AUTOMATA MAGAZINE

Ellen Rixford's *Beautiful/Terrible* puppet

2/1—Jan/Feb 2020

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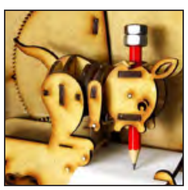
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DEPARTMENTS

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EDITORIAL

Repetitiveness and perfection

by Marc Horovitz

I'd like to wish all *Automata Magazine* readers and their families a happy and healthy New Year! This promises to be a good year for the magazine and automata aficionados in general. We already have some great articles in the bin, and we're looking forward to bringing them to you.

Not long ago, I was discussing the magazine with a friend. I mentioned that, at my former magazine, although I enjoyed the work and the people, I sometimes felt that the content was unavoidably becoming a little repetitive. I told her I felt that this would never become a problem with *Automata Magazine*.

She said, "Why wouldn't the same problem recur with *AM*? After all, it's just people building little machines." That got me thinking.

In some respects, she was correct. We all use similar mechanisms—cranks, cams, gears, levers, etc.—to accomplish our goals. We use similar materials, too—wood, metal, plastic, and so forth. However, the same could be said for other areas of fine art, yet none of these are repetitive.

Creating an automaton is no different. A piece of work generally starts with an idea. From there it proceeds to the design stage, then on to fabrication, just like any piece of art in any other medium.

There are several things that prevent automata from becoming repetitive. The skill levels of the various makers is one. Another is their experience. Workshop and tool availability could be another.

However, the single greatest reason that each original automaton is unique is creativity. We are all different. A hundred different people will approach the same problem in a hundred different ways, resulting in a hundred different solutions. Since making automata is creating art, there are no rules, aside from the laws of physics. Anything goes. Every piece is an expression of its maker. Sometimes this expression is obvious; at others it's more subtle. I like to think that every object created by an individual possesses a tiny bit of that person's essence.

One of the great joys for me in producing this publication is interacting with so many wildly imaginative people and seeing the amazingly creative work produced by our authors and readers. This creativity reflects not only the artists' innate talents but their life experiences as well.

I feel that *Automata Magazine* isn't a publication just about automata—it's a magazine about people. The question of repetitiveness should never arise. I like it that way.

•

I recently came across a wonderful quote by Gwen Marston: "Perfection is not a god to be worshipped, nor does it have anything to do with art."

Gwen was a trendsetting fiber artist and teacher. Her quilts, while perhaps not technically perfect, are things of great beauty and inspiration. Technical perfection might even have diminished their character and appeal.

What she is saying in her quote, I think, is that art is an expression of the soul. None of us are perfect, so why should our work be? We do the best that we can with what we have available to us, and the result is an expression of who we are at that moment.

We may try to improve every time, but absolute perfection will always be elusive. However, that doesn't lessen the quality of our work. Imperfections create nuance and add character. To paraphrase Bobby McFerrin, don't worry, be happy in your work.

NEWS

Timberkits (UK) is currently stocking its *Demon Dentist* and *Magician* kits in the USA, but for a limited time only. Cheaper shipping on these kits is available to US customers. Visit *www.timberkits/shop* and click on "USD."

Automata for sale

Gakken "Yumi-Hiki Doji" (Arrow-shooting Boy") automaton kit. New in unopened box (discontinued model). Wood, fabric, PVC construction. Wind-up spring powered. Seated archer selects arrow and shoots it toward target—four arrows per wind. Price: $250 US + $18 postage in the USA. Randall Rudd, *rudd@satx.rr.com*

Forum report

The *Automata Magazine* online forum continues to grow. Questions are asked and answered. Supplier information is exchanged. Images and videos of "What's On My Bench" are shared. Browse the *forum messages* and consider joining our free forum, as we discuss automata. —*Jim Coffee, Moderator*

EVENTS

Morris Museum presents *The Adventures of Baron von Steubon and Cromwell: A Kinetic Tale* by David Bowman. A series of 18 mechanical vignettes tells the story of two automata and their journey on land, sea, air, and into the past, as they encounter fantastic mechanized beasts, in their quest for long-lost family and treasure. November 14, 2019—March 1, 2020.

Cabaret Mechanical Theatre (CMT) has announced the following touring exhibits:

Curious Contraptions, Exploratorium, San Francisco, California, USA. Through January 26th 2020.

The Poisoned Milk and Other Fairy Tales, phaeno, Wolfsburg, Germany. Through February 16, 2020.

The Mechanical Circus is a collaboration between CMT and Rijksmuseum Boerhaave, the Netherlands. Puke Ariki Museum, New Plymouth, New Zealand. Through April 2020.

Mechanics Alive!, ¡explora!, Albuquerque, New Mexico, USA. Through 2020.

More info: *https://cabaret.co.uk/exhibitions/current/*

AutomataCon

Hosted by The Morris Museum: May 29-31, 2020. More info: *http://www.automatacon.org*.

CALL FOR ENTRIES

Morris Museum

A Cache of Kinetic Art: Tiny Intricacies: March 13-July 12, 2020

Timeless Movements: March 12-July 11, 2021. A multi-year juried exhibition series, *A Cache of Kinetic Art*, showcases contemporary automata and their inventive creators. Prospectus and entry forms for both exhibitions: *https://morrismuseum.org/mechanical-musical-instruments-automata*. AM

In the next issue of AUTOMATA MAGAZINE

- A conversation with Colombian artist **Carlos Zapata**
- **Teun de Wijs** introduces us to his LEGO automata
- **Dominique Corbin** creates an automaton depicting a real-life experience
- **Susan Sharp's** miniature found-object automaton
- **Vincent Crisci** talks about collecting Sam Zell automata

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Merlin's story

Part 2: The mechanics of *Merlin*

by Mike Palmer • Tarleton, West Lancashire, UK • Photos by the author

In the November-December 2019 issue of *AM*, I described the process of designing *Merlin* and bringing the automaton to life. I'll continue on here with a discussion of some of the workings.

Mechanics

Photo 12 shows the bones of the Merlin figure. Due to the fact that his arms and head must be able to move while his body is in any position within the arc in which he turns, the "pushers" that transfer motion from the cams and followers must line up close to the center of the telescoping tubes that finally transfer motion to the arms (one tube for each arm). The head's motion is obtained via a solid rod that runs through the center of the tubes.

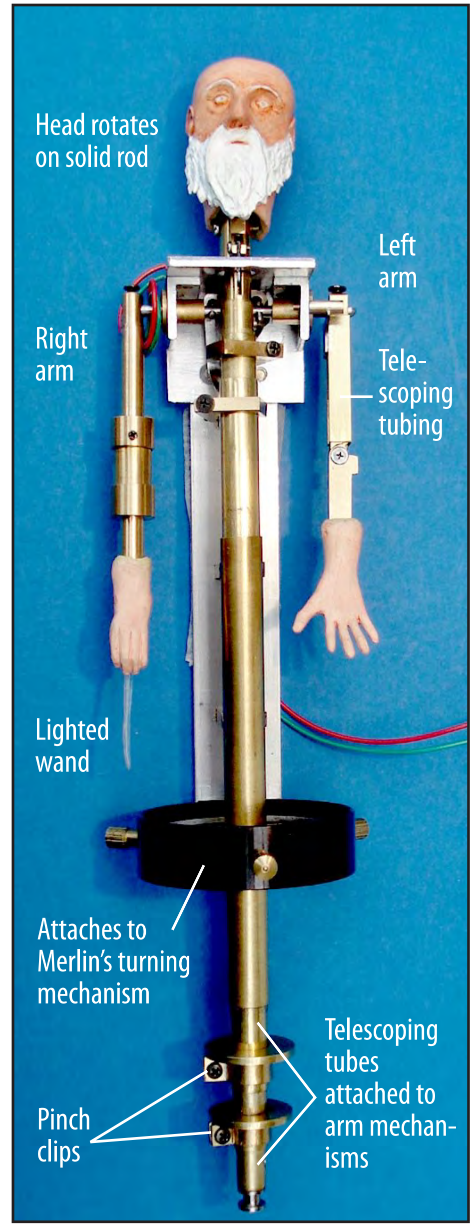
The telescoping tubes that control the arms have shouldered discs placed at different heights, and of differing diameters at the bottom, so that they maintain their relationship with the pushers beneath them in any position. The discs' shoulders are split and are held in place by pinch clips. This enables them to grip the tube over a large area without distorting it and they are, therefore, adjustable. The tubes have similar arrangements at their tops, where the links to the arms are also held by pinch clips.

Merlin's arms

Left arm. Making Merlin's left arm was an extravagant use of time, in that the number of hours that it took to make it was difficult to justify in terms of the resulting effect. However, this provided a challenge, and I like challenges.

So, because magicians always wave their hands over a crystal ball, I decided that Merlin must also wave his hand over his crystal ball. This action would be quite obvious on a larger figure, but he is only 6½" (16.5 cm) tall, with the consequent reduction in apparent movement. Anyway, the challenge had to be met.

The upper left arm is made from telescoping rectangular-section brass tubing (**photo 13**). This allowed the use of a sleeve (no pun intended), which, as the arm lifts, meets a stud on the shoulder that

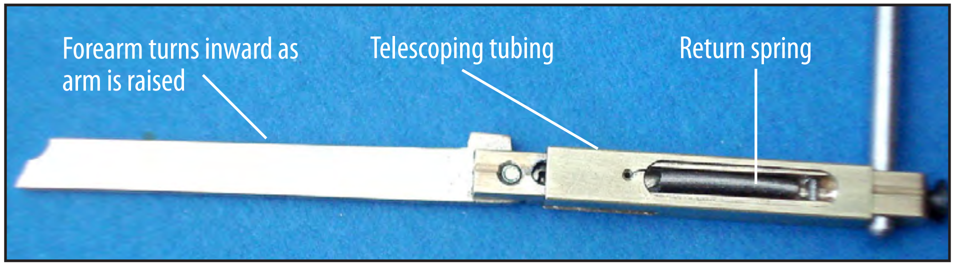


12. Pinch clips toward the bottom are connected to separate telescoping tubes controlling the arms. "Pushers," actuated by cams, push up on the discs to move the arms.

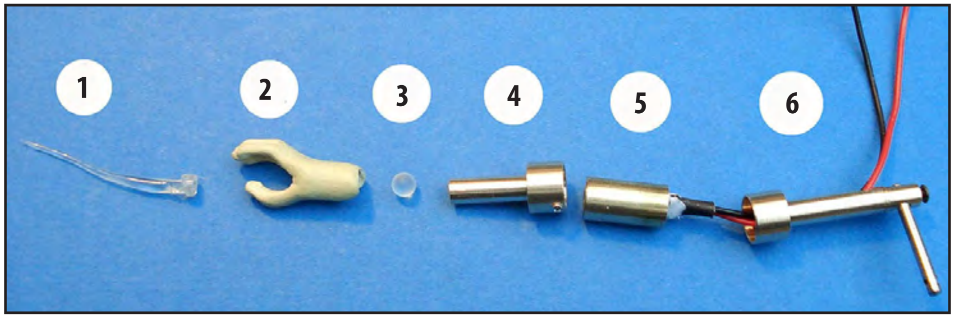
pushes the sleeve down the arm, against the force of a small return spring. As the tube travels down the arm, its lower end engages a nib at the elbow of the forearm, which forces the forearm to turn inward. As the arm lowers again, gravity and the return spring straighten the arm.

Right arm. The right arm is fitted with a laser light, which makes it glow in an eerie, magical way. It is made up of several components, as follows (**photo 14**):

1. The wand, made of clear glue
2. The hand, made of Milliput (an epoxy putty)
3. A diffuser—an opaque soap-dispenser valve
4. An extension piece
5. The tube containing the laser
6. The upper arm, pivot, and mount for parts 1-5



13. Left arm.



14. Right (wand) arm.

The broom

The broom's motion is what I jokingly call my Palmer's Patent Reciprocating Brushing Action with (deluxe model only) Random Variation in Arc, Amplitude, Angle, and Attitude, via a Floating Pivot (**photo 15**). I'm not sure that I understand it myself! It is the result of experimenting with ways of making the broom appear to be driven by some manic force conjured up by the magician.

The arm that holds the broom (1) passes through a hole in a small pivoted bracket on the wheel (2) and ends in the round, brass block (3). A thin spring wire, anchored by a wood screw (5), passes through a large hole in the brass block. The angle of the broom relative to the brass block can be adjusted by a clamping screw, while the position of the spring relative to the block can be adjusted by loosening the woodscrew and rotating the spring. The holding bracket is adjustable via the two slotted screws (4).

15. The mechanism controlling the broom.

16. The firebox and fire beneath the cauldron.

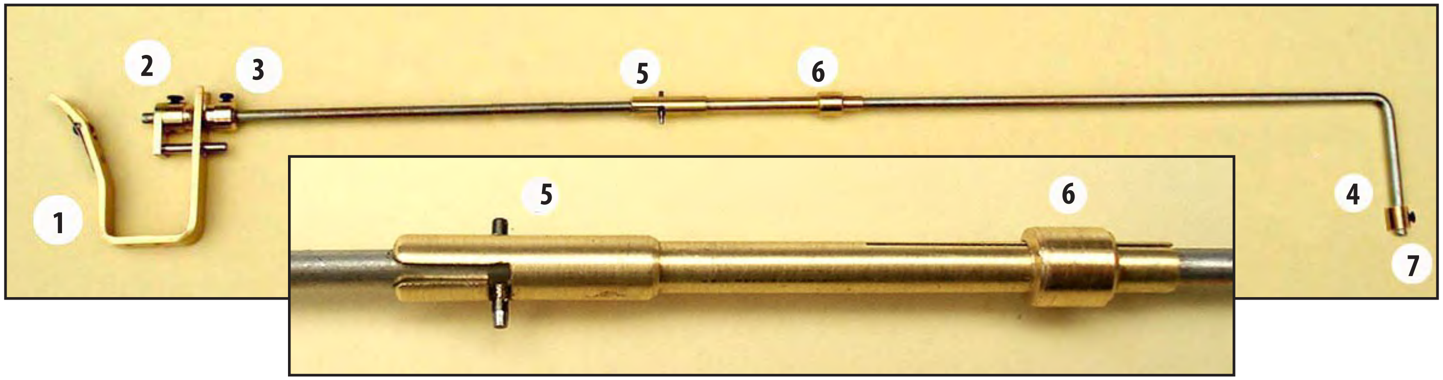
The fire

The fire is an amalgamation of two small fans, several LEDs, colored plastic film, a camera flash unit, and a firebox made by me from strips of mild steel. It can be seen in **photo 16**. The fan blows the colored plastic film strips from below, causing them to wave like tongues of flame. The flash unit and LEDs complete the effect.

The cauldron

There are two stages to the cauldron's movement. The first is achieved by a cam, which pushes the cauldron over the fire via the link. Then, after a short delay, the cauldron wobbles as it boils.

Moving the cauldron over the fire required a linking piece between the cam and the cauldron crane. The linking piece had to be made so that the cauldron-moving cam follower could be discon-



ABOVE: 17. The linkage between the cam and the cauldron. The key (5-6) allows the cauldron to be easily removed from the automaton so that Merlin can be removed.

RIGHT: 18. This simple test stand was made to test magnetic action over the required distance. A small motor drives a pulley that has a couple of magnets attached to it. These interact with a third magnet inside the cauldron.

nected from the crane. This turned out to be an awkward job, as it comprised two pieces that had to be locked together to preserve the push-pull action, yet were only accessible from the outer edge of the underneath of the scene. It was essential that this piece be removable because the cam assembly, with Merlin attached, couldn't be removed from the scene while the link remained attached.

Photo 17 shows the linkage between the cam and the cauldron. The inset photograph is an enlargement of the key—that part of the linkage that allows it to be removed before Merlin can be removed.

The cam follower is part 1. The flat part at the bottom fits into a "shoe" that is pivoted to allow rotary movement. This follower must be sprung against the cam because it both pushes and pulls, and because it has to be removable. The spring is simply a piece of spring wire fastened to the cam assembly base. It presses the crane-cam follower against the cam. Most of the other followers rely on gravity for that.

Because it both pushes and pulls, the joint had to be in the form of a key (5-6) that can be slipped apart but locks in place with a twist. The follower is unlocked by removing the pin (7) from the bottom of the cauldron crane and twisting to free it. A holding piece (4) is on the end of the pin (7) preventing the pin from becoming disengaged from the base of the crane in the event of a jolt. Parts 2 and 3 form a universal joint that allows the follower to move through its rotary path, yet maintain its influence on the cauldron.

For the wobble, my first thought was to try using magnetic force. I didn't think the magnetic action would be strong enough over the distance required, so I tried a small motor with an eccentric weight, inside the cauldron. This failed miserably! The action varied between a mild tremble and manic thrashing that would have destroyed the cauldron and much of its surroundings.

I reverted to my original idea and built a temporary stand to test the possibilities (**photo 18**). This did work over the required distance. The wobbling is now created by the influence of two magnets on a rotating disc behind the fireplace, attracting and repelling a magnet inside the cauldron.

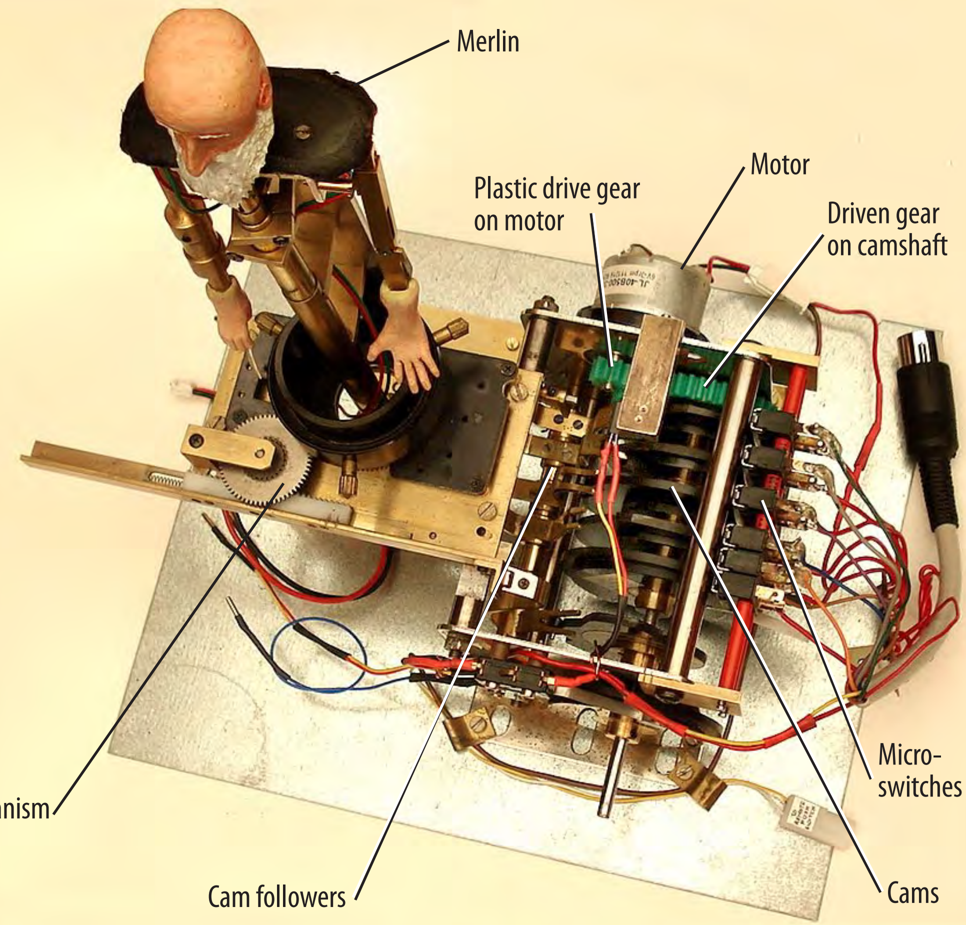
Documentation

When I began to make this automaton, I thought it was obvious that, since *Merlin* was scratchbuilt, anyone who was faced with the job of repairing or maintaining it in the future would need some help. There are elements of the automaton that, if treated improperly, could prevent it from ever working again. So, from day one, I kept a record of my thoughts, methods, and reasoning, both in text and photographs. There were so many different processes, I knew I wouldn't remember them all in detail anyway, so thoroughly documenting the project was as much for my own benefit as anyone else's.

This record contains everything—ideas later abandoned, failures, frustrations, and doubts as to whether or not I would ever get it to work—*and* that very special day when it *did* work for the first time. There is only one version of the document. It would not give an accurate account if it was altered to give the impression that the process had all been plain sailing. It was not!

Here is another view, this one showing how Merlin's location relates to the cam assembly. The unit can be removed as a whole by disconnecting the cauldron link (not shown) and the electrical connections. A section of the floor can then be removed so that the unit can be slid out.

All of the actions of the automaton, with the exception of the writhing dragons and the broom, are controlled and powered by this unit. The dragons and broom have separate motors but even they are controlled by microswitches on this unit.



Conclusion

If I had this project to do again, the one thing that I would do differently would be to *not* do something in the first place! I refer to Merlin's left-arm movement, which moves both at the shoulder and the elbow, to allow him to wave his hand across the crystal ball. If you look closely at the video, you will see that when he faces forward, his arms are straight but by the time he peers at the crystal ball, his arm is bent at the elbow. I doubt that anyone has ever noticed that the arm does that, yet it took me many hours to make it so. On a larger figure, the movement would have been more pronounced, but this one isn't larger.

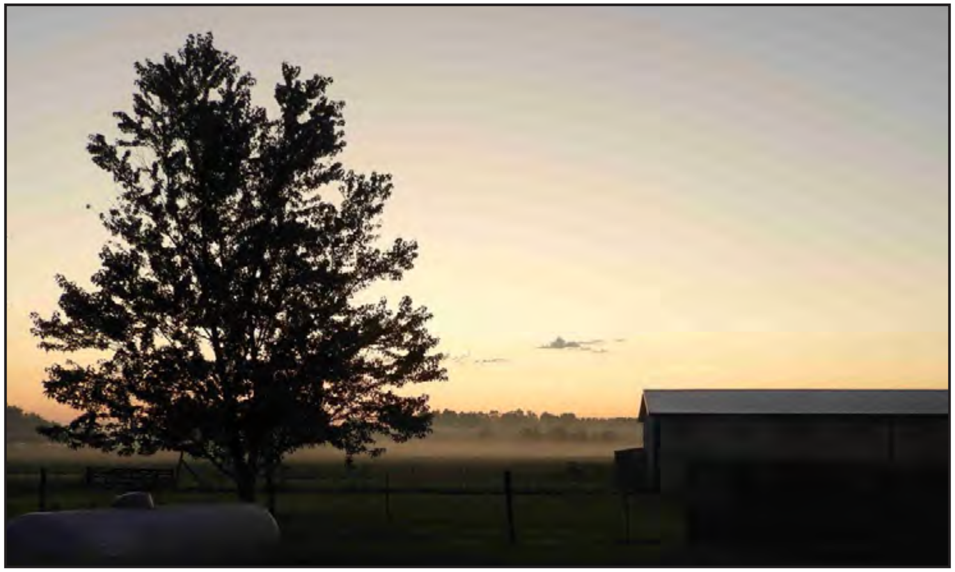
The castle cabinet came out better than I thought it would—that more than met my aspiration. The automaton is capable of also doing that. However, although the timing of the actions and degree of movements are all adjustable, I just haven't gotten around to fine tuning it yet. A1

A video of Merlin doing his magic can be seen at *https://tinyurl.com/mikesmerlin*

A week with John Morgan

Learning to build automata

by Mario Núñez • Buffalo, New York, USA • Photos by the author



1. Mark Adams School of Woodworking at dawn, in rural Indiana.

2. *Tempus Fugit*, a piece by instructor John Morgan.

Marc Adams School of Woodworking (*https://www.marcadams.com/*) is a series of connected steel buildings set in a sea of cornfields in central Indiana (**photo 1**), just south of Indianapolis, near the town of Franklin. The rural setting is part of the appeal of the school—a place where the nearest major highway is a few miles away and there are few distractions. I have been taking courses there for six years, always in subject areas that are new to me.

The school offers courses in all aspects of woodworking, including joinery, finishing, veneering, turning, carving, chair making, cabinetmaking, guitar and violin making, stereo-speaker design, and even a class on making a wooden bicycle frame. There are two-day weekend courses; five day-courses; and some courses that go on for two weeks. These all take place in the well-equipped bench rooms and machine rooms. The school has recently expanded its offerings to include metal-working, forge work, and glass. Teachers and students come from all over the world (there was a student from Uganda and a teacher from Israel while I was there this past year).

Examples of work done by students and teachers from past years are displayed in showcases. It was one of those displays that made me curious about the work of John Morgan. This was an automaton, called *Tempus Fugit*. It was simple but elegant (**photo 2**). Time really flew when one turned the crank.

Last year, when I was taking a cabinetmaking class, I wandered into the shop where John was teaching, and I was fascinated.

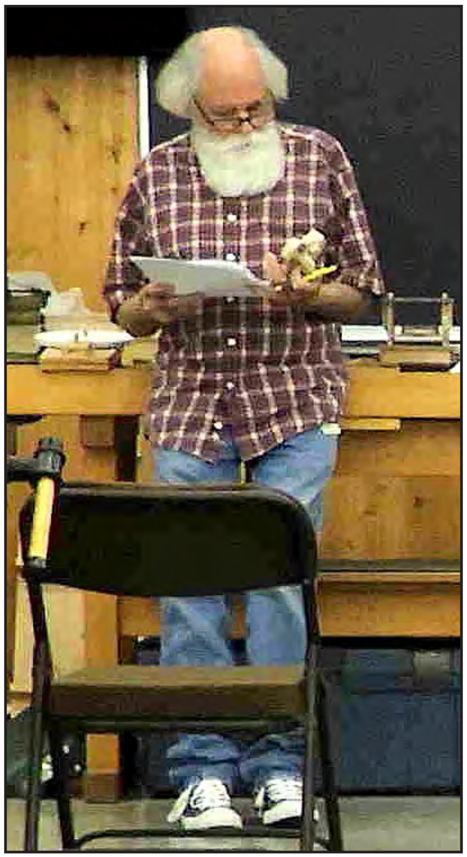
He had several of his automata on display at the front of the room (**photo 3**) and they all had a message to convey through their movement. When the brochure for 2019's courses became available, late in 2018, I planned my summer around the automata class. Even more than with other courses I've taken at Marc Adams School, I approached this one with little knowledge. I had only the vaguest idea of how automata worked.

John Morgan is a great craftsman, as well as an excellent teacher (**photo 4**), and his email signature line—"tinkerer/woodworker/teacher"—says a lot about him.

In five very busy days, he managed to show students the skills they need to create automata. Even if we couldn't all manage to learn those skills in a five-day class, we had an introduction and could then practice those skills in our home shops.

John did warn us at the start that troubleshooting our work with automata would probably involve taking our piece apart and putting it back together 200 times before we were satisfied with it, and that, even after that point, there would be more adjustments necessary, as humidity and temperature changes affected the piece.

3. A display of John Morgan's automata.



4. John Morgan in the classroom.

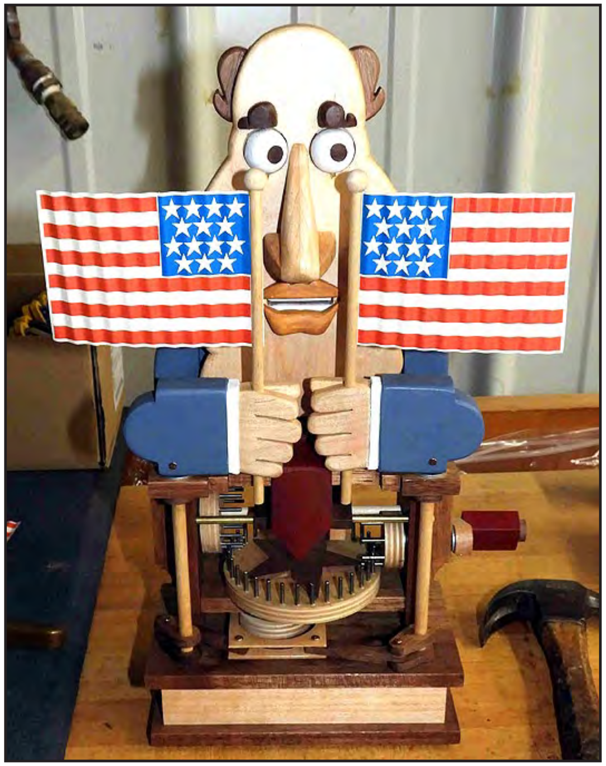
5. A corner of the machine room at the school.

6. The author's bench room. Everyone had their own workbench. Scrollsaws are at the left.

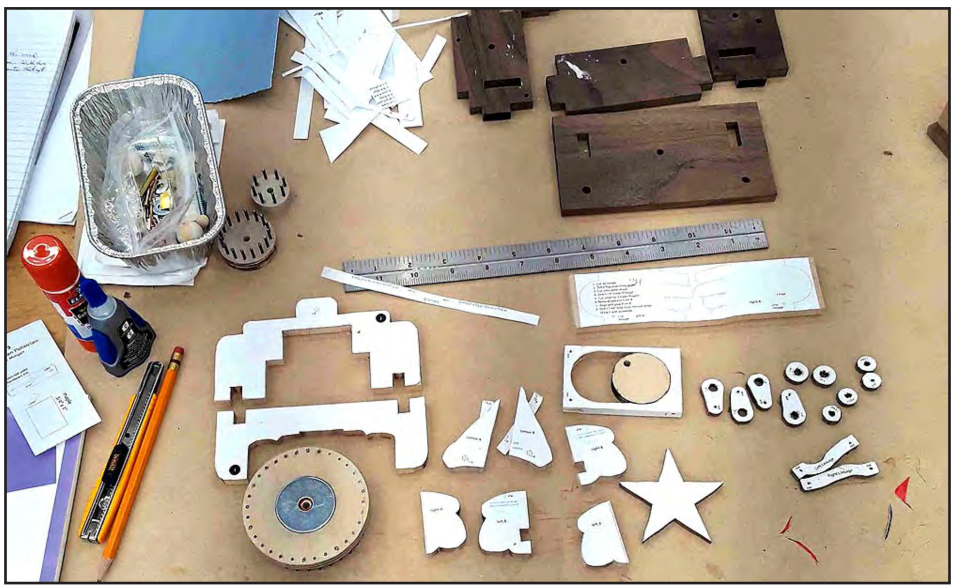
The week began with a talk by Marc Adams on the rules of the school, the schedule, and how things would work. The school's facilities (**photos 5** and **6**) are available for student use 24 hours a day, except for more limited hours on the larger machines, and many students do work very long hours at their bench. The school provides coffee and tea for most of the day, as well as snacks in a basket in the cafeteria and a good lunch every day. There's even a soft-serve ice-cream machine and all the extras to go with it. Students are encouraged to take breaks and see what other classes are doing, which is how I discovered automata.

Our class started with an introduction to kinetic sculpture and automata, with demonstrations by John of how different mechanisms work. Shop assistants talked about tool safety and, after an introduction to our class project, we began to prepare blanks for cutting the parts. That was the start of our work on the scrollsaw, which took up much of the rest of the week, along with drilling precise holes using the drill press. That first day, like all days at Marc Adams School, officially started at 8:00 AM. Some people, though, started much earlier, and went on until late in the evening.

In our class, we all worked on the same project—a piece John calls *US Politician* (**photo 7**). The character starts out hiding behind the flags. As the crank turns and the flags move out of the way, you can see that the politician is not just two-faced but three-faced, and he's speaking out of all of those mouths. The jaws move, the eyes pivot back and forth, and the arms open and close to show and hide the mouths.



LEFT: 7. The class project: *US Politician*. This one was made by the instructor.



BELOW: 8. Parts cut on the scrollsaw by the author. The large pinwheel gear at the lower left is ready for its pins.

Just as John had warned, on the morning of the second day, we were all feeling the effects of having been on our feet on a hard floor for many hours. John told us that we should pace ourselves so we could last the entire time without burning out.

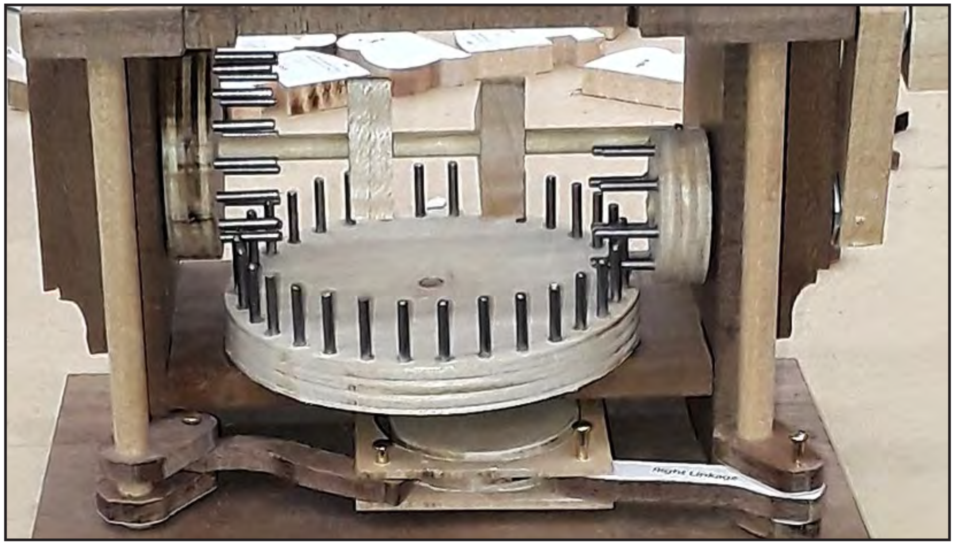
We started working on the base, and we saw a demonstration on making pinwheel gears, using an indexing guide to make holes in the proper places. There wasn't enough time for us to make indexing jigs of our own, but we got the parts and instructions to make one. That will be the first project in my home shop. We also began to glue templates to the maple, walnut, and plywood to make the parts that would come together to form the automaton.

The second day was more frustrating, since some of the students hadn't done much scrollsaw work before, or hadn't in a long time. Many of the parts had to be cut precisely or the piece wouldn't work properly (**photo 8**).

The indexing jig was a huge help in cutting the gear wheels and drilling the holes for the gear pins, as was a jig for sanding the gear disks truly round on a sanding wheel. It did feel like we were making progress, even if it wasn't terribly fast progress. I could understand why there were three students in the class who had been in it the year before and were retaking it.

On the third day, the project really started coming together. I finished getting the parts of the base cut and I began to put them together, with the appropriate gears in place (**photo 9**). It worked! But the advice about having to take the piece apart and putting it back together 200 times was true. I had two small problems with a linkage and a gear. Both were fixed relatively easily after some troubleshooting and I could start to think about the parts that would be added above the base section—the body of the character, the face and jaws, the flags, and the eyes. It was a scary prospect.

On the fourth day we were all feeling the pressure. We wanted to finish the project and knew we most likely wouldn't be able to. Each layer of parts we added produced new potential problems. Sometimes adding a part caused friction that prevented another part from moving freely. Other problems were caused by parts not having been cut exactly on the scrollsaw, which meant trimming them and sanding until they fit. Adding the screws that held large sections of the piece together created stress in the parts, which could throw things off.



ABOVE: 9. The mechanism is coming together.

LEFT: 10. The author's progress by the last day of the five-day course. Students would have to finish their projects at home.

By midafternoon on the fourth day, we knew too well there was only one day left. A fair part of that day would be spent in cleaning up the shop areas and setting things up for the next class that would use our space. The fourth day also involved a traditional dinner for the group. In our case, this was at a nice brick-oven-pizza restaurant and microbrewery in the nearby town of Franklin. It was a chance to sit together and talk in a more relaxed setting than in the shop.

The morning of the last day of class was spent in more testing and troubleshooting of our projects. There was no time to finish the piece or even do any finishing work, since there wouldn't be enough time for it to dry properly, but we had accomplished quite a bit and learned new skills.

Even though we had all worked on the same project, it was obvious that each student had put their own touches on the piece (**photo 10**). After lunch, we cleaned the shop and started packing our cars for the drive home (500 miles in my case) or to the airport for some. Now it was time to put those new skills to work in my own shop.

My wife's tiger

A historical automaton recreated

by Stephen Savage • London, UK • Photos by the author

The author's miniature version of *Tipu's Tiger* mauls a British soldier and even makes tiger-like noises. It has an added bonus over the full-size model in that it can wave its tail.

Since I live in London, I frequently visit the Victoria and Albert Museum—the world's greatest museum of applied and decorative arts. Tucked away in the South Asia Collection is one of the museum's most intriguing treasures and a firm favorite of my family: *Tipu's Tiger*. With my wife's birthday on the horizon, it seemed to me that a small replica of this famous tiger was very much needed in our home, so I created my own *Tipu's Tiger*. But first, some history.

Tipu's Tiger is an automaton, or

mechanical toy, that was created for Tipu Sultan (1750-1799), the ruler of the Kingdom of Mysore in southern India. The carved-and-painted wood casing represents a tiger savaging a near-life-size British soldier. Mechanisms inside the man's body move one of his hands and emit a wailing sound from his mouth. A device inside the tiger makes him grunt. In addition, a flap on the side of the tiger folds down to reveal the keyboard of a small, 18-note pipe organ.

The automaton was discovered by the British, in the palace of Tipu Sultan, after the Siege of Seringapatam in 1799. The Governor General, Lord Mornington, sent the tiger to Britain, initially intending it to be an exhibit in the Tower of London. However, it was first shown to the London public in 1808 in East India House and was subsequently transferred to the South Kensington Museum, later renamed the Victoria and Albert (V&A) Museum.

The original tiger is 68" (1.7 meters) long. My version is somewhat smaller, being about 18" (45cm) from its nose to the tip of its tail. Inside mine are two gear trains. One operates the moving left arm of the soldier and the waving tail. The second train, as described below, controls the sound device.

1. The tiger's works can be seen here. The top is held to the bottom by the four dowels that protrude from the bottom section.

2. The author crafted the crank from brass and turned the wooden handle on his lathe.

Gears were made by the rather unsatisfactory method of drilling a hole at each tooth root, then cutting the gear out with a fretsaw. (I seek guidance on a better way of preparing gears for my future projects.)

To make the body, I took two pieces of limewood and, putting them together, roughly outlined the body shape on two sides. I gauged by eye the size and proportions of the animal and soldier, using as reference the many photos I had taken of the original in the museum.

In the piece that would become the lower body, I drilled four holes the same diameter as panel pins, within the extremity of the body shape. I cut off the pins' heads and inserted the pins into the holes, points upward, so that they protruded slightly. I then pressed what would become the top of the tiger's body onto the lower part. The protruding pins in the one part marked the hole positions in the other.

Removing the pins from the bottom piece, I increased the diameter of the holes to a convenient dowel size (6mm / ¼") and inserted dowels so that they projected above the surface. I then drilled out the holes in the top body piece so that I could press the two pieces together. You can see, in **photo 1**, the protruding dowels in the lower section.

To rough out the body shape, I bandsawed the put-together blocks horizontally and vertically. Then, using a 12mm / ½" belt sander, I improved and rounded the shape, leaving flat the areas where the four legs were to be affixed. Further hours of sanding resulted in the tiger's final shape. The soldier's body was prepared in a similar fashion, as was his moving arm.

Disassembling the finished two parts of the tiger's body, I routed, drilled, and sanded out the interior. I prepared the curved brass part of the operating handle (**photo 2**), again consulting my photos. I turned the crank's knob

ABOVE LEFT: 3. Gears were individually cut by the author. The wire toward the bottom of the picture actuates the soldier's arm.

ABOVE: 4. The soldier's left arm is raised as the tiger attacks. The actuating lever is circled.

LEFT: 5. A rosin-covered wheel rubs against a slotted plywood vibrator, creating the tiger's roar.

RIGHT: 6. The tiger's tail, made of brass, waves as the crank is turned.

and spindle on my lathe. Outside help was required to silver solder the gear-bearing rod onto the lever. When this was done, the crank was inserted into its appropriate position in the body.

By using gears, I reduced the turning speed of the countershaft that operates the arm-raising cam (**photo 3**). A vertical rod in the far-side wall (from the crank) of the of the tiger's body presses down on an extension of the soldier's arm (**photo 4**).

The sound-generating device took some time to resolve. Initially, I used a recording of a tiger roaring. A microswitch, operated by another cam on the countershaft, turned it on. However, Chinese electronics being somewhat limited in reliability, this plan was abandoned. Instead, a circular disc of MDF, coated with violin-bow rosin on its edge, is driven by a second countershaft. When the disc is pressed onto a thin, slotted-plywood "vibrator," it generates a tiger-like roar (if you use some imagination—**photo 5**)!

The moving tail (**photo 6**), which

7. When assembled, the aluminum lever is actuated to move the tiger's tail. Perforations in the body to let the sound out are visible in the back. These are cleverly hidden in the black stripes.

The hapless soldier must spend the rest of his days beneath the ferocious tiger, being perpetually attacked. For a wooden soldier, that could be quite a long time.

is not a feature of the original, came about when I had to prepare the second countershaft. Wedges on either side of the last gear (seen in **photo 3**) cause an aluminium lever (**photo 7**) to pivot and engage an extension of the tapered brass tail that I prepared on my metal lathe.

Multiple coats of spray paint were used, in various shades of orange and brown, with much sanding to achieve a good finish and the required dappled coloring of a tiger. The top is pierced, as on the original, to let the "roar" out.

The project took some three months, off and on. Fortunately, I started early, as I had a birthday deadline to meet. It is important to allow significant time for the painting process, particularly if you are trying to make something look like a tiger.

This proved to be a great gift, well received. Now our family doesn't need to go to the Victoria and Albert Museum when we want to see a tiger (but I was actually there yesterday—it's difficult to keep away from such treasures).

Building the Beautiful/Terrible puppet

Advanced techniques produce sophisticated results

by Ellen Rixford • New York, New York, USA • Photos by the author

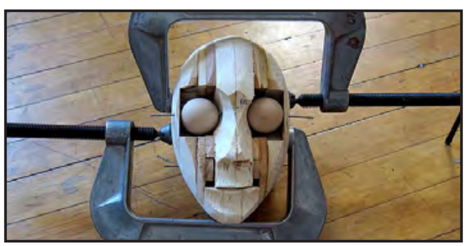
The *Beautiful/Terrible* puppet has two heads, or rather masks: an inner, old face, and an outer, young face, which splits apart to reveal the inner one, as shown in the **lead photo**. The effect is meant to be sudden and frightening.

Beautiful/Terrible was made for a client in the United Kingdom. The puppet is quite large—nearly life size. I did my best to make her as lightweight as possible. Her body isn't very heavy and she has no legs or feet, just a long, diaphanous skirt (**photo 1**). Her elaborate head is the heavy part.

The head

Her head was made using a special wooden head armature, which I designed to use as a base for many different puppet heads. Different faces can be sculpted on this base. Both the young face and the old face were modeled on this wooden armature.

1. The entire puppet. Her costume is made of thin, semitransparent blue and lavender chiffon, and silk flowers. Her wig and headdress is made of mohair and silk flowers.



3. Pieces of the armature have been glued together and clamped. The eyeballs and jaw piece are in place, pivoted on metal rods.

2. The head armature is made of ¾"-thick pine layers, cut and glued together, then carved to the head shape. The jaw part and wooden balls for eyes are separate, and they will be jointed using metal pivot rods.

4. The finished armature, sanded fairly smooth.

The armature was made of layers of pine, cut on a bandsaw from a pattern (**photo 2**), then glued together and carved into a head shape, with a separate, hinged mouth part. Wooden eyeballs (large beads) are set into openings in the face and are pivoted on a rod (**photos 3** and **4**). When a face is modeled and the final model is ready to have a silicone mold made of it, the mouth part is gently removed from the face, then finished so that it will fit into the mouth cavity.

The head and mouth part are molded separately in silicone rubber, to be separately cast in two-part resin. When making the mold of the head, I partially fill deeper areas of the mouth cavity with clay or some other material, so that the rubber will not fill the cavity area. This is only to save silicone rubber, which is expensive. I leave part of the mouth cavity unfilled, though, so that the mold—and subsequent casting—will offer a good support socket for the mouth part, which will need to pivot and hinge stably within the face.

Pivot rods in the face parts are removed for making the silicone mold, but little dimples, showing where the holes for the rods were, must be left intact, so that the silicone mold can capture them. When I put a face together, these little indentations tell me where to drill holes to insert the pivot rods. When the pivot rod is installed, the mouth piece swings smoothly open and shut. Eyes are molded with the head, but when the head cast is complete, the eye sockets are carved out so that separate, rotating eyeballs can be installed to fill the empty sockets.

I use Super Sculpey to create the faces. It's soft to use but bakes hard in the oven, allowing me to sand surfaces and perfect details. The face model can then be either molded in silicone rubber, which could then be used for resin casting, or it could be used as a form for papier-mâché. Either approach allows for multiple casts, which is a must for experimentation.

Beautiful/terrible faces

First, the old face was modeled on the armature (**photo 5**), then molded and cast. I use Mold Max 20 silicone rubber for the mold and Smooth-Cast 300 casting resin for the final casts; products are made by the Smooth-On Company. I then destroyed the old-face model and used my armature to model the young face (**photo 6**), taking care to make the young face a little larger so that the old one would fit inside it.

The inner, old face is cast resin (**photo 7**). This was originally cast from the Super Sculpey model in a silicone mold, with a separate hinged moving mouth. It is strengthened in places with epoxy putty—the kind used by plumbers for permanent repairs to large pipes. The finished eyes in the old face are simply black-painted spheres with brilliant magenta sequins glued in them.

The outer, young face is made of a kind of papier-mâché combination material, made up of multiple layers of soft paper mixed with carpenter's glue. This material becomes rigid when dry and is then painted with several layers of epoxy varnish to protect it against humidity so that it will remain rigid (**photo 8**). This style of construction was necessary to make sure the face would be fairly thin-walled to fit over the inner face.

I had to take great care in cutting the young face into two halves (**photo 9**). It was important that the halves fit together with an almost imperceptible parting line, so that when the face opened, it would be a surprise. Because my client for this project lives in the UK and the climate

5. Super Sculpey model of the old face, sculpted on the armature.

6. The head armature was slightly padded to make a larger Super Sculpey young face.

7. A silicone-rubber mold was made of the old face and the separate jaw. These were then cast in two-part resin. Left: Super Sculpey model. Middle: resin casting. Right: face and jaw molds.

8. The young-face mask being held up to a window to show how thin and semitranslucent it is. The mask is quite rigid and strong.

9. Two castings of the young-face mask. One has been carefully split down the middle.

there is damp, I reinforced the cut edges with the epoxy putty so that they would remain rigid and free of distortion. The back edges of the outer face are screwed to a hinged plywood frame, which helps to keep them rigid.

The eyes, set into eyeholes in the young-face mask, are sections of ping-pong balls with oval holes cut into them (**photo 10**). A glass cabochon jewel (**photo 11**) is set into each of these openings. They glow and appear bright and full of life.

10. Eyes for the young-face mask were made of sections of ping-pong balls. For each of the irises, a cabochon jewel was set into an opening cut into the ball's surface. The jewels give a beautiful, lifelike appearance.

11. These cabochon jewels can be found in special theatrical-jewelry stores in New York's theatrical-costume district. The author found blue, dark blue, amber, and violet. The puppet described here has amber eyes, but she has a sister puppet (just the head) whose eyes are violet.

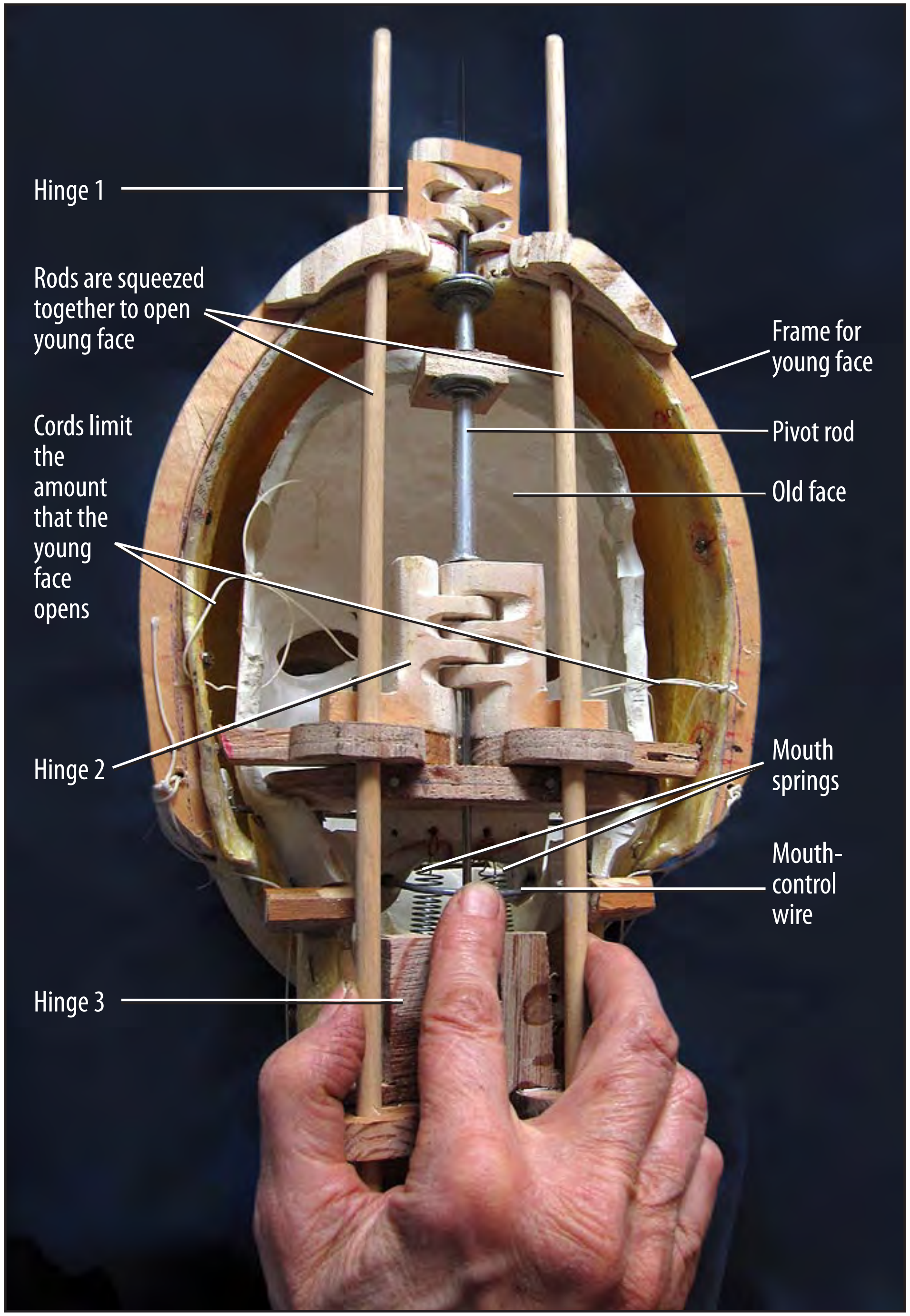
12. The backs of the old-face mask and the young-face mask, before being assembled. In order to keep the young face rigid and strong, and give it a base on which to build the mechanics, the author built a hinged plywood frame. The young-face mask was set onto this frame; the old face was set inside.

The mechanism

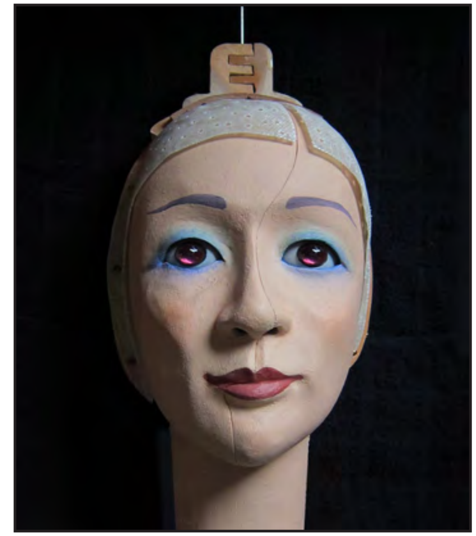
After casting, I attached the young face to the abovementioned wooden frame, hinged with three wooden hinges I designed (**photo 12**). These use interlocking "E" and "F" shapes that fit together and pivot on a central rod. The inner, old face fits inside this frame and it, too, is attached to this pivot rod, so that when the young face opens, the old face is revealed within.

The outer, young face can be split open by manually squeezing together metal rods attached to the sides of the frame. Because the young-face mask is held together tightly at the top and bottom with strong magnets (they can be seen from the front when the face is open), the puppeteer must squeeze strongly, at which point the face will suddenly (and frighteningly) fly open, revealing the "terrible" old face. Thin strings (woven fishing line) at either side of the back of the head limit the distance that each side of the open face will swing back (**photo 13**).

A strong wooden handle, which protrudes out of the back of the puppet, is set and glued into the upper torso. Around this handle is a fabric band with velcro patches. The puppeteer wraps the band around their forearm to hold up the body, so the forearm supports the body



14. A young face (three were made) with the wig forms off, lying next to the head.



15. The wig forms in place on a face.

of the puppet while the hand grips the back of the head, opening and closing the young face, and working the old face's moving mouth.

When the young face is open, one can then work the hinged

LEFT: 13. The full mechanical movement, showing the parts in place. The young face is pivoted around the old one on special hinges designed by the author. These are set into the top, middle, and bottom of the wooden frame that holds the young-face mask rigidly in place. The author's hand is in place here, ready to open and close the young-face mask by squeezing the two rods together, and to work the slider mechanism (under her index finger), which opens and closes the mouth of the old face.

mouth of the old face. Springs, attached to the back of the jaw piece and extending down to attachment points in the neck, hold the mouth closed. The mouth control, a U-shaped wire set into the back of the jaw piece, can be pushed or flipped upward by the puppeteer's index finger, opening and closing the mouth so that the old face appears to speak.

Finishing the head

The hair and silk flowers on the head are attached to two separate, formed fiberglass wig/headdress pieces, one for each side of the face (**photos 14** and **15**). These are made of fiberglass cloth and epoxy resin, molded around the upper head, with flanges at the back, screwed into the plywood face frame. Making them separate from the head enabled me to easily sew on the doll hair and silk flowers, using many small holes drilled into the formed pieces. Once the hair and flowers were attached to these forms, the forms were screwed to the face frame. The faces and hands are painted with acrylic paint, with soft "blushes" of pastel to add warmth and color variety.

Torso and arms

The puppet's torso, shoulders to hips, is made primarily of pieces of blue Styrofoam—the long-lasting kind, often used for house insulation (**photo 16**). Four sections are linked together with strong fabric strips. This gives the body volume and some flexibility, with the ablity to bend forward and back, and a bit to the sides.

The foam also offers a way to fasten her costume, as long dressmaker's pins, which attach the costume parts, are pushed into the foam and hold the costume together. Many parts of her costume, including the blue satin and transparent chiffon/organza fabrics, as well as the silk flowers

16. The back of the body. Shoulders and hands are set into fabric sleeves. Hands are attached to handles that emerge from the back of the sleeves. Styrofoam torso sections are covered with fabric. A handle protrudes from the back, to be attached to the puppeteer's arm.

17. The amber eyes of the young face are clearly seen here. The wig is fully finished, as are details of the costume. Silk flowers and leaves complete the puppet.

UPPER LEFT: 18. The puppet's hands were sculpted in Super Sculpey, formed over an internal wire armature to keep the fingers stiff. Each hand was set halfway into modeling clay, so that half of each hand would be molded at a time. Hands were made in two-part molds because of undercuts.
ABOVE: 19. Half of the molds for the hands have been poured. Here, the hands are embedded in the first half of the mold. After the first cast, a paper wall was made around the mold to prevent the rubber from pouring out where it wasn't wanted.
LEFT: 20. Several resin castings were made of each hand. One benefit of molding and casting is that multiples can be produced.

and leaves that decorate it, are attached to her body this way (**photo 17**).

Attached to the shoulders are fabric tubes that end with the hands. The hands, like the old-face mask, are hollow two-part resin castings, fairly thin and light (**photos 18-20**). Wooden discs are screwed into the ends of the arms, with dowel rods connecting them to wooden handles. The ends of the cloth arm tubes have velcro patches that close snugly around these discs, so that the hands hang from the arm tubes. Handles on rods slide through slits in the backs of the sleeves, so the puppeteer can grasp them during performances of the *Beautiful/Terrible* puppet. A1.

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Marking cams

A real-time method of determining cam shape

by Gustav Klekner
Sydney, Australia • Photos by the author

My automata projects all involve the use of cams for controlling movements. The cams, made of 9mm (3/8") plywood, are fixed to the camshaft by a hardwood collar and a self-tapping screw, the latter only permanently tightened once the cam has proven viable.

I make my cam blanks to a diameter that corresponds to the largest desired movement (**photo 1**).

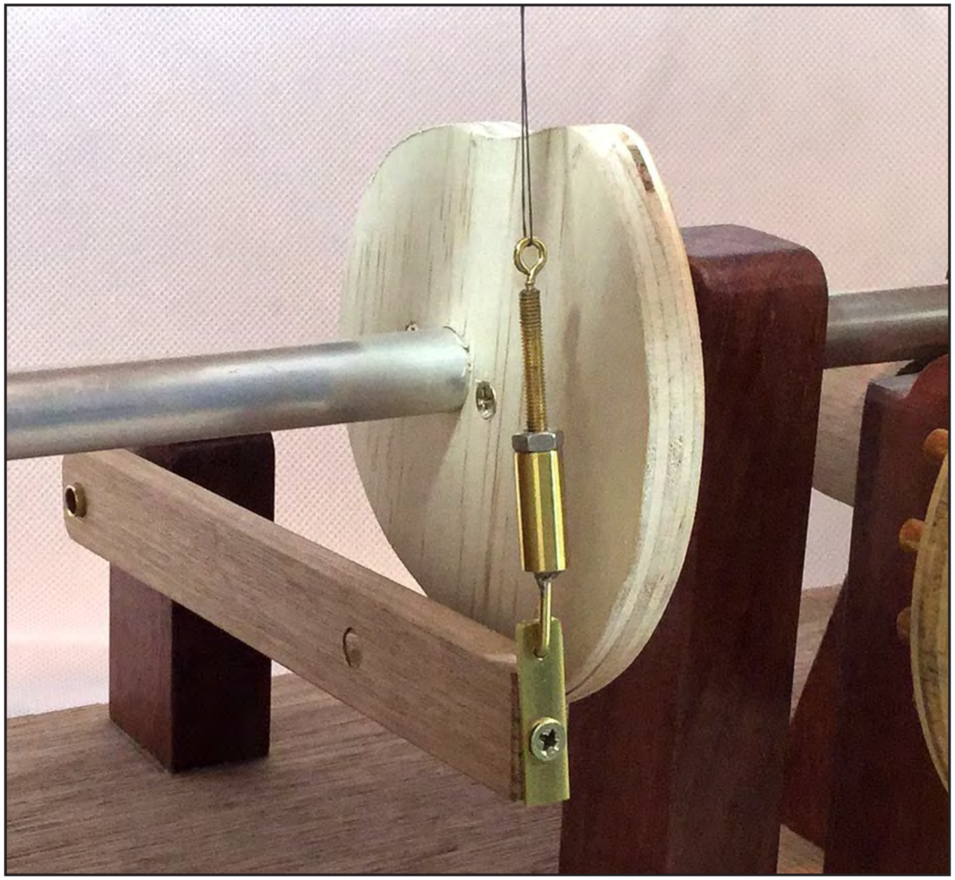
1. This blank cam is attached to a wooden collar on the back side. It's ready to be mounted on its shaft and marked.

Ageing Disgracefully
by the author. The cams for this automaton were marked and cut using the method described in this article.

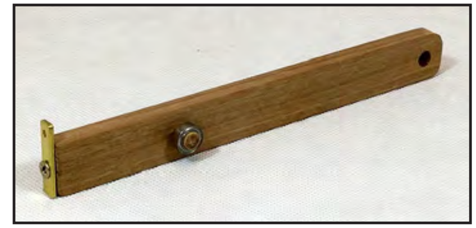
That is, the blank's circumference is the full extent of the movement, from which other movements are made. To put it another way, if, say, a figure's bend from the waist is required, then the outside edge of the starting diameter of the blank would provide the lowest point of the bend. Therefore, the cut cam is always reduced from that point on.

In order for the marking method described here to work as it should, the character to be moved must be "plumbed up." This means that the control methods—linkages, rods, wires, or whatever—have already been attached to the part to be controlled (arm, leg, torso, head, etc.). Once this is done, as the installed cam follower is manually moved up and down, this movement is translated to the character above.

There is no need for the character to be completely finished, painted, dressed, and so on. Only the connection must be established as it was envisaged to be. I do not use external, visible control methods on my automata—internal mechanisms are used for everything. I use braided beading thread, stainless-steel fishing wire, and sometimes hard wire, such as is found in coat hangers, running

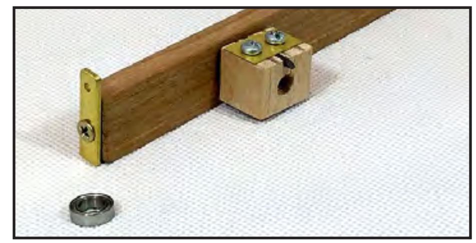


2. A cut cam and follower in their typical positions on an automaton. The follower has been used to mark the blank cam in situ. The blank is then removed, cut, and reinstalled. Note the length-adjustment mechanism between the cable and the follower.



3. A typical cam follower. The bearing on the side contacts the cam, and the brass plate at the left end provides the attachment point.

4. The pencil block, which temporarily replaces the follower bearing for marking.



5. The pencil block mounted in the follower.

inside the body. It is easy (and essential) to incorporate systems for adjusting control cables (**photo 2**).

Install the blank cam onto the camshaft, and the cam follower onto its pivot block, as seen in **photo 2**. The 10mm (.394") bearing on the cam follower (**photo 3**) will run on the cam's lower edge. For the moving part, say a head turning, the means of returning the part to its original position must also be in place. This could be via a spring, weight, or rubber band.

All the cams for any one of my projects are initially the same size. This makes the later job of timing everything a lot easier, because of their constant, common edge speed.

Photo 4 shows a block holding a piece of pencil lead. This block is attached to the cam follower, temporarily replacing the bearing (**photo 5**), so that the point of the lead is at the exact point where the edge of the bearing will touch the finished cam.

Prior to marking the cam, you should make many dry runs, turning the camshaft with one hand while moving the cam follower with the other, and watching the character move. To the camshaft I attach a small bell, which rings to tell me when one revolution is completed. Where a movement requires exact time, say three seconds, a stopwatch or my phone can assist. The cam can be marked in advance with radial lines showing the total sequence time in seconds, but this seems unneccesary when using this direct method.

Practice runs will serve to get you used to the dual task of turning the input handle, while at the same time manipulating the cam follower to create the desired movement. A friendly, reliable, open-to-direction assistant can be handy here.

Once you have a clear vision of how far, how fast, and how often a particular move is needed, remove the cam follower's bearing and install the pencil block onto the follower in its place. Gently push the block against the cam while simultaneously starting to turn the input handle and making the moves (which are now well practiced—**figure 1**) with the cam follower. This will result in a line being made on the cam that will show you the shape to be cut (**photo 6**). If there is a need to repeat this process for some reason, remove some or all of the lines with a rubber eraser.

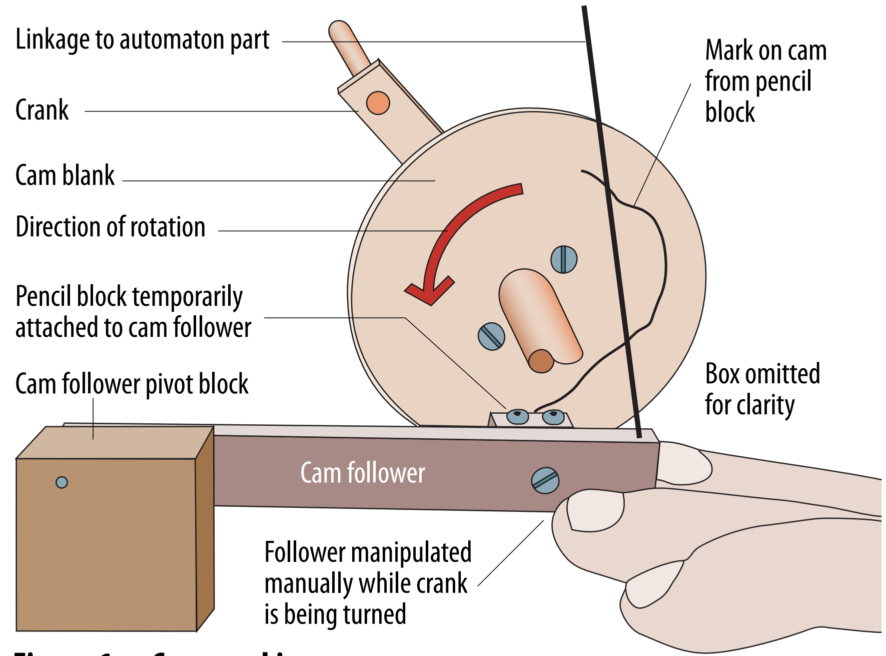


Figure 1—Cam marking


6. A marked cam, ready for cutting.

I cut my cams on a scrollsaw, with a fine blade, taking care to keep the offcut in one piece. If the cam turns out to be a dud, I glue the offcut back on and fling it into the reject box, along with some carefully chosen words. My reject box is a valuable resource. I have repurposed many parts—gears, followers, and more—from there. If there are any aspects of this procedure that require clarification, please contact me at *kleknet@tpg.com.au*.

About the author

After a working life as the founder of a custom-furniture business, I sold the company to my senior cabinetmaker, who now operates it. The business is 47 years old and operates purely on referrals here in Sydney, Australia. The love of working with wood gets under one's skin and seems not to diminish with time.

For me, the accidental discovery of automata has turned its pursuit into an obsession, I freely admit. Over the years, I have constructed 15 automata. These, with one exception, have been based on observations of us humans—our idiosyncracies, behaviors, and habits. As long as my body parts do as commanded, I will continue this fascinating artform.

A brief video of a cam being marked can be found on our website or by clicking **here**.

Get Moving

Galloping unicorn

by Kim Booth • Berlin, Germany • Photos by the author

Riding a snow white unicorn,
He thought it would be easy,
But hanging on for dear life,
Did feel a little queasy.

Wikipedia tells us that the unicorn is a legendary creature. It has been described since antiquity as a beast with a single large, pointed, spiral horn projecting from its forehead. So of course I had to make a unicorn.

There are already plenty of horsey automata around. Rob Ives designed a brilliant paper Pegasus—a flying horse using a clothes peg to hold the mechanism (*https://www.robives.com/product/pegasus/*). Keith Newstead has designed some fantastic winged horses (*https://www.keithnewsteadautomata.com/slide/pegasus/*), and there are a number of laser-cut wood/MDF kits available for both Pegasus and flying unicorns.

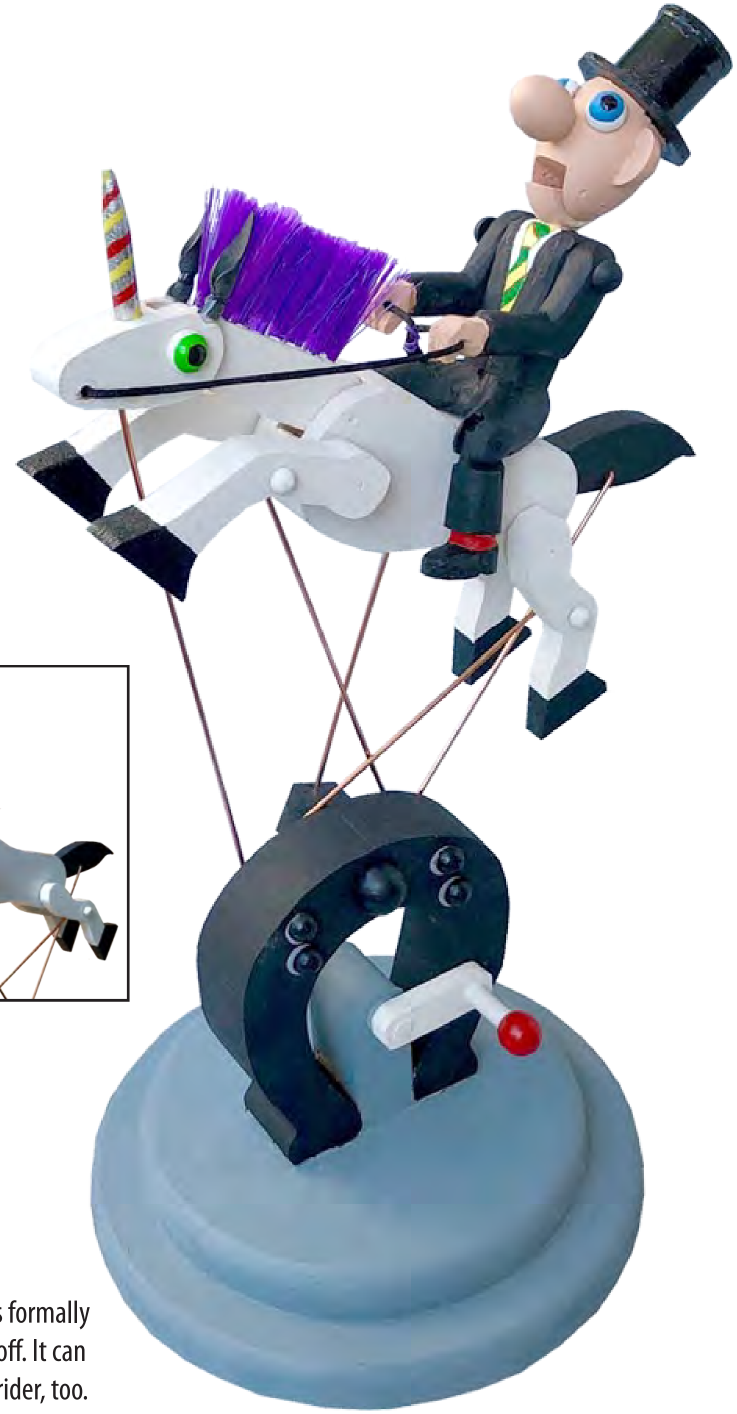
It's great to see how other folk approach similar problems, and to see how they coped with the various challenges of making something appear quite mythical. Here are some YouTube examples:

- *https://www.youtube.com/watch?v=5vZgSu_Ykxc*
- *https://www.youtube.com/watch?v=JmRBzpKx2TU*

The requirements

Some time ago, I bought and assembled a laser-cut MDF Pegasus kit. The movement is good, but my three-year-old friend managed to break off the thin handle at first go. Also, the automaton was so light that it skated around the table while you turned the crank, meaning you needed a second hand to hold the base still.

My first requirement, therefore, was that the automaton



The unicorn, with its formally dressed rider, takes off. It can be built without its rider, too.

must be sturdy and heavy enough to be worked with just one hand, especially if that hand is only three years old.

The force applied to the handle varies as you turn it. The handle must be positioned so that you are pushing down when the most force is necessary and pulling up when the least force is required. This will make one-handed operation easier. A rubber mat under the base should prevent it from slipping about.

To be a genuine unicorn, the animal must have a spiral horn, horsey ears, a splendid mane, a bushy tail, and friendly eyes. And since the base is part of the show, that part shouldn't be boring.

The unicorn by itself would be interesting, but I thought a hapless rider would add to the fun. He would have to be stylishly dressed but fearful of the unicorn's movement, opening his mouth to protest each leap, that he might fall off backwards, to be rescued only by holding tight to the reins.

From the pencil sketch (**figure 1**), it's not too hard to make some card templates (**photo 1**), which will make it easy to mark the wood for cutting with a coping saw or scrollsaw (**photo 2**).

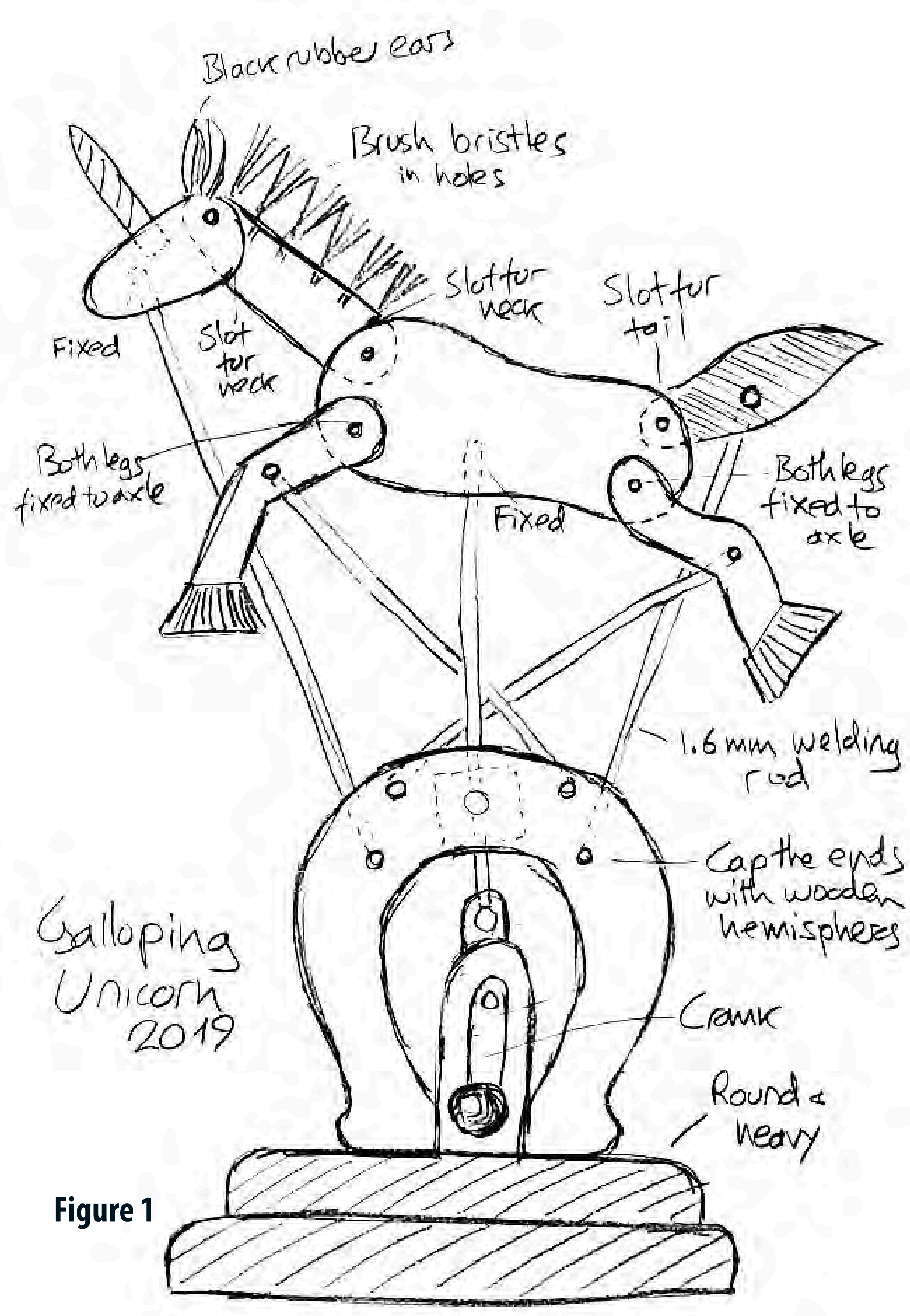
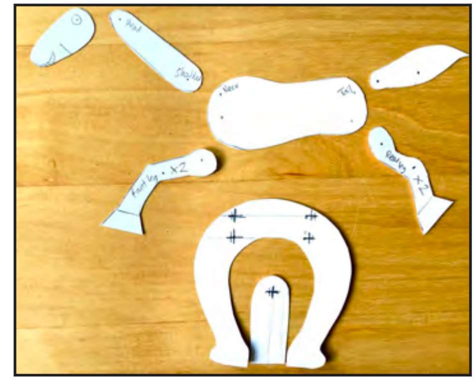


Figure 1



1. Paper templates for the cutouts.

2. The cut-out pieces of the unicorn, ready for painting and assembly.

The base

Two MDF discs, stacked, make a nice, heavy base. A horseshoe, placed vertically, is the perfect shape to hold a lot of the mechanism (**photos 3** and **4**). I did wonder, for a while, why horses can't wear shoes with laces. I suppose not having fingers makes doing up your laces more difficult. Anyway, some creative soul came up with nailing bent metal strips to their hooves. This is such a classic design that nowadays it is instantly recognizable as equine footwear, and not at all boring.

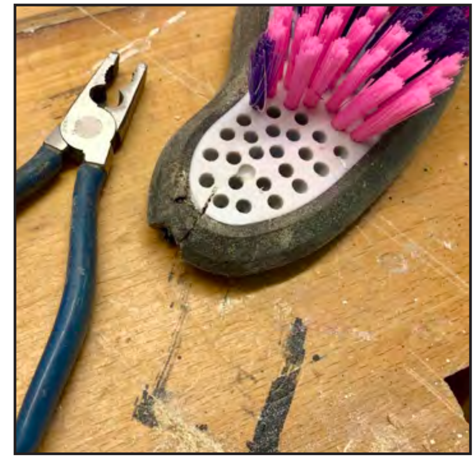
The unicorn

However magical it is, a unicorn needs a horn, a head, a neck, a body, a tail, and four legs. The neck must have a splendid mane, of course. This will come from a brush of your choice (**photo 5**). Drill a few holes at regular intervals along the neck. Measure the required diameter by first using pliers to pull out a tuft of bristles from the brush that is to supply the mane. The empty hole that is left in the brush is the size that you need in the neck. Just push the bristles into the neck, with a small dab of glue on their ends (**photo 6**).

The body is the thickest part of the automaton, as you need to chisel out slots in it for the tail and for the neck. The slots must be wide enough to allow free movement of the other parts (**photo 7**). I used 1.6mm (1⁄16") welding rod for the pivot pins, drilling 1.6mm holes for a tight fit and 2.0mm (.078") holes for a loose fit, to allow movement.

3. Pieces for the base and cranking mechanism. The base itself is made from two MDF discs, glued together.

4. The finished base, viewed from the crank side. The horseshoe shape forms a frame for the mechanism.



5. Bristles are removed from a brush with pliers. These bristles will form the animal's imposing mane.

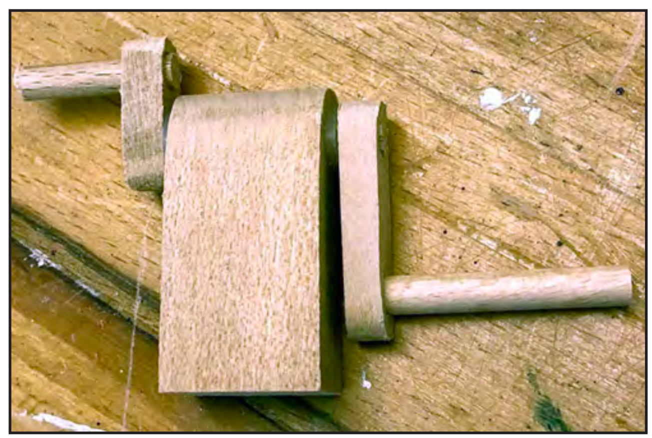
LEFT: 6. The neck segment, with the mane bristles glued in place.

ABOVE: 7. Head, neck, body, and tail parts. The body is the widest part, with recesses cut out for the neck and tail.

The crank and the sliding pivot

The crank is the handle that you turn to get the unicorn galloping (**photo 8**). A small hemisphere on the end of the crank is painted bright red to say, "This is what you turn."

Another crank, on the other end of the crankshaft, provides the action. A small hemisphere on one



8. The crank block. The longer dowel is the crank handle. The shorter one drives the mechanism.

end of it prevents the loop on the end of the central rod from slipping off (**photo 9**). Plastic washers reduce friction.

The central rod slides smoothly up and down through the block of wood in the photo. The block can pivot easily in its mount at the top of the horseshoe (**photo 10**). The hemisphere on the end prevents the axle from slipping toward the back.

Test assembly

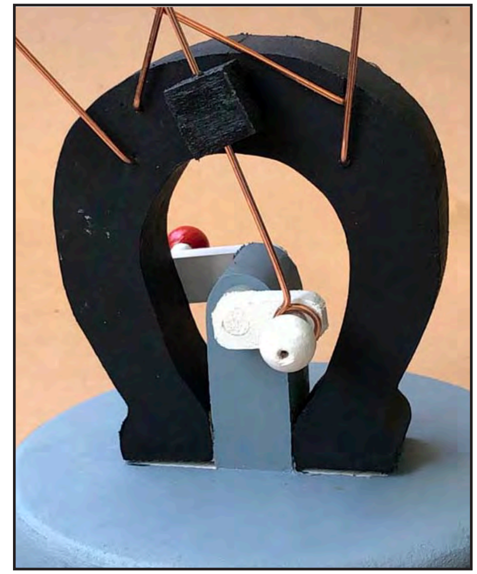
While fiddling about to get everything right, it's useful to leave bent "handles" on the ends of the rods that serve as pivot pins for the head, neck, tail, and legs (**photo 11**). Once everything is okay, these can be cut off to the correct length. The two leg axles are glued right at the ends of the pivot pins to keep the pairs of legs firmly joined together. The rods that pivot in the horseshoe, and in the legs and tail, should protrude enough for a small wooden hemisphere to be glued onto them. These will keep the pins from slipping out and prevent inexperienced jockeys from getting accidentally stabbed by the sharp ends. It's much easier to paint the parts before the final assembly.

Ears and eyes

Once the rod that hinges the head to the neck has been cut to size, glue hemispheres over the holes to conceal them and prevent the rod from sliding out. When painted, the hemispheres make beautiful eyes.

For the ears, I cut rubber sheeting to suitable shapes, rolled them around thin pins, tied them with thread to prevent them from unrolling, and drilled small holes in the head for the pins. Two-part epoxy glue, fairly liberally applied,

ABOVE: 9. A small hemisphere on the dowel prevents the rod (not shown) from coming off. Plastic washers reduce friction.



RIGHT: 10. A rod is attached to the crank arm. This passes through a pivoting block at the top of the horseshoe. The other end is fixed to the unicorn's body. It is this rod that provides most of the motion.

11. The unicorn, assembled but unpainted, ready for testing. Note the bent-wire "handles" left on the ends of the pivot-pin rods. These will be trimmed off when everything is working properly.

12. The functioning, painted unicorn.

holds everything together and in place (**photo 12**).

The rider

There are apparently people around who believe in unicorns, and even think they can ride them. This small, smartly dressed fellow (**photo 13**) is carved from limewood. His arms and lower legs are hinged on 1.6mm rods. His head is a beechwood egg. The jaw is cut out and glued firmly to his shoulders. A rod through a hole at the back of the jaw allows his head to flop forwards and backwards as the unicorn gallops.

There is a hole drilled through each hand for the reins. When the unicorn points skyward (**photo 14**), the reins pull tight and lift the rider's arms, his head flops back, and his mouth opens in a silent appeal for salvation. At the other extreme (**photo 15**), the reins are slack, his arms drop, and his mouth closes in relief.

See the unicorn run at *https://youtu.be/kIVDfysceUU*

13. All of the pieces for the unicorn's rider. His body is pinned to the unicorn's back. Arms are free to move with the reins.

14. When the unicorn is headed upward, the rider leans back, with his head back and his mouth open.

15. When the animal returns to earth, the rider is more confident, sitting upright and looking more dignified.

The Adventures of

Baron von Steubon and Cromwell

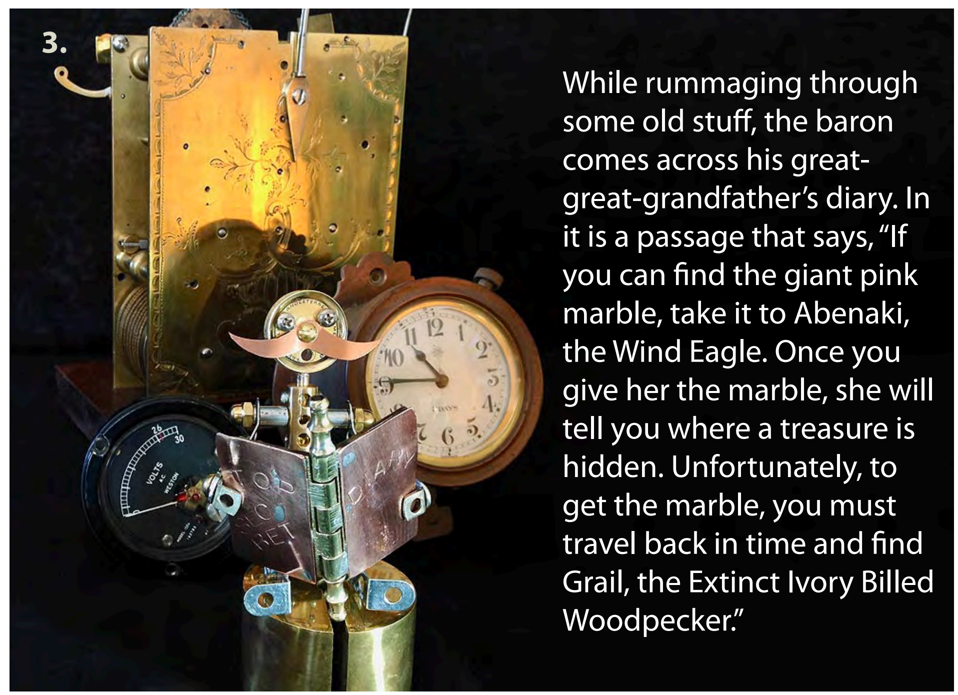
Episode 2: The Pink Marble

by David Bowman • Mechanicsburg, Pennsylvania, USA
Designs, constructions, and photos by the author

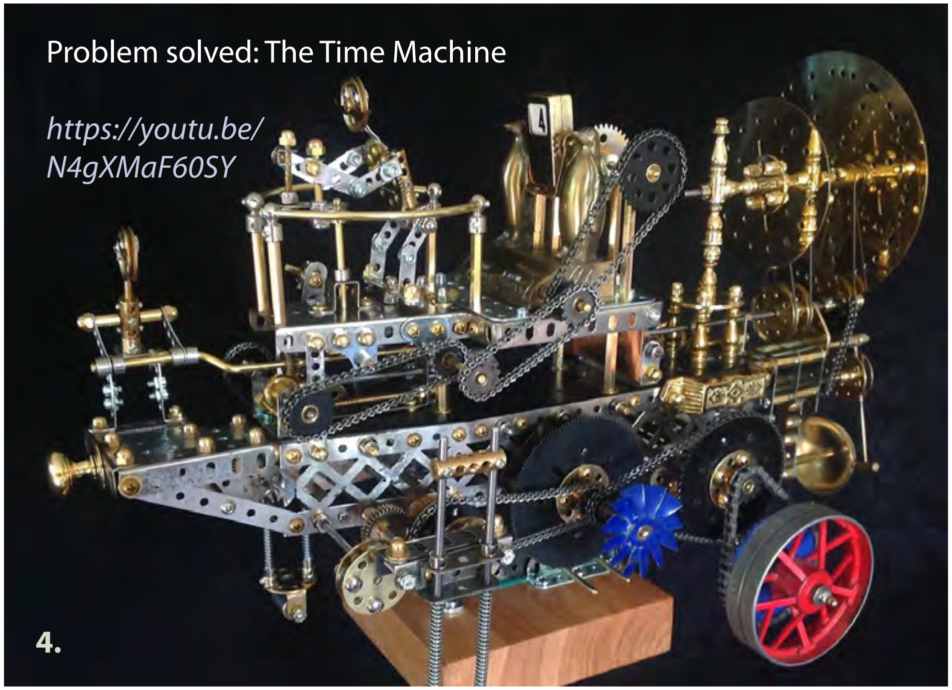
https://youtu.be/xf3m-6ShZBg

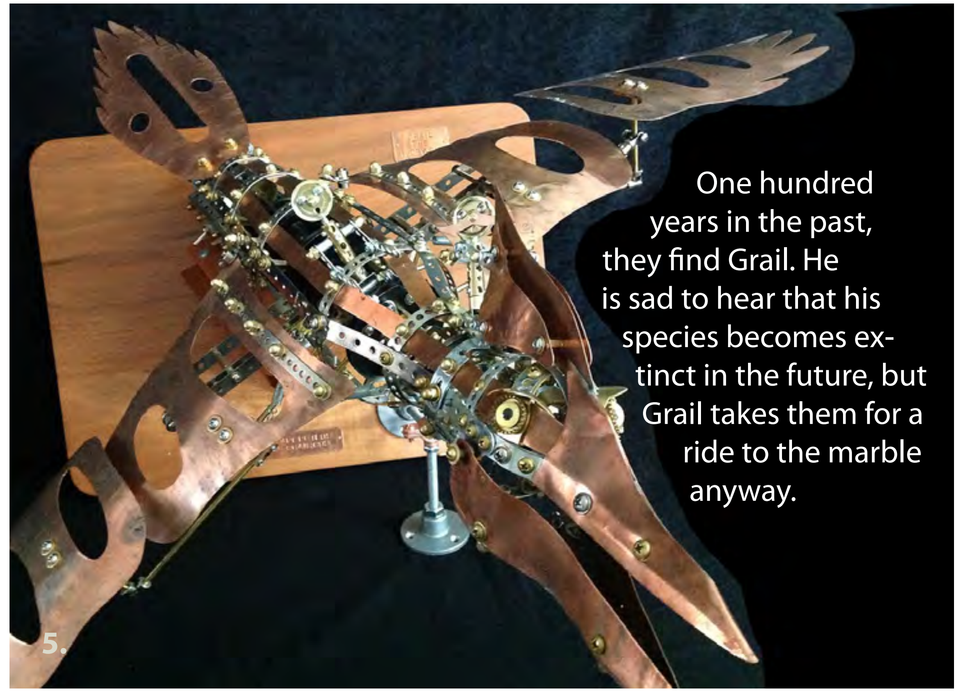
1. On the test drive of their Batcar (see Episode 1), the baron and Cromwell encounter Chiquita, the Fruit Bat. Chiquita thinks they are his long-lost cousins.

2. It's always good to make a new friend!



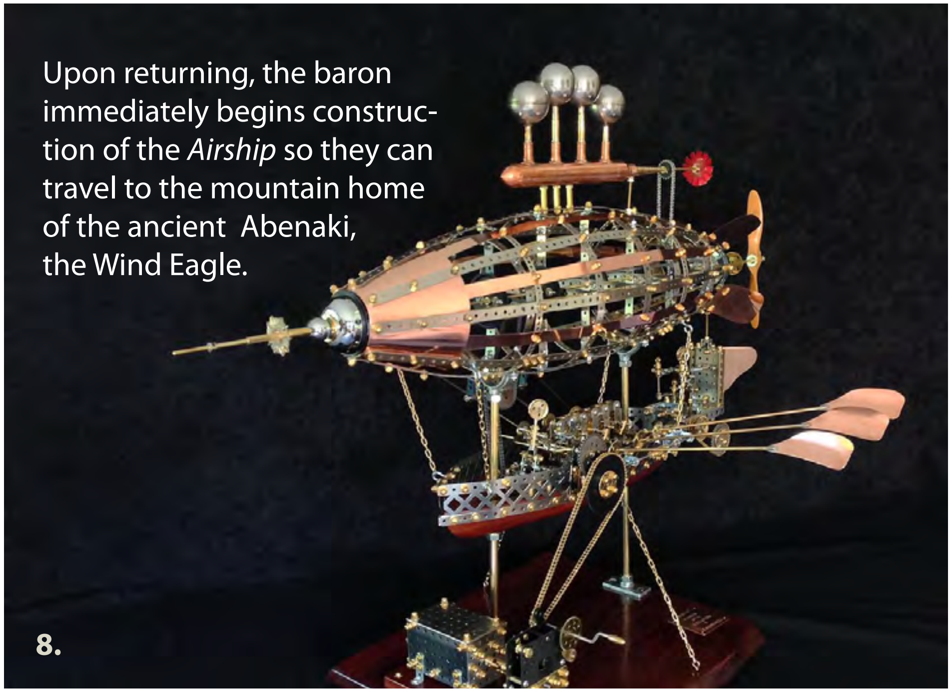
3. While rummaging through some old stuff, the baron comes across his great-great-grandfather's diary. In it is a passage that says, "If you can find the giant pink marble, take it to Abenaki, the Wind Eagle. Once you give her the marble, she will tell you where a treasure is hidden. Unfortunately, to get the marble, you must travel back in time and find Grail, the Extinct Ivory Billed Woodpecker."

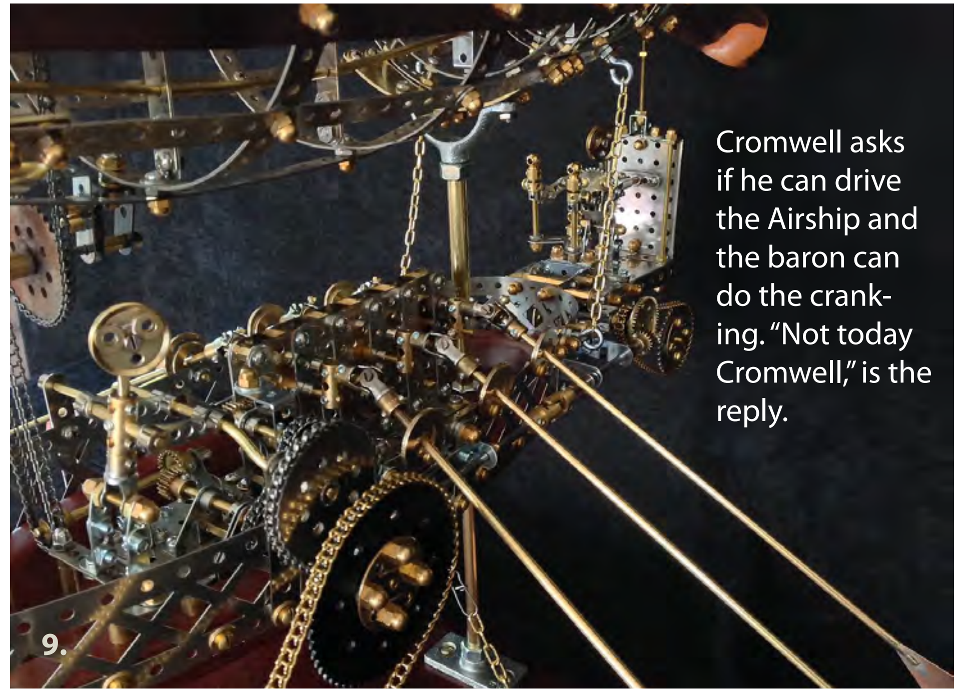

Problem solved: The Time Machine
https://youtu.be/N4gXMaF60SY
4.


One hundred years in the past, they find Grail. He is sad to hear that his species becomes extinct in the future, but Grail takes them for a ride to the marble anyway.
5.


Grail is happy to give Baron the Pink Marble.
He can't remember why he is guarding it anyway.
6.


While traveling home through time, the baron finds a statue of his great-great-grandfather on Easter Island, and he brings it back with them.
7.


Upon returning, the baron immediately begins construction of the *Airship* so they can travel to the mountain home of the ancient Abenaki, the Wind Eagle.
8.


Cromwell asks if he can drive the Airship and the baron can do the cranking. "Not today Cromwell," is the reply.
9.


Eventually they find Abenaki. The baron explains that they are looking for a lost treasure. Abenaki replies: "Only the one who possesses the Pink Marble will be told about the treasure."
https://youtu.be/GTRuqOlg7Fk
10.

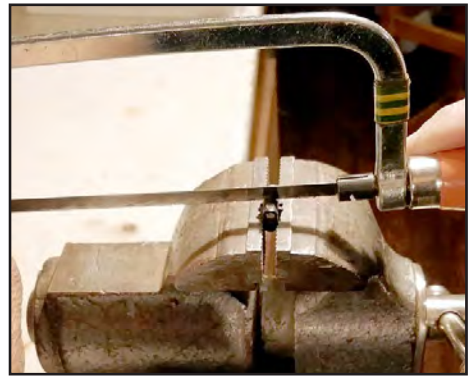

Baron von Steubon produces the marble. Abenaki is excited and she tells the baron that this is actually her long lost egg and now she can hatch it. She explains that the lost treasure of golden coins lays at the bottom of the bay. However, he must find Queenie, the anglerfish. She will help guide him there.
Grateful, the baron and Cromwell head for home.
To be continued!
11.

TIPS

Terminal blocks yield versatile and inexpensive mechanical elements

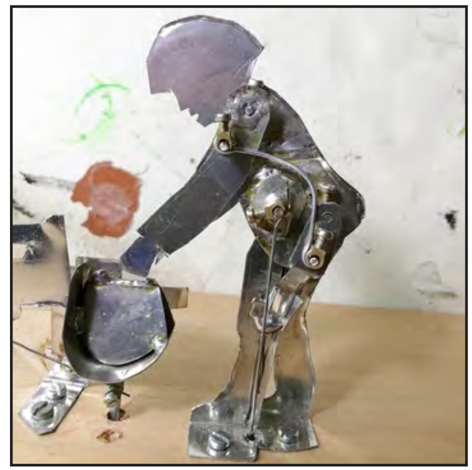
by Dominique Corbin • St. Denis, France • Photos by the author

1. All of these terminal blocks contain hidden brass elements.



2. By cutting one block in half, two usable components will result.

3. At the bottom of the picture are two components cut from one of the whole pieces above.



4. Extensive use of halved terminal blocks has been made in this automaton, shown from the back. Video: *https://youtu.be/rN1_bmsgl7M*

5. An example of a shortened screw. A new slot has been saw-cut into the threaded body of the screw.

Here is an old trick. Plastic terminal blocks often hide useful brass elements (**photo 1**) that can be used for all kinds of things—stop rings, cable or rod couplings, and more. In addition, they exist in a wide variety of diameters. When buying terminal blocks, check to be sure that the metal part is made of brass and not, as is often found, of folded sheet metal or an unknown alloy.

A single terminal tube can be cut in half with a fine-blade hacksaw (**photo 2**) to make two small stop rings (**photo 3**). It is easier to just cut through the plastic body when dividing a tube, especially for small models.

Because the parts are brass, they can be soft-soldered to other pieces of brass, tinplate, or even iron with a good flux (**photo 4**). If you find the screws to be ugly, you can cut off the heads and make new slots with your saw (**photo 5**)!

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Creating automata that can write

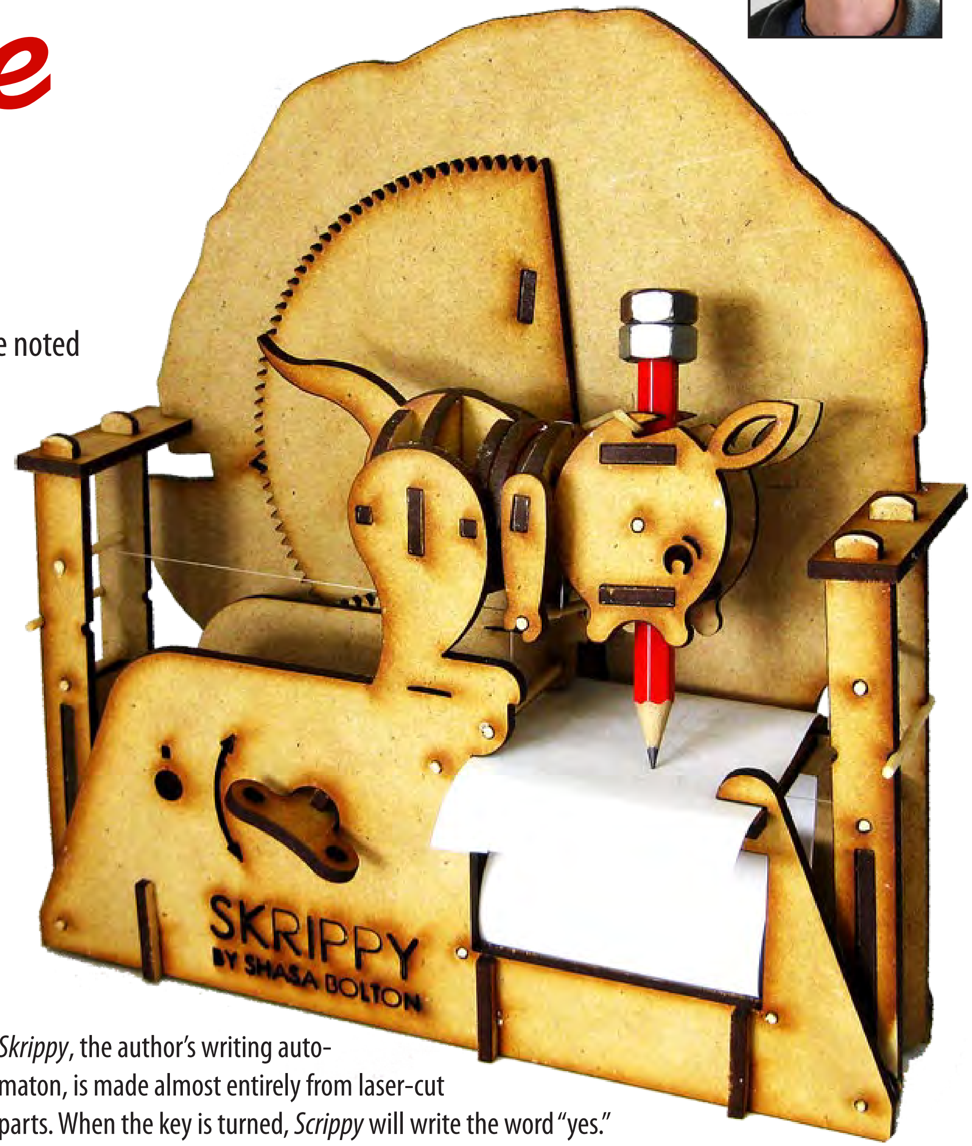
Modern machines inspired by history

by Shasa Bolton • Sheffield, Tasmania, Australia • Photos by the author, except where noted

"Happiness is solving problems." According to the author of my fiance's latest book, we should not be asking ourselves, "What will make me happy?" but rather, "What problems do I want in my life?" Before you start believing that your vast collection of problems must make you about the happiest person on earth, I should stress that *solve* and *want* are important factors in this idea. When scientists and engineers have finally solved all of the world's problems, perhaps the artists and automatists will still possess the key to happiness. Those people who design their own problems, ideally, should never run out.

This is where automata are great. They serve no real purpose but provide an avenue for diligent design and sleepless rumination all the same. Another group of people interested in solving problems, philosophers, historically also seem to have had an interest in automata. The story goes that Descartes even had an automaton doll made of his daughter after her death.

Philosophers' interest in automata likely stems from their quest to understand the hardest problem of all, which one philosopher



Skrippy, the author's writing automaton, is made almost entirely from laser-cut parts. When the key is turned, *Scrippy* will write the word "yes."

WIKIPEDIA

1. A singing-bird automaton, similar to the one seen by the author. This one is by Frères Rochat, circa 1820.

PHOTO USED UNDER CREATIVE COMMONS LICENSE: https://tinyurl.com/pdroz

2. Pierre Jaquet-Droz's automaton, *The Writer*, is able to pen any text up to 40 characters.

cutely called "the hard problem of consciousness." It is said that if we can't make something, then we don't fully understand it. Making a machine that can convincingly mimic a human would then seem like a good approach toward determining whether or not we are just complex, biological, clockwork meat machines.

While these are just my retrospective musings, perhaps they explain why odd people throughout history, and more recently, I myself, have decided that creating a machine that could write and draw autonomously was an ideal problem to add to our lives.

My first encounter with automata was at the age of 22. I had just begun my year long, overseas post-graduation adventure, intending to regain a personality after spending four years inside a brain and a university textbook. I was visiting Siegfried's Mechanical Music Museum in Rüdesheim am Rhein, Germany. After a guided tour through the collection of large, elaborate machines that could play trumpets, drums, violins, and saxophones, what finally caught my eye was a tiny singing bird that popped up out of a snuff box (**photo 1**)! It sang a song, flapped its tiny mechanical wings, then snapped away into its hidden clockwork world.

I had never been aware of such things, but suddenly saw an alternative use for a newly acquired degree in mechanical engineering. While I have a deep admiration for the ingenious machinations residing inside my toilet cistern, they fail to summon the same emotive sense of wonder one discovers upon their first encounter with a mechanical singing bird the size of their thumb nail, or an ancient sketch immortalized in the cams of a clockwork boy.

My next encounter with automata came a few months later, at a mental-magic show in London, and was perhaps my first introduction to the word "automaton." The show involved a small, creepy clockwork boy that was able to tap out predictions with a long stick on a board of letters. I don't suppose this doll was actually from the Victorian era, or even clockwork, as the showman's narrative proclaimed, but it did lead me to later investigations and the realization that similar devices had once existed.

Early drawing and writing automata

You may be familiar with *The Writer* (**photo 2**), an automaton created by Pierre Jaquet-Droz, in the 18th century. This clockwork boy was, and still is, able to scribe custom text of up to 40 letters. Cams position his quill tip in two dimensions, allowing him to write out his pre-programmed message. His hand can also be raised in order to lift the quill from the page, dip the quill in ink, and even shake off the excess. His eyes move from side to side, following the message as he writes.

The Jaquet-Droz family also created *The Draughtsman* (**photo 3**), an automaton boy capable of drawing four different pictures. I believe these devices are still in working order and can be seen in the Museum of Art and History (MAHN) at Neuchâtel, Switzerland. I have not had the opportunity to see these machines in person. Most people probably never will, let alone know that such curiosities exist.

I thought there must be a way to make a much simpler drawing/writing automaton, one that even the average person could put together themself, without being the descendent of a long line of clockmakers. I was not able to find many other examples of writing/drawing machines. There is the Maillardet automaton in Philadelphia's Franklin Institute (**photo 4**), and a modern replica of the Jaquet-Droz writer made by François Junod. Both are very complex machines.

PHOTO USED UNDER CREATIVE COMMONS LICENSE: https://tinyurl.com/pdroz

3. *The Draughtsman*, by Pierre Jaquete-Droz, can draw four different pictures.

DADEROT, COURTESY WIKIPEDIA

4. *The Draughtsman-Writer*, an automaton by Henri Maillardet.

I could not find much information about the mechanisms behind these machines but I believe they achieve two dimensions of movement by utilizing a side-to-side pivoting elbow and a telescopic forearm.

I acquired some photocopies from an automata maker in the US, Anatoly Zaya-Ruzo. In them, I found a diagram of a much simpler writing machine by A. Seguin, of Paris. His was a small man who held a pencil in his arms and achieved two degrees of freedom by pivoting vertically at the shoulders and twisting his body side to side. Seguin used notched profiles cut into two strips of film to control each of these movements. The small drawing surface was spring loaded to compensate for the pencil tip being pushed deeper into the page as it moved through its arc of motion. This seemed to prove the concept of a simple writing mechanism similar to what I had been conceiving, so I set to work designing my first writing machine.

Designing the machine

I had just purchased a new CNC router at that time and was enjoying the challenge of designing machines that used only flat-cut parts that people could assemble in kit form. I decided to apply this constraint to the design of my writing automaton.

The mechanism consisted of a pencil, clamped into a mounting that could pivot and rotate about a gimbal axis. Two rods pulled on this mounting, each attached to levers and their own cams. The drawing page was a receipt roll that could be pulled out and torn off each time a new drawing was desired.

Because I was making this out of CNC-router-cut wooden sheets, there were some limits to the precision I could achieve. The larger the cams, the more information I could fit on them to produce either a longer or more precise sketch. My cam diameter was limited, so if I made the word or sketch too long, I would get too-large gradients in my cam profile for the followers to trace smoothly, and a less accurate reproduction.

I needed a single, small-but-poignant word I could ask my device to write. The word would be forever captured in a set of cams, ready to be scratched out in my own handwriting for years to come—a life-changing word that people would accept in a state of mechanical awe from an enlightened machine. "Yes" seemed like the best three-letter message to share with the world. It was a word that was close to my heart. It said that everything may not be possible, but give it a go anyway.

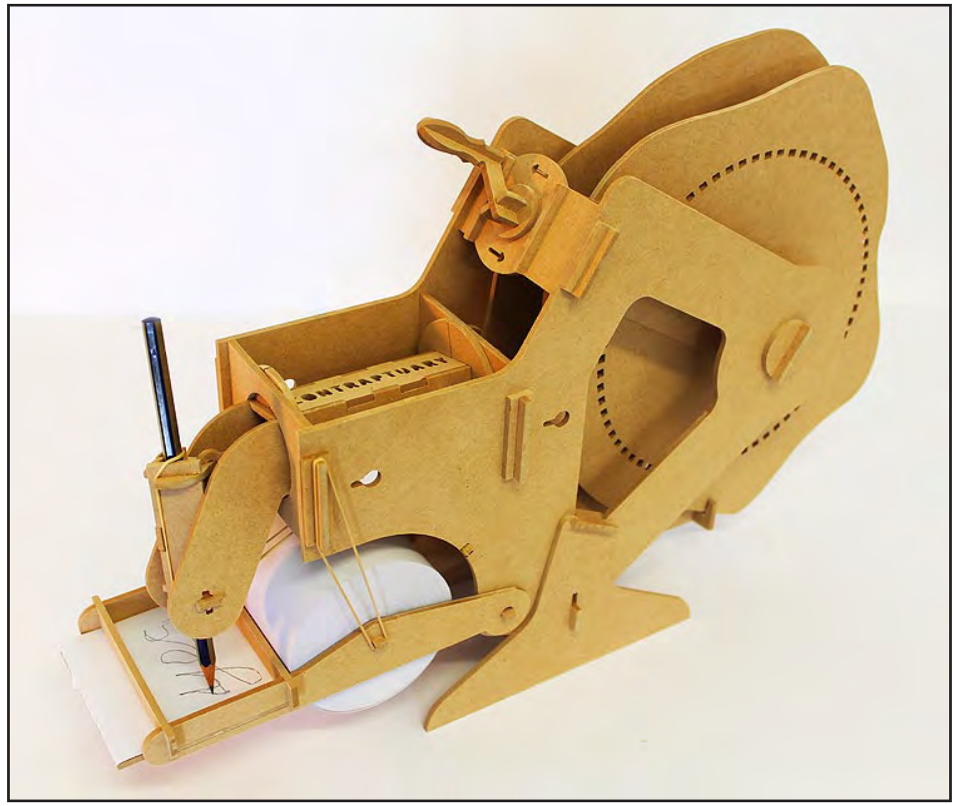
So how could I translate my sketch into the profiles of two cams? This required some trigonometry and ratio calculations along each linkage to determine the formula that equated the cam radius to the pencil tip's X and Y positions. My sketch then had to be sampled into discrete data points and each spaced evenly around the 360 degrees of available cam space. Each angular cam position was then given its radius associated with the corresponding data point in the sketch. I wrote a piece of software to perform these calculations quickly and produce the two cam profiles needed for a sketch that the user would draw with the computer mouse.

Scriblo

A couple of months after starting, I found myself turning the handle of my first writing machine (**photo 5**). It is quite a magical experience to see one's own writing slowly appear on real paper with a real pencil, as if the machine embodies some part of one's brain (**photo 6**). The machine did not at all resemble a small boy, but I managed to attribute to it some anthropomorphic characteristics, and I named it *Scriblo*.

I made a few of these as kits, which went to various places around the world. I have had one on display in my mechanical gallery for the last four years. He must have written "yes" thousands of times and has stood up remarkably well, considering the roughness of the general public and the fact that he is only made from particle board. He has only needed the odd drive-gear replacement and new rubber bands every so often.

A couple of years after the first attempt, I decided to work on a second-generation writing-machine kit. I now had a laser cutter, which allowed me to make more-intricate parts, with better edge integrity. My local supplier had stopped selling the higher-quality MDF sheets, and *Scriblo* seemed less resilient when made from regular MDF. I was also aware that *Scriblo* was difficult to assemble and was prone to breakage if you had to take him apart to correct an assembly step.



5. *Scriblo*, the author's first writing machine.

Skrippy

My criteria for this next writing machine were: to make it smaller, with fewer parts, and easier to assemble; to fit all of the information onto one cam; and to give it more of a character. I was able to make it smaller by using two fishing-line cables to pull the gimbal about each axis. These cables attach to levers with cam followers, each of which follows a different half of the single cam's profile. Rather than us-

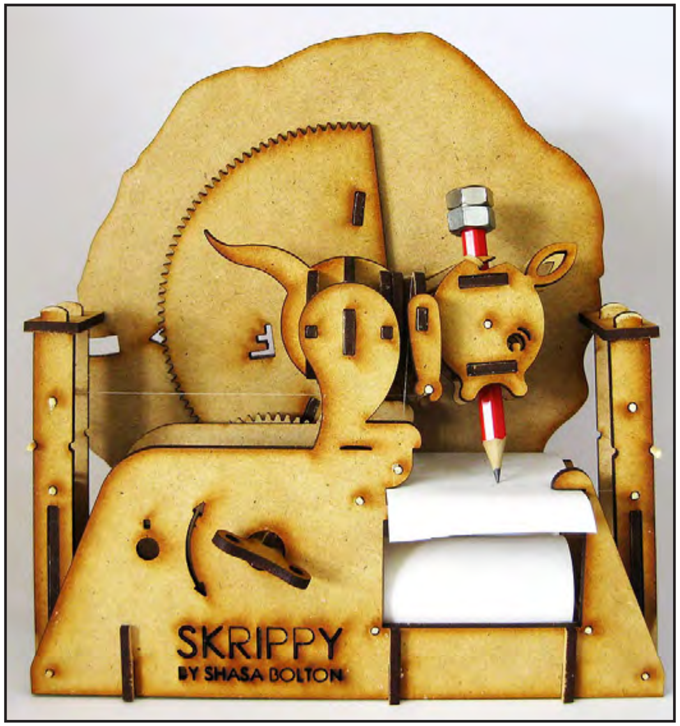
6. "Yes," as written by *Scriblo* on its writing pad. The paper is on a roll. Once written, the word can be pulled out and torn off the roll.

ing a spring-loaded writing surface, I allowed the pencil to slide freely in its mount and added weights to increase the pressure on the page.

This machine depicts a small kangaroo, as he comes from Tasmania, Australia, where I live, along with many wallabies. He is called *Skrippy* (**photos 7-9**) and comes with a cam to write the word "yes" (**photo 10**), as well as some blank cams, and software that lets you create your own small word or picture (**photo 11**). My girlfriend was the test dummy for my design instructions, and she made one that writes "70" for her father's 70th birthday.

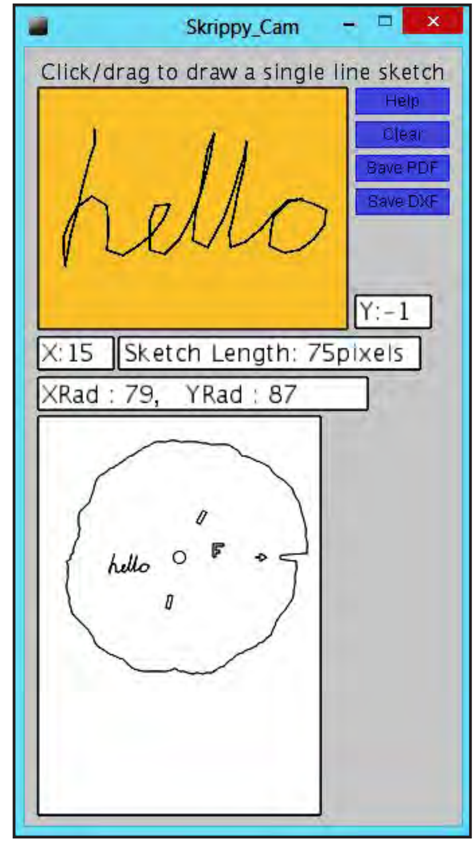
I offer the plans for *Scriblo* free on my website (*http://www.contraption-cart.com/skrippy*), for those who might want to cut out all of the parts with a scrollsaw. Otherwise, purchasers can buy the improved *Skrippy* kit and I'll send them all the pieces to put together themselves.

Creating writing automata may bring us no closer to solving The Hard Problem, but it provides a curiously convincing effect and satisfying challenge, one that I was happy to try solving. We have a long way to go before being immortalized inside little machines, but I shall keep looking for the next stepping stone in the automatist's path of endless problem-solving happiness.

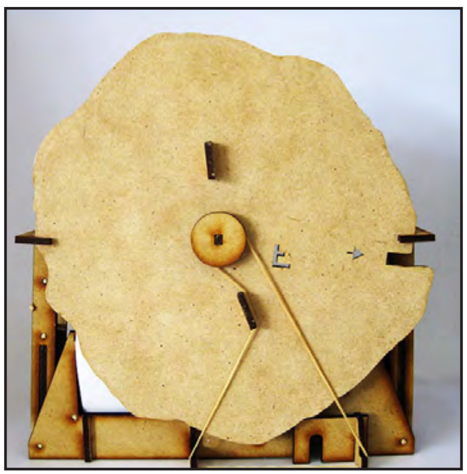


7. *Skrippy* is made of laser-cut parts. The writing head is shaped like a little kangaroo.

8. End view, showing the position of the pencil.



11. When you write the word (or draw the picture) with the mouse, using the author's computer program designed specifically for his writing automata, the computer generates the cam shape to make it happen. The shape can then be printed out and used as a pattern for cutting the cam.



9. *Skrippy's* backside. A single large cam controls the action in two axes.

10. A closeup of the writing head, scrawling out the word "yes."

See the author's writing machines in action—

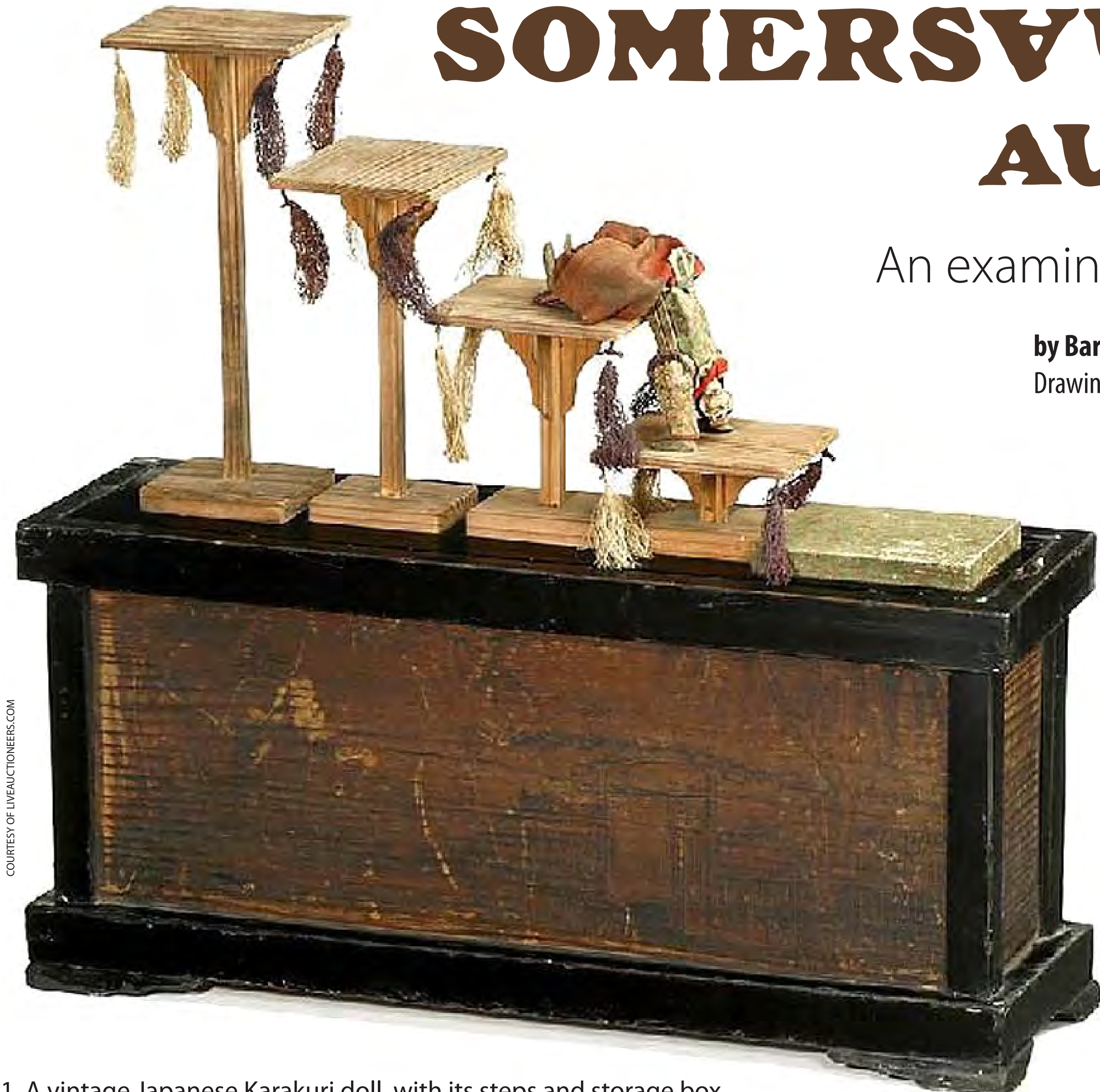
Scriblo: *http://www.contraption-cart.com/scriblo*

Skrippy: *http://www.contraption-cart.com/skrippy*

SOMERSAULTING AUTOMATA

An examination of how they work

by Barry Falkner • Otley, West Yorkshire, United Kingdom
Drawings and photos by the author, except where noted



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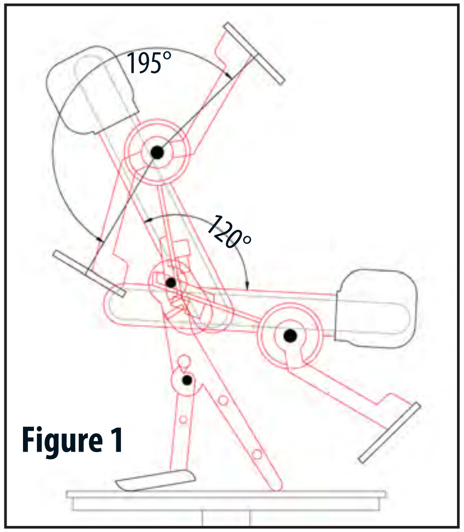
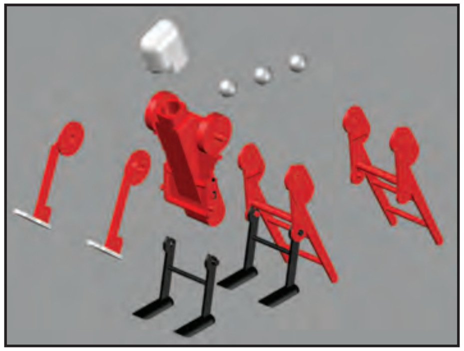
1. A vintage Japanese Karakuri doll, with its steps and storage box.

Backward-somersaulting men and tumbling-acrobat automata have been made for over two hundred years. They were originally produced as toys for wealthy adults—they were not cheap! They were never toys for children, as they were way too fragile. I became fascinated with them about five years ago and set about trying to understand how they work (I love puzzles). In the end, I produced three YouTube videos; links are given at the end of this article. I examined three variants (two being similar).

Japanese Karakuri dolls

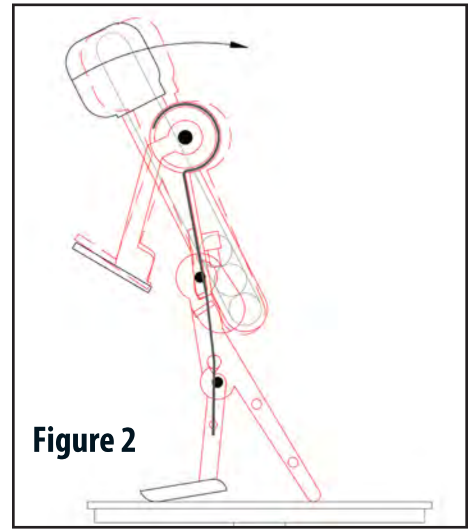
The figure in **photo 1** has a weight within its body that drives the mecha-

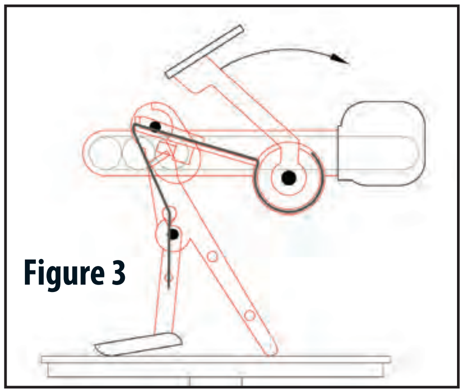


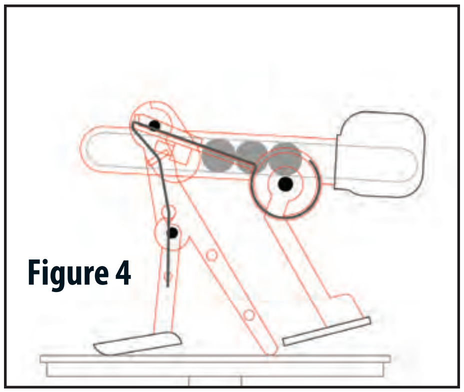


2. An exploded view of the Gakken doll.

3. Gakken's Karakuri Somersault Doll, undressed and standing. Note the large, flat hands.







nism. This originally would have been mercury. I'm using a modern replica (Gakken Karakuri Somersault Doll) to illustrate how these automata work. In this replica, steel balls are used instead of mercury. Arms are hinged at the shoulders and can rotate approximately 195° from the start position, up and over the shoulders (**figure 1**). The body is hinged at the hips and, from its start position (leaning forward), it can fall back approximately 120°. Its component parts are shown in **photo 2**.

The doll will stand upright on a flat surface with its hands forward (**figure 2** and **photo 3**). A slight push of its head will cause the body to fall backward at the hips to a point where the ball bearings within the body roll toward the head end, increasing the momentum of the rotating body.

The clever bit is that cords (fine nylon in these models) run from the arms, down through the body, and are attached to the legs. These cords are essential; the mechanism cannot work without them. The tension of the cord is such that, when the body reaches a horizontal position, the cord pulls the arms over the figure's head to reach downward until the hands touch the floor (**figures 3** and **4**).

The ball bearings have now rolled into the head, causing the automaton to rock from its feet to its hands (**figure 5**). The body continues to rotate, lifting the legs off the floor. The momentum keeps the body rotating until, once again, it reaches the horizontal. Again the cords pull, this time rotating the legs (**figures 6** and **7**).

On a flat surface, this would be the end of the action, but these figures were supplied with a flight of four steps. The figure starts, facing

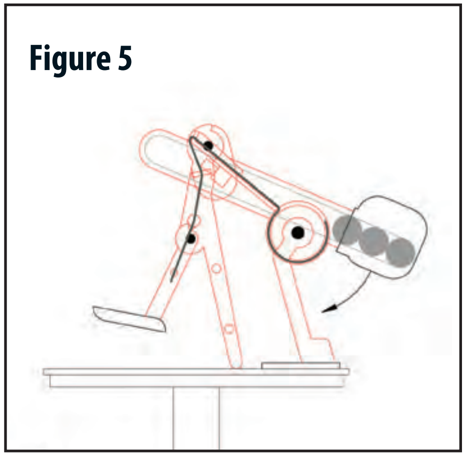


Figure 5

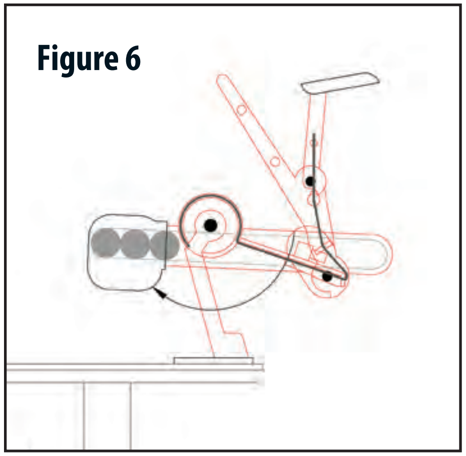


Figure 6

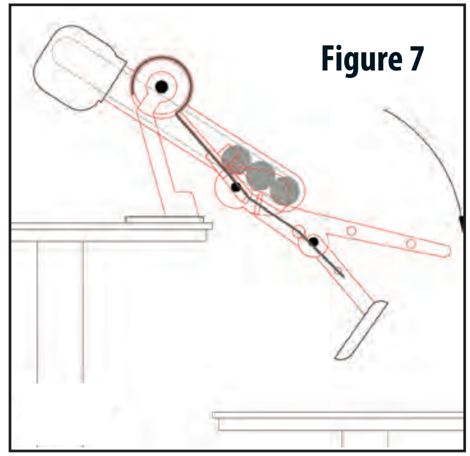
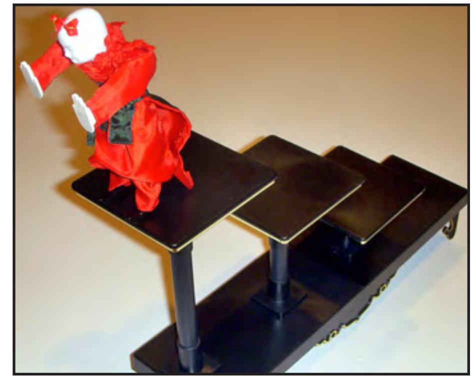


Figure 7



4. The doll, preparing to somersault backwards down the steps.

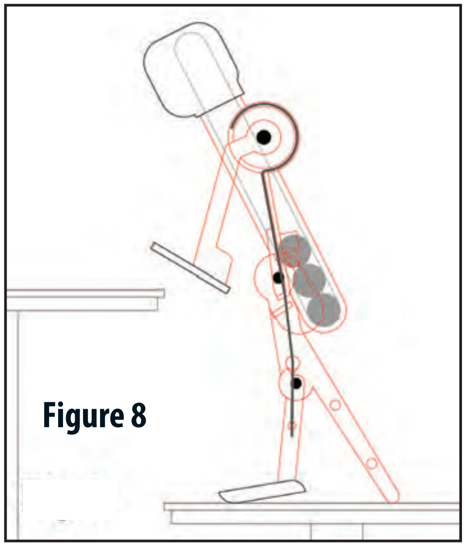


Figure 8

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5. A vintage tumbling man, made in Germany.

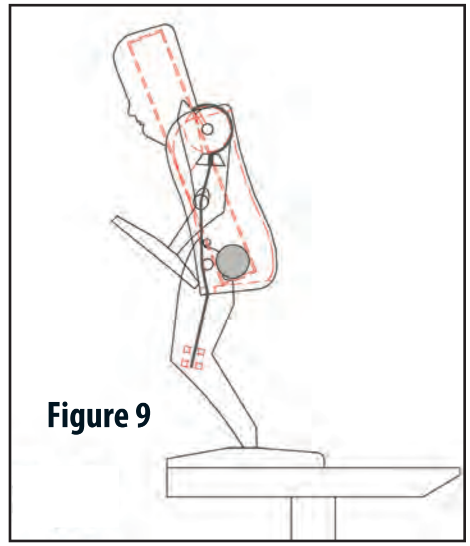


Figure 9

ANDREW NETHERCOTT

6. The cords at the shoulders of the tumbling man are visible.

backwards on the top step (**photo 4**). After the sequence described above, it drops onto the next step down in an upright position (**figure 8**). The sequence is then repeated as the figure descends the steps. After the last step, the figure comes to rest on the level.

German tumbling man

The automaton in **photo 5** is similar to the Japanese version, having hinged legs and arms and the essential cord linkages. The automaton came in a box that could be transformed into a flight of steps. Again, the weight within the body would originally have been mercury. I will show a ball bearing in the illustrations.

The action is almost identical to that described above, but the use of extra-long feet (**figure 9**) does away with the need for the rather strange support at the back of the legs in the Japanese version. **Photo 6** shows the cords attached to the tops of the arms. **Photo 7** shows the neat way this automaton is stored in its box. (At the time of writing, this automaton was for sale on Etsy by Andrew Nethercott.)

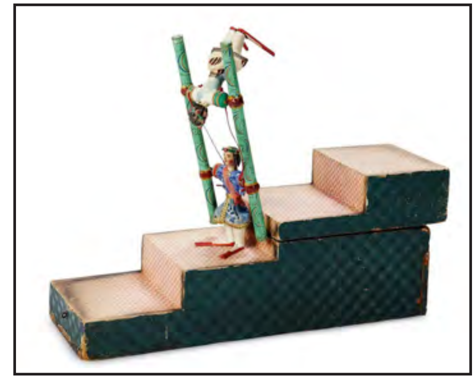
The hole in the figure's side,


ANDREW NETHERCOTT

7. The tumbling man, neatly packed away in his case. The remaining space is reserved for his steps.

8. Werner Toys' version of the tumbling man has typical large hands. The cord around the shoulder extends into the body.

9. Werner's *Sturzmännel*, poised and ready.

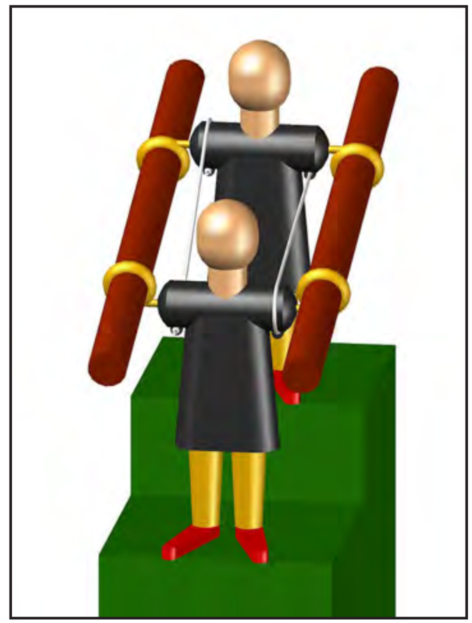

COURTESY OF THERIAULTS.COM

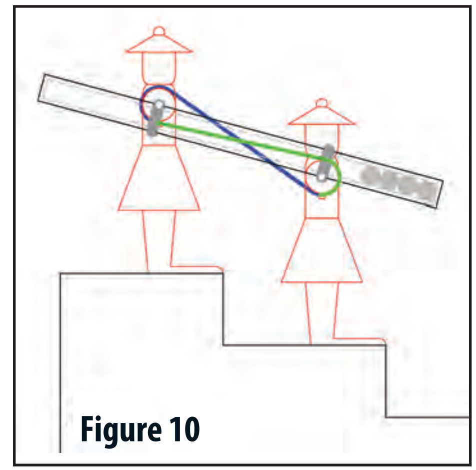
10. Chinese acrobats. The top steps fold down and the figures are stored in the box.


COURTESY OF *antiquetoysandgames.com*

11. Another set of Chinese acrobats. The figures are rigid and rotate between the tubes about the arms.

RIGHT: 12. The illustration shows how the tubes are always above the axle of the forward figure and below that of the rear figure.





where a cord from an arm passes into the body and down to the legs, can be seen in **photo 8**.

Photo 9 shows a modern version of this automaton, still being produced by Werner Toys in Germany. It's called the *Sturzmännel*. You can also view it on the website: *https://tinyurl.com/sommersault*.

Chinese (or Mandarin) acrobats

The automaton in **photo 10** appears to be more complicated, having two figures with linking tubes. Like the others, these tubes would originally have contained mercury as the counterweights. I will show ball bearings.

The figures are rigid—the arms and legs do not pivot on the body. **Photo 11** shows how the figures are attached to the two tubes. Axles run through the arms and shoulders of the figures, with rings on each end to hold the tubes. **Photo 12** shows how the bulk of the tube is always above the axle of the forward figure and below the axle of the rear figure. This photo also shows the linking cords (again, the cords are essential). Notice how the left-hand cord

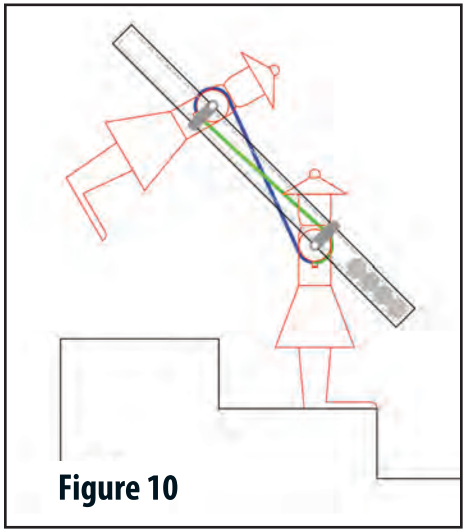


Figure 10

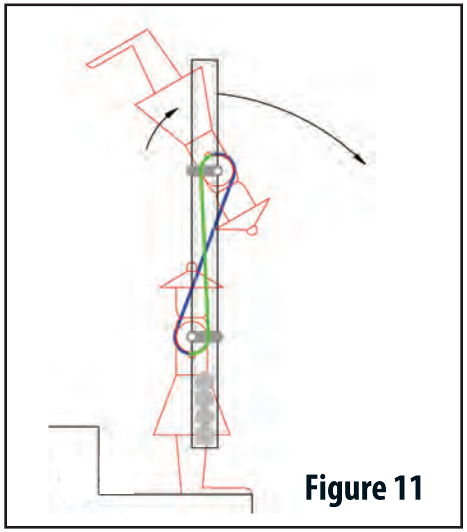


Figure 11

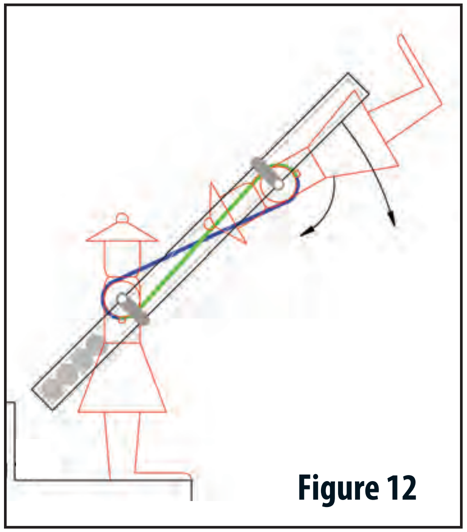


Figure 12

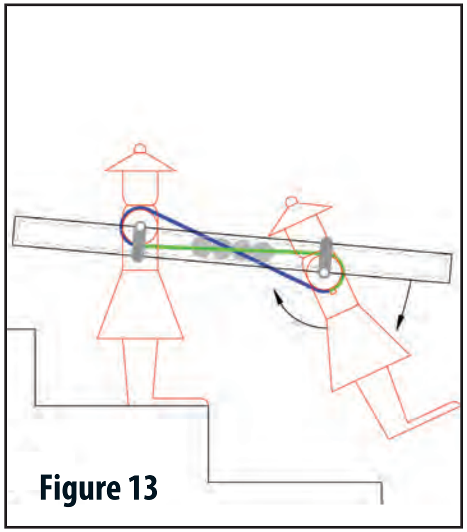


Figure 13

runs from below the front figure's shoulder to above the rear figure's shoulder, and vice versa on the right side. **Figure 10** shows this in profile; a figure eight is formed.

When placed in the start position at the top of the steps (**figure 10**), the upper figure must be restrained. As soon as the figure is released, the ball weights cause the upper figure and tubes to rise. In the process, the blue cord is tensioned, causing the rear figure to begin to rotate (**figure 11**). Once past the vertical (**figure 12**), the now front figure could free fall if it was not restrained by the green cord (**figure 13**).

Once the tubes pass the horizontal, the ball bearings start rolling to the opposite end, and the tubes

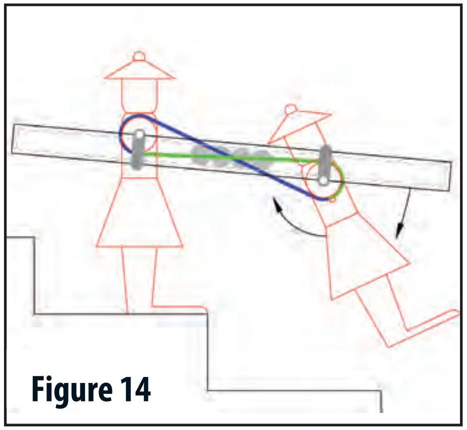


Figure 14

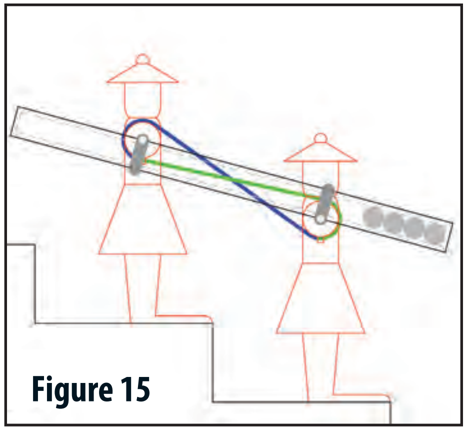


Figure 15

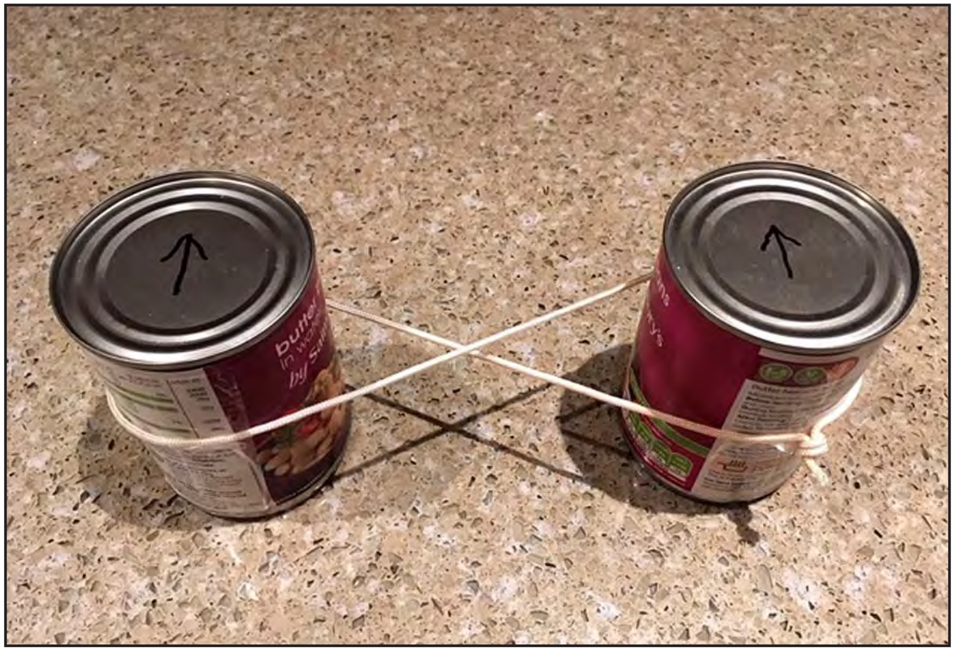
and front figure continue to rotate until the front figure lands on the third step, feet first (**figures 14** and **15**). The sequence is repeated until beyond the last step.

To better understand what is going on, try this experiment. Get two food tins and a loop of cord. Place the cord over the tins in a figure eight. Draw arrows on the tin tops. Tape the string to the face of the tins (facing you, at the foot of the arrows—**photo 13**).

Holding the right-hand tin stationary, slide the left-hand tin through a 180-degree arc to the opposite side of the stationary tin, rotating the tin as you go. The tin that moved has rotated 360 degrees! This used to be a party trick. If you rotate one coin all the way around the perimeter of a stationary one, how many times will it revolve? The answer is twice!

I have not made any Chinese acrobats yet, but they should be far easier to make than a single-figure automaton. The difficult part would be how to fit the axles and tube-support rings. Perhaps one solution would be to make the upper body with a removable back that could accommodate a complete axle/support assembly.

I think that getting the balance right between the weight of the materials and the counterweights of any of these amazing automata would be a real challenge. A lot



13. Setup of the food tins to illustrate the principle of the Chinese acrobats.

of trial and error would be necessary. I have purchased a *Sturzmännel* from Werner Toys. It is a thing of beauty—really well made and, considering the difficulty of its making, a real bargain! AM

YouTube links to somersaulting-automata videos

Karakuri doll

https://www.youtube.com/watch?v=_VKi4xGshF0 (Description of action)
https://www.youtube.com/watch?v=IPAWsN2zpuk (Modern version)

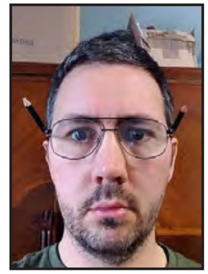
Tumbling man

https://www.youtube.com/watch?v=3pfpXqRyEqo (Description of action)
https://www.youtube.com/watch?v=qzknJhgMkRA (Modern version)

Chinese acrobats

https://www.youtube.com/watch?v=ZNklO_7gBa0 (Description of action)
https://www.youtube.com/watch?v=Rq39YDc0vOo (Vintage)
https://www.youtube.com/watch?v=KELP9SjrSn0 (Lego version)

GALLERY



Dream on a Shoestring
by Dave Hall
Derby, UK
Photo by the author

The dreaming of a frugal Yorkshire man. Even in the dream he chooses the budget option of a modified crocodile over the dragon (cheaper to hire).

Dream on a Shoestring has been displayed in The MAD Museum in Stratford-upon-Avon.

Video: *https://tinyurl.com/DaveHall1*
facebook.com/davehallautomata • *instagram.com/davehallautomata*

BUILDING BLOCKS

Gears: Part 1—the basics

by Paul Giles •Sun City Center, Florida, USA

Drawings by the author, except where noted; photos by Marc Horovitz

There is something magical in watching a series of gears in motion. Even connected, some will move fast while others will be quite slow. You might even see a gear that seems to stand still for a few moments before continuing its motion. In the next few "Building Blocks" articles, I'll show you some of the magic that can be created with gears.

In this issue, I'll lay some groundwork and discuss a few kinds of gears that can be useful in automata, before I get into the basics of gear design.

Gear types

A spur gear (**figure 1**) may be your first choice for automata projects. These are what many of us picture when "gear" is mentioned. If you decide on a single, long driveshaft for your model, you could attach several spur gears along that shaft. Each of these would then provide the driving power needed for different actions. One crank could then control everything that you need. Spur gears are also great for changing speeds or increasing power.

Have you ever looked at a traditional Dutch windmill and admired the simple design that performs so well? If you looked closely at the base of the sails, you might have seen several wooden dowels, interlocking at a right angle with other dowels that were driven into a vertical shaft, similar to **photo 1**. All of those interconnecting dowels were actually two basic gears, commonly called pinwheel gears in automata. Think of them as forerunners to the bevel gears (**figure 2**) that are so often used in today's automobiles. Bevel gears could also be used on that driveshaft just mentioned, but they are more difficult to make. Pinwheel gears, with their interlocking pegs, are quite appropriate in automata.

Gears come in many shapes, sizes, and configurations. In this series of articles, gears for automata will be explored.

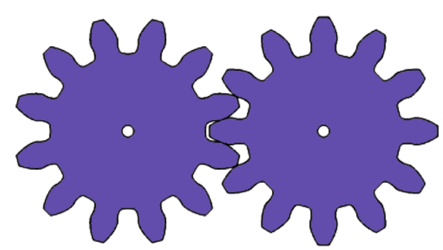


Figure 1—Spur gears

1. Pinwheel gears similar to these, but much larger, were used in antiquity to power machinery, like Dutch windmills.


Figure 2—Bevel gear

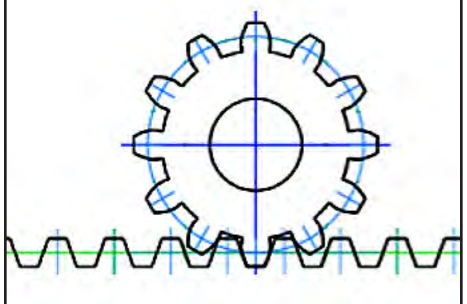
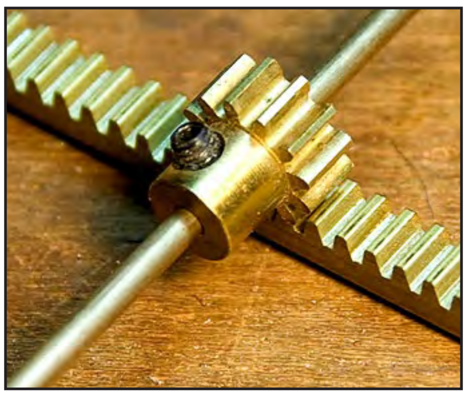


Figure 3—Rack and pinion


2. A rack-and-pinion mechanism is a good way to translate rotary motion into linear motion, or vice versa.

Something that you might not consider to be a gear, but that will fit into any project where some precision is needed, is a rack—as in "rack and pinion" (**figure 3**, **photo 2**). You may decide to use a rack and pinion when you need to move an object along a constant, straight path.

A fun-to-make gear that can add a lot of wow to a project is a roller gear (**figure 4**). In addition to you showing off a little, use this mechanism for a rapid change in speed (gear reduction) when there is little room for other designs. Three rollers are mounted to a revolving circular or triangular plate. The roller part is the driving part, while a grooved plate is the driven piece. Inside the grooves ride rollers that move back and forth. As they move, the rollers push on the grooves and cause rotation. Each pair of rollers and grooves will reduce the speed by half. Two pair could be stacked in a small space for a 4:1 reduction.

Similar in concept, but with a different application, are the delightfully named sun-and-planet gears (**figure 5**). While these are most often found within the drivetrains of automobiles, they can also be useful to our models.

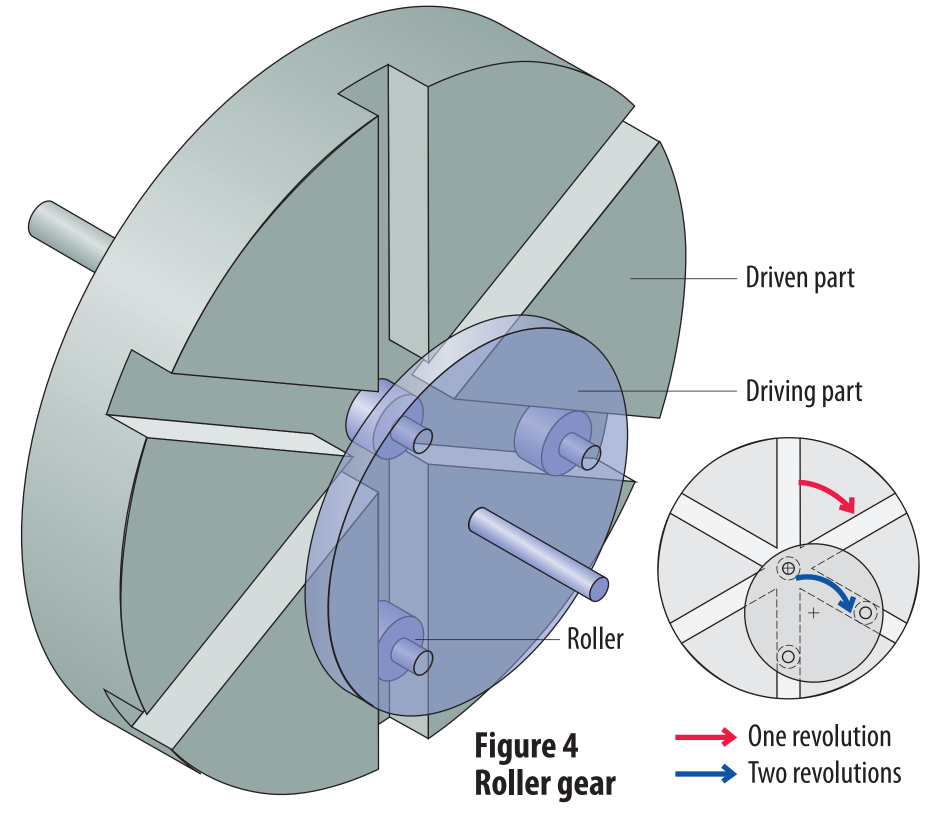


Figure 4
Roller gear

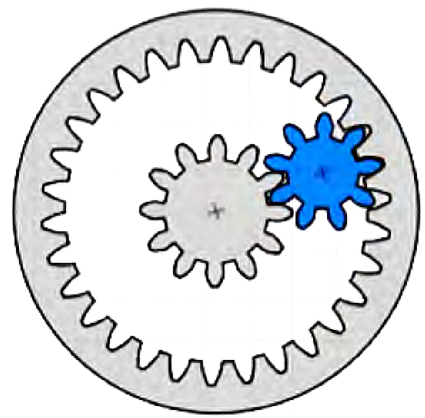


Figure 5—Sun and planet


Figure 6
Variation on sun and planet

Consider using a sun-and-planet mechanism when your design involves a central point with several actions surrounding that center. For instance, one large dog and several smaller canines, all chasing their tails in delight, would be a good use for a variation on the sun and planet (**figure 6**),

I am also going to include ratchets in this gear discussion, as they, too, have teeth. The difference between a gear and a ratchet (in conjunction with a pawl) is that a ratchet restricts direction, unless it is intentionally released. Gears can spin in either direction.

A great use for a ratchet is to ensure that your hand-powered automaon's crank cannot be turned in the wrong direction (**figure 7**). Some unspoken rule has determined that a hand crank should rotate clockwise. So of course children or other curious people will be quick to wonder, "What happens if I turn it the other way?" Typically, that's not a problem. If, however, your device has too many parts, complex pieces, or the wrong shapes in the cams, then those parts are likely to jam. If this is the case, use a ratchet. Ratchets have

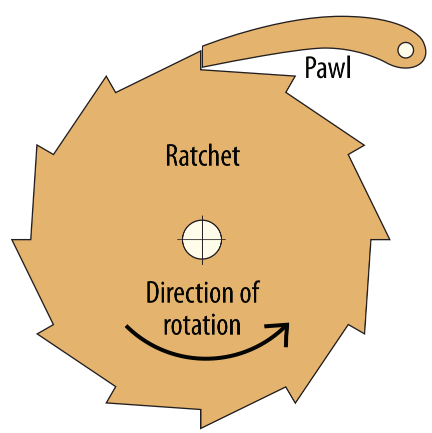


Figure 7—Ratchet and pawl

MARC HOROVITZ

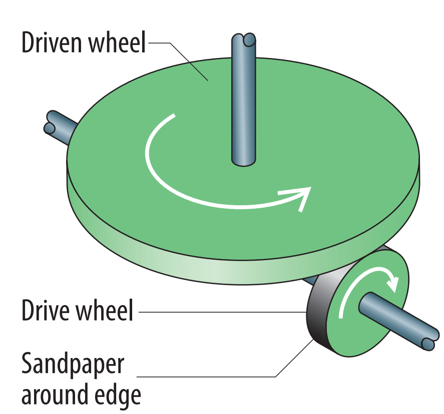


Figure 8—Friction wheels

MARC HOROVITZ

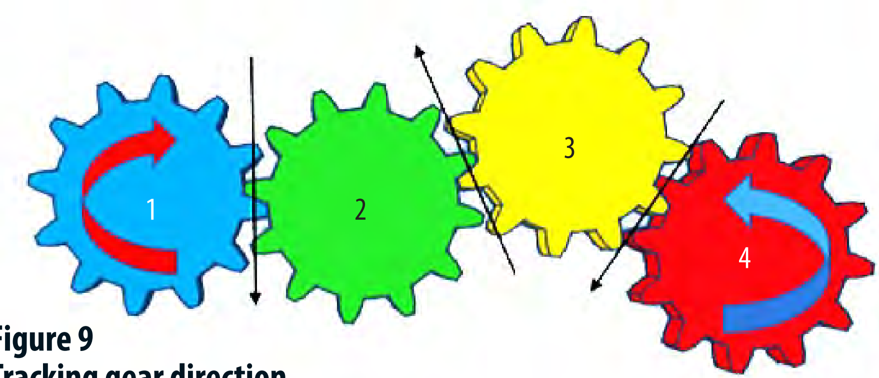


Figure 9
Tracking gear direction

the added benefit of producing that fun clicking sound as the pawl drops off each tooth, which helps bring life to so many projects.

A final option when considering gears is the use of friction wheels. The sandpaper tubes that are often used on drums that fit small rotary hand tools could be used. They will never be pretty and will not show off your talents, but friction wheels do have a few advantages. If you need a gear set that is too small to make comfortably, then putting together a few of these friction wheels can help to keep your fingers intact.

The easiest way to make the several sizes of friction wheels that you'll need for speed changes is to cut lengths of various diameters of dowel rods. Glue narrow strips of sandpaper, like those that lathe turners favor, to their edges. With dowel diameters from fractions of an inch to almost two inches readily available, you can quickly knock out a large number of these friction wheels (**figure 8**).

Friction wheels can also save you the time that would be required to design, lay out, and cut teeth in a gear. This can be a real help if you are first building a prototype to confirm your design. You might also consider friction wheels if your gear train will be concealed.

Gear direction can be confusing if there are too many gears in a row. Does that last gear move clockwise or counterclockwise? There is an easy way to figure it out.

Begin by looking at the first (driving) gear. Draw an arrow between gear 1 and gear 2 where they mesh and in the direction that gear 1 will turn. Now move over to where gears 2 and 3 come together and draw an arrow in the opposite direction. Repeat this for

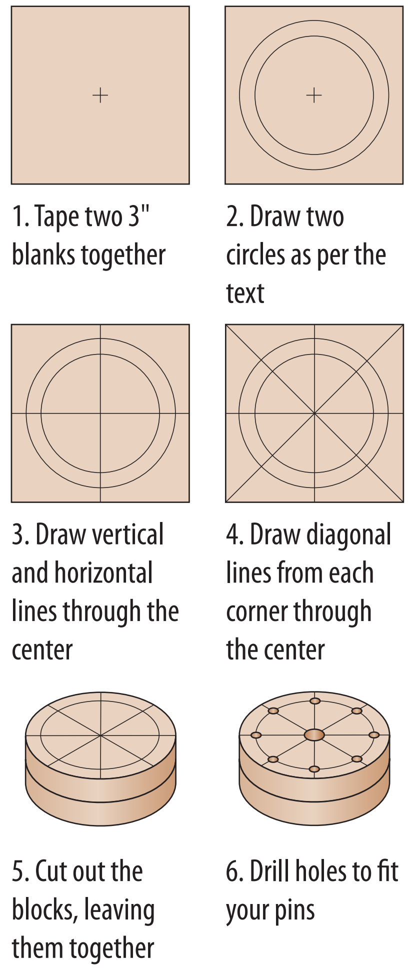


Figure 10—Block drilling

MARC HOROVITZ

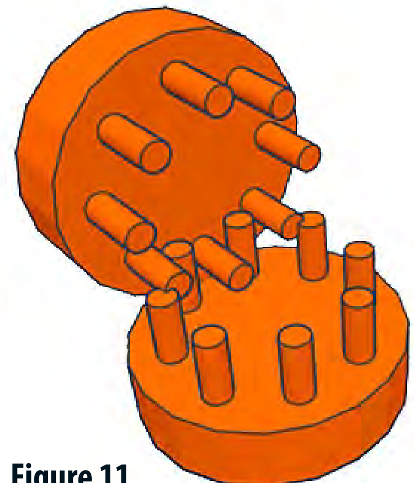


Figure 11
Finished pinwheel gears

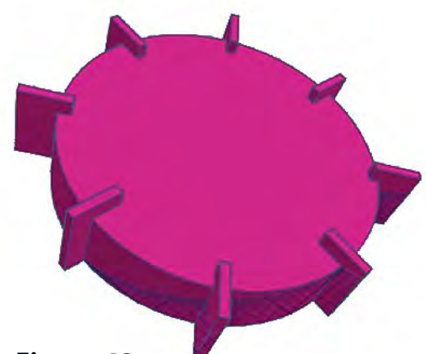


Figure 12
Gear with plastic teeth

each pair of meshing gears. When you get to the end, look at the direction of that last arrow. The final gear will turn in the same direction that the arrow is pointing. **Figure 9** illustrates this technique.

Making simple pinwheel gears

There are times when it can be advantageous to go simple. It is common to have to tweak or even completely change a drivetrain. Gears take a long time to make and I never want to make them twice, just because I want to change the speed of my automaton. I'll end this discussion with two general ways to quickly create gears: a matched set of pinwheel gears that will be suitable when constructing a prototype, and simple gears for side-by-side applications.

The first option is useful for starting a secondary drivetrain powered by the main shaft. Simply drop a suitable number of dowels into the faces of wooden or plywood discs. You can create a same-speed transfer of power with a pair of identical discs.

Refer to **figure 10**. Tape two 3"-square blanks together, one atop the other, with double-sided tape. It's important that the blocks be quite square. Using a compass, draw two circles on the squares around the same center point—one 2" (5cm) in diameter and the other $2\frac{1}{2}$" (6.25cm). I am showing eight teeth per gear in this example because the layout is fast and easy.

With a square and a pencil, draw a line through the center point from the six o'clock position to twelve o'clock. Do the same between three and nine o'clock. Now connect the opposite corners with two diagonal lines. You have just accurately laid out a gear with eight teeth.

Cut out the $2\frac{1}{2}$" circles. Keeping the two round blanks taped together, drill holes at all points where the radial lines intersect the 2" circle. Your drill should be sized for a thin dowel. Don't forget to drill your center hole, too. Now separate the two discs and insert dowels (the pins) into each hole. They should protrude about $\frac{1}{4}$" on one side (**figure 11**).

Option two replaces the pins with sturdy plastic rectangles set into the face of the gear (**figure 12**). This option works best for side-by-side gearing. The plastic cards that so often arrive in business-reply mail are just right. Cut the saw kerfs on each face with a scroll- or bandsaw, then glue a plastic tab into each slot. The saw table will keep your gear teeth straight.

Next time, I'll get deeper into specific designs, software, builds, and uses. AM

AUTOMATA FOR BEGINNERS

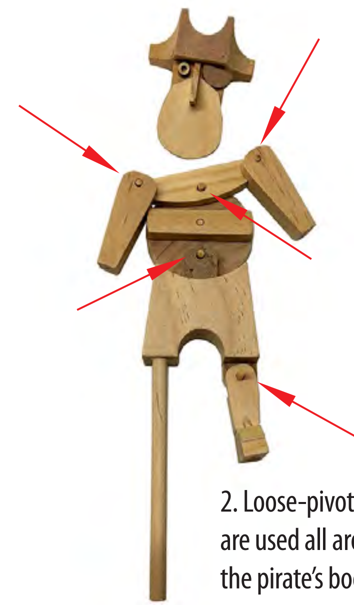
Fling, bounce, and rock

by Sarah Reast • Llanbrynmair, Wales, UK • Photos by the author

In this issue, I am talking about three mechanical principles that you won't see explained in the more academic engineering textbooks. They are *fling*, *bounce*, and *rock*—the arbitrary or accidental movements that rely on a controlled impetus to create an uncontrolled but desirable outcome. Some might say this is cheating. I would say it is letting natural forces make your model seem more alive.

Timberkits' *Pirate Panic* (**photo 1**) is a great example of fling, bounce, and rock. He has good reason, poor chap—he is faced by one persistent octopus who is not backing down, and Mr. Pirate doesn't want to lose another extremity. Sometimes, in order to create an illusion of a dangerous situation, you need to let go of some of the control.

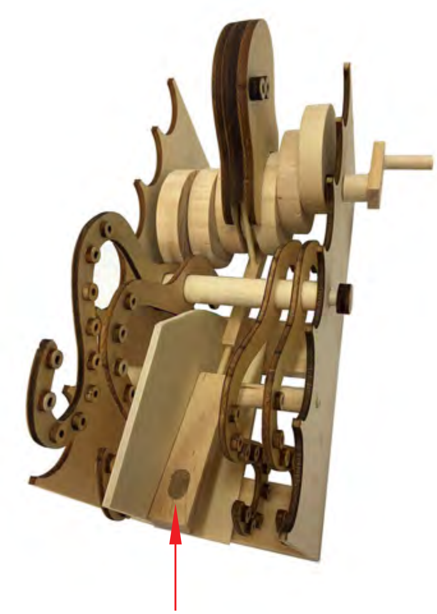
1. The pirate flings, bounces, and rocks in his attempt to escape the octopus, who is also doing his share of flinging, bouncing, and rocking.



2. Loose-pivot joints are used all around the pirate's body.

Because the pirate is loosely pivoted in all his joints (**photo 2**), and because he is not symmetrically balanced, his flinging movement can be quite random, which helps convey the feeling of panic. A dowel that is a continuation of his peg leg is simply rocked backwards and forwards from the octopus' central cam to create the fling (**photo 3**). The faster you turn the handle, the more violent the action becomes.

The pirate also demonstrates bounce, in that the tentacles of the octopus are so loose, they are bounced by—as much as pushed by—the cams. Thus, they have



3. This piece is rocked back and forth by the octopus' central cam to operate the pirate's peg leg.

4. The runner's lower legs are loosely pivoted and can move at random, though not beyond normal knee extension. Linkages in back control the upper arms and legs.

5. A triangular cam provided listless movement in this bug.

6. An eccentric cam with a friction wheel was no better.

a range of movement that goes beyond the control of the cams. You can view the pirate working at *https://youtu.be/oMyKXuQzN2E*.

The runner in **photo 4** is also based on the principle of fling. I am especially proud of it, as my dad, who is very much the senior and preeminent designer here at Timberkits, said it would never work. Obviously, that was a gauntlet thrown down that couldn't be left unchallenged.

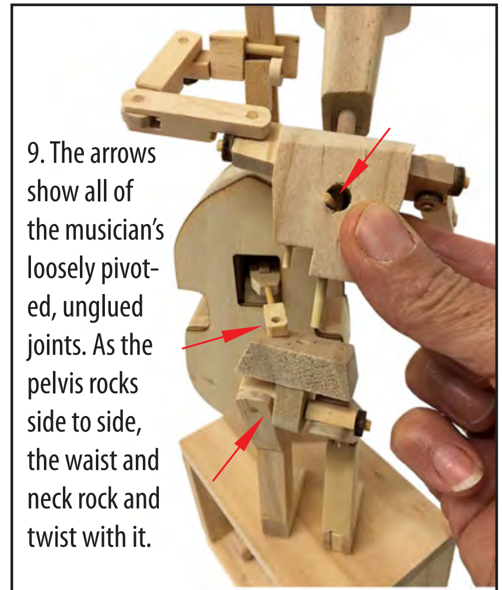
The leverage at the back (lifted by a triangular cam below) is very small and can only articulate the movement in the arms and upper legs. In order to give the lower legs and feet an effective throw, they are loosely jointed. The runner's knees are constructed in such a way that they can't bend beyond a naturally extended straight leg but can flop with gravity to bend mid-stride. This running fling of the legs projects a good sense of energy and propulsion that is far more dynamic than a totally controlled set of linkages. Her ponytail is loosely jointed, too, which enhances the effect.

I thought I might try to illustrate these three principals by making a much simpler model, since this is an article for beginners. However, it turned into a whole new lesson to be learned.

I made a rather unedifying little bug with loose legs and antennae. I thought that, by putting him on a bouncy cam (**photo 5**), his limbs would skitter about comically. Nothing happened. He just jittered a little miserably. So I thought, Let's give him a twist and a lift, so I put him on a cam with a

7. A side-to-side linkage solved the problem! Legs and antennae fly around at random.

8. The *Double Bass Player* has several loose joints, which appear to give his playing a relaxed, laid-back quality.



9. The arrows show all of the musician's loosely pivoted, unglued joints. As the pelvis rocks side to side, the waist and neck rock and twist with it.

friction wheel (**photo 6**). Nothing happened. He still looked sulky but dizzy! I was beginning to feel a bit silly now, and the deadline for this article was fast approaching. I thought I would have one more go, using a side-to-side linkage and—yippee—away he went, legs and antennae flying around all over the show (**photo 7**). This bug looks much more cheerful now, doesn't he?

The lesson I learned from this is that the impetus motion must be quite large and positive to create a dramatic movement. This works on the pirate because the cams are big and the leverage in the tentacles is considerable, so there is plenty of impetus. For the bug, a little cam on its own was not enough.

The *Double Bass Player* (**photo 8**) relies on the rock to give him a relaxed sway with the beat. I think he is definitely a jazz musician, and a seasoned, laid-back one at that. To complete the scene, you could add a smoky bar and a drink of his choice. See him at *https://youtu.be/mlJZcUYxmi8*.

Again, his middle is loosely articulated so that, as his leg bends, his body dips to one side and his upper body rocks around on his pelvis, creating a subtle movement, but one full of character. The head is loosely fitted too, so that it rocks gently from side to side with the movement of his body (**photo 9**). This creates a wonderful illusion of a man at one with his music and totally relaxed in a world of his own.

Allowing fling, bounce, and rock into your mechanisms is a great way of putting energy into your creation. However, as I learned with the bug, its major drawback is that the exact motion is difficult, if not impossible, to calculate and predict. This is where perseverance and experimentation is key. If you decide to go down this route, give yourself time to do several little mock-up experiments before committing to a final model.

Contacting Sarah

If you have questions or comments for Sarah Reast, you can write to her in care of *Automata Magazine*: *automatamag@comcast.net*. Just put "Message for Sarah" in the subject line.

Sarah is the designer and director of Timberkits Ltd., which creates wooden mechanical models sold in kit form. To learn more about her company, visit *https://www.timberkits.com/*.

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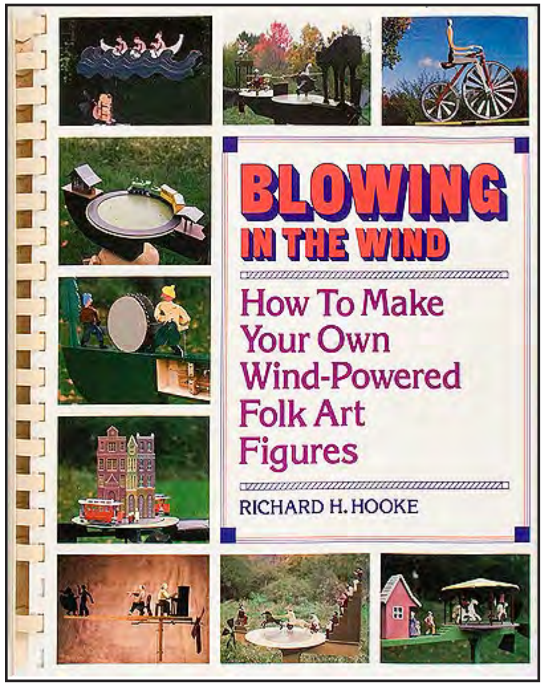
REVIEWS

BOOK

Blowing in the Wind: How to Make Your Own Wind-Powered Folk Art Figures
by Richard H. Hooke
Down East Books, 1987
Camden, Maine
$8\frac{1}{2}$ x 11" (21.5 x 28cm), 212 pp., softbound, comb binding
Out of print
ISBN: 978-0-892-72221-1



Whirligigs have been around for hundreds of years. Their connection to automata is obvious. Indeed, many, if not most, whirligigs are simply wind-powered automata.

There are lots of books about whirligigs. Most are how-to volumes; a few are about history, collections, or specific artists. Most of the whirligig books that I have seen lean toward the simple and traditional: a man chopping wood, a woman churning butter, a hummingbird. *Blowing in the Wind* is something different. Most of the designs in this volume are anything but traditional.

The book begins with a preface, describing how the author became interested in whirligigs. Following this is an introduction that discusses various levels of sophistication in whirligigs, from simple propellers—perhaps taking the place of arms on a figure—to wind-powered devices that include several figures or other objects, doing a multitude of things simultaneously.

A brief history of wind toys and folk art covers the development of the whirligig in different countries. Whirligigs have appeared around the world in one form or another for over 500 years.

Hooke talks about his own design process, which is an excellent introduction to automata design. His approach is intuitive and there's lots of room for trial and error. He makes suggestions about various ways of using the book, from copying his designs exactly to just using them conceptually to create your own machines.

All of this is good, but what really makes this book is the author's creative approach to his designs. To power his creations, he uses traditional propellers with crankshafts, propellers contained within the moving objects themselves (a bicycle wheel, for instance), and wind scoops that turn horizontal turntables or crosses made of wood. Sometimes his mechanisms are quite simple, and at others they are wonderfully complicated.

There are 13 separate projects in the book. These include sailboats that go around, heeling in the wind; a pair of streetcars that endlessly circle a city; a man on a unicycle; a railroad; a jousting contest; a merry-go-round; and square-dance musicians, and more.

All projects are clearly described and illustrated, with an introduction before each one. Full-size plans are provided for most of the components of each project.

The book wraps up with suggestions about how to take your designs further. The author is clearly an out-of-the-box thinker, and he urges the reader to be likewise.

Blowing in the Wind is printed in black and white on uncoated stock. Color photos of each of the finished projects appear only on the front and back covers of this comb-bound volume. Lack of photos is one drawback of the book. However, the drawings contained within are well executed and easy to understand, so photos are not a necessity.

Although the book has been out of print for decades, I found it to be readily available on the internet. The author's ingenious designs, coupled with his personal philosophy about design and construction, make this an excellent book for beginner and experienced craftspeople alike.
—*M. Horovitz*

Many books about automata, and of interest to automatists, are now out of print. However, they are still valuable and most are available through the used-book market. Given that, we'll be reviewing more of these in upcoming issues of *AM*.

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The End