A Robotic Puppet

by John Blankenship
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If you visit a robot club or any robotic function for that matter, it is likely that you will meet someone who is interested in humanoid robots. Often, these enthusiasts are not particularly interested in building robots that perform useful tasks. Instead, they wish to build a robot that looks and moves like a real person. They may or may not want to endow their creation with artificial intelligence (AI), but they nearly always want to create the illusion of life.

My interest in robotics has always been very diversified and I too have always been fascinated with the idea of creating the illusion of life. Perhaps that was a motivating factor that pushed me towards another of my hobbies — ventriloquism. It occurred to me that the techniques used in puppet construction might be of interest to many hobbyists interested in animatronics.

A typical ventriloquist puppet is carved from wood or molded from some form of composite material such as plastic wood or papier-mâché. In either case, the head cavity must be open enough to add mechanisms such as pulleys and levers to control the movement of the mouth and other optional features such as moving eyes, eyebrows, and eyelids.

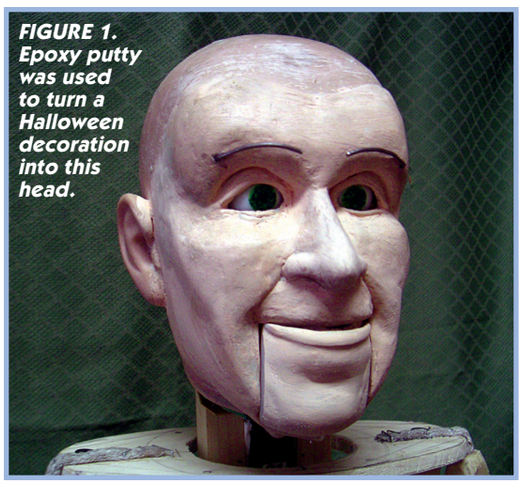

FIGURE 1. Epoxy putty was used to turn a Halloween decoration into this head.

If we are creating a robotic puppet, the head must contain all the moving parts found in a standard puppet plus appropriate actuators (motors or solenoids) to effect the movements. Since I wanted the puppet to appear life-like, it was important to animate some body movements in addition to the facial features.

In order to simplify the programming aspects of the project, servo motors were used as actuators. This meant that the overall size and weight of the puppet had to be kept to a minimum. Keeping the puppet small was no bother. To the contrary, it was actually very intriguing. Normally, a ventriloquist's puppet has to be big enough so that a hand can be placed inside it to perform the manipulations. With a small puppet, everyone would know it was not being controlled in the normal manner.

The puppet's head in this project is smaller than normal and it has to contain even more mechanisms than a standard puppet. If the head was made from wood or composite materials, the required wall thickness would reduce the size of the head cavity even further, adding to the problem. One solution is to use a plastic head from a doll or holiday decoration. The thin plastic shell would provide the maximum interior space.

I found a Halloween prop that was the perfect size, but (as you would expect) it had a ghoulish look that was not appropriate. I used epoxy putty to fill in unsightly wrinkles, alter the lips, add teeth, and lift the cheeks. Epoxy putty is as easy to work with as clay — but for only 10 or 15 minutes — so don't try to do too

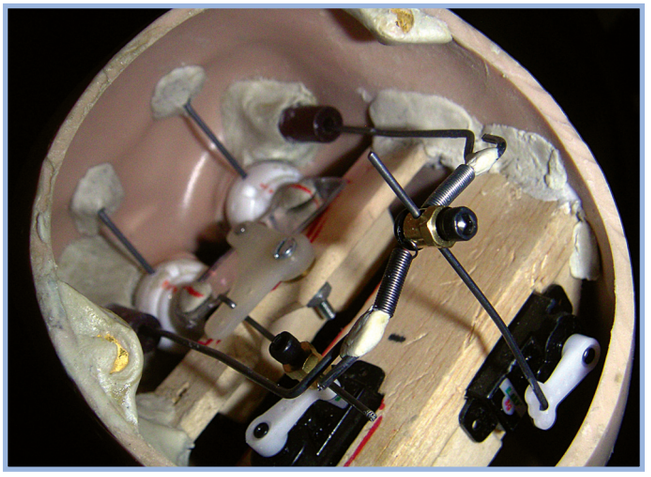

FIGURE 2. The interior of the head is cramped. The miniature servos shown move the eyes and eyebrows. Notice the magnets on each side.

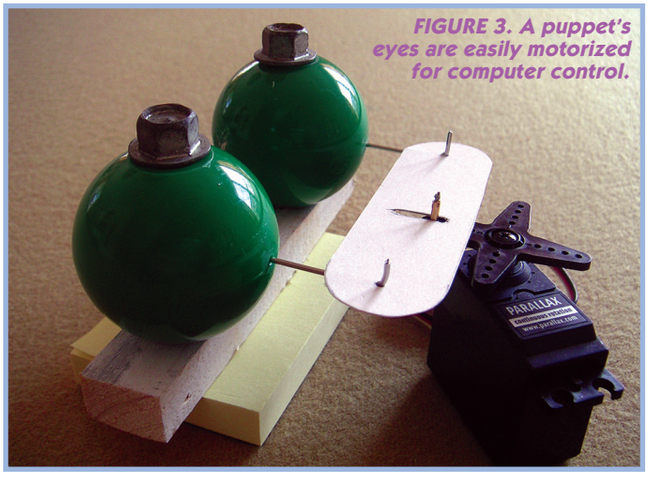

FIGURE 3. A puppet's eyes are easily motorized for computer control.

much at once. Figure 1 shows the altered head before painting.

The back of the head was cut away to allow easy access to the inside. Magnets were epoxied in appropriate positions (on both pieces) to hold the cut piece in place and still allow easy removal for repairs.

Figure 2 shows the interior of the head, which contains three miniature servos: one for the mouth, one for the eyes, and one for the eyebrows. The details of how you mount your servos depends on the features you want and the space available in your puppet's head. It is also important to realize that you can purchase servos in various sizes with a wide variety of torque, speed, and noise levels, so consider your needs carefully.

Most of the bell cranks, disconnects, and other apparatus I use are mechanisms designed for model airplane construction and can be found in many hobby stores. Your local hardware store can also be a great source for small pulleys, lazy-susan bearings, and such.

It is difficult to see how the eye assembly is constructed in Figure 2, so Figure 3 shows an external mockup to provide additional detail. Eyes are easily made from wooden balls that rotate on a bolt or rod. Stiff wires protrude from the rear of each eye and up through a plastic wafer that ensures the eyes move together based on the servo's motion. It is important to use a slot as shown instead of a hole because the opposing rotational motions can cause binding. The use of the bell crank in Figure 2 allows the motor to be mounted away from the eyes. This can be very advantageous when working in a confined space.

The puppet's body is shown in Figure 4 and is constructed primarily from wood. Padding may be needed to make the body look more natural under the clothes. His full height is 28 inches. The legs are made from PVC pipe. One leg of the pants is pulled up to show the pipe.

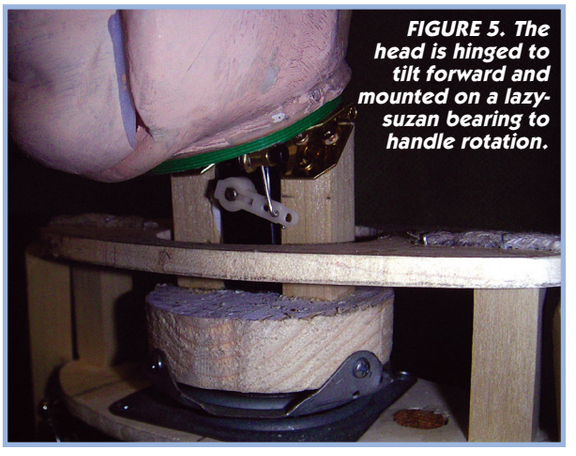

FIGURE 5. The head is hinged to tilt forward and mounted on a lazy-suzan bearing to handle rotation.

Figure 5 shows how the head is mounted on a hinge to allow a forward tilt under control of the neck-mounted servo. The lazy-susan bearing gives the head the ability to rotate. The neck is connected to a servo mounted in the body using a short piece of rubber hose. The flexibility of the hose connection prevents binding by allowing for twisting and bending (much like

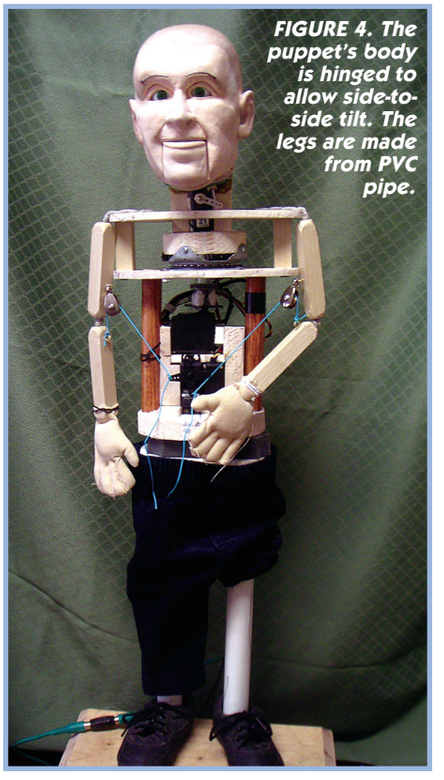

FIGURE 4. The puppet's body is hinged to allow side-to-side tilt. The legs are made from PVC pipe.

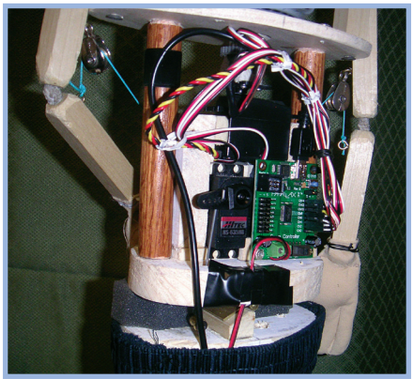

FIGURE 6. The body is hinged at the hips and moved with a servo. The Parallax servo controller simplifies the controlling program.

FIGURE 7. The complete puppet looks very lifelike when being manipulated with the joystick.

universal joints on an automobile driveshaft) while ensuring a secure connection. The body is hinged to the hips allowing a small side-to-side tilt. Figure 6 shows how the servo is mounted to control this movement. The connecting rod passes through a hole in the bottom of the body and connects to an eye-bolt in the hip surface. Figure 6 also shows a Parallax USB servo controller that will be discussed later. The arms aren't functional in a true robotic sense, but the pull of a string creates just enough movement to add to the illusion of life.

Figure 7 shows the fully clothed and painted puppet. Fake fur from a cloth store was used for hair. The USB cable for the servo controller, as well as a power cable are run down the puppet's leg and extend from the bottom of the pants to make connections

FIGURE 9. Partial listing of the Real_Puppet.BAS program for controlling the puppet.

```
//--Constants
  COMMS_PORT      = 1
  JOYSTICK_PORT   = 1
//=====================================================================
MainProgram:
  GoSub Instructions
  GoSub SetUp
  GoSub Initialize
  GoSub Start_Control
  GoSub FinishUp
Exit
//=====================================================================
Read_Joystick:
   GetButton btn
   if btn == Buttons[0] then n=MsgBox(I_M)
   if btn == Buttons[1] then Quit = true
   joystickE JOYSTICK_PORT,jvalue
   jx = jvalue[0,0]/(jvalue[0,2]-jvalue[0,1])
   jy = jvalue[1,0]/(jvalue[1,2]-jvalue[1,1])
   jz = jvalue[2,0]/(jvalue[2,2]-jvalue[2,1])
   jr = jvalue[3,0]/(jvalue[3,2]-jvalue[3,1])
   jb = jvalue[6,0]
   jhat = jvalue[7,0]
Return
//=====================================================================
Start_Control:
   while !Quit
      GoSub Read_Joystick
      //--check buttons first (special movement combinations
      if jb == B_Yes then GoSub Yes_Combo \ continue
      if jb == B_No then GoSub No_Combo \ continue
      if jb == B_Combo1 then GoSub Combo1 \ continue
      if jb == B_Combo2 then GoSub Combo2 \ continue
      //--then move all motors based on joystick's position
      GoSub HeadR_Movements
      GoSub HeadT_Movements
      GoSub Arms_Movements
      GoSub Brows_Movements
      GoSub Eyes_Movements
      GoSub Mouth_Movements
      GoSub Torso_Movements
   wend
Return
//=====================================================================
Yes_Combo:
   //--Yes comination movement
   m = "Yes"
   xyText 0,100,m+spaces(20),"",20,fs_Bold
   ramping = HeadTRamping
   channel = HeadTChannel
   for i = 1 to 3
     nn = 750
     a = char(channel)+char(ramping)+char(nn&255)+char((nn >> 8)&255)
     SerOut "!SC",a,char(13)
     delay 500
     nn = 950
     a = char(channel)+char(ramping)+char(nn&255)+char((nn >> 8)&255)
     SerOut "!SC",a,char(13)
     delay 500
   next
Return
//=====================================================================
HeadR_Movements:
   //--rotate the head
   ramping = HeadRRamping
   channel = HeadRChannel
   if HeadRTime < Timer()
     rHeadR =random(HeadRRandomness)-HeadRRandomness/2
     HeadRTime = Timer()+1000 // random movement every 1000 mseconds
   endif
   nn = HeadRLowLimit+round(jr*(HeadRHighLimit-HeadRLowLimit))+rHeadR
   a = char(channel)+char(ramping)+char(nn&255)+char((nn >> 8)&255)
   SerOut "!SC",a,char(13)
Return
//=====================================================================
```

FIGURE 8. An extended joystick provides control of the puppet's functions.

JOYSTICK ACTION	PUPPET MOVEMENT
• Twisting the stick	• Rotates the puppet's head
• Moving the stick forward/backward	• Tilts head forward/backward
• Moving the stick left/right	• Tilts the body left/right
• POV hat left/right	• Moves the eyes left/right
• POV hat forward/backward	• Moves the eyebrows up/down
• Trigger (firing) button	• Opens the mouth

easy while being hidden from view.

The clothes for a small puppet are not easy to find. An outfit for a 12-18 month old child was tailored and modified to give it the correct proportions.

The features on this puppet allow for a variety of emotions. When the puppet lowers his eyebrows, for example, he looks mad. Raising the eyebrows while keeping the mouth open will express surprise.

In order to make control of the puppet as intuitive as possible, all the movements on the puppet were associated to similar movements on an extended joystick. Figure 8 summarizes these movements.

Some of the puppet's actions are provided automatically by the computer, thus making the manipulation easier for the user. Buttons on the extended joystick, for example, can be programmed to provide specific movements for the arms, or head movements for yes and no. All of these motions could be created by controlling the puppet manually with the joystick, but preprogrammed movements can have pre-selected servo speeds and limits so that the automated movements can be as lifelike as possible. Furthermore, the arms, head, and body all have small random movements programmed into them even when the puppet is not being controlled. This simulates life-like restless shuffling.

At this point, we are ready to create the program to bring the puppet to life. We used RobotBASIC because it has the ability to read and write to all the ports on a PC (parallel, serial, and USB). A Parallax USB multiservo motors controller **www.Parallax.com**) makes it easy to control the servos because it will simultaneously move the servos using the positions and speeds requested by the controller program and maintain those positions without further intervention.

The RobotBASIC program reads the joystick and then commands the servo motor controller module to position the motors accordingly, reflecting the positioning of the joystick and/or button presses. The program is too long to list here in full, but the listing in Figure 9 shows a representative sample of some of the subroutines. You can download the full program from **www.RobotBASIC.com**. It is well commented so it should be easy to follow the logic.

The techniques demonstrated in this article can be valuable in a wide variety of projects. Even this project itself can be the starting point for further ideas. For example, instead of using the humanoid form as a manually controlled puppet, you could place it under automatic computer control. If you combine voice synthesis and voice recognition with the puppet's ability to simulate emotions, it is easy to imagine an amusing interactive robotic display.

Of course, the techniques shown here can be utilized in robotic projects involving humanoid forms and other animatronic characters. Constructing your own computer-controlled puppet allows you to have the features you want along with the ability to control it as you see fit. **SV**