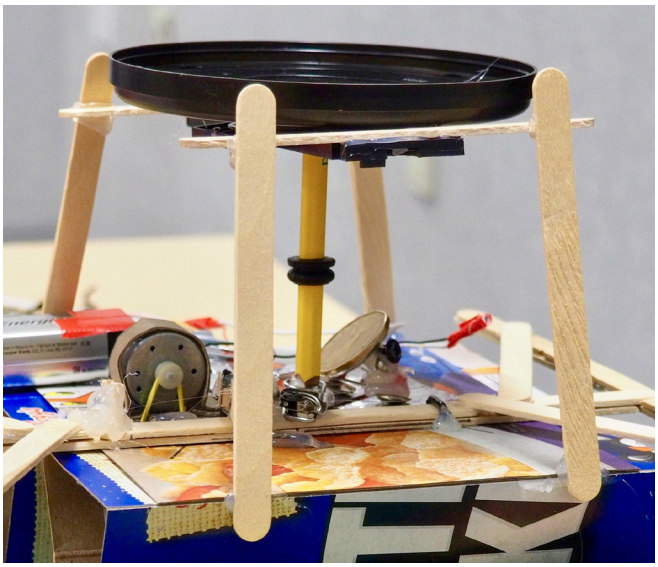


5. Place the **disc support** so the spinning bearing faces up. Glue two Popsicle sticks to the ends. From above, this unit should resemble the letter H.

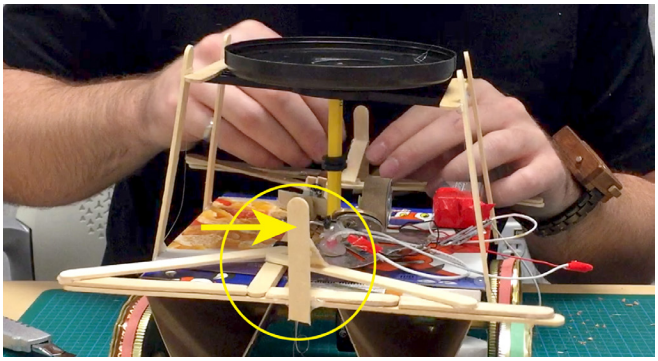
6. Glue the unsharpened end of the pencil into the hole on the bottom of the **disc support**. Place the sharpened end into the **AV port** on the **chassis**. This is the start of the **platform**.

7. Glue the spinning disc to the centre of the top-side of the yogurt lid. (We had to build up the height a bit by gluing additional layers of cardboard between the **disc support** and the plastic lid.)

8. Glue two Popsicle sticks so they extend vertically from the side of Popsicle sticks on the **platform** to the side of the **chassis**. Repeat on the other side. The **platform** is now stable but the yogurt lid should spin freely.

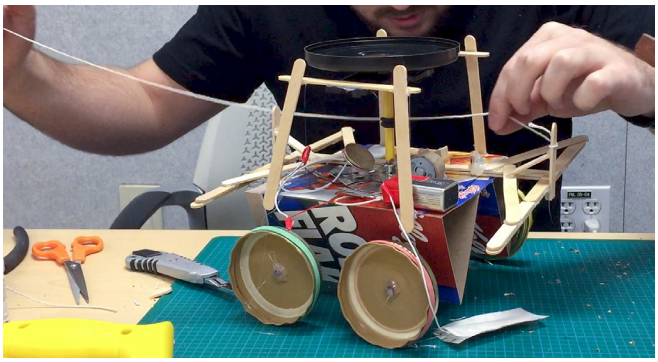


9. Cut a Popsicle stick in half. Glue each half onto the centre of each **bumper** so that it points up, then use the other half as a support brace to hold it in place.



10. Once these are secure, carefully tie a piece of string from one vertical bumper stick to the other, looping it around the pencil the groove of the rubber ring on the pencil. Ensure the string is taut. Now when the **bumper** hits something, the platform will rotate 180 degrees.

11. Finally (yes, finally), glue the tin can **body** to the top of the plastic lid on the platform.



STEP 10: GO!

We'd been building for nine hours when Brenneis steadied the robot for its first voyage. Wheels spinning, arms waving, the robot took off, hit the wall and then, just like the engineer planned it, reversed direction, its tin-can body whipping around to face us. The robot came careening back.

"This is the first time that I've planned something out completely on paper and it worked," Brenneis said. "It actually worked!"