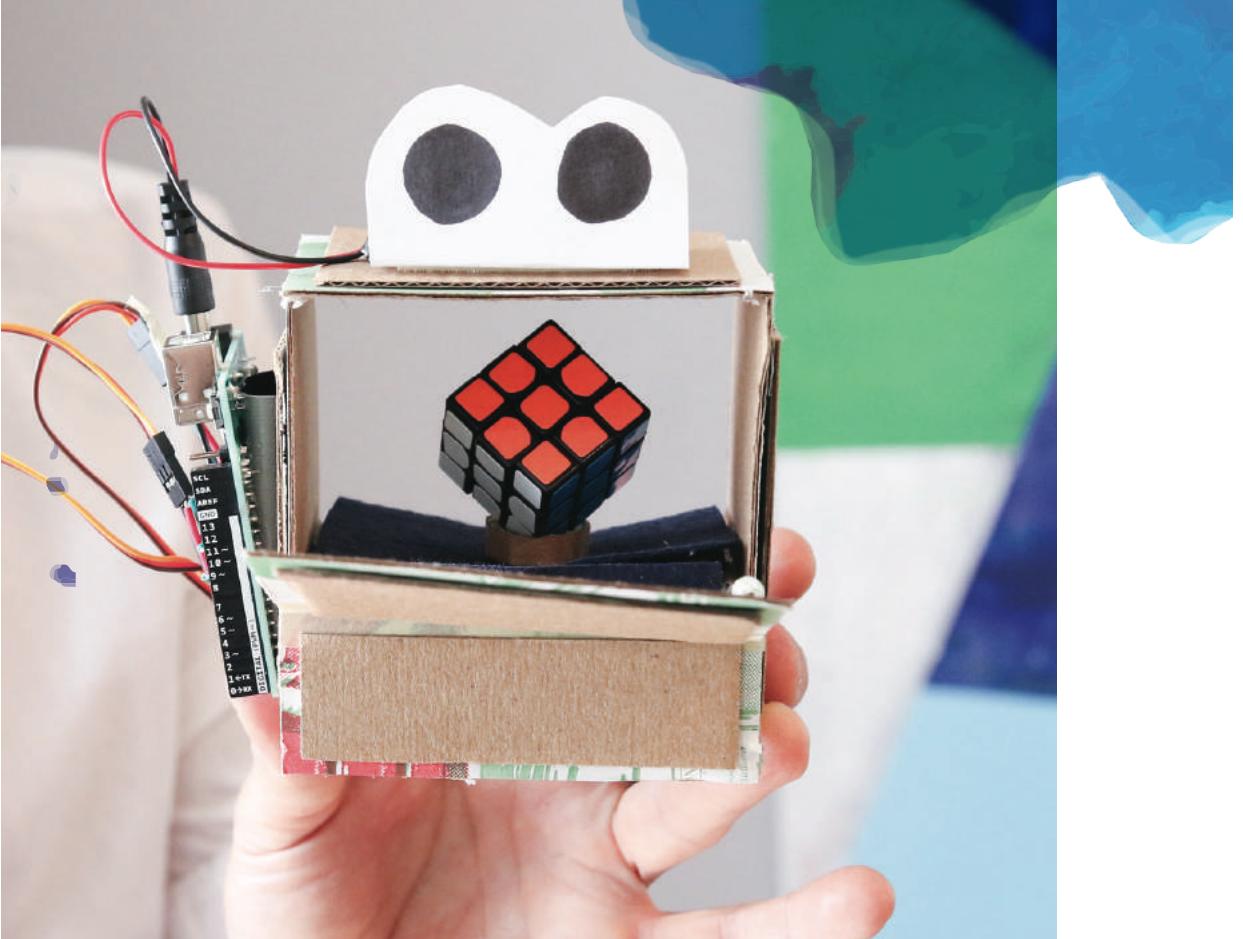




# # CUBER GOOBER

The Rubik's Cube was invented by sculptor Erno Rubik in 1974, and aptly enough for our purposes, he originally called it the Magic Cube. Names aside, imagine creating a piece of art that would one day evolve not only into an iconic toy but also a worldwide sport! It's been said that it took Rubik himself an entire month to solve his puzzle upon first creating it! There are so many ways the cube can be mixed that the chance you might accidentally solve it is nearly impossible. Now, decades later, over 350 million cubes have been sold worldwide, and the world record time to solve a Rubik's cube is under four seconds! That is pretty amazing... memorizing movements and recognizing patterns of color to achieve a solution so fast.

Adobe Stock-Eva Kali



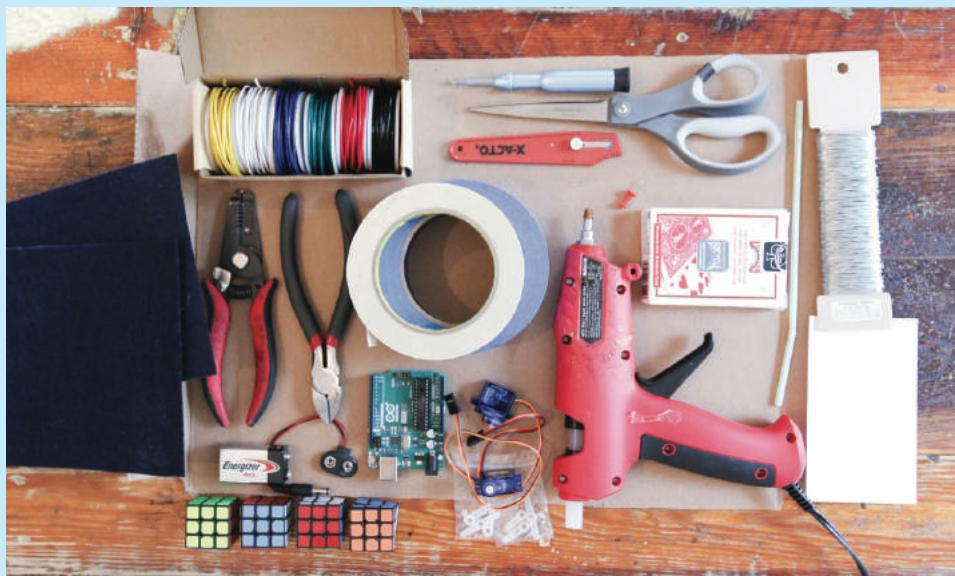
In the magic world, the cube has become a fixture in many magicians' acts, too. Some magicians have made whole careers centered around Rubik's Cube magic! It's a powerful puzzle and a powerful prop, and with this next project, we will create a *robot* that performs with it. We will adapt traditional principles of magic with robotics as a fun exercise to see how a human and robot can work together in rhythm to fool an audience. My favorite part of this build is how compact and strong the magic is! The whole thing is self-contained, and the effect is clear and easy for an audience to follow.

## THE EFFECT:

The performer shows all sides of a small, mixed Rubik's Cube and introduces a small cardboard robot. The cube is placed inside the robot. The robot opens and closes its "mouth" several times, finally revealing the cube once more, but this time it's solved! The solved cube is then taken out of the robot and shown on all sides.

## MATERIALS & TOOLS:

- 4 mini Rubik's Cubes
- 1 piece of cardboard (a pizza box is a good source!)
- 1 sheet of stiff black or dark felt
- 1 playing card box
- 1 index card
- 1 roll of floral wire
- 1 plastic drinking straw
- 1 push pin thumbtack
- 1 hobby X-Acto knife
- 1 Arduino UNO
- 2 micro servos
- 1 9V battery plug
- 1 9V battery
- 6 male to male wires (or 22 gauge solid core wire)
- Hot glue gun + glue
- Scissors
- Painter's tape
- Masking tape
- Small screwdriver
- Wire cutter and stripper
- Pliers
- Ruler





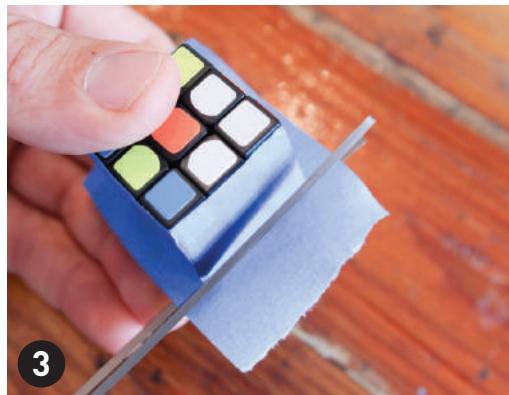
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## THE BUILD:

- Take *one* of the four small Rubik's Cubes, and mix it up (Figure 1). (Notice that as you mix it, the center square of each side never changes. This is important to keep in mind for later.)
- After the cube is thoroughly mixed, hold it between your thumb and fingers, and turn it so you only see three sides of the mixed-up cube (Figure 2).
- Cover those three sides with painter's tape, removing any excess tape with scissors (Figures 3 and 4).
- With the aid of an X-Acto knife, carefully remove any stickers from the un-taped sides that *do not match* the center sticker for that side. Leave the center stickers and any stickers that match that side's center sticker in place. Be sure not to damage the stickers. Set the stickers aside for now, saving them for a later step (Figures 5 and 6).



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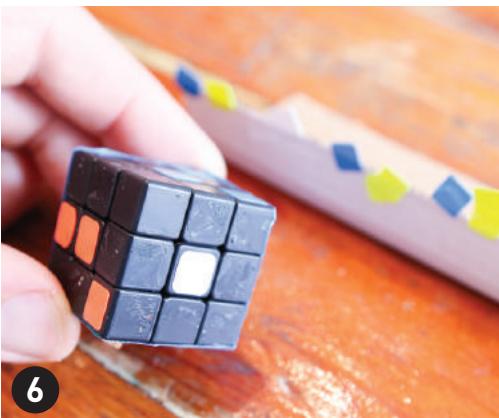
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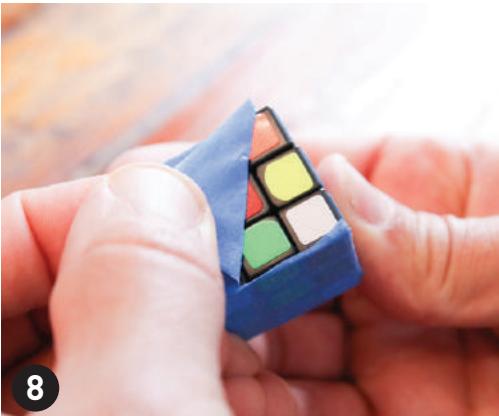
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- Now, put the stickers back on the un-taped sides, filling in each side with just one color each, so those three sides of the cube appear to be “solved.” Be careful to position each sticker as straight as possible, so nothing looks altered! (You will need to take some additional squares from a second cube to complete each of the three sides, and some of the originally peeled stickers will be left over (Figure 7). You can discard those.)





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- Carefully and slowly remove the painter's tape from the other sides (Figures 8 and 9).

Let's pause the build for a moment. Hold the cube with your thumb and fingers, so that only three mixed sides are visible to you (Figure 10). Now, turn the cube so that only solved sides are visible to you (Figure 11). This movement is the core of the illusion we are creating! By spinning the cube 180 degrees on its diagonal axis, you can change an apparently mixed cube to an apparently solved one. But how can we make a servo do this for us? And how can we make it look like magic? Let's get back to the build!



- Take a thumbtack and carefully twist and push the pin into the corner of the cube. Make sure the corner you select is one that simultaneously touches at least one



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mixed side and at least one solved side (Figure 12). Take your time with this to ensure that the hole you create is straight.

- Take out a one-armed servo horn and a mounting screw from your micro servo package.
- Mount the screw in the second hole from the center of the servo arm, screwing it in from the underside of the servo arm (the underside is the side that has the hole protruding.) We want the screw to be all the way in first (Figure 13), and then unscrew it back out so only the very tip of the screw is peeking out on one side (Figures 14 and 15). By doing this, we are pre-threading the hole for easier mounting later.

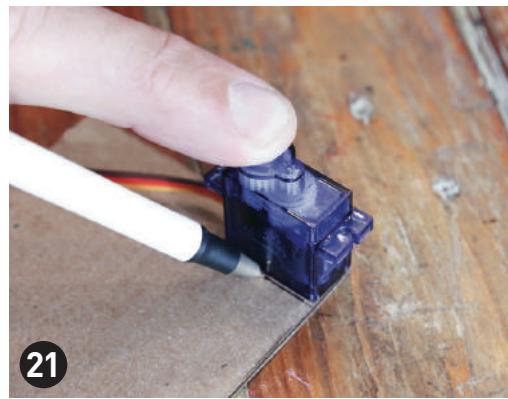


- Place the tip of the screw into the hole you created in the corner of the cube (Figure 16).



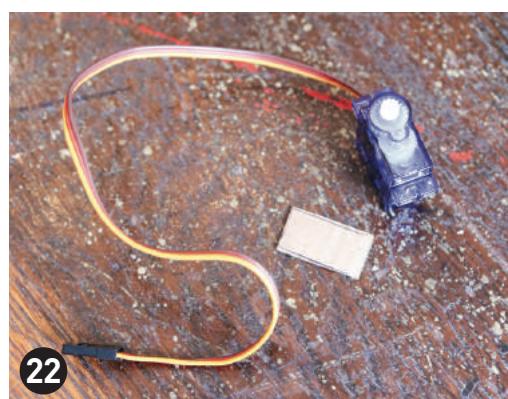
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- Hold the cube and servo horn in place as you slowly screw it in all the way until it is snug, but not too tight (Figure 17). This is the most fragile part of the build! Once complete, set the cube and attached servo arm aside.



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- Using your playing card box as a template, cut out seven pieces of cardboard (Figures 18 and 19).



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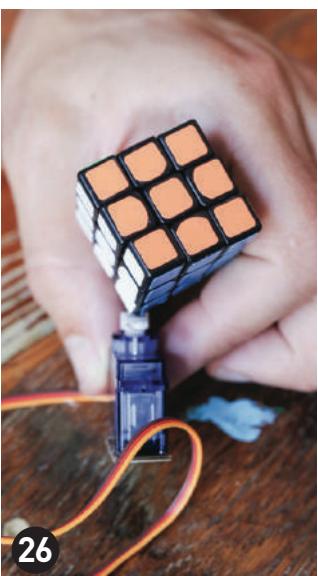
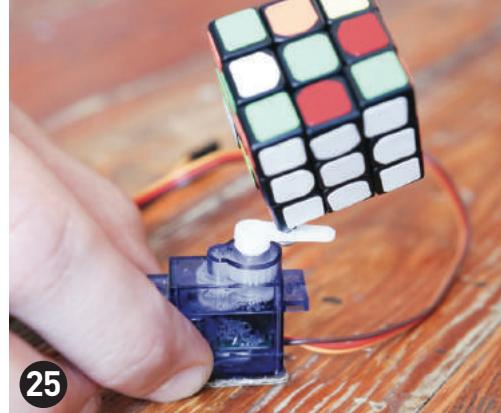
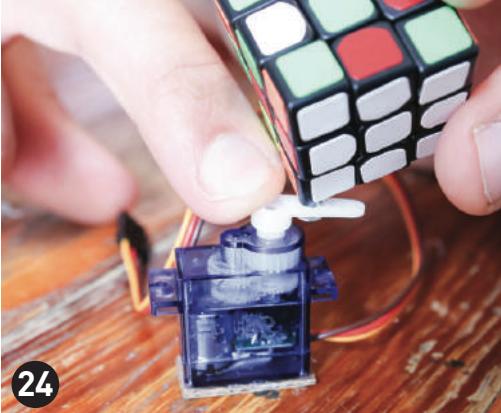
- Construct a 3D square with four pieces of cardboard, securing each side with hot glue (Figure 20).



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- Get out your micro servo. Using the bottom of the servo as a template, trace and cut out a small piece of cardboard (Figures 21 and 22).

- Hot glue the small piece of cardboard to the base of your servo (Figure 23).



- Press the servo horn that's attached to the cube into the micro servo without putting pressure on the cube itself (Figure 24).
- Hold the servo with the horn facing you, and gently turn the servo horn clockwise until it stops. We need it to stop at about the imaginary six o'clock mark... if it stops before or after, carefully lift the servo horn off and put it back on, so that the servo arm does line up properly (Figure 25).
- Adjust the cube by gently turning it so that the sides are aligned as in Figures 26 and 27.
- Attach the servo centered on the inside of one side of the cardboard square with just enough hot glue (Figure 28).
- Take another piece of cut-out cardboard from earlier, and cut it in half the long way (Figure 29).
- Use hot glue to attach one-half of the piece to the front bottom of your square structure (Figure 30).
- Cover the rest of the opening on that side of the square structure with another of the playing card-sized pieces of cardboard. Do not hot glue this piece in place, though (Figure 31).
- Use masking tape to attach this piece of cardboard to the lower piece, essentially creating a hinge (Figure 32). We want to leave an approximately  $\frac{1}{8}$ " gap between the bottom cardboard piece's top edge and the top cardboard piece's bottom edge, bridged with masking tape. This will allow the front "door" to open easily.





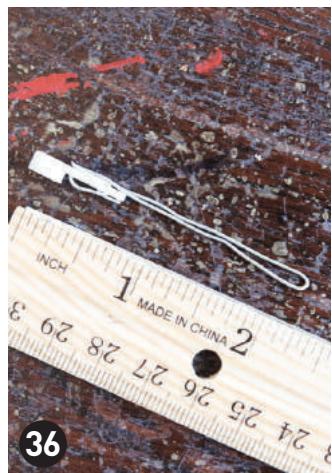
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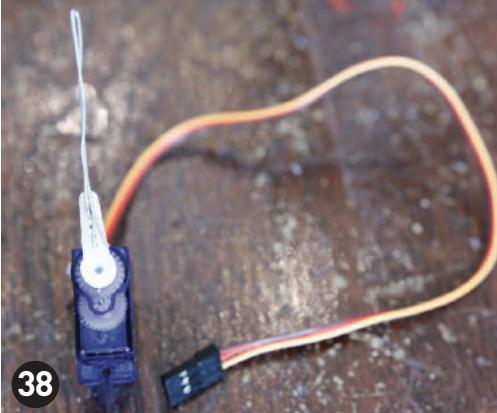


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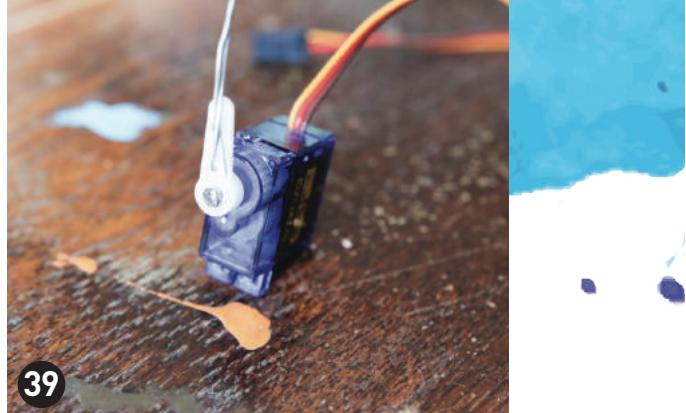


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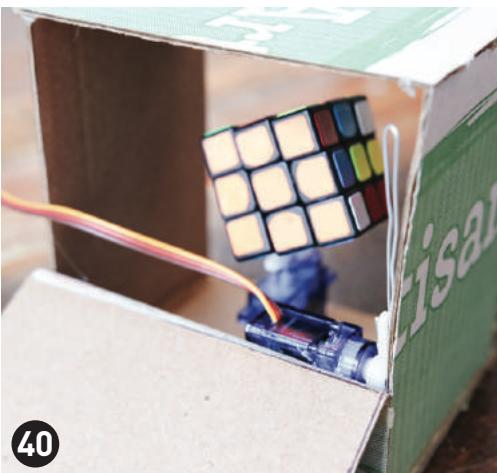
- Take another micro servo, and with pliers, slowly bend and break off the mount on the side closest to the servo shaft. A few bends back and forth and a little twisting will do the trick. Set the servo aside while you complete the next step (Figures 33 and 34).
- Cut a 5" piece of floral wire and thread it through the holes in a single-armed servo horn to create an arm extension, as you see in Figures 35, 36, and 37. Use pliers to press it all snug. The whole servo arm with the extension should be  $2\frac{1}{4}$ " long.
- Attach the extended servo horn to the servo.
- Turn the servo horn clockwise until it stops. If it does not already land at the "12 o'clock" position, adjust the horn to the "12 o'clock" position by taking it off and putting it back on in proper alignment (Figure 38).



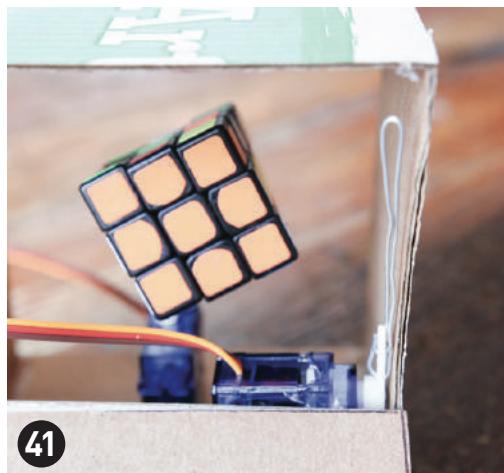
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- Screw your servo horn in place (Figure 39).
- Hot glue your servo to the right side of the inside lower front panel of your cardboard structure, sticking above the lower piece's top edge about  $\frac{1}{4}$ " (Figures 40, 41, and 42).
- With the piece of cardboard that you cut the servo-sized piece from, cut one 2" x 1" strip and one 2.5" x 1" strip (Figure 43).
- Place your last two Rubik's Cubes inside the



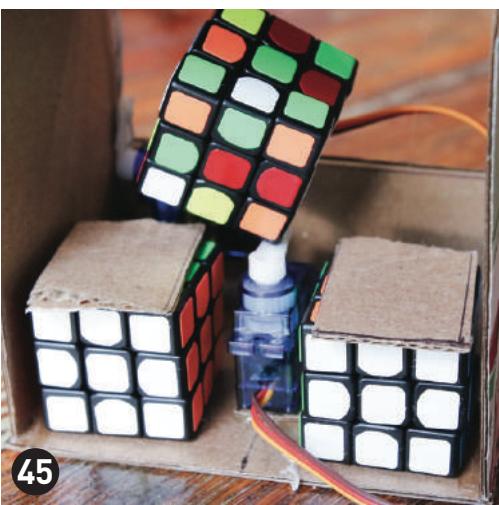
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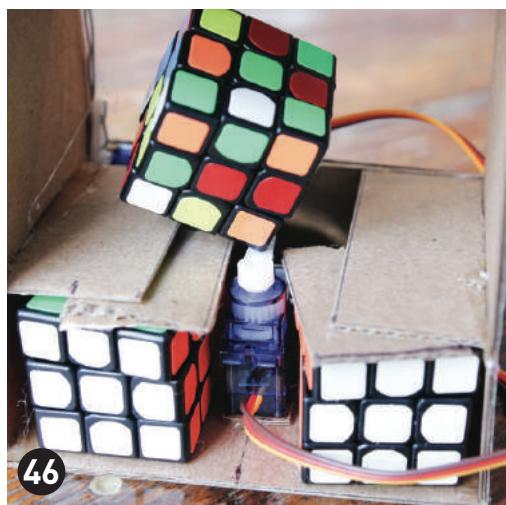
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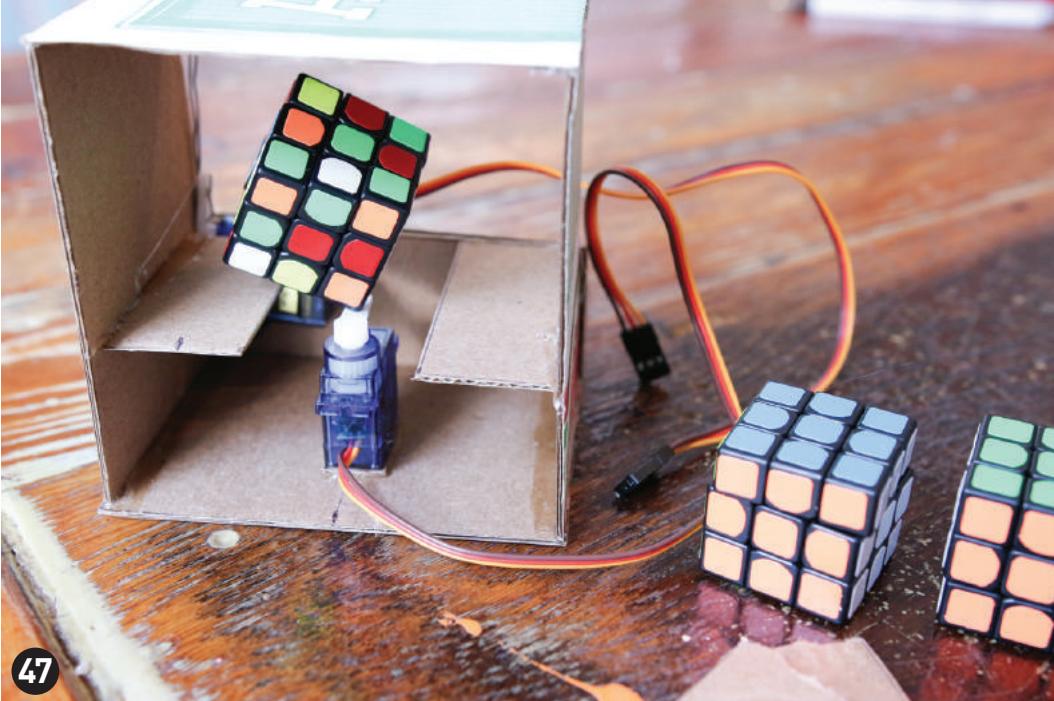
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floor of your structure, on either side of the servo that's attached to the floor (Figure 44). Set a small scrap bit of cardboard atop each cube, to add a little buffer for the next step (Figure 45).

- Hot glue the 2" x 1" and 2.5" x 1" cardboard strips to the inner sides of the structure, as ceilings just a tad above each cube. The shorter strip will be on the side with the second servo attached (Figure 46). You don't need a lot of glue... just a few dots along the edges will do. Be careful not to accidentally glue your cubes or scrap bits of cardboard! Remove the cubes and set them aside for later. Discard the scrap bits of cardboard (Figure 47).



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- Trim any excess cardboard that extends past the back of the structure.
- Using your playing card box as a template, cut a rectangular piece of dark felt (Figures 48 and 49)
- Fold the felt piece in half widthwise as a guide, and cut halfway through (Figures 50 and 51).





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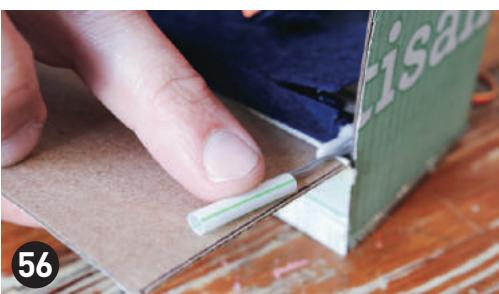
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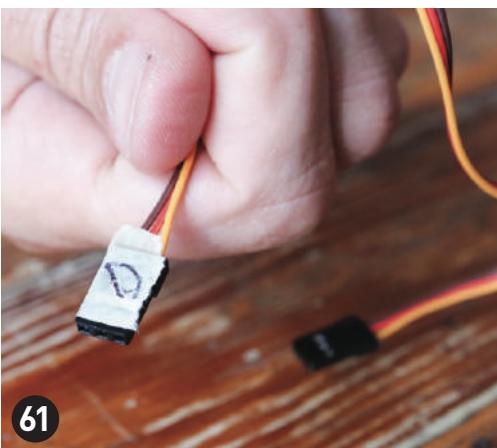
- Slide the felt piece into place from the front door opening of the square structure, so it acts as a “flooring” right under the servo-attached cube. The slit in the felt will allow it to fit around the servo shaft, but you may need to widen the slit slightly to avoid any obstruction of the servo movement (Figure 52).
- Snip the right front corner of the felt a bit so the servo mounted on the side can move freely. You’ll also want to adjust the felt along the edges for a good fit. If necessary, trim it slightly so it lays flatter on all sides. You may also wish to put a small loop or two of masking tape under the felt to hold it down (Figure 53).
- Now cut an additional  $\frac{1}{4}$ "  $\times$  3.25" strip of dark felt, to cover the gap on the front edge of the felt. A very small amount of hot glue on each end will work perfectly to attach it in place (Figure 54).
- The servo horn with the wire extension will make the structure’s door open and close. Gently turn that servo horn — making sure to hold the servo horn and not the wire extension — so that the wire extension rides straight across the edge of the cardboard door (Figure 55).
- Cut a 1" piece of plastic straw.
- Thread the straw piece onto the wire extension, covering half of the wire, from tip to mid-shaft (Figure 56). Put a drop of hot glue to tack the straw down in position on the door (Figure 57). Carefully close the cardboard door (Figure 58) by pushing gently at the cardboard right outside the servo horn, making sure the wire does not bend.



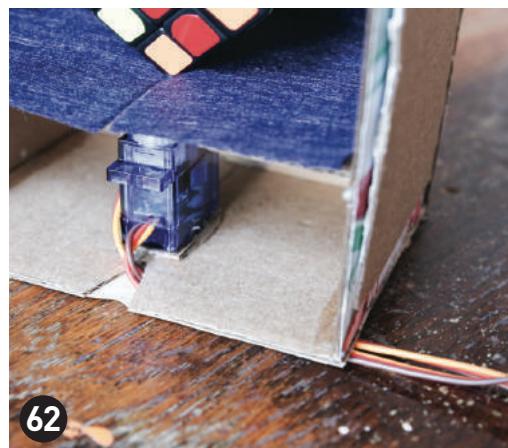
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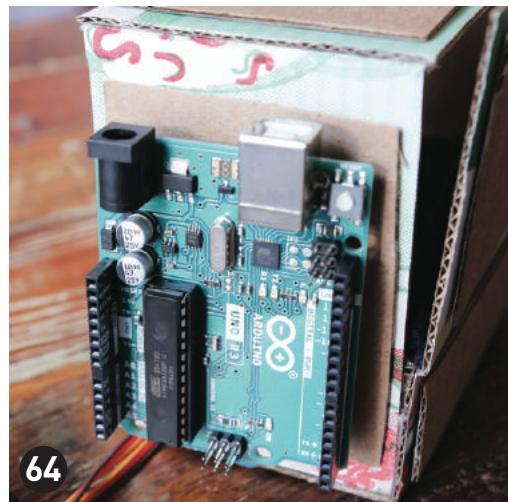
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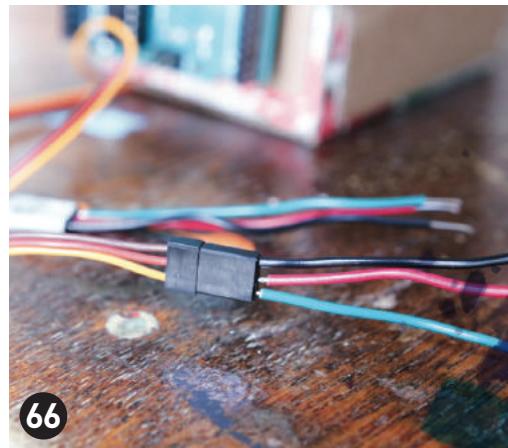
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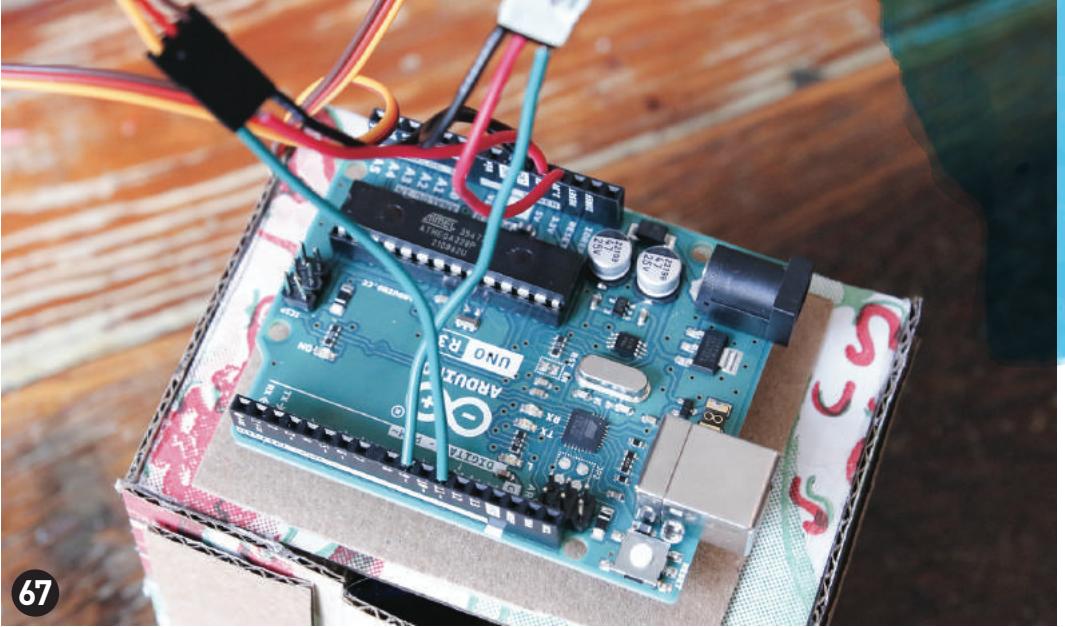
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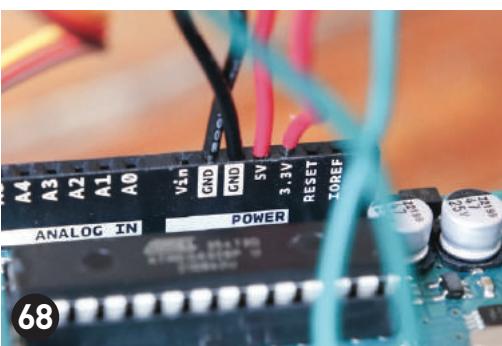
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- If you'd like, for decoration, cut some smaller cardboard rectangles and mount them around the outside of the cardboard box structure with loops of masking tape (Figure 59).
- Cut a slit out of the floor of the cardboard structure, from the center of the back edge just to the edge of the servo (Figure 60).
- Place a small piece of masking tape to the end of the servo wires of the door servo. Mark it with a "D." This is so we will be able to easily identify it later (Figure 61).
- Slide the wires from both servos through that slit, and tape them down on the bottom of the structure so the ends stick out on the side of the structure (Figures 62 and 63).
- With a loop of duct tape, mount your Arduino board to that same outer side of the structure, with the USB port facing up (Figure 64).
- Cut six 3" pieces of 22 gauge solid core wire: two red, two black, and two green. Strip the end of each wire about  $\frac{1}{4}$ " (Figure 65).
- Connect your new wires to the servo wires: black to brown, red to red, and green to orange (Figure 66).

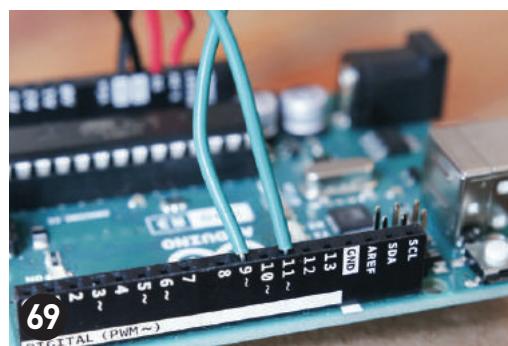




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- Now, let's connect the other ends of the red, black, and green wires to the Arduino board:
  - Both black wires go to GND on the board.
  - The door servo's red wire goes to 3v, and the cube servo's red wire goes to 5v.
  - The door servo's green wire goes to digital pin 9 on the board. The cube servo's green wire goes to digital pin 11 (Figures 67, 68, and 69).
- Draw some eyes on an index card, cut them out, and tape them to the top of your cardboard structure. Our robot is starting to come to life (Figure 70)!
- With a loop of duct tape, attach your 9v battery and plug to the cardboard behind the eyes (Figure 71).
- Cut a thin strip of cardboard about 3" long and  $\frac{3}{16}$ " wide. Curl it into a ring and wrap it loosely around the base of the mounted cube, like a little collar. Carefully use a small dot of hot glue to tack it in place, without dripping any glue on the felt. The purpose of this is to hide the servo shaft and make it seem like the cube is just resting on this little cardboard base (Figure 72).

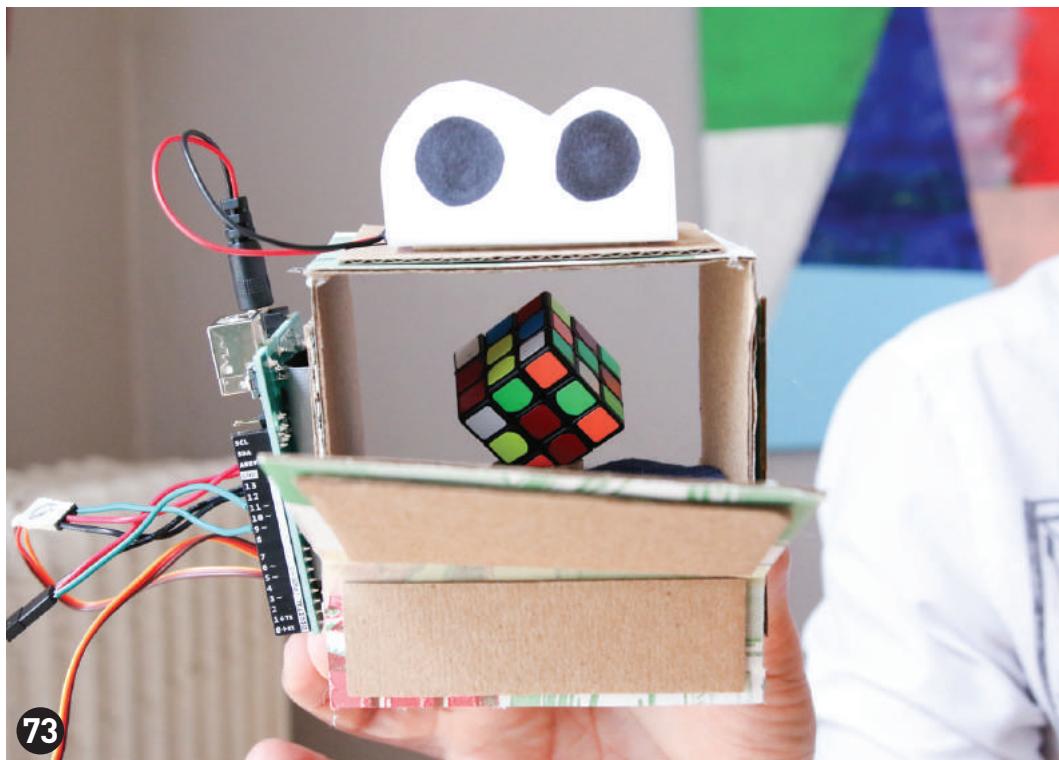
During the next phase of this project, keep in mind that we'll need to test and adjust, test and adjust, tweaking angles, motor movements, and speed. The smallest of adjustments can take the illusion from okay to amazing!

Before uploading the sketch, gently unplug the two black GND wires from the board. Then, open the Arduino application on your computer and upload the sketch found at [mariothemagician.com/robotmagicchapter7](http://mariothemagician.com/robotmagicchapter7) to your board.

- Once uploaded, unplug the board from your computer, and plug both black GND wires back into the board.
- Plug the battery into the Arduino, and ten seconds will pass before the robot's mouth begins to open.

### Now, let's go over the tweaks:

- The first thing to look for is your cube. Make sure the three mixed sides are facing forward and that none of the solved sides are visible from the front (Figure 73). If the cube is not positioned correctly, gently turn it into position.
- Make sure the door — the robot's mouth — closes and opens well with the code. In the closed position, the mouth should not be showing the cube at all. If it's not closing enough, gently bend the wire extension from the servo horn and adjust. If that doesn't do the trick, go back





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a few steps and remount the servo horn in the correct position until it functions well.

The final time the robot's mouth opens, the cube should appear solved (Figure 74)! Once everything is working well, and the robot is successfully performing the cube illusion, we need to prep it for performance:

- With your two extra cubes, mix one up and keep one solved. Slide them both into their hiding places within the robot (Figure 75).

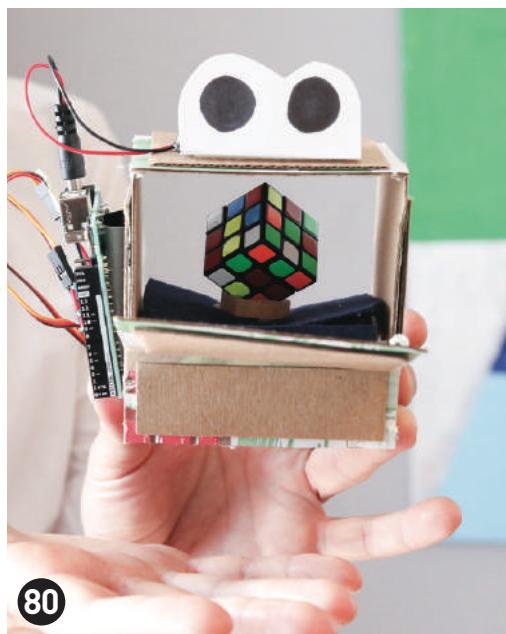
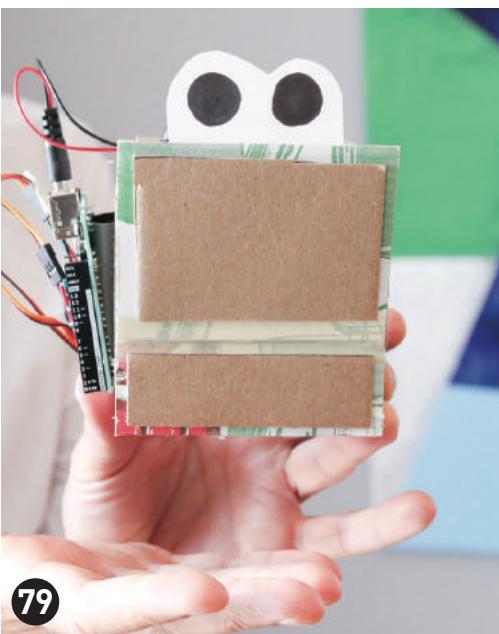
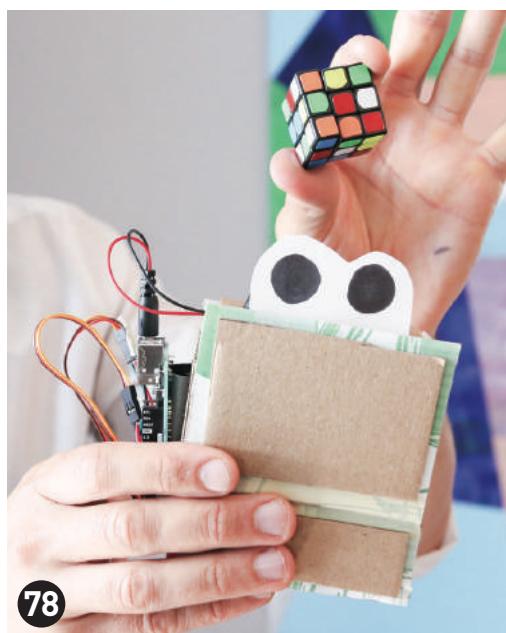
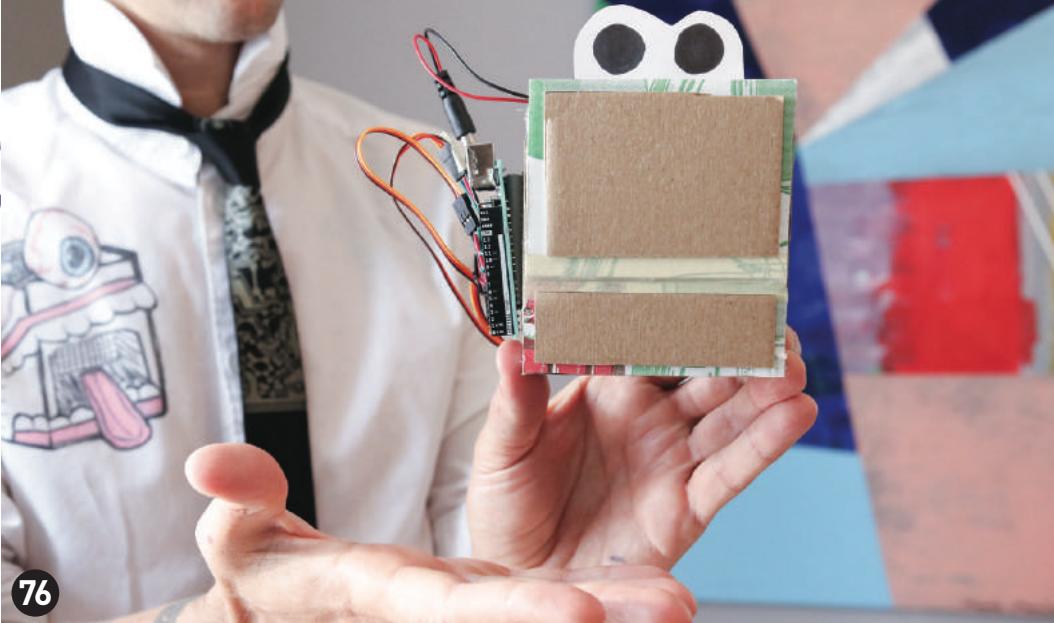




## THE PERFORMANCE:

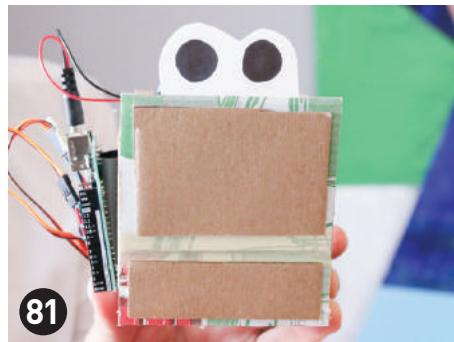
Alright! We have two loose hidden cubes and one mounted cube. Be aware that like most magic tricks, angles are important with this illusion! This works when your audience is directly in front of the robot.

- Hold the robot from the bottom with one hand (Figure 76).
- With your other hand, push the battery plug into the board. This will start the routine!
- Immediately, tilt the robot back to remove the loose unsolved cube with your right cube, while holding the loose solved cube in place, so it doesn't fall out (Figure 77).
- Show all sides of the unsolved cube to your audience (Figure 78), and place it back in its hiding place. This all needs to be done within ten seconds, before the robot's mouth opens (Figures 79 and 80). (Your audience will not



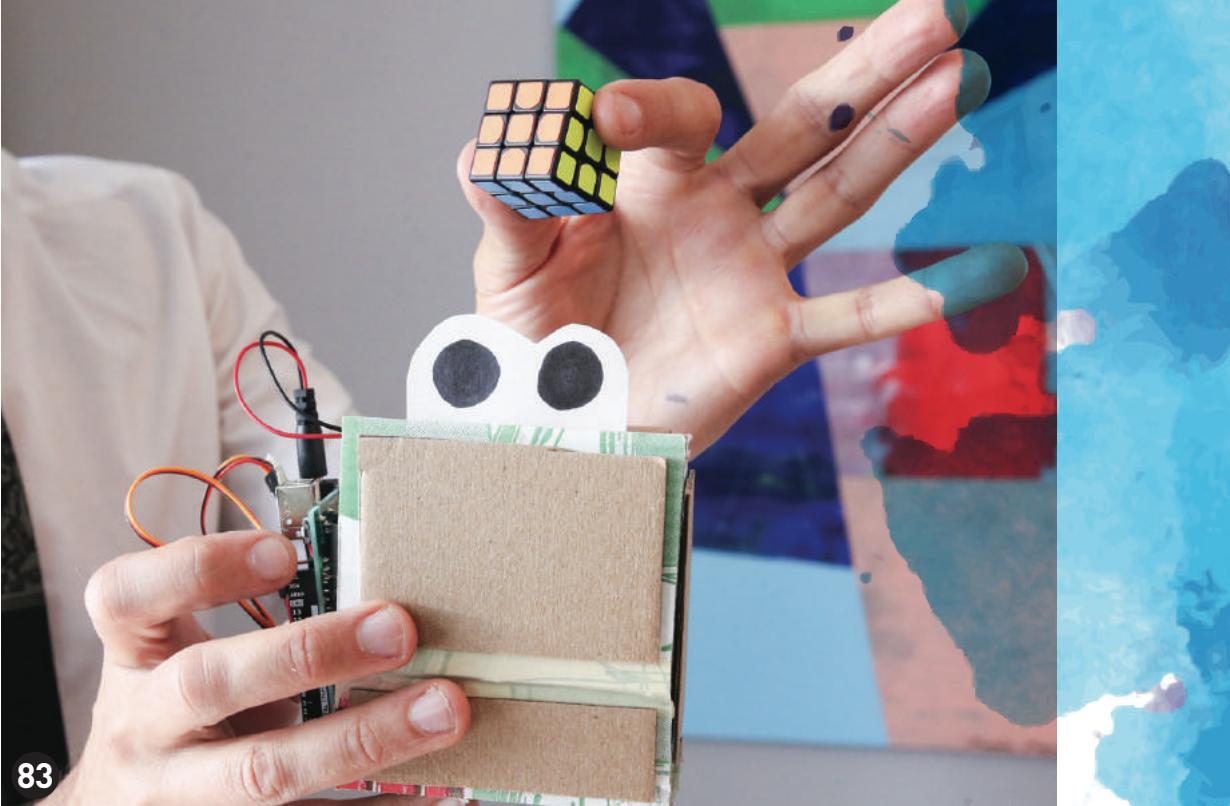
realize that the cube you just showed them is not the same cube that they see when the robot's mouth opens. To assist in this deception, keep your fingers close to the mounted cube before the mouth opens. As the mouth opens, pull your hand away. This subtlety strengthens the idea that you just placed that cube in the robot.)

- Now, with just one hand holding the robot, let it do its thing to reveal an instantly solved cube! BOOM! This is the big reveal! Ride this powerful moment (Figure 81)!



- Then, immediately after the robot closes its mouth after solving the cube, pinch the bottom of the robot by its sides. Use your fingers to block the loose mixed cube from falling allow the loose solved cube to fall into your hand, creating the illusion that you are removing the solved cube the audience just saw (Figure 82). Hold the loose solved cube up to show it on all sides to your audience as you unplug the robot and put it away (Figure 83).





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## Tips:

- In the code, just below `void loop()` you'll see `delay(10000);` — this is the 10 second wait period before the mouth starts opening. Feel free to change this number based on how you decide to perform the routine.
- Once the mouth opens you'll notice it moves at different speeds. We can control that in our code, too. Take the time to look over each line of code to understand how it works. Try changing the `delay(25);` to a higher or lower number and see how it affects the routine. For now, it's a slow opening and then a slow closing, then fast and slow again. I find that the small unexpected speed changes keep the audience alert, and when the surprise solve happens, it's even more striking. Play with your performance style and adjust the code to play along. See what works best for you!