Appendix D

Sample Automata and Mechanisms

From the beginning of the testing, users had access to three completed automata and about a dozen simple mechanisms that had been created with various versions of MachineShop. These machines were used as reference and to stimulate ideas by all users, although the amount of interaction varied from user to user. This appendix provides a brief look at these objects.

D.1 Ralphie's Dream

Ralphie is the mascot of the University of Colorado at Boulder. His stylized profile is ubiquitous on and off campus and it was that profile that was used in creating this automaton. Building Ralphie served two purposes. First, it allowed those of us involved in this research the chance to actually construct an automaton in order to get an understanding of the difficulties that we could expect future users to encounter. Second, it served as a proof of concept of our early attempts at building software for this purpose and as a vehicle to learn about the process of carbon dioxide laser cutter fabrication. By all of those measures it was a tremendous success.

The idea for Ralphie comes from an automaton designed and built by Keith Newstead that featured a flying pig [15]. The path taken by Ralphie's body is elliptical and is provided by a crank-slider mechanism that utilizes an eccentric cam with a ring follower (see Figure D.9). The wings are first order levers that pivot at the wires anchored to the framework. As the body moves up, it brings the inner ends of the wings with it and, since the wires don't move, this forces the tips of the wings down. The reverse happens as the body moves down. The combined motion quite

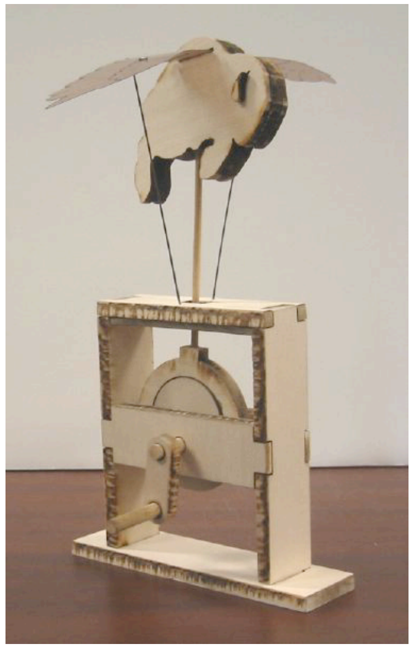

Figure D.1: Ralphie the flying buffalo. Ralphie is the mascot of the University of Colorado but he is generally found with a majority of his feet on the ground. This was the first automaton built using nascent software tools that would eventually become MachineShop and was fabricated with a crude second-hand laser cutter setup.

realistically mimics the motion of birds in flight.

The mechanism components and Ralphie's body pieces were cut from basswood on the original laser cutter in our lab. The slider rod and shaft for the crank are birch dowels. The wings were printed on overhead transparency material and cut out with scissors, while lengths of small diameter music wire were bent to serve the wings as fulcrums.

D.2 Nessie the Sea Serpent

While one crank-slider is generally found in automata that use them, Nessie was created to see what might be possible by using three. This is an original design that was not influenced by other automata. Nessie's body is divided into three segments, each attached to the ring follower rod of an eccentric cam. Each of the cams is rotated about 120 degrees from the one ahead of it. As is the case for all crank-slider mechanisms, each segment follows an elliptical path, but unlike the front to back path in Ralphie, the paths in Nessie are side to side. When viewed from the front or back, she appears to swim with an undulating motion appropriate to her kind.

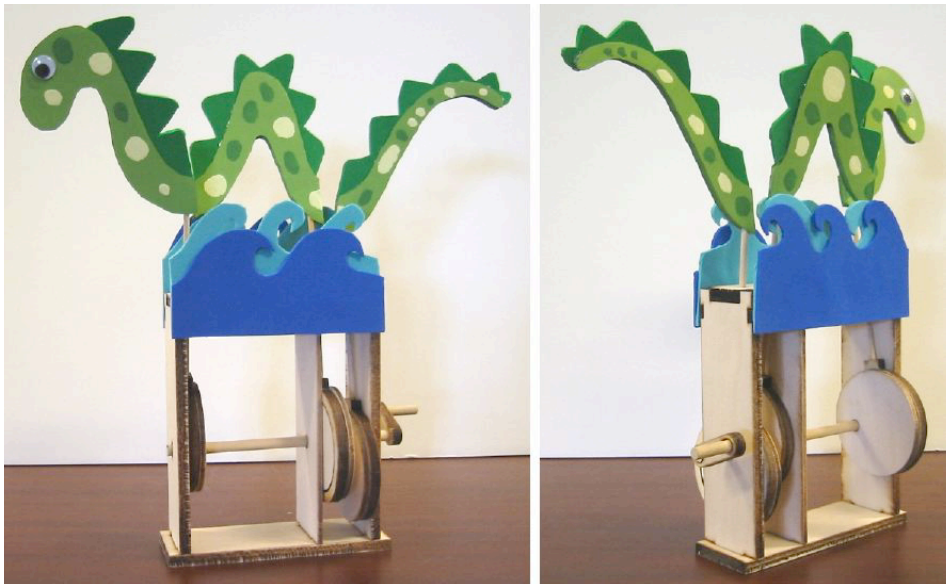

Figure D.2: Two views of Nessie the sea serpent. On the left, a side view showing the general layout including the three eccentric cam crank-slider mechanisms that move her body segments. On the right, a view showing the side to side motion that accompanies the up and down movement of the body.

The support framework and mechanical components are cut from basswood with the laser cutter. The shafts and slider rods are birch dowels. Her body is foamcore board, while her spines and the waves attached to the framework are craft foam, both cut with the laser cutter. She was painted with acrylic craft paint and her spines were attached with hot glue. Her eyes were purchased at a craft store.

D.3 Big Top Celia

Celia's design arose from the desire to take an existing automaton mechanism and, without altering it, create a new automaton in which the tableau appeared completely different. The mechanism shown here is the same one found in Peter Markey's *Angry Cat* [15]. To make Celia appear unlike the cat, the relation of her body to the mechanism was reversed from that of the cat and a new set of motions to be provided by the mechanism were designed.

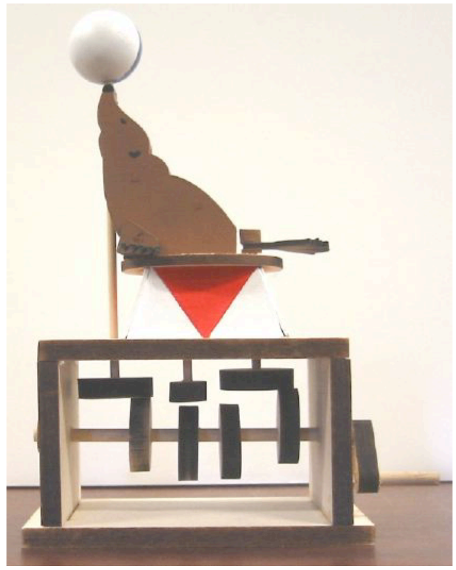

Figure D.3: Through the use of eccentric cams and discs, Celia moves her tail and flippers while balancing the spinning ball on her nose. The mechanism seen here was modified by two of the test users for inclusion in their automata.

The spinning ball on her nose is driven by a disc on the main shaft that turns a disc connected to the ball by the vertical shaft. By placing the driving disc at the outer edge of the driven disc, the ball spins at nearly the same rate as the crank is turned. In the cat, this mechanism rotates the cat's tail. Celia's front flippers rock back and forth around a shaft set into her shoulder. Inside her body, this shaft is attached to a lever such that the vertical motion of the lever results in the rocking motion of the flippers. The lever is actuated by the follower of an eccentric cam. In the cat this mechanism raises and lowers the cat's arched back. Her tail flippers move from side to side through the use of a Markey oscillator. In the cat, this mechanism opens and closes the mouth while moving the tongue from side to side.

A moment should be spent here to briefly discuss the Markey oscillator as it appears frequently in contemporary automata and provides a terribly useful motion without requiring a large investment in mechanism creation. The mechanism has, as far as can be determined, no official name and was given this label during the user testing. It is named for the artist Peter Markey who has used it to great affect in a number of his automata. The oscillator consists of two eccentric cams attached to a common shaft, spaced some distance apart, and rotated so that their high points are some angular distance apart. A disc at the end of a second shaft is placed with its face parallel to the shaft that holds the cams with the shaft midway between the cams. As the cam's shaft is rotated, each cam will come into contact with the disc, one at a time, and will lift and rotate the disc. But, because the cams are located on opposite sides of the disc's shaft, the disc will rotate in one direction for one cam and in the opposite direction for the other, rotating whatever is attached to the shaft one way and then the other. By varying the size, lift, and angular separation of the cams, the motion can be controlled. To keep the disc from rotating too far, it is common to find stops added to the disc to constrain its motion. In Celia, her body keeps the tail from moving too far in either direction.

Celia's body, pedestal, support framework, and mechanical components are all cut from basswood with the laser cutter. The shafts and followers are birch dowels and her tail and flippers are craft foam also cut with the laser cutter. The ball is a decorative wooden item purchased at a craft store. Acrylic craft paint and aerosol paints were used to decorate the automaton.

D.4 Example Mechanisms

In additon to complete automata, the users had access to a number of simple mechanisms. These mechanisms were originally created for use in short videos that were incorporated in the Movement Explorer tool in the MachineShop software (see Section 5.1.2), but proved helpful when users were defining a mechanism or stumped by some aspect of their design. Not all components that can be made with MachineShop have had these kinds of examples built (levers are conspicous by their absence) and when there is the ability to create many variations on a component only one or a few were made. For all of these examples, the support structures and components were cut from basswood on the laser cutter. Shafts, followers, and rods are birch dowel. Other materials such as matte board or acrylic plastic were used rarely, but were also laser cut.

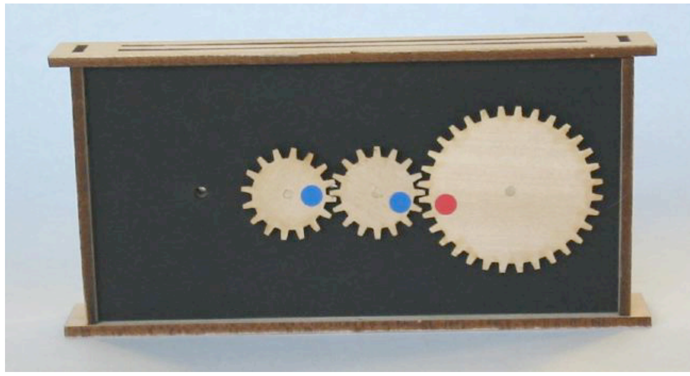

Figure D.4: Spur gears keep rotation in the same plane. Gears that mesh rotate in opposite directions, and power and speed can be changed as a property of ratio of the gears. The support structure for this example has several holes that allow the gear sizes to be changed and to create gear trains of either two or three gears. Colored dots aid in determining gear ratios.

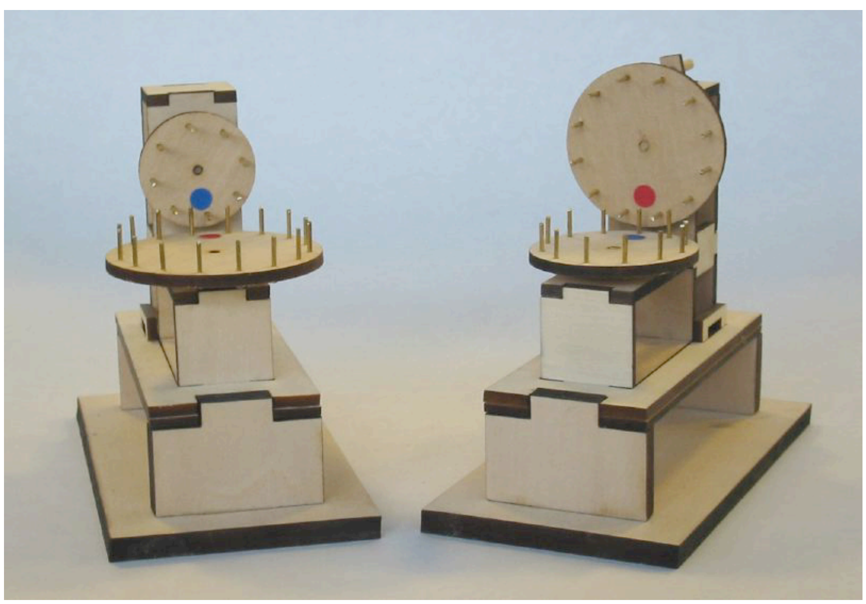

Figure D.5: Pinwheel gears move the plane of rotation through 90 degrees. As with spur gears, meshing gears rotate in opposite directions.

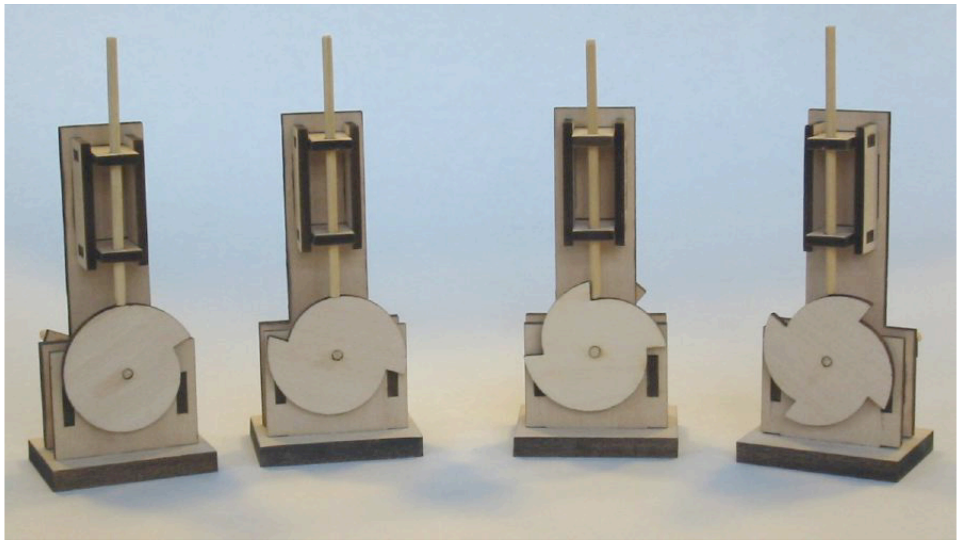

Figure D.6: The follower of a snail cam moves gradually away from the cam's shaft and then returns quickly. Shown here are snail cams with (from left) one, two, three, and four lobes. The height of each lobe (lift) can vary independently and all lobes do not have to have the same angular dimension (dwell) as can be seen in the three lobed example. This cam produces a galloping rhythm as the follower drops.

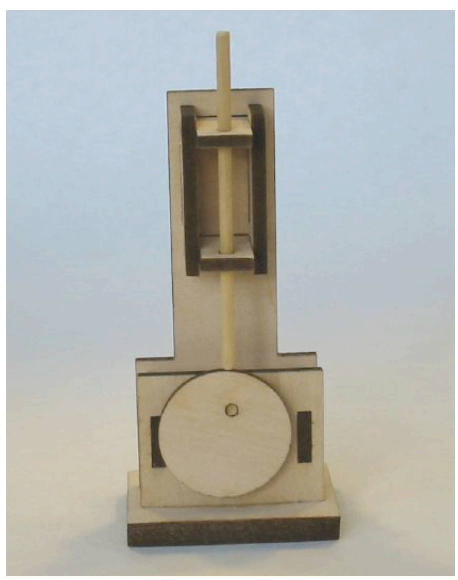

Figure D.7: The follower of an eccentric cam moves at a regular rate between the extremes of its travel. In effect an eccentric cam has just one lobe so the dwell cannot be changed, but the lift can be modified by changing the distance from the shaft hole to the edge of the cam.

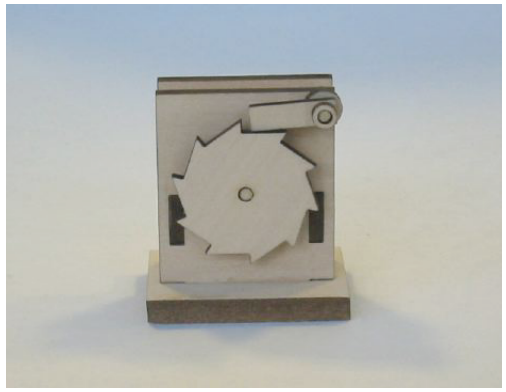

Figure D.8: The rotation of the ratchet is limited to one direction only (counterclockwise in this example) by the action of the pawl (upper right).

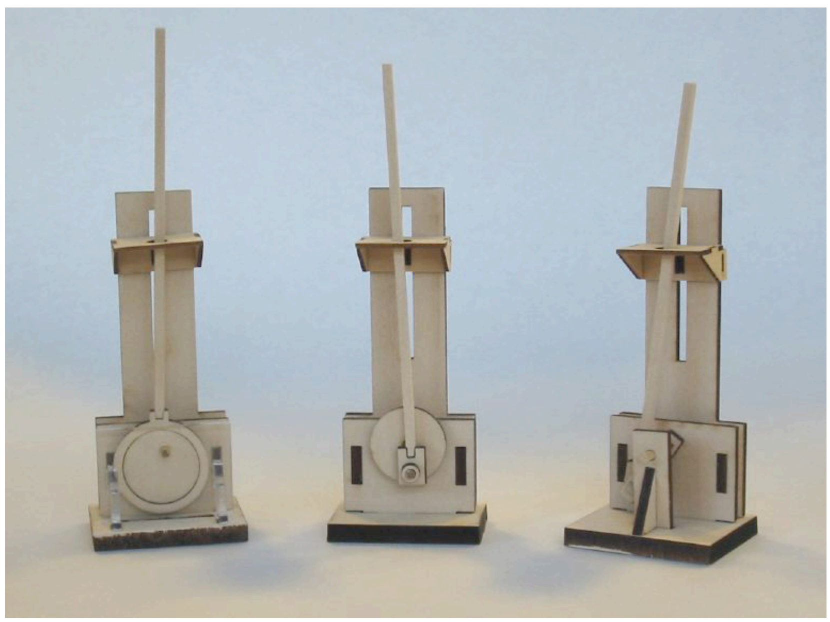

Figure D.9: Crank-sliders are not a simple component that can be created with MachineShop, but the pieces necessary to build them can. Crank-sliders turn their rotary input into an elliptical output at the tip of the slider rod. The exact shape of that ellipse depends on two factors: the offset of the crank and the distance from the crank to the support bearing for the rod. In these examples, that bearing location can be changed by moving the bearing up or down along the slots seen in the backs of the support structures. Having the bearing near the crank will result in an ellipse that is wider than it is high, while having the bearing far from the crank will create a tall and narrow ellipse. Three styles of crank are show here. From left, an eccentric cam with ring follower, a disc with offset pin, and an offset crank.