

## Chapter 4

### Automata as a Domain for Exploring Mechanical Reasoning and Spatial Cognition

Chapter 3 described a number of software applications and construction kits with which mechanical and spatial thinking could be explored. Those examples that provide the most freedom with respect to design lend themselves to a variety of mechanical domains without favoring any. While this can be desirable for designing in the real world, the absence of limits on the types of objects that can be designed and their complexity would make asking reasonable questions about mechanical and spatial thinking difficult and would provide no easily manageable context for examining and comparing the disparate objects that could be created. This makes it necessary to select a single domain which can be defined and constrained in such a way as to allow significant freedom in the design of mechanisms while still allowing the products to be similar in important fundamental ways. For this research the domain that I have chosen is mechanical automata, specifically automata of the style known as *contemporary automata*.

What is an automaton? This simple question is surprisingly difficult to answer. Webster defines automaton (automata in the plural) as “a machine or control mechanism designed to follow automatically a predetermined sequence of operations or respond to encoded instructions” [79]. Bailly offers a nineteenth century definition: “a machine which has the form of an organised being and contains within itself a mechanism capable of creating movement and simulating life” [4, page 13]. Peppé [97] suggests that definitions are of little value since each automaton is unique mechanically and in its artistic aspirations. Bailly (echoing Peppé) points out that no capsule description gets at the essential quality of automata; their power to fascinate and engage.

Still, automata are so far removed from the experiences of most of us that a concise description is warranted. For the purposes of this research an automaton is a moving sculpture of people and/or animals whose motions repeat and are controlled by mechanical means.

This chapter will first provide a brief and incomplete history of automata leading up to the contemporary automata which comprise the research domain for this work with an emphasis on the pairing of cutting edge technologies and automata throughout history. This is followed by a discussion of the reasons that the design and construction of automata was chosen for this research. Next two automata are presented to provide examples of the domain. The chapter concludes with a discussion of current uses of automata in education.

#### **4.1 A Brief History of Automata**

The history of automata is intimately woven into humankind's desire to understand and comment on our existence. From the first representations of daily life painted on cave walls, we have wanted to understand and reflect on the world around us. Two-dimensional representations spawned those in three dimensions. Static representations became dynamic and the desire to do more than model became a quest to understand and mimic nature. That, of course, required technology beyond that currently available and the simulation of life as captured in automata took advantage of many breakthrough technologies.

##### **4.1.1 Automata in Antiquity**

Moving and articulated statues can be considered the progenitors not only of automata but also of mechanical toys and puppets. These statues and busts were found in many cultures and served both iconic and prophetic functions, making them anything but everyday objects. Precisely when these moving figures found their way into the secular world is unknown, but early writings suggest that the direct line to automata as we know them may have been in place as early as the third century BCE at Alexandria[18].

Around this time the Alexandrian School was formed by a group of philosophers, physicians, mathematicians, and engineers and it became the most important and productive center of learning in the Classical world. The power of water, steam, and compressed air were harnessed for a variety of purposes religious, secular, and military. Notable among the engineers in Alexandria were Ctesibius [117] and Philon [125] (both in the third century BCE) and Hero [118].

Ctesibius of Alexandria was a prolific inventor<sup>1</sup> who also spent considerable effort refining the water clock (clepsydra). Some of these refinements included using floats to actuate mechanisms, and in at least one case a clock of his design used a moving human figure to indicate the time.

Philon (or Philo) of Byzantium's work focused primarily on the military use of machines. Interestingly, he saw war machines as a single component of military strategy and his work also included topics such as besieging and defending towns, constructing forts and seaports, and general topics in strategy. His work would not be considered in the context of automata if not for a single volume of his nine volume treatise *Mechanica* which was entitled *On Automatic Theatres*. These devices were miniature theaters in which stories were told through the actions of automated figures and settings [80]. While this volume has been lost, Hero builds on this work in his own descriptions of automatic theaters.

Much of what we know about the mechanical knowledge and technology of ancient Greece comes from the work of Hero (or Heron) of Alexandria. Exact dates for Hero are hard to determine, but Drachmann places him in the first century CE [28]. Hero wrote extensively on geometry, surveying, optics and mechanics. Five complete works survive: *Pneumatica* and *Automata* in Greek and *Mechanica*, *Metrica*, and *Dioptra* in Arabic. Other writings survive in fragments while many have been lost. Hero described and expanded on the work of others (most notably Ctesibius and Philon) as well as describing his own discoveries and inventions. Hero described how the power of water, wind, and steam could be used to (among other things) automate the opening

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<sup>1</sup> Ctesibius has been called the "Edison of the Alexandrian School". Among his inventions were the suction pump (which is still used today in many applications including fire engines) and the hydraulis, the first musical instrument to be played using a keyboard and the ancestor of the pipe organ.

of temple doors, power sound effect machines and automatic theaters, and provide sound and movement to automata. In the *Pneumatica* he uses many examples of automata to illustrate his technical discussions.

With the destruction of the Library of Alexandria and the fall of Rome, both in the fifth century CE, Byzantium and the Arab world became the repository of most of the remaining learning from the Classical period. It was from Byzantium that this knowledge would make its way to Europe at the end of the Dark Ages.

#### **4.1.2 Automata come to Europe**

With the beginning of the Renaissance in the thirteenth and fourteenth centuries there was a rediscovery of the ancient classical texts and a desire to apply this knowledge to the arts and sciences. Water clocks were fitted with mechanisms to chime bells or to activate rope driven human and animal figures (called jacquemarts or jacks). These clocks gave way to weight-driven mechanical clocks which featured not only jacks but often a variety of astronomical and holy day displays, calendars, and sometimes even a dial for telling the time [101]. As clock mechanisms grew more advanced, so did the automation of the jacks. Rope movements were replaced by sophisticated collections of strings which in turn were replaced by arrangements of gears and cams. These mechanical clocks were immensely popular and were added to cathedrals and town squares across Europe for the next three hundred years, becoming a part of everyday life.

Another mostly independent line from water clocks to automata can be found in water works and water gardens. Expensive to build and maintain, they were toys of the nobility. Some were elaborate complexes of grottos connected by vaulted galleries. Fed by water from nearby rivers or lakes they often contained large, multi-level fountains. The water also powered organs and mechanisms to animate tableaux, often of a mythological nature [7]. These application of the hydraulic and pneumatic devices and processes of the Greeks coincided with a number of translations of Hero's *Pneumatica*, first into Latin, then into Italian and English. Some of these translations acquired beautiful illustrations to show the translator's impression of what these de-

vices should look like. One example appears in Figure 4.1.

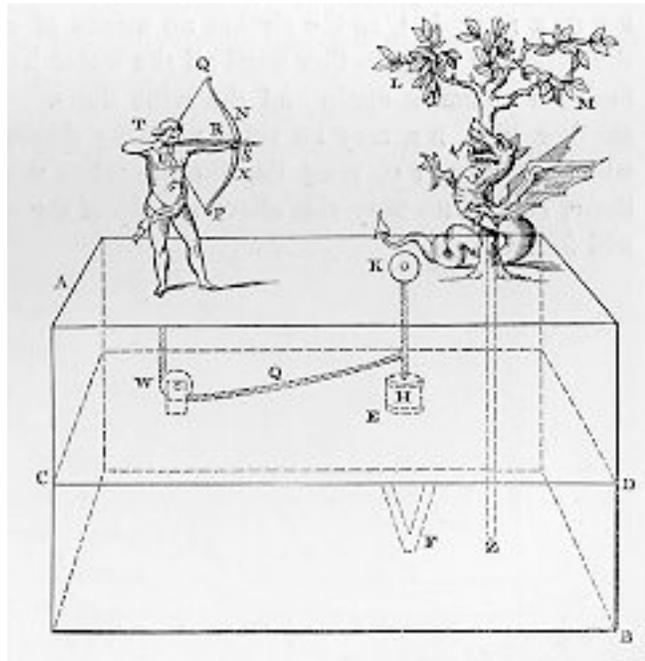


Figure 4.1: On an Apple being lifted, Hercules shoots a Dragon which then hisses. When an observer raises the apple (K) from the platform, Hercules fires his arrow at the dragon. Originally described by Hero of Alexandria in his *Pneumatica*. Illustration from Woodcroft [132, Section 40].

### 4.1.3 The Golden Age of Automata

Clockwork evolved into the watchmaker's art in the sixteenth century. Portable clocks using spring driven movements rather than weights were followed by early pocket watches in the seventeenth century. Also around this time the pinned cylinder (familiar to anyone who has examined a music box movement) was applied to the control of organ pipes for the automated playing of music. These developments were not lost on automata makers who adopted and refined these mechanisms. The new precision with which mechanical components could be created allowed for more robust and lifelike movements to be imparted to automata. The new spring driven movements meant that the size of automata could be reduced to make them more approachable and even portable; an attribute not previously associated with automata. Clever watchmakers started

building automata to showcase their skills in novel ways.

The eighteenth and nineteenth centuries can truly be called the Golden Age of Automata. This period saw some of the most beautiful and complex automata ever created and in many cases the technology was elevated to art. Galleries were rented, exhibitions were mounted, and the paying public flocked to be amazed and astounded. Many talented makers found prominence during this period. Notable among them were Jacques de Vaucanson and Pierre Jaquet-Droz.

Jacques de Vaucanson (1709-1782) "... is unquestionably the most important inventor in the history of automata ..." [7, page 36]. Vaucanson initially became interested in creating a "moving anatomy" which, for a variety of reasons, he never completed. In 1735 he had the idea to raise money by creating several machines that could excite the public's curiosity. By 1738 he had completed two life-sized musicians. The first, a flute player could play eleven different tunes by forcing air from its lips and moving its fingers over the holes in the flute. The second played twenty tunes on a three holed pipe in the same manner while accompanying itself on the tambour [60] (Figure 4.2).

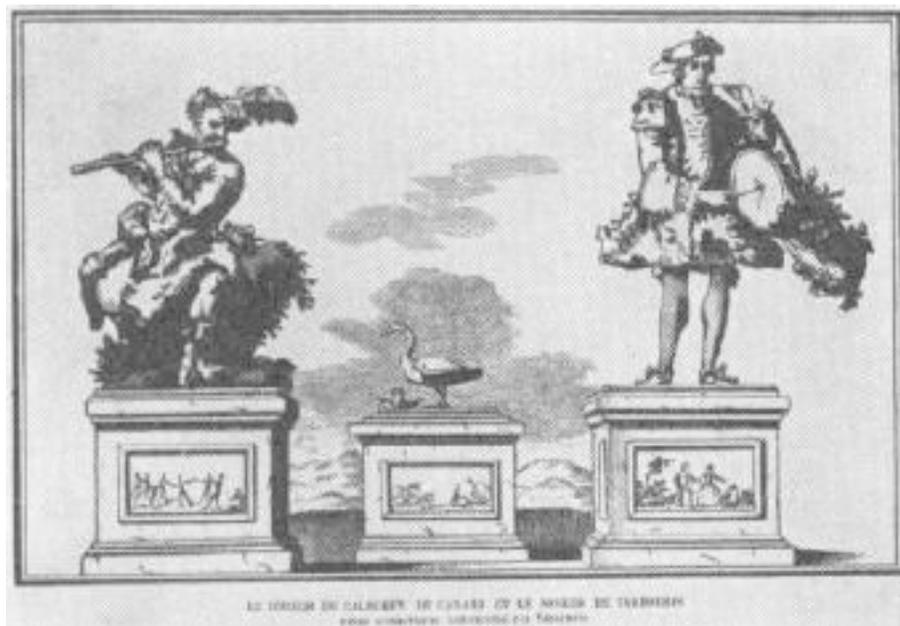


Figure 4.2: Three Automata by Vaucanson. In this wood cut, Vaucanson's famous duck is flanked by his equally well known flutist (left) and tambourist (right).

Vaucanson then went on to best himself by creating and exhibiting a life-sized duck. His prospectus declared it to be “An artificial duck made of gilded copper who drinks, eats, quacks, splashes about on the water, and digests his food like a living duck” [18, page 233]. This is arguably the most famous automaton ever created. The mechanisms which controlled the actions of this and other automata of this period were very complex, made use of the newest technologies available and were finely crafted. Vaucanson was not very forthcoming with details of how the duck worked leading to much speculation as to the mechanism. Figure 4.3 shows one guess as well as a photo purported to be that of the actual mechanism which was housed entirely in the pedestal.

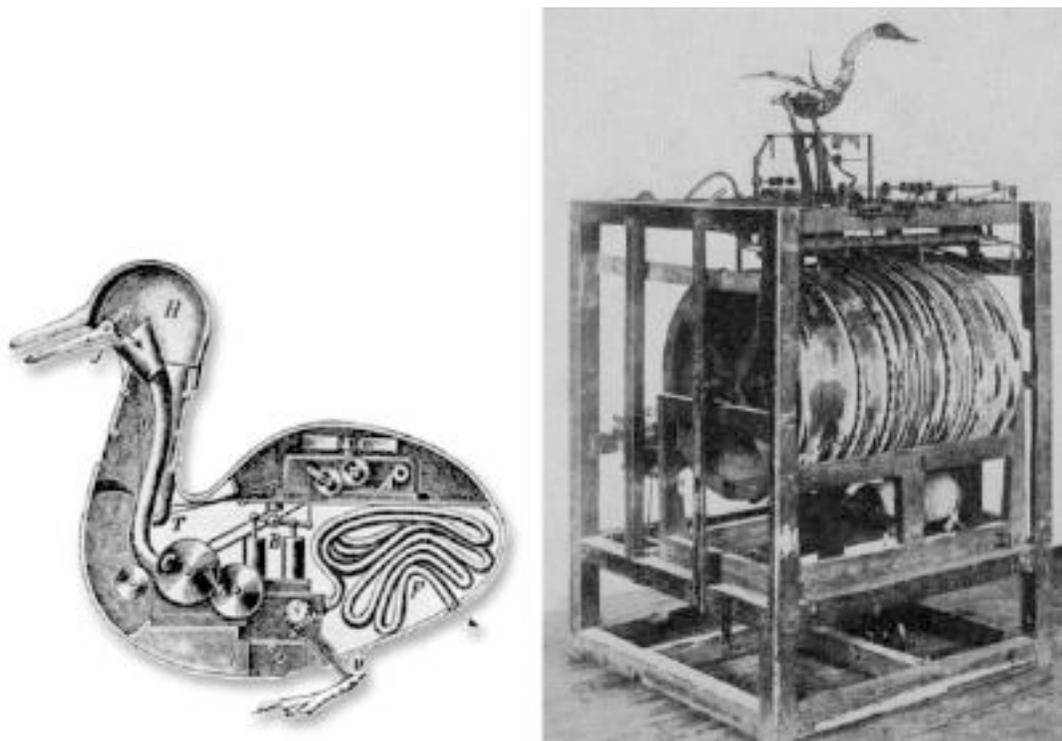


Figure 4.3: On the left, a contemporary woodcut speculation on the internal workings of Vaucanson’s duck. On the right a photograph of the actual mechanism for the duck taken in the mid-nineteenth century and claimed to be of the original.

Pierre Jaquet-Droz (1721-1790) and his son Henri-Louis (1752-1791) brought their expertise and skill as watchmakers to the building of automata. Unlike the automata of Vaucanson,

there are at least three Jaquet-Droz automata still extant in the Museum in Neuchâtel Switzerland [18]. The *Musician* plays a harpsichord by pressing her fingers to the keys and her general body and facial movements are meant to suggest that she is somewhat self-conscious of the attention being paid her. The *Writer* sits behind a mahogany table and, with the appropriate changes to his mechanism, can write any text of up to forty letters in length using a quill pen. The *Draughtsman* uses a pencil to produce any one of four drawings: Louis XV, King George III and Queen Charlotte of England, cupid riding in a butterfly drawn chariot, and a dog on which he also writes “my bow-wow” in English. A hidden bellows allows him to blow the pencil dust from his drawings. These automata are shown in Figure 4.4.



Figure 4.4: Three Automata by Jaquet-Droz. The *Musician* flanked by the *Draughtsman* on the left and the *Writer* on the right. These automata are now preserved in the Museum of Art and History in Neuchâtel, Switzerland. Photo: Musée d’Art et d’Histoire, Neuchâtel.

The automata of Jaquet-Droz followed those of Vaucanson by about forty years and differ in several ways that show how much the craft had changed in such a short period of time. Where the human figures of Vaucanson had been adult in size and appearance, the figures of the Jaquet-Droz automata are those of children. Perhaps one reason for this is the different emotional response that a viewer has to a talented and precocious child. Another reason may be to emphasize the

degree to which the mechanisms had been miniaturized. Where Vaucanson had placed his figures on pedestals which contained the mechanism, the Jaquet-Droz automata have their mechanisms enclosed in their bodies. This trend would continue up until the popularity of automata faded early in the twentieth century. There were, to be sure, artists who would keep the tradition alive to a limited extent, but with the death of Carl Fabergé (perhaps the last of the great craftsmen [7]) in 1920, the Golden Age was over.

#### 4.1.4 The Contemporary Automata Period

By the turn of the twentieth century, the industrialization of Europe and North America had shifted the focus of new technologies into the production of goods. Clockwork mechanisms were replaced by steam, internal combustion, and electricity. It was often more important to produce objects quickly and cheaply and automata suffered the same fate as many other products. Cheap wind-up toys and banks became their legacy. The quality of these later devices was often only good enough so that they didn't break until they had been briefly used. Cheap materials and mass production made the fine automata of only a century before little but a memory.

But the creation of automata was not a lost art. In the late 1970s a small number of European artists started making automata in a totally new style; one called *contemporary automata*. Where previously the goal of automata had been to inspire wonder, reverence, or awe, these new automata have a decidedly humorous intent. Where previously automata had been made as life-like in appearance and motion as possible, the new trend is often cartoonish or abstract. Where previously automata had hidden their mechanisms from view, these new automata are often brazen in offering their movements as part of the overall viewing experience. And where previously automata had been operated by mechanical, hydraulic, or pneumatic means, these new automata are, for the largest part, hand cranked by the viewer. These differences may at first seem subtle, but they have a profound impact on the viewer, making the experience more intimate and personal.

One central force in this rebirth was Cabaret Mechanical Theatre in England [14]. Here

artists such as Peter Markey, Paul Spooner, Keith Newstead, Tim Hunkin, and Ron Fuller were able to present their work to the public much as Vaucanson and the Jaquet-Droz had done two hundred years earlier. This public space introduced thousands to automata in an entertaining and educational way. Figure 4.5 illustrates this style. Using many of the same types of components as were used by Vaucanson (cams, gears, levers, even a bellows), Paul Spooner is telling a story; the milk is better because it belongs to someone else. And in addition to amusing us, he is also giving us the chance to see all of the intricacy of the automaton by exposing the mechanism to our view.



Figure 4.5: Cat Drinking Someone Else's Milk by Paul Spooner. The cat nervously looks from left to right to avoid being caught as it laps up the milk. Photo: Cabaret Mechanical Theatre.

#### 4.2 What Makes the Design and Construction of Automata an Appropriate Task?

As mentioned early in this chapter, there are a number of domains and approaches which could lend themselves to research on the acquisition of mechanical reasoning and spatial cognition. Why then choose the design and construction of contemporary automata? Before answering

this question it is important to ask a related question. When learning about mechanisms, why design and construct physical objects at all? It could be argued that sophisticated simulation programs running on fast computers could provide children with the opportunity to explore far beyond the bounds of what they are physically able to create. After all, much of engineering education has abandoned construction for simulation. But that seems to shortchange children who no longer have the opportunities to observe and interact with machines that were available to children as recently as thirty years ago. Many of the common machines that children now encounter day-to-day no longer have mechanisms in the traditional sense, being primarily electronic. And of those which do have mechanical elements, they are often enclosed and sealed so as to prevent them from being observed and understood. It seems evident that the exposure to and understanding of machines is critical to gaining the ability to reason mechanically and that exposure can no longer be obtained in daily experience. Building machines seems to be indicated in this case.

To support this assertion, there exists a body of historical and educational practice. Historically, the design, construction, and maintenance of machines has been a skill passed down from master to apprentice for centuries. By doing at the elbow of a skilled craftsman, a novice gains both the knowledge and the understanding that leads to proficiency. It was perhaps the success of this traditional model that led Friedrich Froebel to invent Kindergarten. He believed that engaging with the world through practical work and the direct use of materials allowed understanding to unfold. This led directly to the creation of the *gifts* (play materials) and *occupations* (activities) that were the core of his educational method [10]. Piaget claimed that cognitive development is facilitated by placing learners in situations or activities that require them to interpret events in terms of their existing cognitive structures (*assimilation*) and to change those structures to better make sense of those events (*accommodation*) in a process he called *adaptation* [41]. Papert cites his early experiences with gears and his use of that knowledge as a foundation for mathematical learning as an instance of Piaget's notion of assimilation [92] and he argues that learning is greatly facilitated when the learner is engaged in the creation of some *thing* [91]. Designing and building automata is very much in keeping with these schools of practice and exhibits several

attributes that makes it particularly attractive.

#### **4.2.1 Automata Tell a Story**

Turning the crank on an automaton does more than set it in motion. The viewer is told a story through the actions of the character or characters. The story is rarely involved, but when done properly can carry all of the impact of a well written and illustrated cartoon. This is because, in many instances, automata and cartoons (especially single panel cartoons) share a similar sensibility; extract the essence of the story and tell it as economically as possible. The story telling aspect of contemporary automata provides much of their initial appeal and, when done correctly, that appeal continues. Like all good stories it begs to be shared, making automata a focal point of social interaction.

#### **4.2.2 Separation of Story and Mechanism**

Contemporary automata can be divided into two units: the story components (the figures and supporting story elements) and the mechanism. While the telling of the story is in large part due to the design and function of the mechanism, from a pedagogical standpoint they can be viewed separately. This allows a designer to come to the process with an idea for the story to be told and to develop a mechanism that will provide the desired behavior that will tell that story. That allows for the study of mechanism design, mechanical reasoning, and spatial cognition in a more purely mechanical setting. A set of actions and dependences are defined that are necessary to tell the story and those become the constraints on the design of the mechanism.

#### **4.2.3 Domain Knowledge and Constraints**

Compared to some other domains, the mechanisms in contemporary automata are relatively simple and often composed of only a handful of components. This provides opportunities to explore both the properties of individual component families (such as cams) and the interactions between components in a mechanism, allowing domain knowledge to be constructed both

from the bottom-up and from the top-down. When mechanisms are assembled it is rare that individual components are tightly placed or hidden from view which provides the ability to fully examine components before, during, and after assembly.

The mechanisms in these automata also lend themselves to the kind of constraints necessary for this type of research. Constraints can be placed on the design and construction of these mechanisms that allow a more direct focus on mechanical reasoning during the design and construction phases while placing minimal restrictions on the behaviors of the resulting mechanisms. This occurs primarily by limiting the number of component families offered and by restricting the number and types of members of those families. Careful selection of components can still allow the knowledge gained to be applicable to a large number of mechanical systems in other domains. Additionally, the very nature of contemporary automata provides a number of very useful constraints. First, as already mentioned, these mechanisms are most often composed of a small number and type of components. Second, in very many cases contemporary automata are small enough in size to be easily held and manipulated by children, but still large enough to be constructed without difficulty and operated reliably. Third, the materials from which contemporary automata can be made are ones that many children will already be familiar with. And fourth, in most automata, the mechanism moves at a relatively slow speed requiring less precision in its fabrication and assembly and more readily allowing it to be observed and analyzed.

#### **4.2.4 Unexpected Results**

Designing and building contemporary automata is not an exact science. Unlike high precision mechanical systems, there is rarely any attempt made to simulate the operation of an automata before building a prototype. This can lead to a number of unexpected results, not all of them bad. Paul Spooner mentions that unexpected friction at the hip joints in his automaton *Press-up Anubis* (Figure 4.6) allowed the shoulders to precede the hips as Anubis lowers his body which he finds more pleasing than what he had originally anticipated [120].

Unexpected negative results are rarely critical problems. Because of the relatively simple



Figure 4.6: Press-up Anubis. As Anubis pushes up, his body straightens but when it moves back down, friction at the hip joint allows the shoulders to touch the table first. Built by Paul Spooner and Matt Smith. Photo: Fourteen Balls Toy Company.

mechanisms involved, diagnosis of problems and the creation of solutions is a more straightforward process than many other domains would allow. The failed results become excellent learning opportunities for the user and provide yet another means by which reasoning about the mechanism can be done.

### 4.3 Contemporary Automata

What is it that distinguishes contemporary automata from other categories of automatically moving figures? There are five principal features that are evident in contemporary automata. Not every contemporary automaton may have all of these features, but these do help us establish some subjective guidelines.

- (1) Contemporary automata interact with viewers in an intimate way. These automata are not exhibited to large audiences, but are viewed by one or a few individuals at a time.

The viewer is responsible for setting the automaton in motion and determining how long, and in some cases how fast, the automaton will operate. The power source for that automaton is often supplied by having the viewer turn a crank or otherwise provide some mechanical input. The viewer may be able to lift and hold the automaton and to view it from many angles. In essence the viewer does not observe the automaton's actions but participates in them.

- (2) The mechanisms found in contemporary automata are commonly simple, being constructed from a small number of components whose type and function can be discerned without extended study. The viewer no longer needs to be an engineer or mechanist to understand the workings of the automaton and understand how the design of the mechanism contributes to the experience of viewing.
- (3) The mechanisms found in contemporary automata are commonly exposed to the viewer. Traditional automata conceal the mechanisms in the bodies of the automata or in the base or clock to which they are attached. Viewers were allowed to marvel at the motions, but not allowed to see how it was done. Contemporary automata take a holistic view that all of the parts are important to the viewer's experience.
- (4) The figures and scenes presented in contemporary automata are caricatures of life rather than exact copies. Rather than the perfectly life-like motions and appearances sought as ideals in traditional automata, contemporary automata embrace cartoon-like motions and appearances which engage the viewer in the same ways that print and animated cartoons do.
- (5) Where traditional automata were created to inspire reverence, awe, and wonder in their viewers, contemporary automata are generally humorous and playful. The humor is sometimes dark but the maker establishes an emotional link with the viewer through the automaton that doesn't exist in other types of automata.

To illustrate these principles, two examples are briefly presented here. One was designed by a professional automata maker and constructed from a kit while the other is the work of a skilled novice.

#### 4.3.1 The Camel Simulator

This automaton (Figure 4.7) was designed by Paul Spooner and built from a kit. It depicts Anubis, the the Egyptian god of the dead, practicing for the fast getaways necessary when his customers got wind of the poor quality and pricey funerals he had sold them.



Figure 4.7: Practicing fast getaways was a critical survival skill for the ancient flim-flam undertaker. Here Anubis, Egyptian god of the dead, stays in tip-top shape. Built from a wooden kit designed by Paul Spooner.

The mechanism consists of three cams (see Section 5.1.3.1 for a description) attached to the crank via a single shaft. Two of the cams are eccentric cams with ring followers to move the camel's head and tail. The remaining cam is a three-lobed snail cam that lifts and drops the camel's hump. The lobes on the snail cam are not evenly spaced, but are designed to produce a galloping

rhythm in the motion of the hump. Anubis' body articulates at four locations: his heels articulate at the camel's neck, his legs articulate at the hips, his hands articulate at the reigns, and his arms articulate at the shoulders. This creates a quadrilateral (legs, torso, arms, camel's neck) that can move at each corner. As the camel's hump rises, so does Anubis' torso. When the hump falls, Anubis follows along. While the motion of the head and tail comes about because the eccentric cams pull them down as well as push them up, the downward motion of the hump and Anubis' torso results strictly from gravity.

#### 4.3.2 Celia the Sea Lion

Celia (Figure 4.8) is the prototypical pinniped made good; she balances on her pedestal while spinning the ball and moving her flippers.

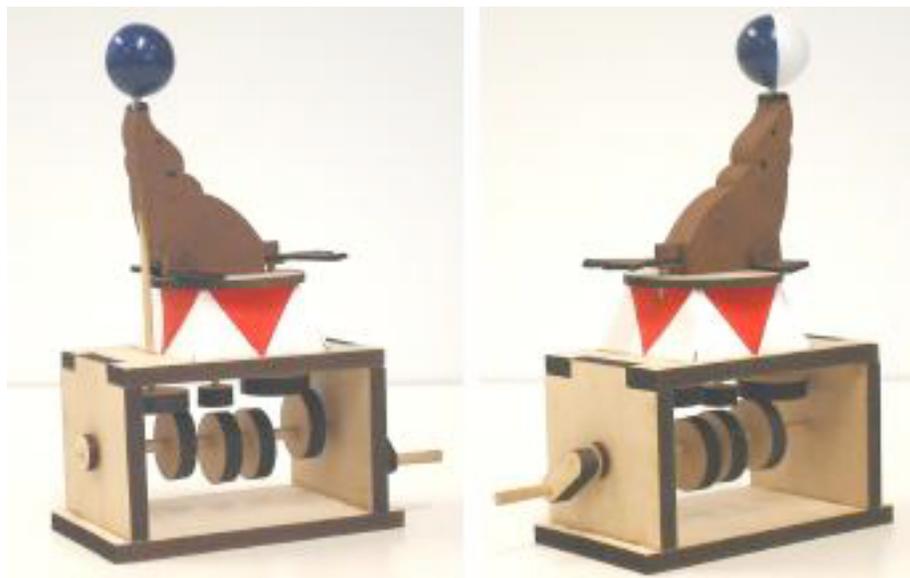


Figure 4.8: Balanced on her pedestal, Celia keeps the ball spinning on her nose while constantly moving both her front and back flippers. The mechanism is based on one created by Peter Markey and used in his *Angry Cat*.

The mechanism consists of three cams and one disk attached to the crank via a single shaft. The disk rotates another disk attached to a second shaft set perpendicular to the first. This causes the ball to rotate continuously as long as the crank is turned. The first eccentric

cam moves its follower up and down. This follower moves a lever hidden inside the body that is attached to the front flippers, causing them move. The remaining two eccentric cams are arranged symmetrically at opposite ends of perpendicular disk. Because of this placement, a continuous turning of the cams causes the disk to turn back and forth. This causes the tail flippers to move from side to side.

#### **4.4 Automata in Education**

The use of automata is not a new idea. For example, in both Canada and the United States automata are used as students study basic science, mechanics, and mathematics. In the UK, the National Curriculum [87] has included a Design and Technology (D&T) component since 1995. During Key Stage 2 (ages 7-11) all students must make a mechanical toy with the goals of increasing their building skills and learning about how motion can be controlled. While the standards call for the design and construction of a simple toy with a cam mechanism [25], many teachers take this opportunity to engage the children in designing somewhat more complex mechanisms that might also include gears or levers. In many instances, the resultant artifacts exhibit many of the attributes of contemporary automata.

The mechanical toy unit has much in common with the research described here. A number of the challenges by both students and teachers have helped shape the MachineShop system (Sections 5.1 and 5.2) and the experimental method (Section 6.1). Among these are:

- Information about mechanisms of the type under study is not abundant. In many cases students bring no prior knowledge of machines to their first design and the lack of ancillary materials to provide examples and explanations makes the process more difficult.
- With the software design tools available to students even the creation of simple mechanisms is quite challenging. The same CAD/CAM (computer aided design and computer aided manufacturing) tools used in higher grade levels are also used in the mechanical

toy unit. Younger students are not a target audience for these tools and their interfaces and feature sets make them a poor choice for this activity.

- The time limit set for completion of the unit restricts the amount of time available to students to experiment and refine their designs. In some cases students are only given one work session in which to develop an idea and produce preliminary drawings. And as the unit progresses little or no time is available to iteratively prototype and improve.
- Children at this age are still learning to use tools and to understand the properties of the materials that they are working with. To expect them to be able to produce mechanical components with any degree of precision is Panglossian.

It might seem that these issues would make the mechanical toy unit frustrating for the students and that the results would not be very interesting. Nothing could be further from the truth. One can wonder, however, what the results might be like if these issues were addressed.

#### **4.5 Summary**

Automata are moving sculptures of people or animals with repeating motions controlled by mechanisms. The ancestry of the machines that we identify as automata goes back over 2000 years and we find descriptions of automata in the writings of members of the Alexandrian School as far back as the third century BCE. Powered by steam, wind, and water, these early automata were used for religious purposes, as entertainment, and to illustrate many of the latest technological advances; a role they would play throughout most of their life. Much of what the Greeks knew lay dormant or was lost during the Dark Ages, but by the thirteenth century CE a large portion of that knowledge was being rediscovered in Europe. Water clocks gained automated figures and eventually were made obsolete by the weight-driven clock mechanism of the town square. Water gardens with elaborate automata adorned great palaces, and the ancient writings of the Greeks were translated and studied. The spring replaced weights in clockwork allowing the mechanisms for automata to become smaller and more intricate. Automata building was raised to high art.

The late twentieth century found two primary schools of automata building: the traditional and the contemporary. Contemporary automata differ from traditional automata in a number of ways mostly dealing with aesthetics and the connections between automata and viewers. Contemporary automata provide a good domain in which to study the acquisition of mechanical reasoning and spatial cognition because children find them interesting, because the mechanisms are simple and easily studied, because the amount of knowledge and skill necessary to design and make simple automata is small, and because designing and building automata gets directly to many of the core components of designing and building any mechanical system.

While automata have been and are being used in education settings, they often are relegated to the role of educational manipulative in the teaching of important concepts. In the UK the creation of a mechanical toy or automata is a required exercise with the goals of increasing a student's ability to make physical artifacts and as an introduction to controlling mechanisms. This task is not without its difficulties, and the design of the MachineShop system reflects a desire to address some of these problems. This is more fully discussed in Chapter 5.