Then and NOW

ROBOT ARMS

by Tom Carroll

Ahh! Robot arms. You've got to admit that we've all thought about robot arms somewhere along the line. We may have never placed them on one of our robots, but these unique appendages certainly add a lot to a robot's capabilities. As a combat robot enthusiast, we may have imagined our robot grabbing an opponent with its arms and throwing it across the arena to the cheers of the crowd. As a kid, we probably wished that we had a humanoid robot that could pick up our clothes off the floor, make our bed, and do our chores. Hey, we even like that idea after we're grown!

Sedentary seniors may wish for a robot assistant that could help them into and out of a chair or bed, or go to the kitchen and prepare a simple meal and do simple household chores. To design a robot to assist the elderly is a dream that I've had for years. All of these designs require some sort of articulated arms for the robots to accomplish these tasks.

Robots of Fiction Evolve Into Robots for Industry

When did arms for robots first appear? Probably with the very first 'robots.' Long before Karel Câpec wrote the play "RUR" — where he coined the word robot from the Czech word, robota meaning indentured servant or slave — people always assumed that mechanical men had arms. The robots of movies always had arms until cute little R2D2 made the scene in Star Wars.

It was not until the mid '50s and into the '60s that robots in industry became possible. George Devol, Jr. in 1954 developed the multi-jointed artificial arm that led to the modern industrial robot. When Devol filed for a patent in 1961 for a "programmable method for transferring articles between different parts of a factory," the idea of a real robot in a factory was starting to become a reality. He later commented, "The present invention makes available for the first time a more or less general-purpose machine that has universal application to a vast diversity of applications where cyclic control is desired."

This was the first programmable robot and Devol coined the term Universal Automation for his products-to-be. He later shortened this name (at the suggestion of his wife, Evelyn) to Unimation, the name of the first robot company.

Evolution of the Robot Arm

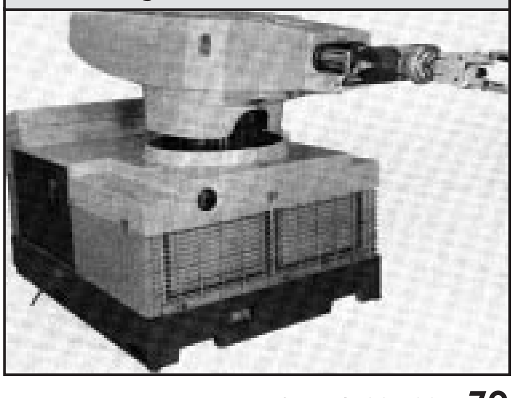
Devol, the dreamer and inventor, met young nuclear physicist/electrical engineer, Joe Engelberger at a cocktail party in 1956 and the two joined forces and began to develop a universal tool for industry to move work pieces between the different types of tools required in manufacturing processes (see Figure 1). Devol had always thought of an arm of sorts as the only way to move things in a factory — a material handling robot.

Machine tools such as a lathe made round things, milling machines cut slots and holes in things, drill presses drilled round holes, presses squashed things, but no machine moved the parts. Only humans could accomplish such a complex and varied act.

Applications soon were developed for welding and painting. The first

Figure 1. Joe Engelberger and George Devol.

Figure 2. Unimate robot.



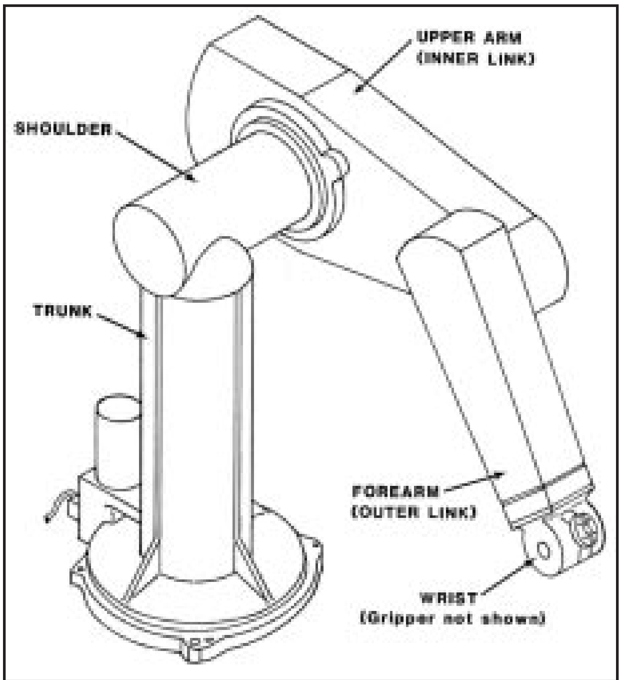


Figure 3. Drawing of Unimation PUMA arm.

'Unimate' robot was sold to General Motors in 1960 and installed in 1961 to remove hot metal pieces from a die-casting machine and stack them (see Figure 2). It was a slow sell to the automotive industry and Unimation did not show a profit until 1975.

Industrial robots were always thought of as a robot arm mounted to a fixed, swivel base. The original Unimate robot arm seemed to be nothing more than a gripper mounted on the end of an extendable piston that protruded out from a tank turret type of structure that could bob up and down and rotate. The later Unimation PUMA robot was the next generation — an articulated arm with more degrees of freedom (see Figure 3).

Articulated robot arms use the term degrees of freedom (or DOF) to describe the number and axes of the joints in a particular robot arm. It can also refer to the number of motors driving each of the joints. A typical industrial robot arm may have five to six DOF, whereas the human arm actually has an infinite number of DOF due to the ball joints of our bone's attachments and their many numbers of directions that the joints may be extended.

The larger Cincinnati Milacron T-3 robot became very popular on automotive assembly lines for spot welding and painting tasks and their different joint structures. Then, Japanese robot companies seemed to take over and very few American companies still remain. Web search Google 'robot arms' to see the many configurations and degrees of freedom required for various factory tasks.

Robot Arms for the Experimenter

Industrial robots have not been popular with experimenters, mainly because of their cost and larger size. Not counting the Heath robot series and the RB-5X robots (that were mobile first and each happened to have a single arm), the Rhino XR-1 robot was one of the first experimenter arms in the early '80s. Sandhu Machine Design in 1982 did an excellent job of machining this remarkable experimenter's robot arm, as it is the stunning machined structure that captures one's eye (see Figure 4).

The arm had a payload limitation of about one pound due to its long length, but this longer reach allowed a greater work envelope for the user. The shoulder joint (the base joint) could rotate from minus 45° to plus 135° and the elbow from minus 135° to plus 90° at about 30° a second; not as great as a typical industrial machine, but perfect for the lab experimenter. A student is shown in Figure 5 with a computer-controlled Rhino robot arm. Sandhu Machine Design also marketed a mobile robot base in the '80s called the Scorpion that sold fairly well.

Two other robot arms of the '80s that sold fairly well were the Microbot Mini Mover 5 (see Figure 6) and the Mitsubishi Move Master RM-101 (see Figure 7) marketed by E&L Instruments. Both of these $1,000 desktop robot arms were designed for the experimenter and educational use and were to be controlled by a single-board computer or the typical home computer of the day, such as the Tandy or Apple.

My friend (Jim Hill of Covina, CA) who built Charlie featured in Figure 8 is an excellent example of a robot experimenter who designed and built some of the most complex robot arms using only basic hand tools and surplus automobile parts such as electric seat motors. Jim's Charlie was featured on the front cover of *Popular Mechanics* in a 1984 article that I wrote and brought him much deserved media attention. It goes to show that a dedicated robot experimenter does not require an extensive machine shop to build a world class robot.

Figure 4. The Rhino robot arm.

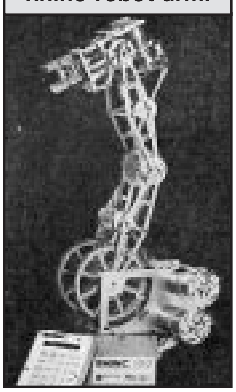


Figure 5. Student at Vermont Technical College with Rhino robot.

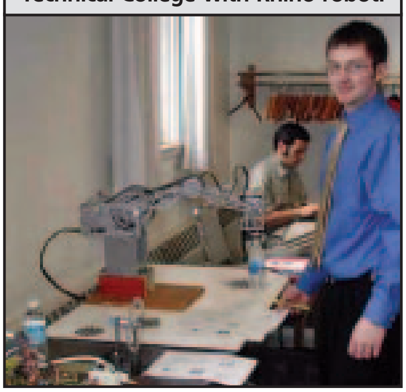
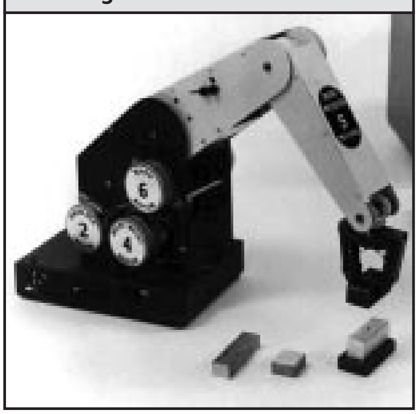


Figure 6. Mini Mover 5.



The Armatron Robot Arm

Another very interesting robot arm that was widely used by experimenters is the Armatron (see Figure 9). Manufactured by Tomy and later distributed by RadioShack, this five axis arm plus a parallel jaws gripper was intended as a toy. Robot experimenters — including yours truly — snapped them up by the droves. Albeit plastic, this all mechanical arm was well designed and used a single electric motor to drive all its functions. Two joysticks engaged or disengaged various gear assemblies as required to drive all six functions. Many were hacked, and solenoids, linear car door lock actuators, or model airplane servos replaced the dual two axis joysticks and the twist controls of the joysticks. These were connected to a PC or microcontroller and a rather nice robot arm resulted from this $20 toy.

Figure 7. Move Master.

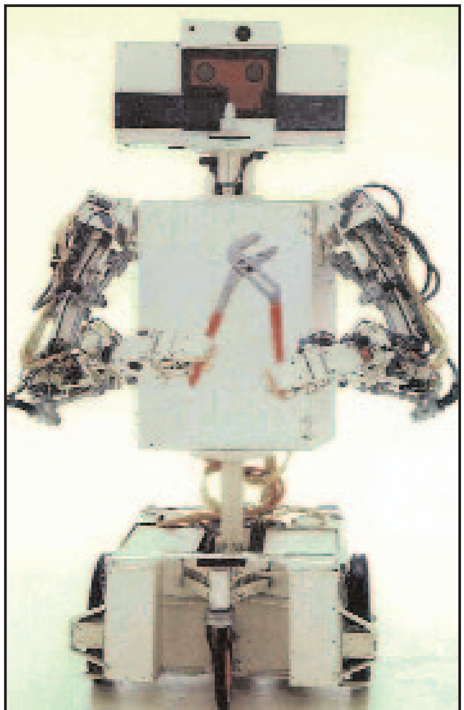


Figure 8. Charlie's great set of arms.

If anybody can turn a simple robot into a steam-powered machine, it is the guys at CrabFu as you can see in Figure 10. Resourceful experimenters have placed two of the Armatrons on Androbot TOPOs and upgraded the armless, bobbling robot into a dual armed bobbling robot. The object of the game is to manipulate the arm and gripper to pick up and place several plastic rings on a stand within a certain length of time.

An energy level monitor was just a timer that could be set to start to allow the person time to complete the stacking task before the time counted down to zero and disabled the manipulator arm. My pre-RadioShack model is collecting dust on top of a file cabinet in my office but I still have fun with it every so often. You can find over 27,000 links for the Armatron on Google.

Robot Experimenter's Arms of Today

A quarter century hasn't diminished the robot experimenter's interest in robot arms. Today's experimenters quite often look at mobile base robots as a platform for autonomous machines or go the other direction to experiment with a multi-jointed arm mounted on a non-mobile desktop base. Many look to join the two to form a mobile robot with one or more arms.

Many of the smaller arms of today utilize model airplane radio control servos as the driving force of each joint rather than stepper motors used in many earlier arms. The advantage of the R/C servos is the positional feedback. Utilizing a stepper motor, for example, a computer can deliver 24 pulses to the motor and think that the arm moved so many degrees when, in fact, the arm did not move at all because it was jammed. Potentiometric feedback, as in the R/C servo, or shaft encoders with a basic DC gearmotor allow the controlling computer to know where each joint is positioned. Algorithms in the program can determine the arm's overall position, avoid kinematic singularities, and plot a path for the end effector (claw/hand).

The Lynxmotion Robot Arms

Figure 9. Armatron.

Lynxmotion's Lynx 5 and 6 arms are some of the more popular arms available to the robot experimenter today among many other offerings from other manufacturers. The 4-DOF Lynx 5 robot arm (see Figure 11) features base rotation, shoulder, elbow, and wrist motion, and a functional gripper. The arm is made from tough laser-cut Lexan structural components, black anodized aluminum servo brackets, and injection molded components. The arm assembly utilizes ball bearings and includes five Hitec HS-422 servos — one for the base, two for the shoulder, and one each for the elbow and wrist. A smaller Hitec HS-81 servo is used

Figure 10. CrabFu Steamatron.

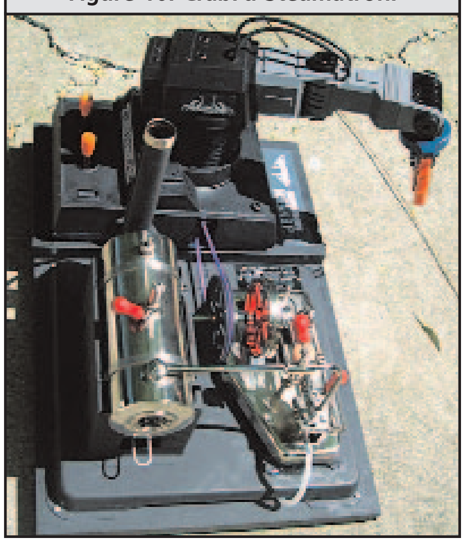
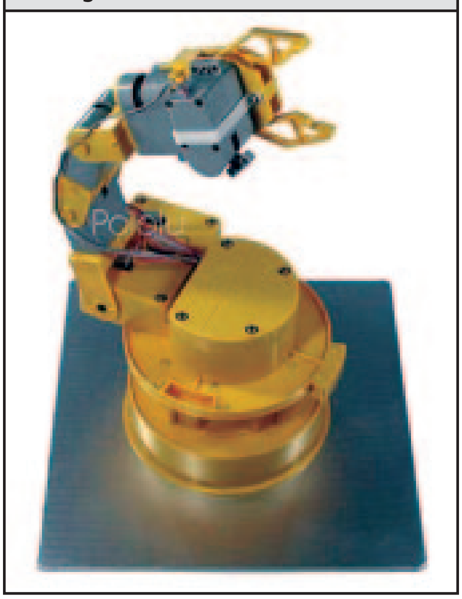



Figure 11. Lynx 5 arm.


Figure 12. Lynx 6 arm.

for the gripper.

The Lynx 6 (see Figure 12) arm includes four Hitec HS-475 servo motors and the same HS-422 for the base on both models. An HS-85 and an HS-81 are used for the Lynx 6 gripper.

Figure 13. Pololu Joinmax arm.


Lynxmotion has developed RIOS (Robotic arm Interactive Operating System), a Windows program for controlling the L5 and L6 robot arms and is to be used with their SSC-32 servo controller. They state: "With RIOS, your robot can be taught sequences of motion via the mouse or joystick. The inverse kinematics engine makes positioning the arm effortless. If-then, for-next, and do-while are supported for the inputs. External outputs can also be controlled. If stand-alone operation is desired, RIOS/SSC-32 can actually create the Basic code to control the arm from our Bot Board and Basic Atom or the BASIC Stamp 2. Alternately, the servo motors can be controlled directly from a microcontroller, such as an OOPic-R or IsoPod. The arms servo motors can also be controlled with a PC using your own electronics or using the serial RIOS-02 software (RB-Lyn-60)."

The arms start at under $280 and go up to $380 and more, and they offer many end effector and mobile base options.

Pololu Joinmax Robotic Arm

The Pololu Joinmax Robotic Arm with six degrees of freedom retails for $225 and is quite a bit different from the Lynxmotion arm. Pololu is a Hawaiian named robot company based in Las Vegas that markets this Chinese-built experimenter's robot arm (see Figure 13). The arm has seven servo motors for the robot arm's base, arm, forearm, fore wrist, back wrist, and the gripper (clamp, as they call it). They furnish a servo control card and mini-servo Explorer software (Win98/2000/XP compatible) for the tabletop robot experimenter.

Summary

There are a lot of great arms and robot arm kits designed for the robot experimenter. Several of the robot companies advertising here in *SERVO* have other fine designs. As I always say, let this article be the catalyst to get you to delve further, whether through the Internet or fellow robot experimenters that you'll meet at the various robot clubs and societies. When you build your first robot with arms, you may never be satisfied with just a roving mobile base again. **SV**

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