# AUTOMATA MAGAZINE


The automata of Pat Keck

2/6—Nov/Dec 2020

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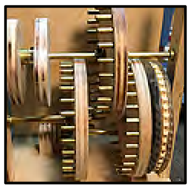
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## DEPARTMENTS



*Automata Magazine* is published six times a year by Sidestreet Bannerworks, Denver, Colorado, USA.
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# EDITORIAL

## Closing out our second year of publication

by Marc Horovitz

Well, it's been a strange two months since the last issue. The pandemic that we had hoped would be gone by now is on the rise again, with no end in sight. A contentious election in the US is just around the corner. And, personally, I suffered a back injury at the end of August that cast an additional pall over everything.

Because of my injury, I was unsure if the magazine could continue. I finally, reluctantly made the decision to shut it down, and sent an email to you subscribers to that effect. I was frankly astonished—and gratified!—at the outpouring of support that letter generated.

I received well over a hundred emails of support, most expressing sadness that the magazine was going but wishing me well in my recovery. I can't tell you how much that meant to me, and I thank all of you from my heart for your support and encouragement. Everyone's message strongly reinforced my sense of community—almost family—with our readers, so thank you again.

Additionally, several people stepped forward see what they might do to help keep the magazine going, offering their services. This was so encouraging and it opened the door to the idea that the magazine might yet be saved.

As I write this, I've been in discussion with a core group of people who are spread out across the globe, about laying the groundwork for the distribution of responsibilities and to figure out how we can make it all work.

With today's amazing technology, there's no reason that the magazine can't be produced by different people living in far-flung places. After all, people work from home all the time now. It should make no difference if your home is across the street or in Timbuktu

I'm excited about the prospect of working in this way with these generous people. The January•February issue is already in process and the future is looking bright.

However, this brings up our never-ending need for ever more material to fill our pages. Over *Automata Magazine*'s short life, we've been privileged to feature a lot of fine, interesting, creative, and informative work, and we want to continue in that vein. We need your help to do so, though.

Please consider writing something for the magazine. We want to publish everything relating to automata, including their construction, exhibition, history, repair, restoration, diversity, etc.

If you've not written before or are unsure about writing, it really isn't that hard. We have a page on our website that might help you: *https://automatamagazine.com/write/*. Check it out.

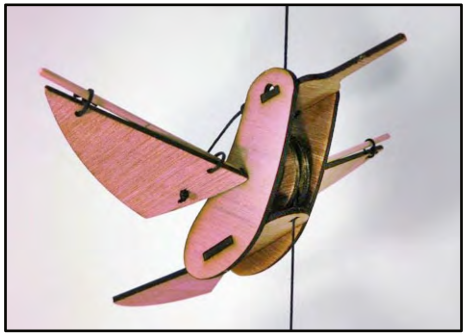
Also, keep in mind that this is *not* a literary magazine. You'll not be judged or graded on your writing ability. And you won't look bad in print—that's what editors are for. So think it over. In this quirky microcosm, we all need each other. You can write to me at *automatamag@comcast.net*. I look forward to hearing from you.

Best wishes to you all for the upcoming holiday season. I hope that you stay safe and well.

• • •

Building Blocks in this issue will be Paul Giles's final column. Thanks, Paul, for all of the mechanical knowledge and wisdom you've imparted to us through your words and pictures. We're sad to see you go and we wish you all the best.

# NEWS



**Contraption Cart** (Shasa Bolton) has a new automaton kit: the Pulley Pet Hummingbird. Based on a simple string-climbing mechanism, when the strings are put under a little tension the mechanism mysteriously rises.

This simple kit can be assembled in under 40 minutes with the instruction video. More information: *https://tinyurl.com/ContraptionCart*

**Puppets in Prague** is offering two online workshops of interest to automatists: Marionette Carving Workshop (January 4-21) and Breakaway Skeleton Marionette Workshop (January 5-28). Each course includes live lectures by Mirek Trejtnar, regular individual consultations, prerecorded videos, and an instruction manual. Each workshop meets three times per week, from 7-8:30pm, Central European Time. More information: Leah Gaffen, *puppetsinprague@gmail.com*, *http://www.puppetsinprague.eu/*.

# EVENTS

**Morris Museum: A Cache of Kinetic Art: Tiny Intricacies**

March 13, 2020-January 10, 2021. Morris Museum, 6 Normandy Heights Road, Morristown NJ 07960 USA.

Due to the recent four-month closure of the museum, the exhibition has been extended into 2021.

Contemporary mechanical works in *Tiny Intricacies* are designed to delight and surprise. Some employ traditional construction—wood, metal, and paint—others utilize electronic components. Pieces are installed alongside 19th-century novelty pieces from the Guinness Collection known as "precious smalls." They embody the spirited sense of imagination and curiosity of artists from the past and the present. Cost: free with admission. Info: Michele Marinelli, *mmarinelli@morrismuseum.org.* Website: *https://morrismuseum.org/*

**Morris Museum: Natural Essence: Motion Perceived**

March 18-August 15, 2021

Contemplate the hidden beauty and majesty of movement within the essence of nature, featuring the works of five artists. Explore and appreciate this enchanting collection of kinetic and illusory works that speak to the imagination of the spirit and richness of the natural world.

**Cabaret Mechanical Theatre (CMT)** presents: **Mechanics Alive!**, ¡explora!, Albuquerque, New Mexico, USA. Through 2020. More info: *https://cabaret.co.uk/exhibitions/current/*

**AutomataCon**, hosted by the Morris Museum: May 21-23, 2021. *http://www.automatacon.org*.

# CALL FOR ENTRIES

**Morris Museum: A Cache of Kinetic Art: Timeless Movements.** Friday, March 18-Sunday, August 7, 2022 The new submission deadline is Friday, Sept. 10, 2021. Check the website for new dates, updated prospectus, and entry forms. *A Cache of Kinetic Art* is a multi-year juried exhibition series showcasing contemporary automata and their inventive creators. Prospectus and entry forms for both exhibitions: *https://tinyurl.com/MMentries*.

Follow *Automata Magazine*

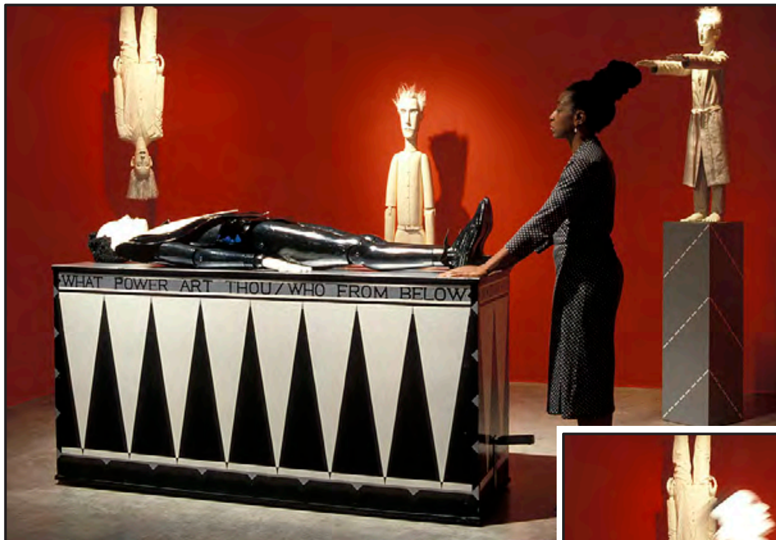
**In the next issue of**

AUTOMATA MAGAZINE

- **Michele Marinelli** begins a fascinating three-part history on clown automata
- **David Mernitz** offers a lesson on how to make a functioning wooden worm gear
- **Ivan Morgan** discusses the construction of his flexible dog automaton
- **David Soulsby** takes us on a tour of automata donation boxes in the UK

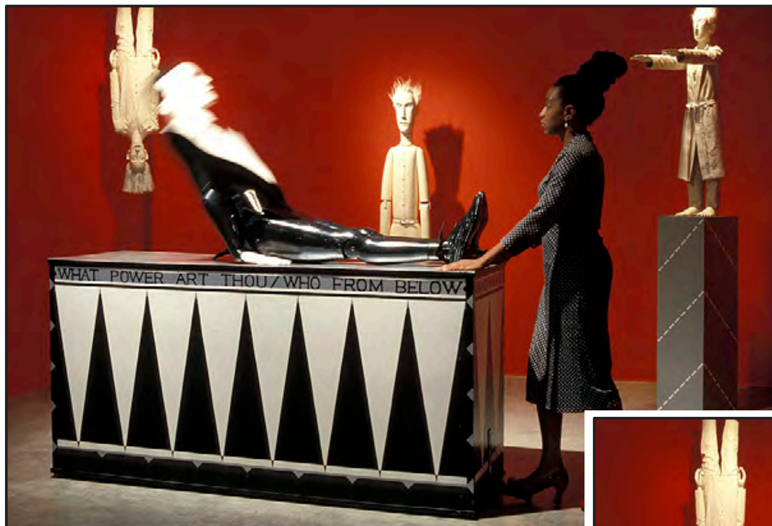
# EVERYTHING'S RELATIVE

## The automata of Pat Keck




1. *Memorial to Klaus Nomi* (1985) at the McColl Center, in North Carolina, 2005.

**by Pat Keck**
Andover, Massachusetts, USA
Photos as noted




ABOVE: 2. The figure slowly rises, as creative director Ce Scott depresses the foot pedal.


RIGHT: 3. The legend reads: "What Power Art Thou / Who from Below / Hast Made Me Rise / Unwillingly and Slow."

Photos this page courtesy of The McColl Center for Art + Innovation

The funny thing is, I consider myself more a fan of automata than a maker. Like puppets, dummies, and scarecrows, automata are subject matter for me but technically way out of my league. However, it was my good fortune to land in a talented, supportive family.

My father, James Keck, was a mechanical engineer. He always seemed like a person who could do anything. As a kid, I often built things that couldn't hold themselves up. He'd help me out when things started collapsing. He'd say, "You do know, it's easier if you start with the armature rather than trying to insert it after you're done?"

When the wonderful, otherworldly singer Klaus Nomi died in 1983, I was devastated. I was a huge fan. I was living to see him perform and now I couldn't. So I decided to resurrect him. I built a life-size, solid-wood effigy of Nomi lying on a bier. Then I asked my dad, "Can we make him sit up?" Needless to say, this is not how you go about building a mechanical figure. In the end we did get him to sit up (**photos 1-3**), with the aid of an enormous counterweight in the base. That piece really taught me a few things about engineering. It also opened my eyes to the possibilities of animating my work.

After that experience, rather than blithely starting to carve, I would begin by broaching my ideas to my dad. I started making careful drawings, and an entirely new level of precision entered my work.

Photo by Earl Kage/Museographics

4. *Man with Time Running Out* (1994). Closeup of the figure flipping the hourglass.

I had an idea about making a figure who was staring at an hourglass, watching the sand run out—*Man with Time Running Out* (**photo 4**). When the sand was gone, I wanted him to pick up the glass and flip it over.

I had a deadline for finishing the piece and knew that building the arm was the key. Somehow my dad came up with a design for a mechanism that did this with one cycle of a motor. I built the mechanism myself and I still don't know how it works! Even other engineers marvel at it. One thing we needed was a means of turning the motor on, for one cycle every ten minutes. That's when my brother, Bob Keck, a computer-control expert, entered the picture. He spent his New Year's Eve building a little circuit to make that magic happen. Once again, my eyes were opened to further possibilities.

Being a fan of automata, I loved the figures of fortune tellers who dispensed actual fortunes when


5. *Answer Man* (1995).

6. The wheel spins while he ponders a question.

Photos this page by Robert Keck.

you put money in; loved them not the least because it seemed like a way to generate some income out of all this folly. I thought it would be cool if the figure would type out the fortune while you watch, but making a working typist was most certainly not in the cards. Instead, I made *Answer Man*, an automaton that answers yes-or-no questions. It is a figure in a booth, with a wheel behind him that has alternating yeses and nos around the rim (**photos 5** and **6**). You ask your question and put in a quarter. He lifts his head and the wheel begins to spin while he thinks about it. At some point, he hits a bell in front of him, the wheel comes slowly to a stop, and you have your answer.

One night, watching the TV show "Morse," I realized that the music for the end credits was the name *Morse* being spelled out in Morse code. I thought, That I could do! As is always the case, it got way out of hand when I decided it didn't make sense to have just one telegraph operator, and it would be boring if multiple operators all worked the same way. But at least I knew that, before I began, I had to work out everything I wanted the piece to do from the moment the coins were deposited—the individual movements, the lights going on and off, the sound the keys made, and the printing of the messages. Afterthoughts were not going to be an option. My dad helped me with the mechanics, while my brother, in faraway Rochester, New York, clued us in to the wonders of servo motors and microswitches. He'd come home at holiday times and string miles of wire through the thing. It took two-and-a-half


LEFT: 7. *Messengers* (2001). This piece measures 85" tall x 60" wide x 30" deep (216cm x 152cm x 76cm, respectively).

BELOW: 8. Closeup of the figures in *Messengers*. Each moves in a slightly different way.

Photos this page by the author.

years to complete *Messengers* (**photos 7** and **8**).

One of the things I love about computer control is the range of control you have. You can change intervals, speeds, and—best of all—program in randomness. In *Messengers*, which messenger will deliver your message is completely random. It might give you a message for a quarter or it might keep asking for more. When it was on display at a mid-career retrospective show I had at a local museum, people were playing it like it was a slot machine. They thought they could get the sleeping figure, who delivers the dollar messages, to wake up. He rarely did, given there are only twenty dollar messages (out of a thousand) in it. I made out like a bandit from people trying to get one of them.

A few years ago my friend Jim Ramsay, who introduced me to many of the fabulous people in the world of automata, asked me to build him a *tau tau*. This is an Indonesian burial figure who watches over your remains. Jim thought it would be nice to be able to watch over his own burial figure until he died, when it would take over the job.

I drew a figure seated on a well-secured chest, where Jim's remains would ultimately go. *Tau Tau* has a pocket watch that he stares at while he waits for Jim's time to run out. It turns out there aren't many known *tau taus* in existence because people steal them. I thought we needed to build in some protection, not just for the remains, but for the figure itself. So, whenever anyone comes close, he looks up from the watch and glares (**photos 9** and **10**). Of course, before I began, I ran all this past my brother, who said we could use a motion detector to trigger the action.

I decided I really liked motion detectors because they allow people to interact with a piece without touching it. As anyone who makes interactive pieces knows, once you allow people to play with something, they are inclined to test its tolerances.

In the fall of 2015 I got an email from Tom Haney, who was co-curating a show of automata in San Francisco in the spring of 2016. He asked if I'd participate. As flattered as I was to be considered an automata artist, I didn't see any way of completing a piece in time, given my track record. But when I found out the amazing Paul Spooner was going to be in the show, that was too much, so I said I'd try! I knew that, to complete something in time, I needed the mechanism to be simple. I thought, Why don't I just immobilize the whole figure so only its head can turn? What I wanted was for the figure's head to follow the movement of a viewer as they passed by.

Again I called on my brother. It turned out that a device that followed motion was not something you could just go out and buy. Bob was going to have to devise

9. *Tau Tau* (2015) watches owner Jim Ramsay's time run out...

10. ...while also watching anyone who comes too close.

Photos this page by Robert Keck.

a way of getting the head to follow the movement. All I had done was neatly transfer the problem of getting the piece ready in time to Bob. *Man with Some Restraints* (**photo 11**) did indeed make it to the show, albeit with one or two glitches. I thought I was being clever in having it be motion activated, but because these were automata being shown, many of the other pieces had buttons. People assumed the lens of the camera that tracked their motion was a button, and they kept trying to push it. Sigh.

Okay—people like to push buttons. That's not the reason I decided to tackle *Ghost Elevator*, which has nine buttons. I had three impossible ideas, none of which would see the light of day without a lot of help from Bob. So I let him pick my next project and *Ghost Elevator* was it.

For a long time, I'd had the idea of making a figure disappear. I'd even worked out a way of making it happen on a previous piece, *Tricky Man* (**photos 12-14**)—before beginning *Ghost Elevator* (**photos 15** and **16**).

11. *Man with Some Restraints* (2016) can't go anywhere but can keep track of where you are.

BELOW LEFT: 12. *Tricky Man* (2010) has two buttons, one on either side of the base.
BELOW: 13. Now you see him…
BELOW RIGHT: 14. …now you don't.

Photos this page by Robert Keck.

But once I started making drawings for *Ghost Elevator*, I clearly saw that I needed a different mechanism. I built the mechanism and constructed the elevator car and a shaft, which I showed to Bob for his approval when he came home. He said, "That looks alright but the tricky part of this is going to be the doors." As usual, he was right. I did a lot of drawings, measuring everything as carefully as I could, but I could not get the doors to open symmetrically. I finally decided that, if they met in the center, no one would notice if one door opened a wee bit more on one side. I sent the prototype off to Bob.

Engineers do not like not knowing why something is off, even if no one can see it. He worked out the geometry (which he admitted was quite tricky) and fixed the problem. However, the change he made required two extra levers and some retrofitting. With nine doors and their countless tiny pieces, this was a huge headache.

One time, when we were working on something together and I was cursing away at it, Bob said to me, "Your problem is that you don't like the fun part." That's kind of true, although I've become fonder of it. Maybe that's why I don't think I quite qualify as an automata artist. I'm not naturally mechanical. I love making the figures and will do things over and over to get them right, spending hours poking in hair or making tiny finger joints. But I was pleased to learn from reading Elizabeth King's wonderful forthcoming book, *The Monk: A Sixteenth Century Automaton and Its Legend*, that early automata were constructed not by a single artist but by teams of specialists from various guilds—clockmakers for the mechanism, sculptors for the figures, and dressmakers for the clothes. So now I view my father, my brother, and myself as kind of mini-guilds, each with our own specialties. Sadly, my dad passed away ten years ago, but every day I call upon all he taught me. AM

15. *Ghost Elevator* (2020), front view.

16. Rear of *Ghost Elevator*.

Photos this page by John Davenport / Pucker Gallery.

Pat Keck's work will be on display at her new show, *Hide 'n Seek: The Art of Pat Keck*, at the Pucker Gallery, 240 Newbury Street, 3rd floor, Boston MA 02116, USA, https://www.puckergallery.com/, from November 21, 2020 through January 10, 2021.

Readers who would like to know more about the electronics and mechanics involved in Pat's work are invited to visit her brother Bob's blog, where much is explained: https://electronicsmachining.art.blog

To see a video of the *Ghost Elevator*, click https://youtu.be/PwCcaacBDCM.

# Once upon a time

## The story of a book

**by Guido Accascina** • Castelnuovo di Farfa, Italy • Photos and drawings from the book *Automi*, courtesy of Guido Accascina

Once upon a time there was a book by Jorge Luis Borges called *The Aleph and Other Stories*. "The Aleph" is the story of a man who goes down to the cellar, falls down the stairs, and passes out. When he wakes up, his head is leaning against a step and he sees a small gap between one step and another. Looking more closely, the man discovers that he can see the whole world through the crack. It is a wonderful little crack, and on the other side is the entire world—its stories, its past, its future.

The beginning of my story of automata is similar. In 1980 I saw Borges's crack, in a small automata museum in Covent Garden—Cabaret Mechanical Theatre. You entered this magical place and walked through a labyrinth full of surprises and adventures. Each automaton was a small artistic and mechanical wonder. There is a quote from Paul Spooner that could well describe the feeling inside this magical museum: "Turning a handle, we see the world's adventures, and sometimes our own." At that time, in that place, I thought, This is what I want to do, as soon as I grow up.

The permanent collection at the Modern Automata Museum, in Italy.

I grew up a few years later. I lived in a beautiful place in Sabina, between the hills of Central Italy, amid olive groves and woods, in a 9th-century castle, Vezzano. There was an empty stable there, perfect for my museum. We arranged the floor, then the walls, the shelves, the electrical system, the doors, and the windows. The space was quite welcoming. It was cozy but empty. I didn't have a single automaton. Not one. For an automata museum, that was a problem.

But I had a video of Paul Spooner's workshop. In the video you could see the chair where Paul sits when he works. It's an iron-and-wood chair, with armrests. A few days later I had built my first automaton: two people (my partner Marina and I) are kneeling and moving their hands up and down, adoring Paul's chair. The writing on the front says: "Turn the handle ten hundred thousand times and Paul will appear." I sent the automaton to Paul Spooner, whom I didn't know, with a note saying, "Dear Mr. Spooner, I found this object in the stable. I don't know what it is. Maybe you, who are an expert on these strange mechanical objects, will be able to give me an explanation." I think he laughed, and so we met.

From that day, I developed good working relationships with many artists, in many places in the world—many beautiful relationships, many beautiful people. The museum gradually became a real museum, with a lot of awards and appreciation.

Hellenistic automaton: *The Organ of Ctesibius*, 3rd century BC.

There was a new problem, though. The museum was full of automata but I had no idea of how they worked or of their history. I had built a museum for pleasure that was only playful and aesthetic. Once I realized my ignorance, a great curiosity arose in me. What is the history of automata? When were they first made, how did they work, who were the creators and artists, and where were they from? What were the purposes of these automata—were they intended to be aesthetic, artistic, didactic, experimental, or…? The creators obviously had fun making them. In what cultural climate did they breathe?

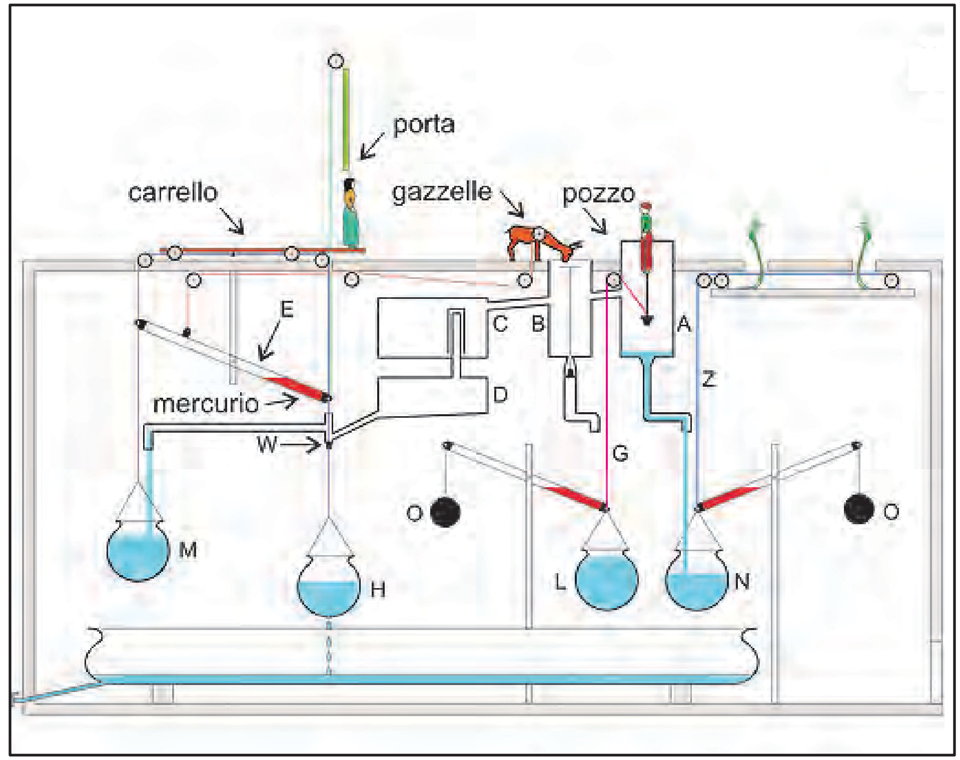
The answers were in the traces left by the automata over time, in the form of myths, archaeological finds, builders, artists, legends, stories, testimonies, images, and books. But the information was widely scattered, like a gigantic jigsaw puzzle made up of many pieces. Some pieces were very light, some were faded, some were missing, and some were ruined.

I was looking for a text that would tell me the whole story, from the beginning to today, but from around the world I found only pieces of a puzzle. There were so many beautiful pieces. So I thought of putting the pieces together and writing a book for myself that would tell me the entire story, from "once upon a time" to today, just as I wanted to know it. Thus, my book, *Automi*, was born.

I started writing the book ten years ago, in 2010. I felt that the best way to track the history was to follow it backward. For this, bibliographies are fundamental; they are like the map of a labyrinth. I looked for paradigm changes, as much as possible. In this sense, I have employed, by analogy, a useful book by Thomas S. Kuhn—*The Structure of Scientific*

Reconstruction of al-Muradi's Clepsydra of the Gazelles, a medieval water clock with ten automata figures.

*Revolutions*. The book talks about physics but, in my opinion, it can also be used to study history, both forward and backward, as well as other things, such as psychology, architecture, or art. I am preparing another book on this topic, a book on the history of art from Manet to Manetas, which will be called *This is Not Art*. This is a popular phrase, commonly used when you are faced with something that is not understood. Even automata often shocked their au-




Mechanism of the reconstructed clepsydra.

diences, who didn't understand how they worked. Hence, the sense of wonder or magic.

There were many problems to overcome in this research. The tales and stories are written in various languages, some ancient. I had to check the validity of their content by drawing or building the automata, or parts of automata, as presented by these stories, imagining the structures in space and redesigning historical projects. This is a great exercise to do when you want to understand how something works and why it is made in a certain way. In *Automi* there are various drawings and redesigns, both mine and from other sources.

About a hundred people helped me in writing this book. Some were friends I met in my travels. Some would be two thousand years old today, others less so.

To name just a few, first is Mark Rosheim, who runs a robotics factory in the United States and who

*Couple on a Park Bench* by J. Marie Phalibois (18th century), with the restorer Anna Pamidoro.

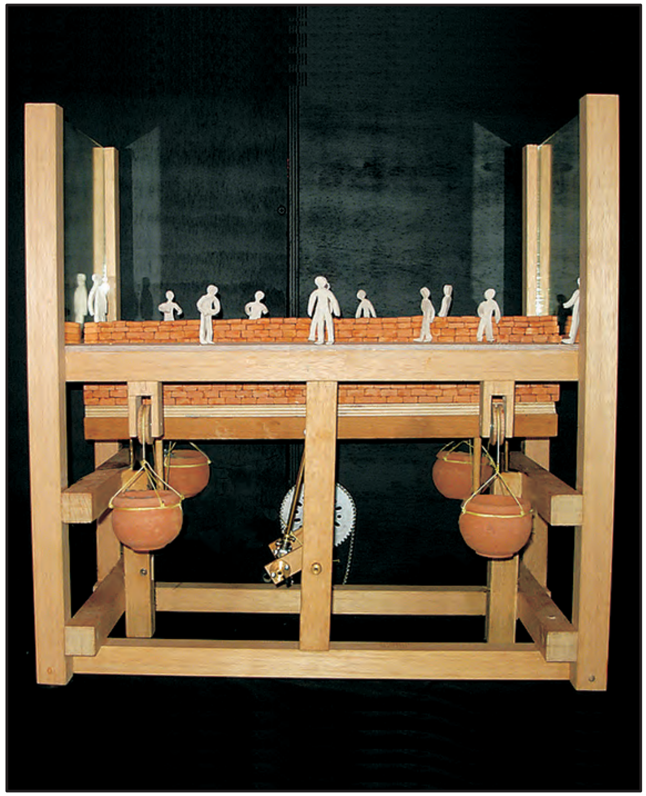

*Circus* is comprised of automata by many individual artists.

has studied, recreated, and written about Leonardo da Vinci's automata. One winter evening I was reading the introduction to one of his books on Google Preview, but it stopped two pages before the end. It was a compelling story and I was curious about how it ended. I searched for Mark's email address on the web and shamelessly wrote to him around three in the morning. "You don't know me, but I'm reading the preview of your book and I'd like to read the last two pages of the introduction. Can you send them to me via email?" He did! I couldn't believe anyone could be so kind to a stranger. Mark has a thorough understanding and has written some very precise and accurate things about da Vinci because he has recreated his models and made them work.

Another friend, Anna Pamidoro, is a doll and automaton restorer who lives in a large house on a lake in Central Italy. Anna has a maternal love for both her own automata and those of others. She spent three months restoring one of our automata, built by Phalibois at the end of the 19th century. She reconstructed the face, fingers, and costumes, using the materials and fabrics of the time. She explained how to sew a suit for an automaton, which is completely different from making a dress for humans or dolls. She worked for three months on the project, just for the pleasure of doing it, and charged me nothing.

For those who study automata, another valuable person to know about is Donald R. Hill, who died in 1994. He studied the automata of al-Jazari and al-Muradi in a

Keith Newstead's *Sabina Bird*, from the *Automata with Recycled Materials* collection.



An automaton by Marina Gigli, for the traveling exhibition *Against the Idea of War*.


Paul Spooner's *Turkish Soup*.

comparative way, with interesting explanatory schemes. In some cases, Hill recreated the automata himself. His writing also contextualizes the work of the automata builders, discussing the atmosphere of the time. In my book, I created a sequence of drawings, starting from Hill's drawings, in order to give an idea of the dynamics of the movement of the elephant of al-Jazari.

Finally, I would like to mention one other person, a Greek named Kostas Kotsanas, who first recreated and exhibited the Alessandrini automata, and created the Kotsanas Museum of Ancient Greek Technology, in Katakolo, Elis, Greece. The museum contains replicas of automata by Ktesibios (Ctesibius), Philo of Byzantium, Antikythera, and Heron. For those with a passion for automata, Kostas's museum is absolutely one of the most important places to visit. His book, *Ancient Greek Technology: The Inventions of the Ancient Greeks*, tells in detail, with many diagrams and photographs, about automata from the third century before Christ to a century after Christ. Kostas's reconstructions are all functional.

One hundred travel companions, one hundred stories. There isn't enough room to talk about them all, but they all helped me along my way and contributed to *Automi*. There is a list at the end of the book. I am grateful for what they have built, written, and transmitted.

Guido Accascina's book, *Automi* (in Italian), can be purchased here: *https://tinyurl.com/AutomiAccascina*

# A GRAVITY-POWERED AUTOMATON

## Action at the press of a button

**by Marc Horovitz** • Denver, Colorado, USA • Photos and drawing by the author

I have long been fascinated by the idea of using gravity as a power source to drive an automaton. It seemed to me that being able to press a button, then watch the figure go through its motions without a motor or any other source of power, would be kind of magical.

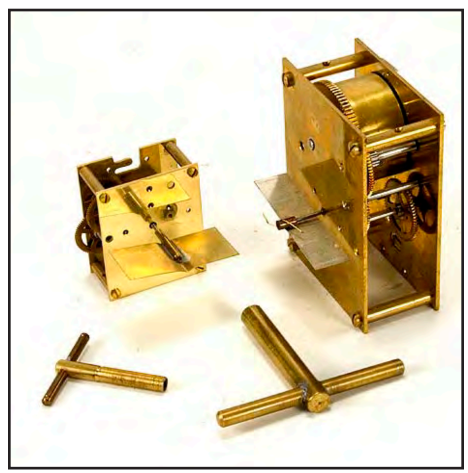
The obvious way of doing this would be through the use of a weight, as in a long-case clock. In most geared machinery, the gears are used to reduce speed and/or increase power. Small gears drive larger ones to give mechanical advantage. In that way, they make hard jobs easier and make it possible to use smaller power sources (motors).

In a clock, however, the opposite is true. Instead of small forces being used to move heavy loads through gear reductions, a large force, through gear increases, is used to move relatively tiny loads. A heavy weight is used to rotate the slim hands of the clock, which weigh almost nothing. By using gear trains that *decrease* mechanical advantage, a mechanism that will move a tiny load for a very long time is created, instead of—with *increased* mechanical advantage—a mechanism that will move a heavy load quickly.

The weight in a clock provides a constant force. When coupled with a regulatory mechanism—a pendulum and an escapement—that force can be doled out over time, in tiny increments. In powering an automaton, though, faster motion would be required than would be provided by even the second hand of a clock, so the pendulum and escapement would not be feasible.

### The mechanism

I had done some playing with spring-driven clocks, turning them into windup motors by removing the escapements (**photo 1**). I found



1. Windup motors from clock mechanisms.


This automaton, which was also produced in hand-crank form, is mounted to the end of a bookcase. The piece is powered by the weight hanging from it on a chain.

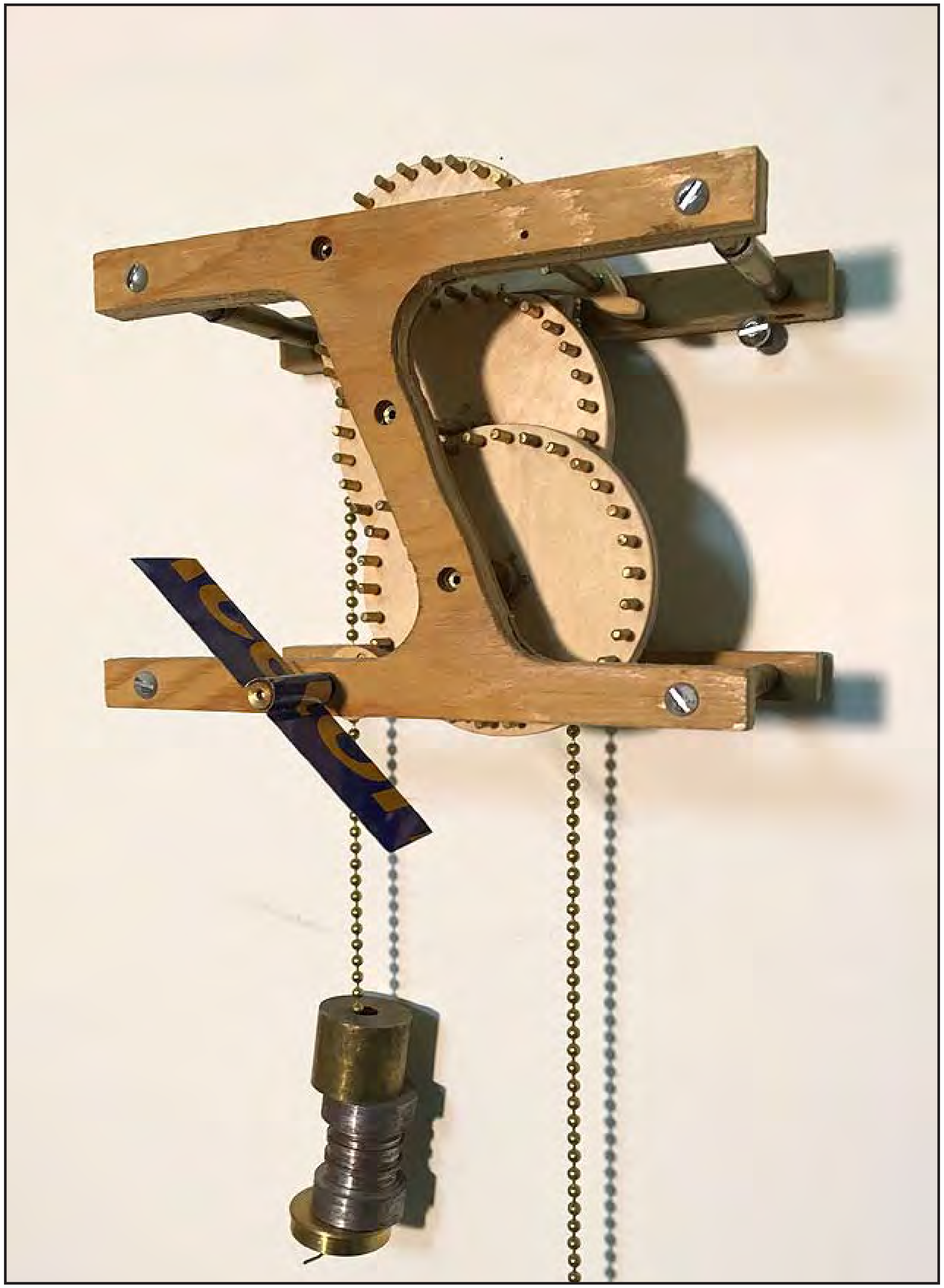
that they seemed to work okay, but they ran very fast and were quickly exhausted. Some form of speed control was necessary, but not something as extreme as an escapement mechanism. A flyball governor, such as was used on stationary steam engines and old windup phonographs, was a possibility but was more complex than I wanted to get into for a modified-clock motor. The answer, I found, was a fly-fan governor.

A fly fan is basically a fan with wide blades, the flat part of which are parallel to the axis. It relies on air resistance to keep its speed down. These are commonly used in music boxes. I have fitted these to several clock motors, with good results.

The next step was to design a mechanism that would work with a weight and be controlled by a fly fan. What I came up with is the test mechanism shown in **photo 2**. A weight, via a ball chain, drives a 30-tooth gear on the first shaft. This, in turn, drives a 6T/30T compound gear on the second shaft, so the ratio is 1:5—for every revolution of the drive gear, the driven gear rotates five times. This second gear was similarly geared to a third shaft, increasing the ratio from the first gear to 1:25. This was still too slow for the fan, which needed a much higher ratio. The fan was therefore attached to yet another shaft, increasing the ratio to 1:125. This worked. However, as the gear ratio of each succeeding shaft increased, its power decreased.

I found that the second shaft in this train could be used to power an automaton. Its speed was slow enough but its power was still high enough, I felt, to make something go.

The chain to which the weight was attached is looped over a sprocket on a free-wheeling pulley. This, in turn, is connected to the back of the first gear by a one-way ratchet-and-pawl mechanism, so that when the weight has pulled the chain to near its end, the chain's opposite end can then be pulled, thus raising the weight so it could do its work all over again, as in a clock.



2. The test apparatus for the automaton's mechanism. Between the drive gear and the fly fan, the gear ration is 1:125.

## The automaton

So how to tie this mechanism into an automaton? I had previously done multiples of *Billy Bob the Magician* and had some spare

3. A trio of Billy Bobs in progress.

4. Billy Bob, who could not afford a rabbit, displays his substitute.

parts in a box for some uncompleted ones (**photo 3**). I decided to finish them up, making one into the experimental gravity-powered automaton.

You can see the hand-crank version at *https://www.youtube.com/watch?v=wkXAc1Ltrzl*. The automaton has only two actions, each controlled by a cam on a single shaft. Billy Bob looks down into his hat, then proudly raises his hand, holding his substitute for a rabbit (**photo 4**).

An important point is that, even in their hand-crank form, these actions take little force and the mechanism is pretty smooth throughout its cycle. If there are any lumps, the gravity system would be defeated.

I designed a new box to accommodate the gears seen in **figure 1**. The placement of the gears was reconfigured, making the mechanism more compact (**photo 5**). Cams to run the automaton were mounted on shaft Nº 2. Construction was pretty straightforward and I was gratified and relieved that there were few bugs to be worked out before the automaton performed as hoped.

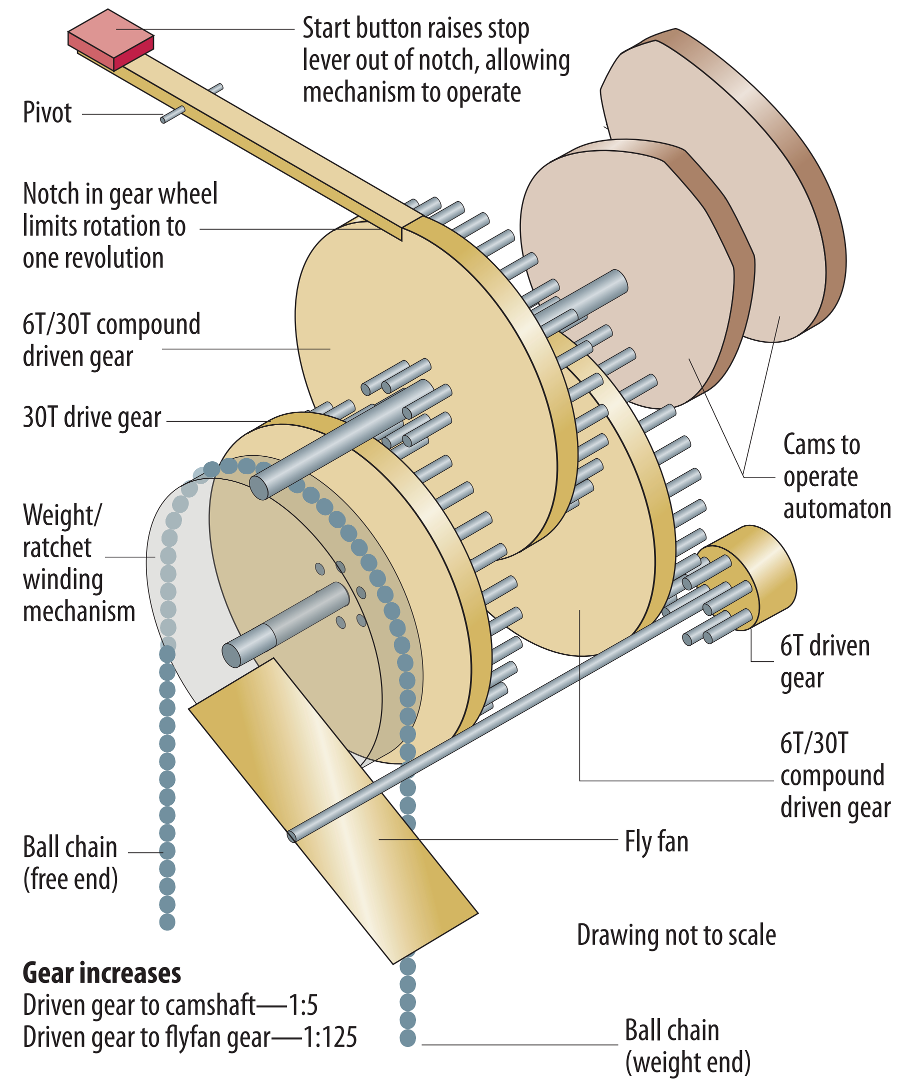


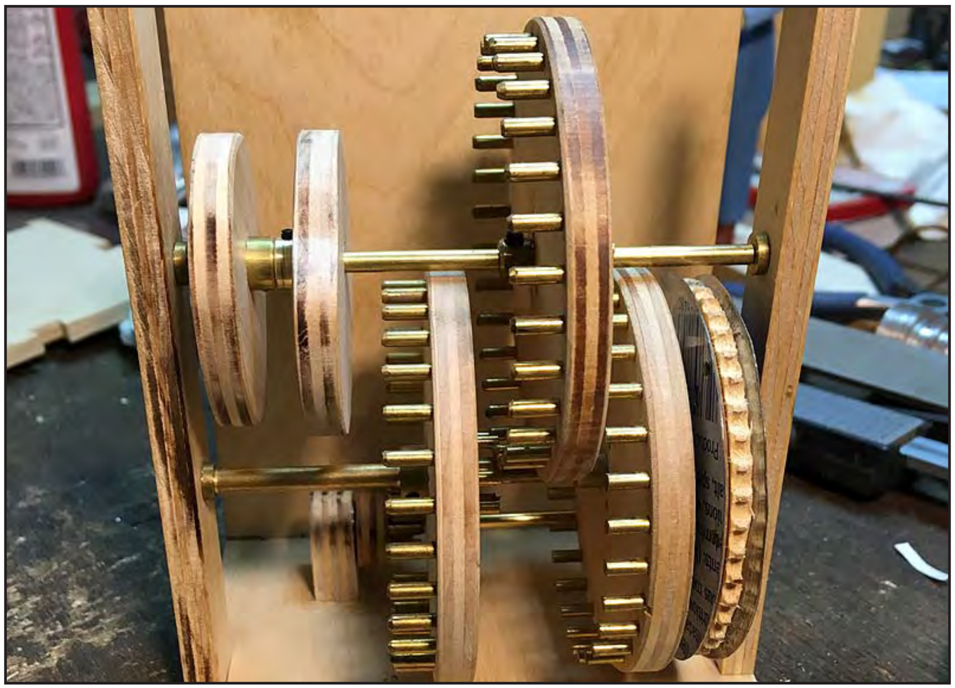

**Figure 1—Weight-driven mechanism**

The fly fan is a piece of brass sheet soldered to a shaft. I experimented with its size until I found one that governed the automaton at a reasonable speed. Air resistance is proportional to the velocity of the fan squared, so the faster the fan spins, the more resistance there is.

A quick tap of the button on one end of a lever is all that's required to set the automaton in motion. As on the original test mechanism, I put a notch in the gear on whose shaft the cams are mounted. This notch engages the button's wooden lever, pivoted into the side of the box. By pressing the button, the lever's end is raised clear of the notch, allowing the weight to do its work and the mechanism to function. After being released, the lever rests on top of the gear until the notch comes around again. The lever's end then drops into the notch, which can be seen in **photo 6**, and the action stops, the figure having gone through one cycle of its actions. The chain I used is 36" long, which allows sixteen cycles before the weight must be raised again.

Billy Bob is now mounted to the end of a bookcase near my shop. It's fun to give the button a tap as I pass by, then watch him do his trick without further human or electronic intervention. AI

To see the gravity-powered automaton in action, click *here*.



5. The gears from the test unit were reconfigured and built into the automaton's base.


6. The works of the finished automaton. The cams that control the action are hidden behind the gears. The blue-and-yellow disc in front, made from tin-can metal, is part of the sprocket that engages the chain. The red button on the upper left side of the box initiates the action. The notch in the wheel, engaged by the button's lever, can be seen in the picture.

# A bird automaton in a special case

## An enameled silver violin holds a surprise

**by John Moorhouse**
West Midlands, United Kingdom
Photos and drawings by the author



Tiny birds move and chirp in the author's enameled-silver violin. This is the open position, showing the silver operating button and the engraved, pierced silver grill.

Form watches—watch movements housed in a specially shaped and decorated gold or silver case—were made in Europe, primarily in the 19th century. They were made in various typical forms, including fruit, such as an apple or pear; insects; or a musical instrument, such as a harp or a violin. These watches were highly decorative luxury items, often finished with enamel that was inlaid with gold cloisonné wires and overlaid with a fired-on painted decoration (**photo 1**). They have conventional lock and fly springs for the case lid, so that they may be

1. A form watch housing a verge watch movement.

2. Acrylic-plastic profile and trial pressing in gilding metal.

opened and the watch face read.

Having already made a number of silver pieces containing transparent vitreous enamel over engine-turned patterning (guilloché), I was attracted by the superb enamel work of Phil Barnes,[1] who made use of various types of hand-engraved decoration within recessed fields (champlevé). I therefore chose to make a small-scale silver violin with hand engraving, covered in a suitable colored enamel to help replicate the appearance of varnished wood. I was tempted by the idea of making it to house a watch movement, such as a good-quality verge movement lacking its original gold case, but rejected this idea in favor of making a unique item. I adopted the bulbous shape of the stringed-instrument-case styles, based on the need to house a circular movement, which gave a more cello-like result.

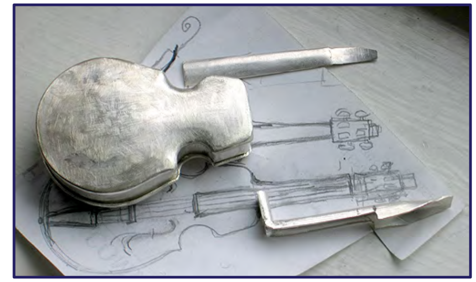
## The case

The body and back of the violin were each formed by hydraulically pressing a 0.8mm-thick (.031") silver sheet into a violin-shaped acrylic-plastic cutout (**photo 2**), using a urethane-rubber pad. This is a highly flexible rubber that returns to its original shape. This created an attractively domed form for both the front and back, with the edged knocked over to create a stiff rim. For the body, now 60mm long by 42 mm wide (2.36" by 1.65"), a shaped strip was bent to match the inside profile of the rim. It was a bit tricky to bend the strip to fit neatly, but patience won and the strip was then soldered in position (**photo 3**).

A stiffening plate was also soldered into the body, at the neck end, and a hinge was fitted for the back (**photo 4**). Care was needed in making the hinge fit well so that the back closed neatly. After enameling, there is little scope for changing this. The neck and peg box of the violin were built up from silver sheet to recreate the look of a real instrument, with four pegs. A strip of thin silver sheet was rolled up and soldered to the end of the peg box to form the decorative scroll.

In order to attach the neck to the body, enough thickness was left in the neck for two blind holes to be drilled and tapped for internal screws. Consideration also had to be made in the assembly for the subsequent engraving and enameling of the body and the underside of the fingerboard.

Two small pieces were soldered in position inside the back, prior to enameling. These were a short post as a part of the lid lock, to engage the lock spring, and a pad near the hinge in which to seat the tip of the fly spring. These were located with an appreciation of how they would function. All soldered joints prior to enameling were made with hard-grade silver solder (melting point 745-778°C [1,373-1,432°F]) to minimize any risk of softening during the enameling processes. I chose not to use enameling-grade solder (melting point 730-780°C [1,346-1,436°F]) because it flows a little less easily.



3. Components and assembly of the body, back, and neck parts of the violin.

4. The back, hinged to the body. The overall length is 98mm (3.85").

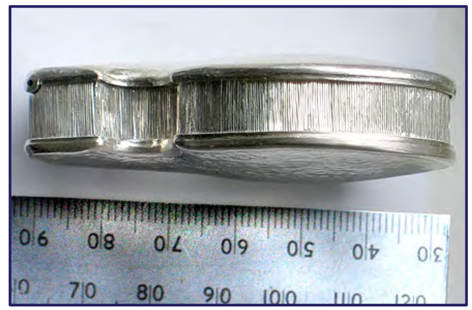
Four tuning pegs were turned up from hard silver wire, to fit their peg-box holes, and the peg holes were drilled to suit the correct position for each string. A slightly raised portion at the peg end of the fingerboard—the nut—serves to lift the strings, and four V-cuts were engraved in it to allow each string to sit neatly and securely.

## Decoration and enameling

Once the body-construction phase was complete, the engraving was begun. A shallow, chamfered recess was engraved around the perimeter of both the body and the back, this to hold the edge of the enamel when molten. Within this, a series of many short, straight cuts were made with a rounded engraving tool, to simulate a wood effect. On the front of the body, the cuts were all aligned with the central axis to copy the fine straight-grain spruce used in real instruments (**photo 5**). On the back, in the manner of matching pieces of maple, cuts were angled in from either side to create a straight centerline, again copying the real instruments (**photo 6**). Engraving on the neck was done in a fine checkerboard pattern; on the body sides, simple vertical lines were made to replicate the straight grain on full-size instruments (**photo 7**).

5. Engraving in progress on body face within the engraved recess around the edge.

6. Engraving of the matched grain on the back.



7. The side wall, with its vertical engraved pattern, soldered in.

8. Enameling in progress.

Light Ruby Red enamel (Schauer transparent enamel SJE 116, firing temperature 730-770° C) was chosen to create a rich varnished-wood effect (**photo 8**). This was done with the knowledge that red enamel can be rather fugitive and become a bit brown in color after too many firings. Within the engraved areas, three layers were added and fired. They were stoned down between each layer to get an even result.

The rounded neck was enameled on the lower surfaces with the same Light Ruby Red, leaving a bare metal strip along each edge. The top of the fingerboard was enameled matte black. The loose tailpiece, with four holes drilled for anchoring the strings, was enameled glossy black. All of these steps aimed to make the parts look in keeping with what a full-size stringed instrument would look like. Particular care was taken during the design and assembly stages to minimize the chances of solder coming into contact with the enamel, since this could lead to problems of enamel security and color change.

Enameling presented some particular challenges, especially in leaving appropriate areas, such as the edge of the fingerboard and edges of the end scroll, free of enamel. Also, while the formed shape and turned edge made the hinged back more rigid, and hence, more resistant to deformation during firing, some deformation did unfortunately still occur (**photo 9**).

A thin coat of white counter enamel was therefore fired onto the inside, as is normal enameling practice. This helps to even out the thermal stresses on cooling but the neat fitting of the hinge was still affected. The remedial step taken to correct the deformation was to put a close-fitting, blued-steel rod through the parts of the hinge on the back, fire the piece to soften the enamel, remove the hot back quickly from the kiln, place it on a steel sheet with the steel rod supported at one side, and a press the hot enamel with a heavy steel object (an old iron) to press it back into a better flatness. This stressful process had to be done twice to achieve a satisfactory outcome.

Trials were made with various colored—as well as black and gold—painting enamels for possible extra decoration. Two f-holes were painted on and fired onto the front of the body, in matte-black enamel. The main body, being much stiffer, did not suffer any undesirable deformation. However, the risk of additional deformation of the back by further firing persuaded me not to apply any more decorative enamel onto that surface.

9. Distortion of the back, prior to correction.

## Automata design

My previous projects have involved small mechanical performing birds, requiring research into their makers and design details. I decided to try to incorporate birds within the small space available in the violin, to create a unique item. At the outset I had only outline ideas for the mechanism; the design decisions developed in stages. Key requirements were a mechanism that would be enclosed within the case and be released to perform. Two birds, supported in a carriage and moving in tandem, seemed to fit the bill, to give a balanced appearance.

To allow the bird carriage to rotate on pivots between the closed and open positions, two mounting blocks were chosen. These would be mounted on a sub-baseplate, each provided with a screwed-in pivot. Within the carriage, each bird would have a mounting stem, allowing rotation by a pinion drive system beneath. To enable contrary rotation, the two pinions could be driven simultaneously using a double-sided rack. This approach is found in a few antique singing-bird boxes[2, 3] to provide either contrary or (with a simple rack) co-rotation.

After the bird carriage and its mounting were resolved, the other vital requirements included a system to lock and unlock the carriage, combined with the need to easily move the rack from side to side. Also, the rack had to provide reliable engagement when the birds were released from their closed (i.e., lying) position.

To allow easy rack movement, I first considered a rack that could be pulled or pushed from one end, as in some antique bird boxes, perhaps with an added spring for reversing it. This idea was rejected because of the need for adequate space at one end of the rack, which was not easily compatible with a carriage that rotated.

Total rack travel was unlikely to be large in this space, but to achieve a reasonable degree of bird movement, the double-sided rack travel needed to be as long as practicable. The limits were set by the need for the carriage to rotate to its closed position without impeding the rack.

The solution was, with the birds being in their closed/lying position, to have the rack at its right-

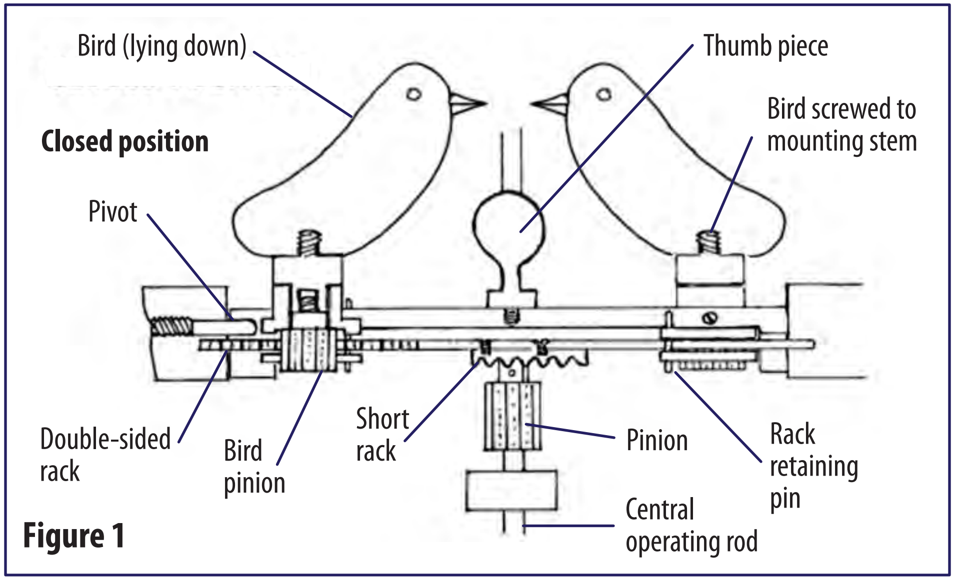
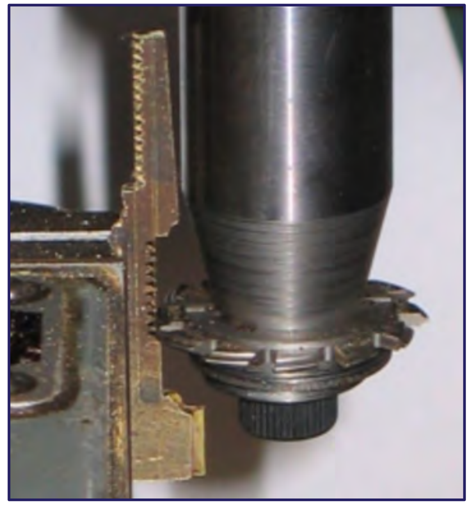
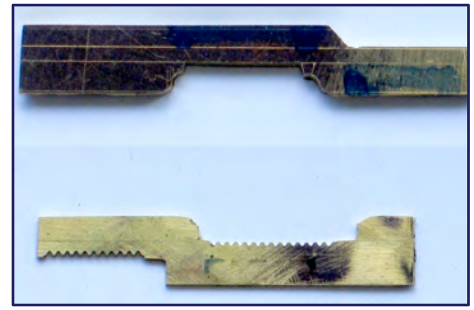


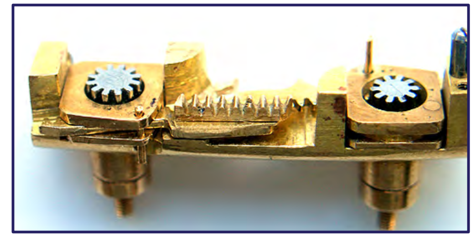

**Figure 1**



10. Milling the teeth on the second side of the rack. Rack and pinions have cycloidal teeth.



11. Rack blank (above) and after milling the teeth.



12. The double-sided rack, retained by pins and on a tangent to the two bird pinions, with the short rack attached (seen from the underside).

hand limit of travel. This would bring the left-hand end just clear of the end of the carriage, allowing unimpeded rotation. The right-hand end of the rack needed to extend beyond the right-hand end of the carriage, requiring the mounting block to be cut away to allow 90° of rotation of the rack and carriage to the upright position. The rack could then be moved to travel to and from its left-hand limit. This design required that, on closure, the rack must be moved to its right-hand limit.

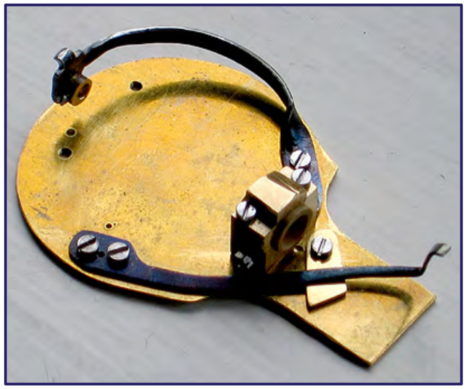
The option selected for rack movement was to move it from beneath. This required a small pinion on the central operating rod to engage with another short piece of rack, attached to the center of the double-sided rack (**figure 1**).

On release of the carriage, the short rack can swing into engagement with the pinion below on the operating rod. The slight freedom of movement of the main rack enables the short rack to drop into engagement without jamming. This was a key feature of the design for this cramped space, and it proved to be quite successful. The central operating rod was also chosen to serve the purposes of both releasing the catch for the hinged back and also releasing the bird carriage from the closed to upright position.

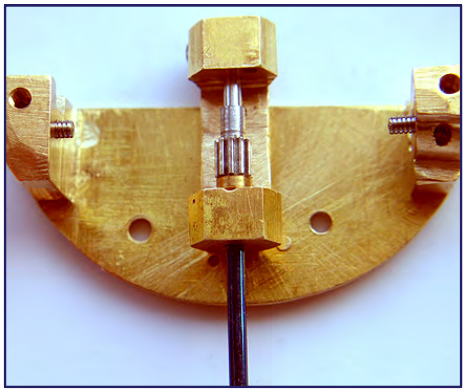
## Making and setting the gearing

The double-sided rack was 0.8mm (.031") thick and 34mm (1.339") long. The short rack, 8mm long, was made a little thicker to provide adequate depth for its two retaining countersunk screws, which were inserted from the top side of the main rack. Both racks were made in brass and cut with 0.25 module cycloidal teeth (tooth pitch was 0.79mm [.031"]), with a round-bottom wheel cutter (**photos 10** and **11**). An important aspect was that, because the double-sided rack ran across the tangent of the two bird pinions, the subsidiary rack had to be attached to allow movement normal to its drive pinion.

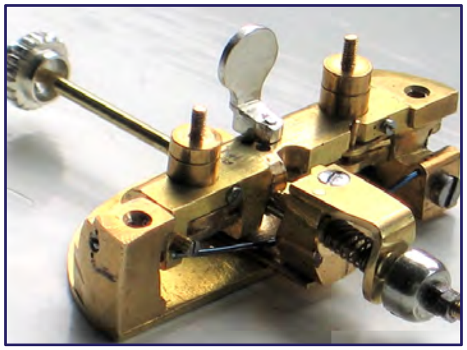
Correct depth of engagement of the main rack with the bird-rotating pinions was achieved by each having a pin to retain the rack from behind, which allowed the rear face of the rack to be reduced (parallel with the line of action) until depthing was correct (**photo 12**). It was different at each side because I chose to have a 10-leaf pinion on one side and a



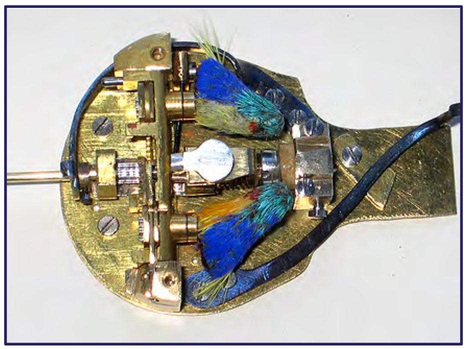
13. Main baseplate, with lock, fly springs, and wedge all screwed in place.



14. Mountings for the carriage and operating rod.



15. The carriage assembly on the sub-baseplate.



16. Assembled carriage and birds in the closed position, on the main baseplate.

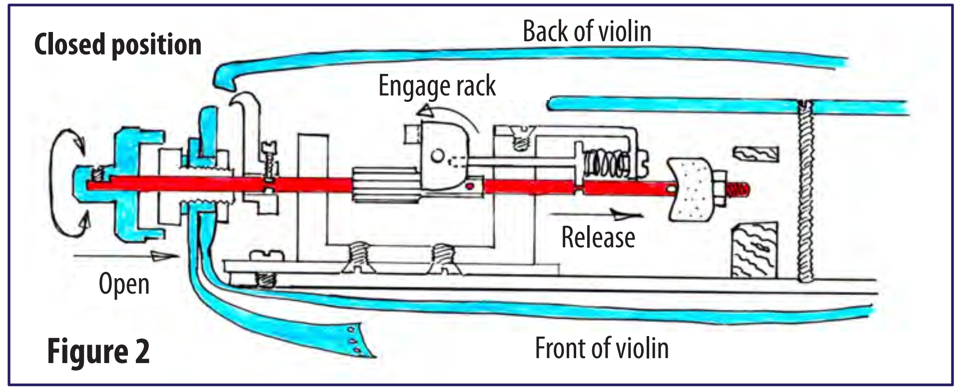



Figure 2

12-leaf on the other—2.9mm (.144") and 3.4mm (.134") diameters, respectively—to create different amounts of movement in each bird for the same rack travel. Correct engagement of the small rack with the driving pinion (10 leaf, 0.25 module) was achieved by fitting a shim beneath it.

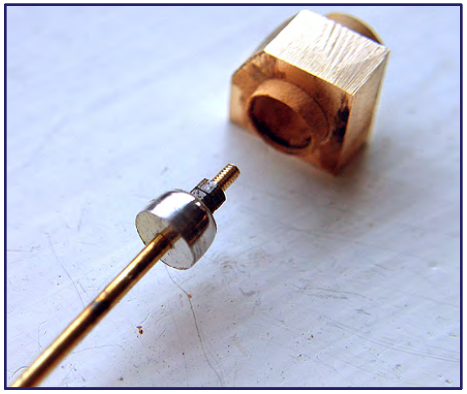
Each bird pinion was made with a short 10BA thread, to be screwed securely into the brass bird stem, which ran freely in a round brass insert in the carriage. These inserts, which were secured with steel side screws, had turned slots around their bases to locate the rack and allow it to slide easily across the pinions. On the top of each bird stem, a 1.2mm thread projected to allow each bird body to be screwed into position.

Lock and fly springs for the back were cut from sheet steel. They were shaped to fit the available space as required, then hardened and tempered. Considerable patience was needed to make the springs fit and operate correctly, with the correct stiffness. As an aid for the fly spring, it was fitted with an adjustable and lockable wedge between it and the baseplate. This allowed its stiffness to be set more easily (**photo 13**). Each spring was secured to the baseplate with two 10BA steel screws.

The design of the release and relocking system for the bird carriage was left until the bird-rotation system was completed. This was done to allow various options linked to the central operating rod to be considered. Available space and reliable operation were paramount.

The method ultimately adopted ensured that the carriage was held captive by a brass pin driven from behind by a soft coil spring. The pin was located in a hole in the closed carriage. A flange at the other end of the pin was located freely in a slot in the central actuation rod, so that when the central rod was pressed, the pin was withdrawn, releasing the carriage to rise smartly, driven by its strong wire spring.

The operating rod ran through the two rigid pillars attached to the sub-base plate. Between the pillars, the rack-drive pinion was pinned to the rod (**figure 2, photos 14, 15**). Clearly, the position of each component on the central rod was important to obtain the correct sequence of actions. During con-



17. Pewter plug and mating wood block in a trial brass housing.

struction, alignment of these pillars and other parts was accomplished with a temporary rod running from the outside of the case through a central hole in the end wall. This allowed the subplate to be screwed in the correct position on the main plate (**photo 16**).

Each bird is solid brass, with thin copper wings soldered on. The whole was then covered in a layer of thin zephyr, (fine cotton gingham) painted an ochre color. Beaks were filed to shape from bone and glued in. Layered feathers—lots of very small ones—were glued onto the body, followed by the attachment of ruby watch end stones for small, reflective eyes. One bird is intentionally slightly larger and more brightly colored than the other. This is an older, wiser bird that is mounted on a 12-leaf pinion and moves less.

## Adding sound

A final addition to the automaton was a small device to create a birdlike noise. This was a suggestion from a friendly automaton maker and collector. He kindly gave me an original birdcall device to study. In this, a pewter plug rotates and binds in a hardwood block. There is a light dusting of powdered wood resin between the plug and the block. This binding creates the tweet noises. I adopted the same approach and fitted a miniature version.

A hardwood block is screwed onto the baseplate, its hole aligned with the axis of the actuating rod. On the end of the rod is a turned block of pewter, screwed on with a 12BA thread and secured with a small cross screw to prevent it from loosening (**photo 17**). Correct positioning of the block is vital to allow adequate engagement when pressing the control rod. An occasional top up of resin dust helps.

Means of assembly of the mechanism were a consideration during construction. Proving the reliability of the complete carriage system on the subplate was quite helpful. On assembly, the main plate was first inserted, secured by a threaded brass rod through the silver inner body. The partly assembled subplate was then added, followed by individual components, such as springs, etc.

18. Closed position, with the birds lying in their recesses.

The violin strings were made from 18k gold wire, drawn down to 0.4mm (.015"). They were fitted to the violin in the annealed condition so that, on fitting, they would work harden and set, and (I hoped) better retain their position in use.

The bridge was made from 9k gold, shaped and pierced to look like a miniature of the real thing.

LEFT: 19. The finished violin.

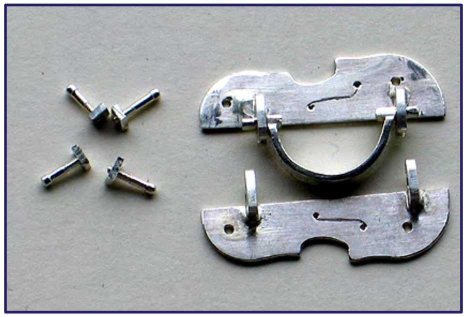
RIGHT: 20. The case, with silver fittings.

BELOW LEFT: 21. The violin in its plush-lined case.

BELOW RIGHT: 22. Violin, face down in its case, with the back removed.

Since it could be easily dislodged, two special measures were taken. First, the bridge had a slightly wider-than-normal base soldered on. Second, just below each of the nicks in the bridge for the four strings, small holes were drilled, through which the strings were threaded. This provided a convincing appearance, but with increased security for both the bridge and the strings.

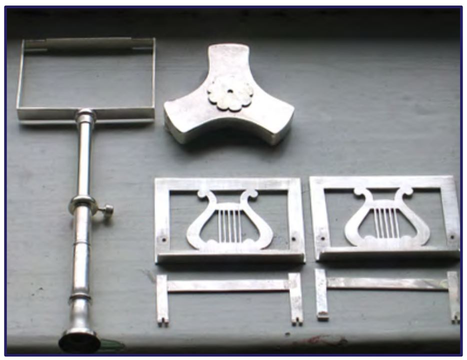
When the back is opened, the pierced and engraved silver grill serves to hide the mechanism, but allows the two birds to appear

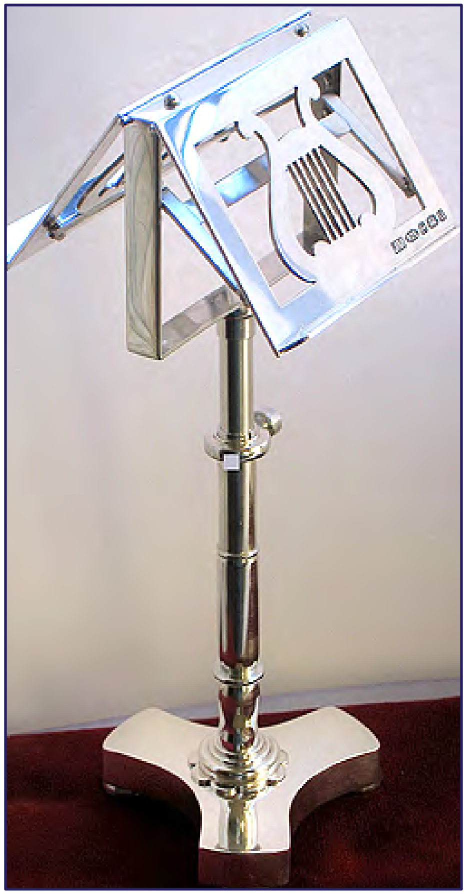


ABOVE: 23. Locking clasp for the case, with its fastenings.

BELOW: 24. Parts of the music stand, ready for assembly.

RIGHT: 25. The finished silver duet stand, as a complement to the violin.





The violin and stand were Hallmarked for 925 silver , Birmingham UK, 2019, with the makers mark JM.

## Safe operation of the bird automaton

The sequence of operation is as follows:

1. While holding the body face downward, between finger and thumb, clear of the violin back and avoiding the strings, press the button gently to release the lid catch and allow the lid to fly open.
2. Press the button more firmly to release the bird carriage.
3. Rotate the button carefully, being aware of the limits of safe travel, to cause the rotation of the birds.
4. Press the button firmly and rotate at the same time to engage the pewter plug and make tweeting sounds.
5. Rotate button to bring the birds and rack to the right-hand limit.
6. Press the button firmly, while at the same time pressing on the central finger piece to cause the birds to fall, and to engage the carriage lock. The finger piece ensures that there is no need to press on the feathered birds themselves.
7. Release the button.
8. At the tail piece end, with thumbs and forefingers, close the lid to the body to engage the case lock spring, taking care to not disturb the strings, bridge, or tail piece.

in their repose (**photo 18**). Because the birds' beaks were chosen to be rather prominent, the starting position is with the birds angled slightly outwards to prevent their beaks from fouling each other. A silver tab was screwed into the top of the carriage to provide a finger piece for use during closure. The finished violin can be seen in **photo 19**.

To complement and provide protection for the finished piece, a violin-style case was made (**photos 20-22**). This was covered in very thin, stained hide. The case was lined with plush velvet and fitted with silver hinges and a special locking clasp. These were all attached to the thin wooden case with 1mm-diameter silver nuts and bolts (**photo 23**), providing a secure means of attachment. And to complement its display, a silver adjustable duet music stand was made (**photos 24, 25**). **A**

This article previously appeared in *Model Engineer* and *Horological Journal* magazines.

## Notes

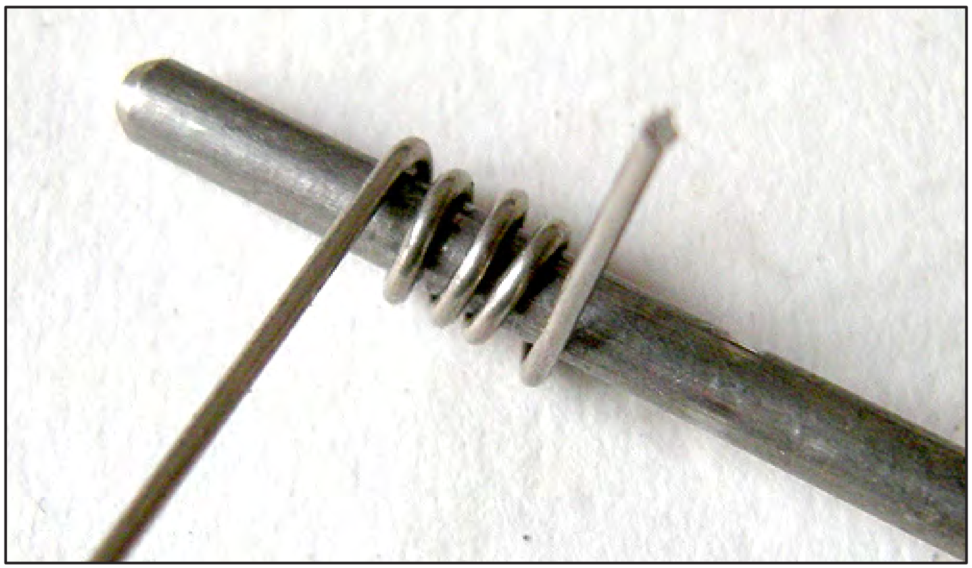
1. *Engraving and Enamelling: The Art of Champlevé*, by Phil Barnes, published by The Crowood Press, ISBN: 978 1 78500 545 9
2. *Mechanical Singing Bird Tabatières*, by Geoffrey T. Mayson, published by Robert Hale, London, ISBN: 0 7090 6303 2
3. *Oiseaux de Bonheur* (*Flights of Fancy*), by Christian Bailly, published by Antiquorum, ISBN: 2 940019 28 2

# TIPS

## A poor man's stop collar

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

Stop collars for shafts less than 4mm (.157") in diameter are expensive and difficult to find. The internet is a good place to look for them, from suppliers of model-aircraft parts. On the other hand, you can make your own, as described here.



Wind a few turns of piano wire or other stiff wire onto a rod slightly smaller than the desired final diameter. Here, a 0.8mm-diameter (1⁄32") piano wire is being wound onto a 3.3mm-diameter (.130") rod for use on a 3.5mm-diameter (.138") rod.

Trim the ends, as shown in the picture above. Loosen the spring by pressing the ends apart to slip it onto the shaft at the desired location. There it will lock on its own, thus preventing anything else on the shaft from sliding off.

Here, a finished stop collar securely grips its shaft, preventing an automaton's arm from falling off while still allowing the arm freedom of movement.

# ADDING SOUND TO AUTOMATA

## Several methods of audio enhancement

**by Andrew Alden**
Huddersfield, West Yorkshire,
United Kingdom
Photos by the author

1. The author's steam radio.

Sound adds an additional dimension to an automaton. In this article, I'll describe some different methods that I've explored.

### Cassettes

The first automaton I made, some thirty years ago, wasn't really an automaton. For some strange reason, I decided what I really needed in my life was a steam-powered radio. So, with an old Mamod stationary steam engine and a handful of vintage-radio spares, I put one together. It wasn't really run by steam, it just looked as if it was. When it started up, a light appeared under the boiler and a few moments later the engine started running, turning the "generator"—actually an electric motor that drove the piston assembly. Then Laurel and Hardy's warbled tones of "The Trail of the Lonesome Pine," supplied by a small cassette player hidden in the base, emerged from the horn loudspeaker (**photo 1**).

The cassette itself was the interesting bit. It was an endless-loop type, so my 30-second snippet played continuously for as long as was required. Surprisingly, endless cassettes are still available on eBay (**photo 2**). They were used to record the greeting on old fashion, tape-based answering machines.

However, it isn't difficult to modify a standard cassette tape to be an endless loop. There are quite a few how-to guides about this on YouTube. One advantage to making your own is that you can create a loop of exactly the right length to fit the music or sound effect chosen.

Sound quality can be pretty good with this method and it is a cheap option if you are using a cassette player/recorder sourced from a charity shop or a car-boot sale. Of course, you need space for this player inside your creation. Just one tip, though—if the machine is not to be used for awhile, don't leave it in "play" mode, or you may end up with a flat on the drive idler, which will make the recording sound pretty weird!

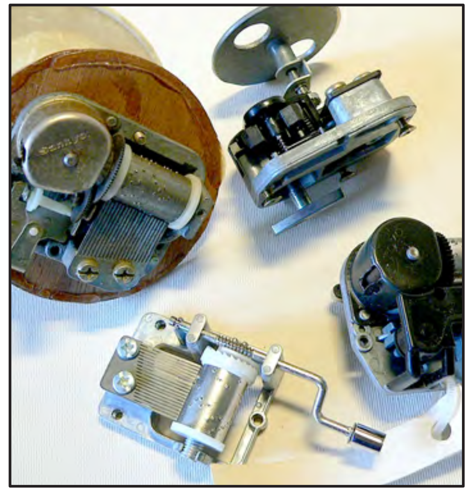
## Music-box movements

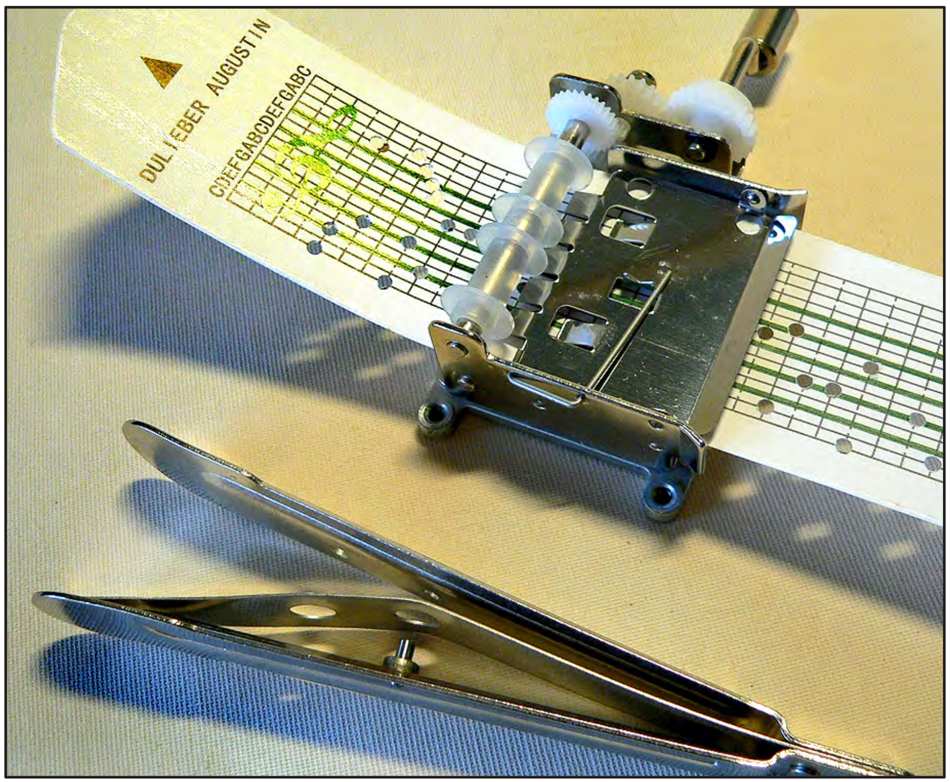
Over the years, I've salvaged music-box movements from all sorts of items because I was sure they would come in useful one day (**photo 3**). Unfortunately, all I've ended up with is a large box of music-box movements that don't have quite the right sort of music that I wanted. Interestingly, though, some of the mechanisms I've found have the added benefit of a rotating stage or a bit that jiggles up and down, so if the tune is particularly annoying, you can easily unscrew the sound comb and just use the clockwork motor from the music box to power the automaton. All is not lost.

I then came across programmable music boxes—specifically ones that use a punched- paper tape in a loop (**photo 4**). These are usually hand cranked but can be fairly easily converted to electric-motor power. These movements come in a variety of qualities. The basic ones have fifteen notes, while the better ones have thirty. By punching holes in the tape, it is possible to produce any required tune…theoretically!

These machines are widely available on eBay and other websites and normally come with blank paper tapes, plus an example of a ready-punched paper tape, and a special hole punch. Fortunately, there is an active online community using these, so have a look at *musicboxmaniacs.com* or do a search on YouTube for hints and tips. There is a vast free catalog of tunes available that enthusiasts have already converted to punched-paper-tape format. These guides can be printed out and temporarily fixed onto the tape as templates for where to punch the holes. I was chuffed to get Bjork's

2. Endless-loop cassettes from eBay.


3. Assorted music-box movements.



4. Tape-programable music-box movement with its special punch.

"It's Oh So Quiet" working well after a few hours.

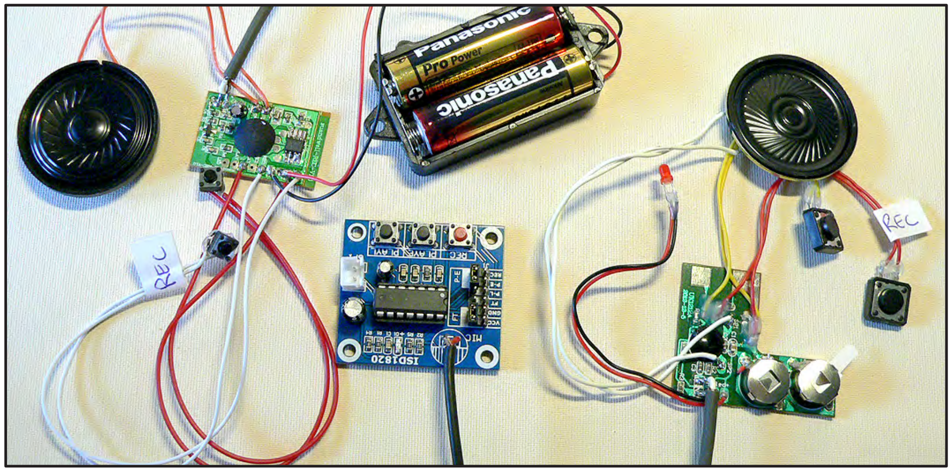
Music boxes produce much better sound when they are firmly screwed down onto a solid body that allows the sound to resonate properly. This helps to overcome their intrinsically tinny nature.

If the sound of a music box suits your project, then fair enough. However, I wanted something that could do sound effects, as well as just music.

## Electronics 1

Again scouring eBay, I came across several different types of small electronic sound-recording boards intended for inclusion in musical greeting cards and other craft projects (**photo 5**). Most of them cost only a few pounds each. All of these boards have what is called non-volatile memory. This means that the recorded sound is retained even after the power to the board is removed. Once it's on the board, it stays there until recorded over by something else.

Typically these boards come with button-cell batteries or holders for a pair of AA or AAA cells, plus a couple of microswitches, one controlling the recording, the other controlling the playback.




5. Assorted sound boards from the internet.

Also included is a speaker, usually a very thin one, so it can go inside a card. Recording time on many of these boards is limited to a maximum of ten seconds, although some go up to thirty seconds. They usually come with a microphone, to allow a personal message to be recorded, which is okay for voice but certainly not for music.

I desoldered the microphone on one and attached a lead to connect it to the line output of my CD player. It worked, but the sound was very distorted, as the line output level turned out to be about a hundred times greater than the output of the little electret microphones used on these boards. I made up a simple circuit board to attenuate the line output to a suitable level

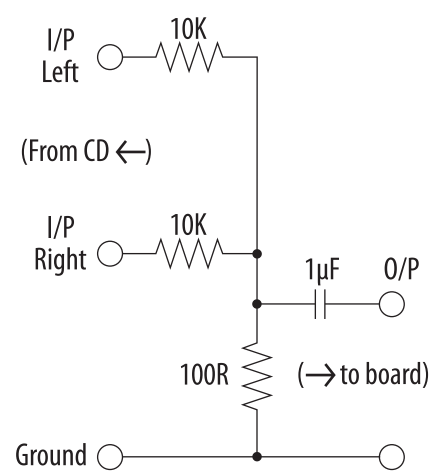



**Figure 1**
**Signal attenuation circuit**

(**figure 1**). With this in place, and using the CD player as a source, the sound quality was good, once a decent speaker was substituted for the original.

## Electronics 2

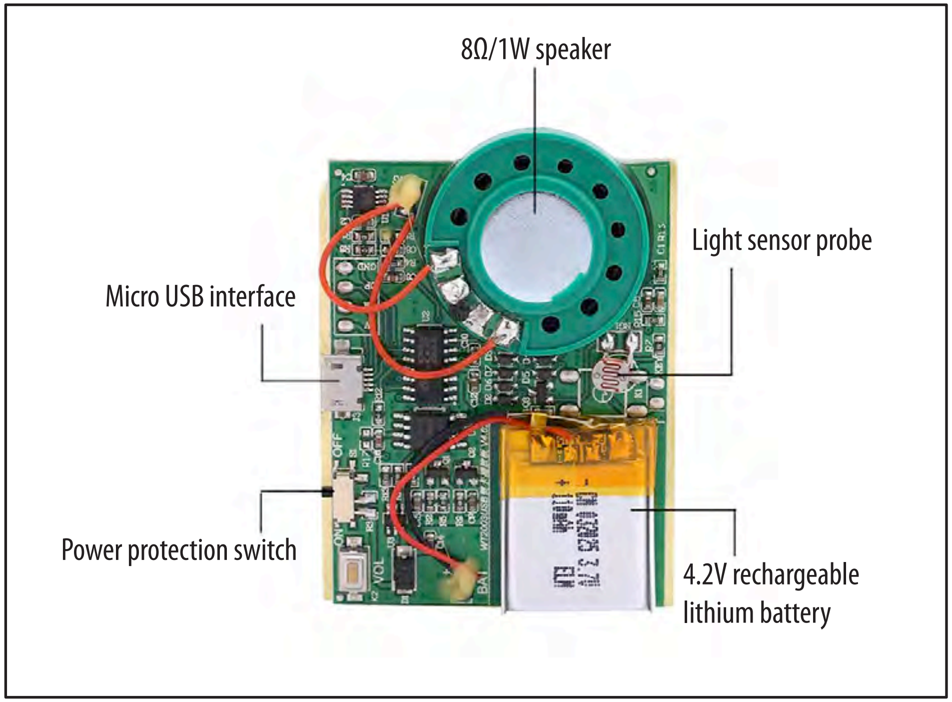
I found a board for just over a fiver, including postage, that had a recording time of up to four minutes. It had a built-in rechargeable lithium battery and a micro USB port that is used to both charge the battery and input a sound file to the board (**photo 6**).

When the unit is plugged into your computer, it shows up as a file on the desktop. Opening this gives a list of weird Chinese sound files. Throw these in the trash and drop your chosen sound file into the folder. This needs to be in MP3 format and there are plenty of free programs to do a conversion, if needed. The particular board I was working with had the option of being operated by a photocell or a button, so it was pretty versatile.

## Enough electronics—at last, an actual automaton!

Ever since I saw *Tipu's Tiger* at the V&A Museum, I'd thought about creating my own version. I finally started making it after I came across a smashed-up Indian folding table at a rather posh antique fair, where the entry fee was more than what I paid for the table.

I actually quite like the concept of first finding an outer casing into



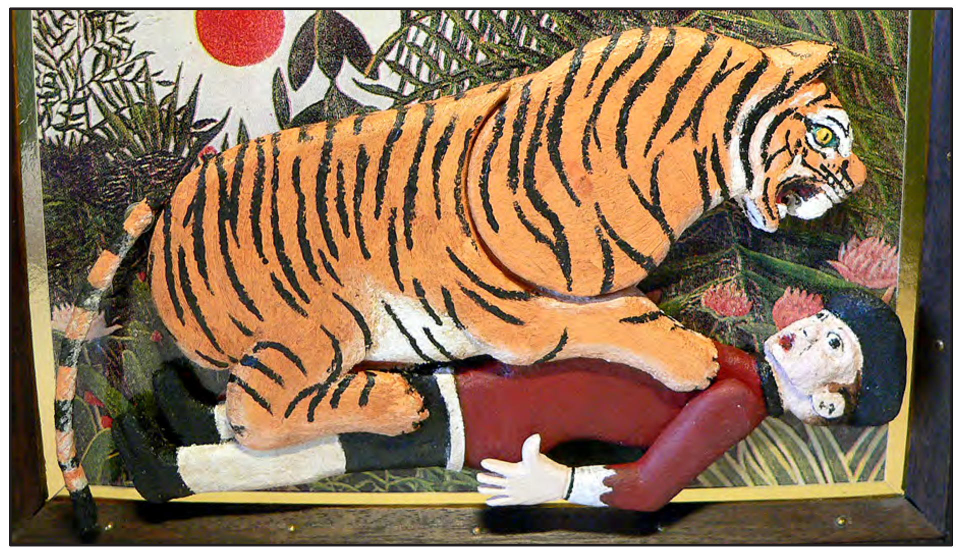

6. USB sound board.

7. The front of the author's *Tipu's Tiger*, closed. Tipu Sultan appears on the left side of the triptych.

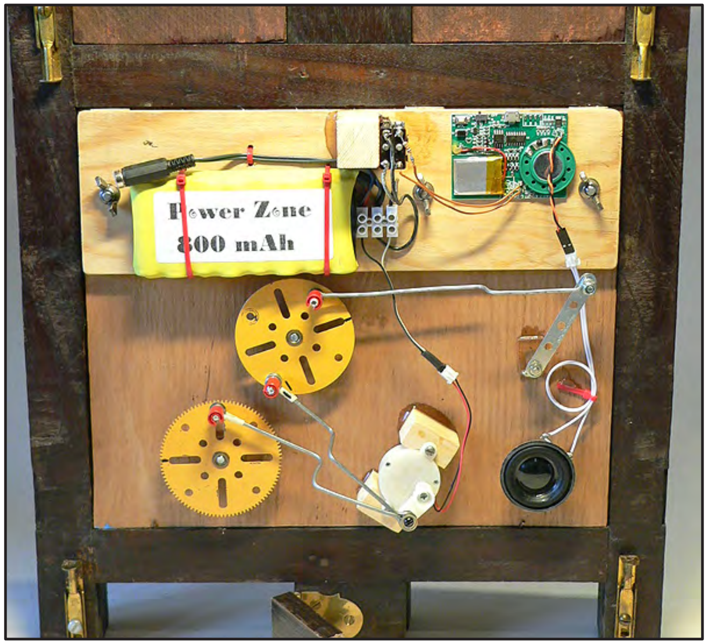
which I then have to shoehorn the automaton mechanism. (Over the years, I have also had a thing about glass domes, the result being a collection of every conceivable size, each dome waiting to be filled with an automaton.)

Once the finely carved table was dismantled, there were four usable sections. Two of these I glued and screwed together, to form the main part. Then I hinged the remaining sections—one at each end—to form a folding triptych. My idea was to make a two-dimensional version of *Tipu's Tiger*. A sort of diorama is revealed when the doors are opened out (**photos 7-9**).

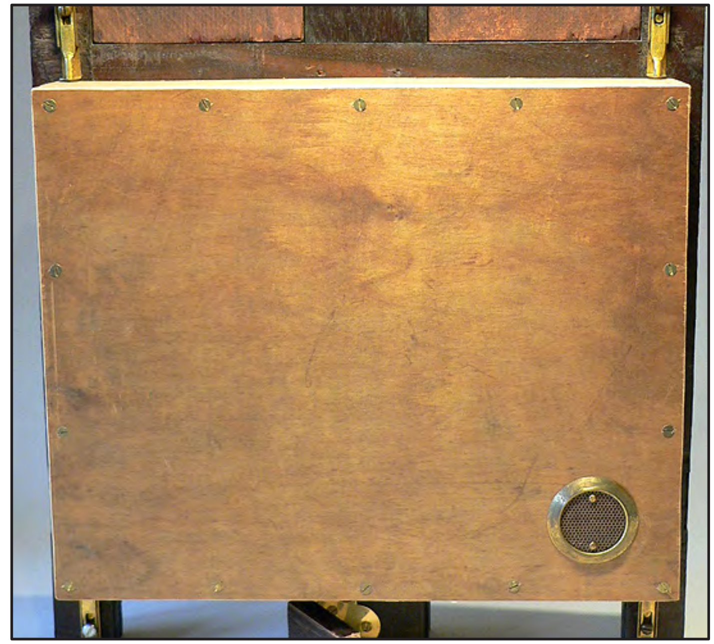
8. The front of the open triptych.



9. A closeup view. The tiger's head lowers, his tail waves, the soldier raises his arm.



10. Rear view of the automaton, with the cover removed.


11. Rear view, with the cover on. Speaker grille is at lower right.

My tiger and its victim, a British soldier, were carved out of fiber board and painted with PVA glue to stiffen the surface. Once dry, they were rubbed smooth, ready for painting.

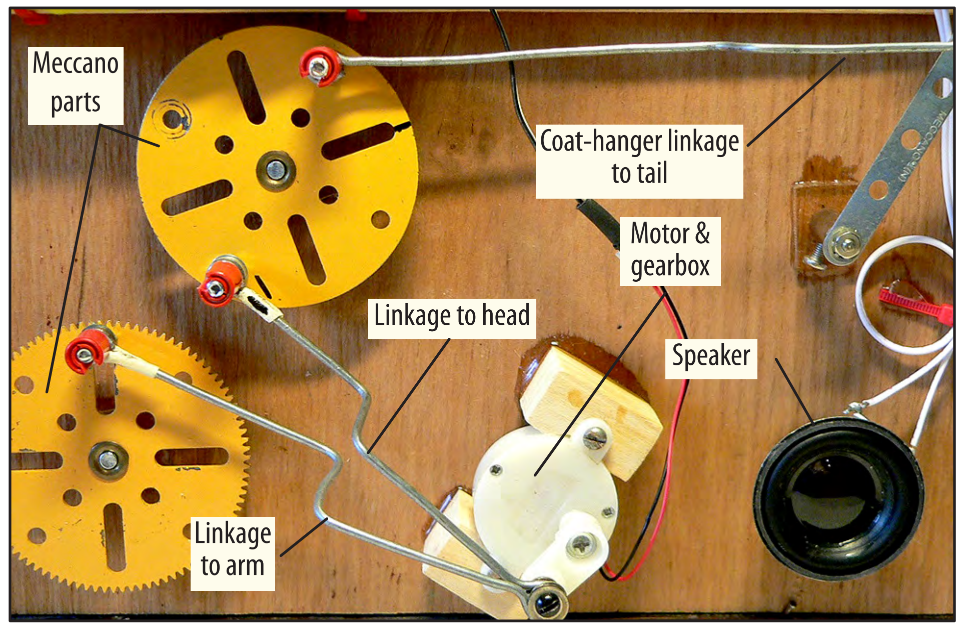
Articulation here is fairly simple. The head of the tiger moves up and down, while the arm of the soldier waves ineffectually as he tries to defend himself. The tiger's tail, made from some window-sash cord, switches around angrily. The background of the main picture is a bit of a cheat. It's a color photocopy of one of Rousseau's jungle pictures.

Motive power is an electric motor with a built-in reduction gearbox and eccentric arm (**photos 10, 11**). This arm rotates between 8 rpm, with an input voltage of 6V, up to 16 rpm, with an input voltage of 12V. There are all sorts of DC motors available on eBay, from only a few pounds each. DC is important, as these motors are simply powered by batteries.

A small electric motor on its own will rotate at 10,000 rpm or more. This motor is not of a lot of use in an automaton—it's rotating far too fast and also has very low torque (turning force). A gearbox does two jobs. It reduces the speed of the motor and increases the output torque. A motor with built-in gearbox is much easier to use than than adding the complexity of using a high-speed motor and an external gear train.

In my *Tipu's Tiger*, I used stiff linkages between the single motor and the soldier's arm, the tiger's head, and its tail. Good old Meccano gears and shafts complete the mechanical connections (**photo 12**).

A double microswitch is operated by a rod that comes through from the front, released when the



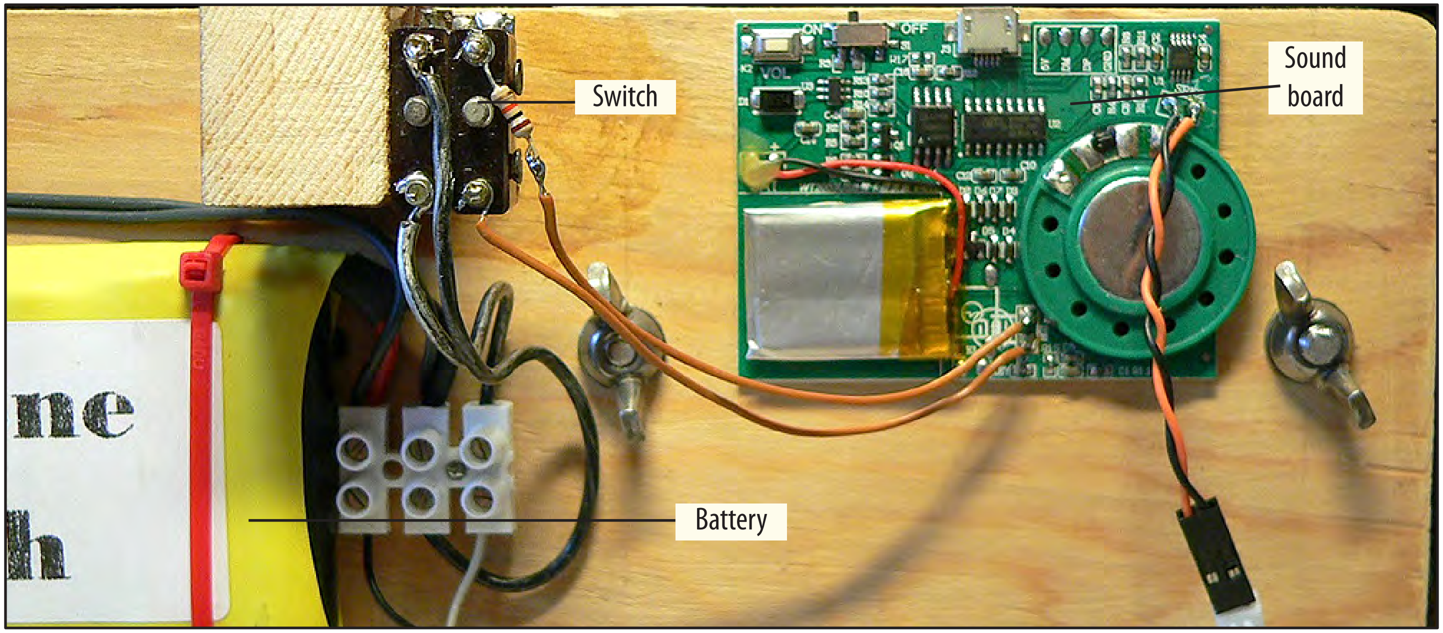
12. A closer view of the mechanics.

doors of the diorama are opened (**photo 13**). One side of the switch closes the circuit to power the motor while the other side of the switch starts the audio, in this case "Hunting Tigers out in India" by the Bonzo Dog Doo-Dah Band. Power to the motor comes from a 12V NiMH rechargeable battery. The whole works is concealed in a wooden box at the back, stained to match the vintage patina of the original table.

Inside the tryptich, on the left-hand panel, is a picture of Tipu Sultan. On the other side is some text about his life. On the outside is another picture of the Sultan, on the left, while on the right side is a faked-up, aged label that says "Calcutta Educational Diorama Company" (**photo 14**).

I hope you enjoyed this article. I tried to keep it from getting too technical but if anyone needs any further information or help in the area of adding sound, I will do my best to assist. My email address is *andrew.alden1@btopenworld.com*

To see and hear the author's *Tipu's Tiger* attacking its victim, click ***here***.



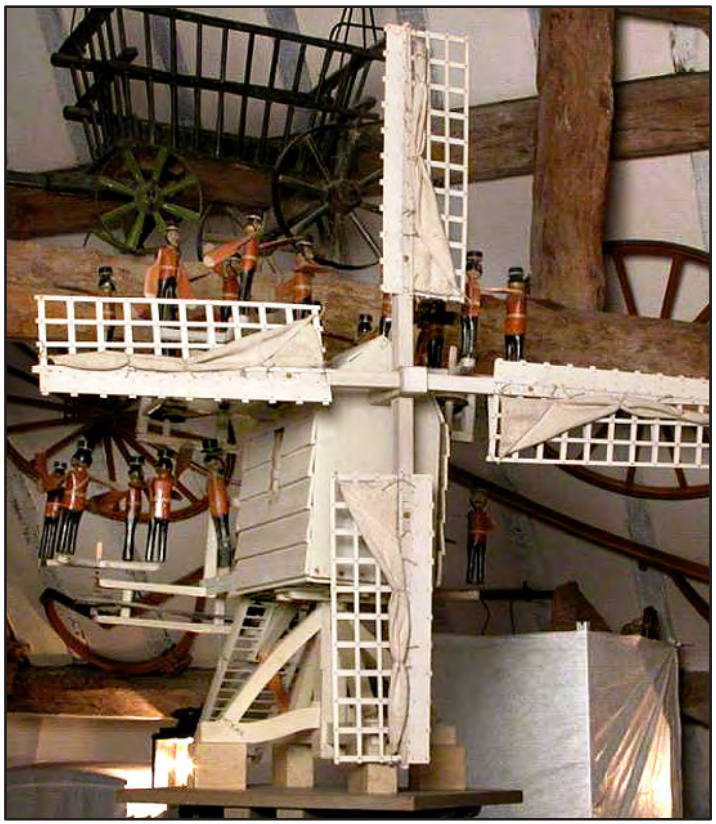

13. Closeup of *Tipu's Tiger* electronics—microswitch, sound board, and battery.


14. The Tipu's portrait and documentation from the fictitious Calcutta Educational Diorama Company, on the exterior of the triptych.

# The Snowshill Manor windmill automaton

## A fascinating old model with an obscure history

**by Bill Goldie** • Moreton-in-Marsh, Gloucestershire, United Kingdom • Photos by Barry Silcock, except where noted

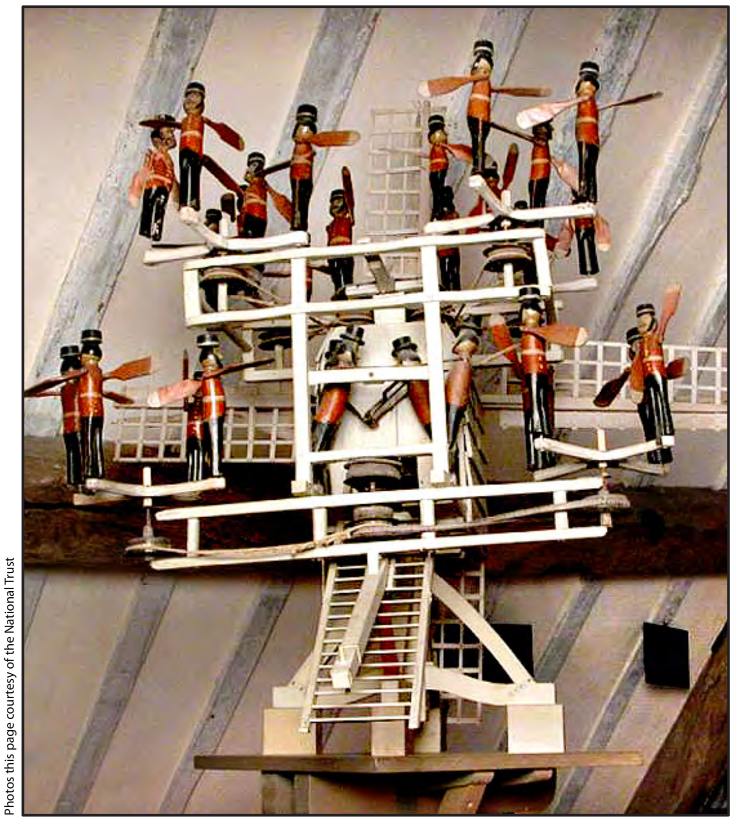


This mill is an accurate representation of a European post mill.

In Gloucestershire, at Snowshill Manor, now a museum operated by Britain's National Trust, the room called "100 Wheels" contains, among its many treasures, a wonderful model of a windmill. This is an automaton with a small army of soldiers clustered on it that may have once stood on a pole in a garden or field. When the wind blew and the sails rotated, the army would spring into life and activity.

Unfortunately, little is known about the origin of this fascinating automaton. We know for sure only that it was purchased by Charles Paget Wade in 1938 for £4—about $5 (the equivalent of £200 or $250 in today's money)—to add to his collection at Snowshill Manor. He was of-fered it by

Photos this page courtesy of the National Trust

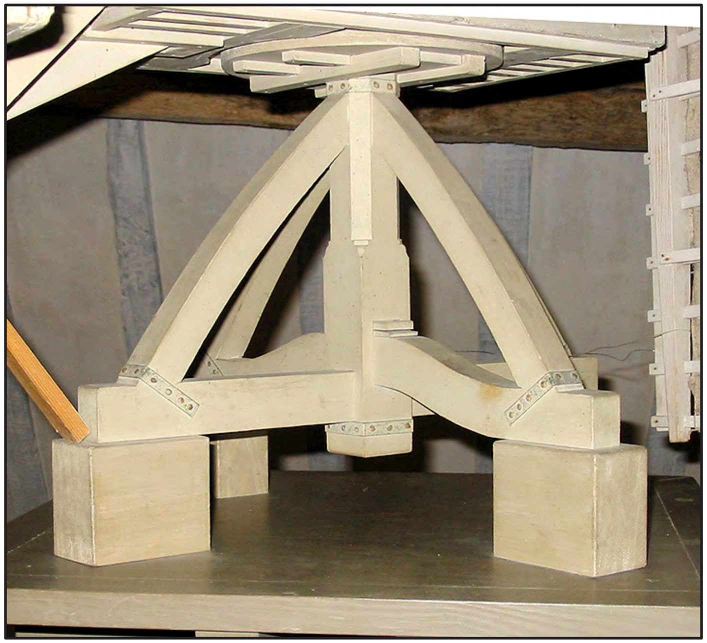


Inexplicably, more than two dozen animated soldiers cavort on the mill.

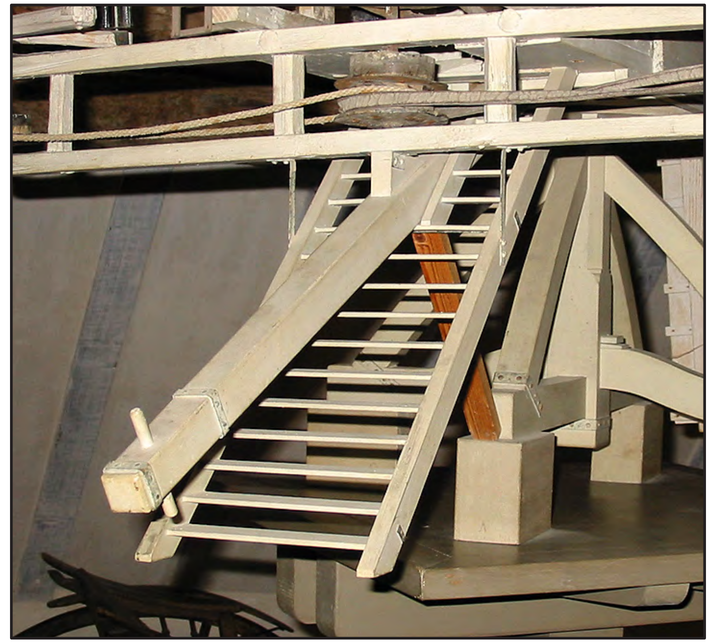
Roger Warner, an antiques dealer, in Burford, Oxfordshire, who had frequent dealings with him. Warner, in turn, had purchased it from Agnes Price, another antiques dealer, in Malvern, Worcestershire. All we know from her is that the previous owner had allegedly used it as a bird scarer. We don't know who made it, or when, or why. We hope to find out more in the future.

The model is clearly based on a European post mill, as it has the classic construction of a braced supporting structure with a single central bearing post (**photo 1**), on which the whole body, or "buck," of the mill can be turned into the wind. There is a rear door and a set of stairs for entry, and a beam extending rearward that the mil-ler would use to push the entire mill around to face the wind (**photo 2**). The sides of the mill are weather-boarded and the double-pitched roof has a gothic-arched profile. The sails on the model reflect authentic construction, with cloths mounted. The sails are reefed in "sword-point" mode—about one-quarter cover (**photo 3**). "Dagger-point" is more cover than "sword-point" but less than "full sail."

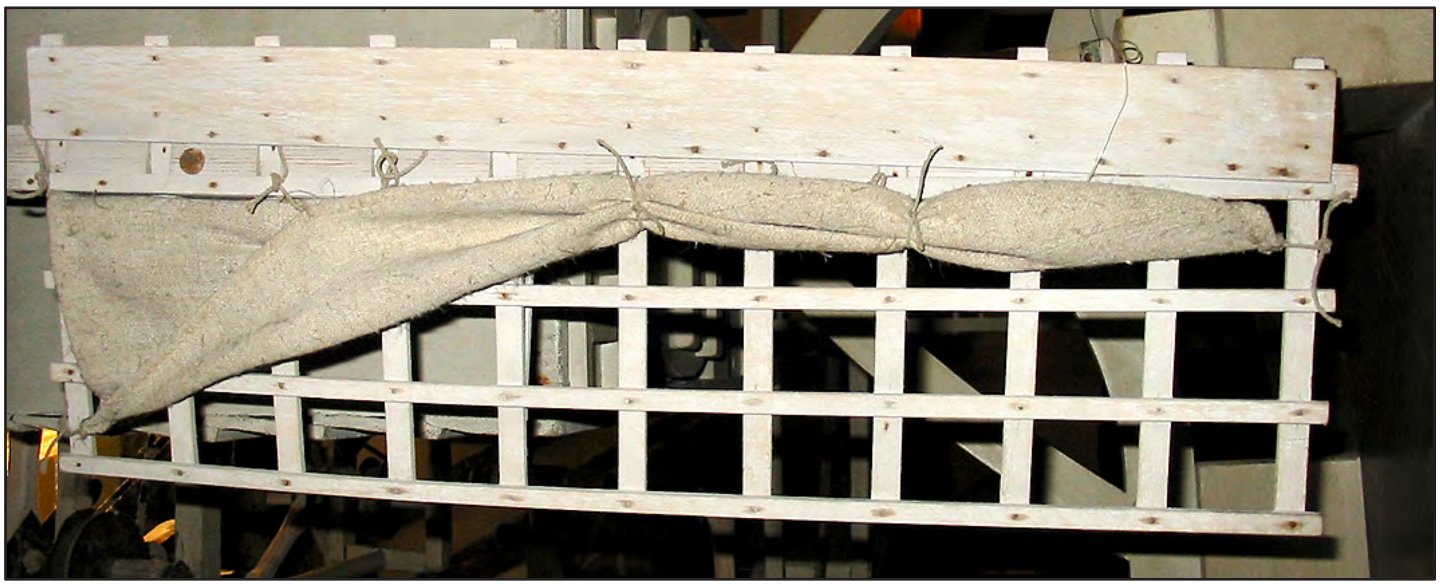
While the mill in itself is impres-



1. The understructure of the mill is typical of full-size post mills, where the entire structure can be rotated around the central post.



2. The large beam at the left would be used by the miller to rotate the structure to face the wind.



3. One of the sails, authentically furled in sword-point mode.

sive, the maker then added external frames that carry a small army of thirty little soldiers (**photo 4**). These are driven by the internal mechanism as the sails turn.

We can't know why the creator chose this design, or even when he made the model. The style of the soldier figures seem to echo the British army at the time of the Crimean War (1853) and the whole arrangement could even be seen as poking fun at authority. There are two top-hatted figures in full coats who occasionally look out of side windows, four top-hatted figures in parade uniform who are industriously turning a crankshaft, and twenty-four rotating figures, each wearing a regulation shako and flailing their arms wildly as the mill turns. The impression is of NCOs making hard work of trying to run the army, while the officers take little interest and the lowly "squaddies" dash around aimlessly. Was the craftsman who made the model a veteran soldier from the Crimean War who wished to show his opinion of his leaders? We would love to know.

Inside the body of the structure, the resemblance to a real post mill continues, in that the sails drive the main shaft, on which there is a bevel pinion gear driving a bevel crown gear on a vertical shaft extending downward. Below, where the grindstones would be on the real mill, is a pulley with a long, flat leather drive belt extending rearward through the back door. This drives another triple pulley on the lower frame, which carries a belt to each side, that goes to single pulleys. These pulleys' spindles each carry a rotating carousel on which ride four soldiers.

Each soldier has paddle-shaped arms—one each of two kinds—secured to a loose spindle through his shoulders (**photo 5**). The flat surface of the right arm is in line with its spindle, while the left one is at right angles to the spindle, so that however the wind strikes them, at least one is broadside-on. We assume that is the intention, anyway, because not only do the figures proceed in a circle, so that the wind direction is constantly changing, in practice the forces will either balance out or turn the arm for a quarter rotation only. It looks a bit like a propeller blade but it doesn't work like one. However, this arrangement does mean that the arms

4. Most of the thirty soldiers are visible in this photo.

5. A closeup of one of the carousels. The photo clearly shows how the soldiers' arms are arranged. Note the rope-turned pulleys. All wooden parts were hand carved.

don't so much whirl as flail back and forth, which may have been the intention if it was a bird scarer.

That only accounts for eight of the twenty-four "privates." The main shaft continues at a higher level and ends in a spur gear meshing with another on a layshaft just below it. That layshaft, in turn, extends rearwards through the back wall of the body and connects with the crankshaft that is so enthusiastically turned by the four hard-working NCOs (**photo 6**).

The layshaft input gear also carries a pinion-and-crown-gear set driving another vertical shaft, this one going upward (**photo 7**). The spur gears are carved from solid wood and the crown gears have individual teeth carved from hardwood (probably traditional hornbeam). Each tooth is pinned with a dowel for strength. This vertical shaft carries another spur gear that meshes with one more on each side. These side gears each carry double pulleys with drive belts going to the outer four corners of the upper frame, where they drive the spindles of another four carousels, each again carrying four private soldiers (**photo 8**). There is an extra covering plate

ABOVE: 6. These four gentlemen (one is obscured by the column) mysteriously turn a crank as the windmill blades rotate.

ABOVE RIGHT: 7. Hand-carved spur and crown gears. The crown's teeth are shaped to match the spur's and are pinned in place with little dowels. This set controls the two soldiers who alternately look out of the side windows.

RIGHT: 8. The upper tier of four carousels, each revolving with four soldiers. The soldiers themselves are loose on their pins and free to rotate about their own axes in the wind.

9. This soldier periodically leans out of the window. The mechanism that controls him and his opposite number can be seen at the right. In this photo, the wall with the window has been removed.

above the roof to shield the exposed gears from the weather.

We have now accounted for twenty-eight of the thirty figures. We seem to have ignored the two "officers" (which is probably all they deserve). In fact, the layshaft extending rearward to drive the external crankshaft also extends forward, ending in a short crank that prods the officers to alternately stick their heads out of the side windows (**photo 9**).

We don't know whether Charles Wade ever displayed the model

10. Barry Silcock's splendid recreation of the original is on display at Snowshill Manor.

outdoors, nor do we know how old it was or its condition when he acquired it. However, it is now in a very fragile state and is statically displayed indoors, protected from further damage. One side panel has been removed so that visitors can see the internal mechanism, but rotation would be damaging, as some of the drive belts have knots holding them together. Consequently, no one is allowed to touch it. However, visitors can now see the model working outdoors exactly as intended because a talented volunteer helper at the manor has made a working replica!

Almost twenty years ago, Barry Silcock spent around six months examining and measuring the original model and then, over the next seven years, built and refined a close replica. He donated the replica to the National Trust in 2009 and continued to repair and maintain it for another ten years. Barry's replica model is mount-ed on a post in the orchard at Snowshill Manor, where it greets visitors with the stunning sight of the Small Army doing its thing (**photo 10**).

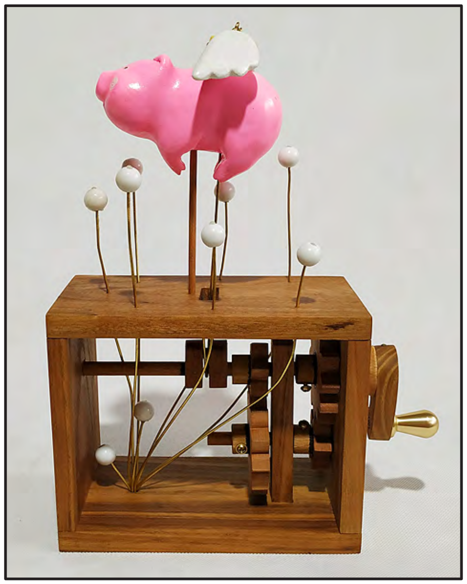
Someone eventually noted that the wind doesn't always blow when the visitors need it, so a small, geared internal electric motor and battery were added so that the model would work for the whole day. Last summer the windmill stopped working, due to some internal breakages, and it was taken down for repair. On examination it turned out to need a full makeover, which was carried out over the winter. The model is now back in its place in the orchard at Snowshill Manor, and we hope that Barry's incredible achievement will continue to enchant visitors for many years to come.

Snowshill Manor may be visited online at *https://tinyurl.com/Snowshill*

# Is your automaton broken?

**by Li Zhanlong**
Shijiazhuang, Hebei Province, China
Photos by the author

## Suggestions for preventing or mending wooden-automata problems



1. This little flying pig's gears are stuck.

2. The flying crane's up-and-down motion is not smooth.

3. The cams are stuck on this one.

I started learning how to make automata in the spring of 2019. So far, I've made forty-seven of them. However, at this time, there are only fourteen that still operate properly. The rest of them are stuck, to varying degrees (**photos 1-3**). Where are the problems?

I looked at all of my work, searching for the places where problems have occurred, and I sorted them out. After a thorough analysis, I came up with some possible solutions. I found that the root of all my problems is the deformation of the material.

My automata are all wooden constructions, including the mechanical parts. Wood as a building material has certain disadvantages. It easily expands and contracts and its stability is relatively poor. When the temperature and humidity of the environment change, the wood will deform. Not only that, but wood of different densities and hardnesses will deform differently.

### Examining the problems

When the wood begins to deform, which parts are the most susceptible? I have found the following places to be the most at risk.

**Gears.** When wooden gears (**photo 4**) expand, the gap between them narrows, which may cause them to seize. If the gear is handmade and the cutting is not accurate, the chance of error increases as the wood deforms.

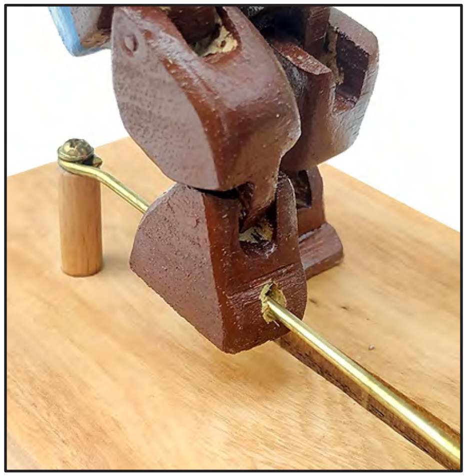
**The contact point between the rotating shaft and the shaft hole.** When we make holes for a rotating shaft, the hole diameter is a little larger than the diameter of the shaft (**photo 5**). When the rotating shaft and the board through which the hole has been made expand at the same time, the hole diameter becomes smaller and the rotating-shaft diameter becomes larger. At some point the hole will become too small and the shaft will seize.

**Sleeves.** A sleeve or casing is generally used to guide the movement of a wooden stick in a certain direction (**photo 6**). The stick has a reciprocating motion, moving back and forth in the casing. The deformation of the wooden casing can reduce its inner diameter, affecting the movement of the wooden stick.

**Crank mechanism under heavy load.** When we make a crankshaft from wood, we may find that an odd-shaped structure is unstable (**photo 7**). When the load on the crankshaft is too large, the ends can be unevenly stressed. After much use, the crankshaft may be easily broken.

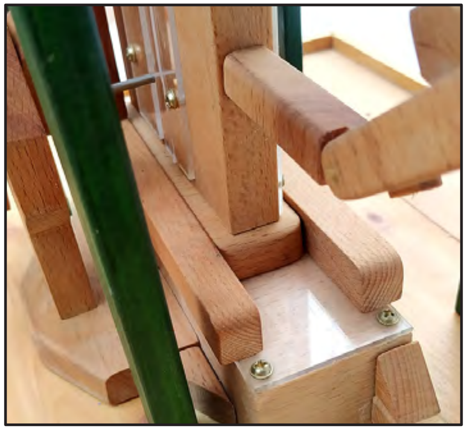
4. Wooden gears can bind and lock if they become deformed.

5. If wooden shafts and bearings expand, friction is created.

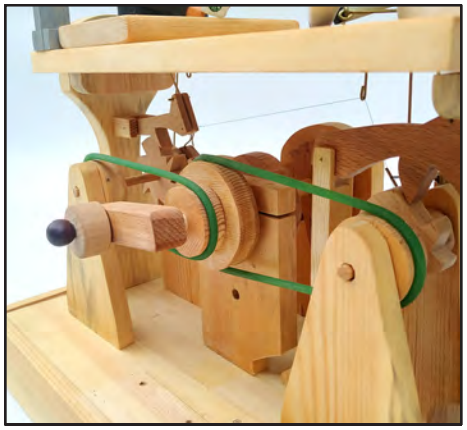


6. Shafts that run in sleeves can bind if the sleeves expand.

7. Odd-shaped crankshafts or cranks with cams can experience intermittent heavy loads.



8. Mechanisms that operate in confined spaces must have freedom of movement.



9. Belt-driven pulleys can experience wear in their shaft holes, causing timing problems.

**Mechanisms in tight spaces.** When certain mechanisms are made, a small space is allowed, to ensure that the parts move smoothly (**photo 8**). The above-mentioned sleeve is an example. Another example might be if a rocker arm is too close to a board. If the board expands enough to interfere with the rocker, the rocker's motion will not be smooth. This is also true if a gear is too close to the board.

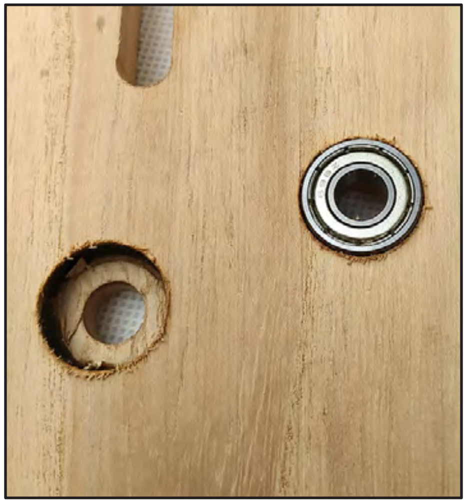
**Pulley and belt.** When a pulley is actuated by a belt (**photo 9**), its rotating shaft will bear against the shaft hole. The resulting frictional force will be amplified as the wooden shaft deforms, thus deforming the hole. Eventually, the pulley spacing becomes compromised, the belt becomes loose, and the pulley cannot run synchronously, altering the action of the automaton.

## Find the problem, find the cause, propose a solution

**Gears.** A gear set should be designed from two angles. First of all, the gears should be cut as accurately as possible to ensure that they run smoothly together. CNC can be used for this, if possible. Secondly, wooden gears should be of solid wood of high density and high hardness, and be finished with wax. Of course, you could also make your gears from imported eucalyptus or birch plywood, which is more stable, or you could use metal.

**Rotating shafts.** Install bearings wherever shafts and shaft holes are involved. These could be of metal (**photos 10** and **11**) or plastic. I use ball bearings. Bearings will not only reduce the friction of rotation but will also prevent the expansion of the shaft from jamming.

**Sleeves and confined spaces.** For any wooden structure that in-



10. Metal ball bearing set into the wood.

volves a tight space, try sealing the wood with wax. Waxing is a technique invented by ancient Chinese carpenters to prevent wood from deformation and cracking. Wood deforms because wood fibers easily release and absorb water. Cooking the wood in hot wax can remove the air and moisture in the wood fibers, and will introduce wax into the fibers instead, so that the wood will no longer deform and crack with changes in the outside temperature and humidity. You could also replace the parts with other materials that are not easily deformed, or increase the gap space between the parts.

**Crankshafts.** Design the crank-

11. This piece is equipped with bearings, and the operation is smooth and stable.

shaft and its structure so that it is not under a heavy load.

**Pulleys.** Try not to use pulleys or gears. Certain actions can be attained by other means. Try to use simple mechanisms to achieve the correct action. The simpler the structure, the stronger its stability.

## Preventive measures

If parts are damaged during the lifetime of your automaton, can the machine be disassembled for repair? I see that many designers abroad often use mortise-and-tenon joints to make wooden boxes for the mechanics of their automata. Once the wooden box is glued and fixed, it cannot be disassembled. When there is a problem with the parts inside, this can only be solved by first destroying the wooden box, which is needless and painful for any automaton maker or collector.

As automata makers, we can use screws to assemble our boxes and also for some parts that are too complicated or that are prone to wear. This may sacrifice the beauty of the appearance somewhat. However, from a practical point of view, this method makes it easier to maintain and extend the life of the machine, which can be easily disassembled.

As a wooden-automaton maker, I really like the texture of wood and its unique attributes. Wood is easy to work with and its cost is low, which is why I chose it for my work. I hope that the wooden automata I made will have long lives and still be able to operate properly after many years.

Take a look at your own automata. Do they still work well? If you encounter the same problems that I did, I hope this article will help you solve them.

# LEGO AUTOMATA

## An interview with Daniele Benedettelli

**by Teun de Wijs** • Amsterdam, Holland
Photos courtesy of Daniele Benedettelli, except where noted

One of the nicest things about the internet is that it allows you to find and meet people with similar interests. Italian LEGO artist/engineer Daniele Benedettelli and I met online after he posted a YouTube video of a new and much-improved version of one of my own models. And, after seeing his mind-blowing website and portfolio, I was happy to learn that he was not only a crazed genius but a nice guy, as well.

Benedettelli has been described as a modern Renaissance man, and indeed, the term *homo universalis* fits him quite well. He is an

Photo courtesy of Francesco Rossi—*fr-ph.com*

Daniele Benedettelli, with one of his most ingenious creations—the drawing robot, *LEGONARDO*.

engineer, programmer, inventor, robot builder, musician, high-school teacher, and active father of two. He has also drawn comics, written books, and composed rock operas. Fortunately, he was more than happy to take a moment off from his busy schedule to talk about his love for automata.

**Teun:** Hi Danny, thanks for taking the time. Could you tell us a bit about yourself and what you do?

**Daniele:** My name is Daniele Benedettelli. I'm 36 and I live with my wife, Lucia, and my two children, in Toscana, Italy. I have a MSc Degree in Information Engineering (Automation curriculum), which, in short, makes me a robotics engineer. My simple-to-explain and credible job is teaching electronics and robotics in high school. My other, hard-to-explain, and incredible job is being a freelance LEGO designer. I design custom LEGO models for clients all over the world.

I don't like static LEGO models, such as sculptures and houses. I mainly design functional projects, from small robots and contraptions for companies working in the field of after-school education and entertainment, to large, working industrial models for big companies.

Photo courtesy of the Strong National Museum of Play

1. Zilotone (Wolverine Supply & Mfg. Co. circa. 1930). It used a windup motor as its power source, and was sold with a set of interchangeable cams that allowed the clown to play different melodies. Benedettelli's *Ludwig* automaton was inspired by this charming and inventive tin toy from the past.

**Teun:** You have a background in robotics, but what got you interested in automata? Do you remember the first automaton you ever saw? Who inspired you in this field?

**Daniele:** As a kid, I saw a TV documentary about the *Tympanum Player* by Peter Kintzing, and Jaquet-Droz's set of three automata—*The Musician*, *The Writer*, and *The Draughtsman*. I was mesmerized! Also, I love the work of Paul Spooner, especially for his humor and smart storytelling.

I shouldn't say this, but I hate programming! Sure, programming gives you the power to give machines a "soul," but large, complex projects are alienating in the end. I find the fact that every movement of an automaton is completely regulated by a finely crafted mechanism to be fascinating and timeless. An automaton will work even in the event of a blackout, by the romantic light of a candle. Maillardet's and Jacquet-Droz's artworks have survived for 300 years and still work! What will become of a computer-controlled robot in 300 years? Will we find the right batteries? Will the electronic memory retain its data? An automaton works by turning a crank—no software at all! I find this very relaxing and relieving.

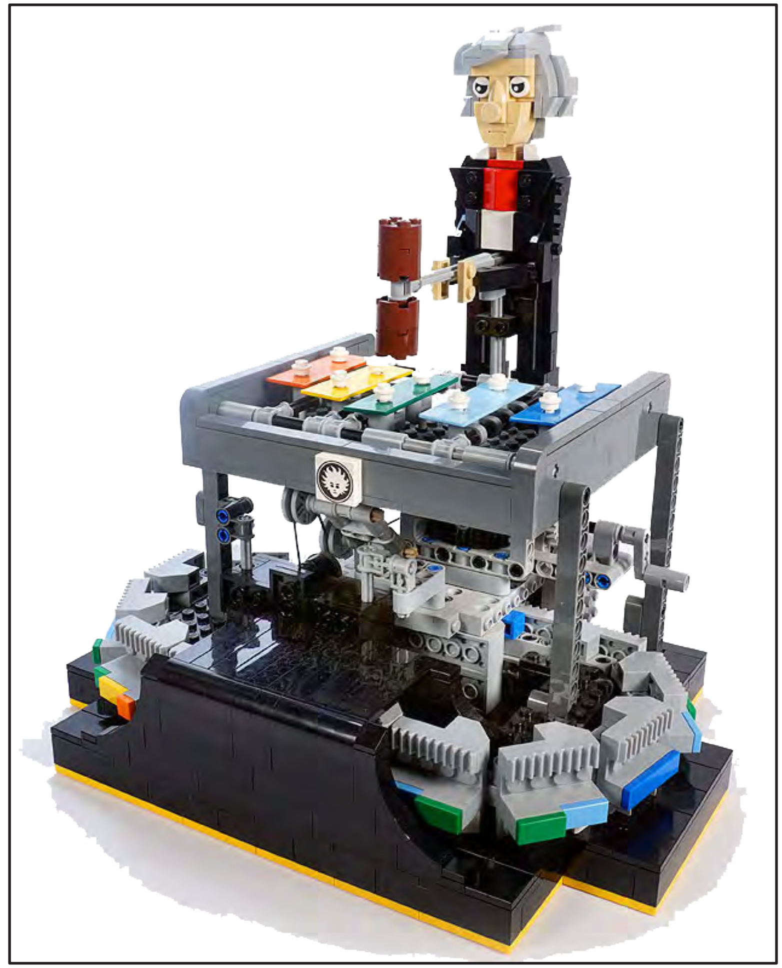
Right after my Dark Age of LEGO (a period of life when people stop playing with LEGO, or pretend they had stopped, like I did), I became fascinated by the LEGO Great Ball Contraption modules. In 2012, I started sketching a prototype of a glockenspiel-playing automaton, based on the old Zilotone tin toy (**photo 1**). I didn't get anywhere close to creating something functional, and thought it was impossible to achieve with LEGO. I started following the nifty kinetic sculptures by Jason Allemann. They were not super complex, but really well executed.

Then, my jaw dropped when I saw your LEGO *Wizard* automaton in 2017. So, it *could* be done! It was possible to create such complex and compact stuff out of old and common LEGO parts. I became obsessed by the mechanism, and spent days reverse engineering it. This took quite a lot of guesswork, and I eventually added something of my own, which resulted in my own wizard automaton, *Cycle of Life* (**photo 2**).

So encouraged, I finally dusted off my old idea based on the Zilotone, and in 2018 I completed *Ludwig*, a five-key glockenspiel-playing automaton (**photo 3**).

**Teun:** Wow, I'm glad I helped to get you back into the realm of automata! I think your approach to new models is quite fascinating. Could you tell us something about how you work?

2. *Cycle of Life*. A YouTube video on an automaton by the author inspired Benedettelli to build his own elegant and improved version. This magician nods his head, flicks his wand, and reveals the head of a LEGO minifigure successively going through the stages of life, from the cradle to the grave.



3. LEGO glockenspiel automaton (*Ludwig* version). Apart from the xylophone pieces, this amazing model is 100% LEGO. When the crank is turned, Mr. van Beethoven bangs out the main "Ode to Joy" theme from his Symphony No. 9. His movement is timed and "programmed" by means of an ingenious, colorful rotating chain at the bottom.

**Daniele:** My approach to a new creation is simple to describe but hard, if not impossible, to teach. I get an idea or a commission, I sometimes sketch something on paper, and I start to tinker. Then, at some point, it's like my creations come out on their own. You might think I'm just bragging, but believe me, I'm not. This just happens when I can get into the so-called state of flow (or "optimal experience," to quote Mihaly Csikszentmihalyi). This requires time, and no distractions around me. Sometimes even listening to music can be distracting.

When dealing with a mechanism, or something functional in general, I need actual LEGO elements at hand to test the kinematics, action of gravity, flexibility, tolerances, etc. For simple static models, big or small, I can just sit at the computer and model the creation using CAD, without touching a single LEGO brick. From there, I create a wish list, buy the parts online I'm missing, and finally get to build it. I have a lot of LEGO parts in my studio, but not of many kinds; my wife does not believe me when I tell her I'm missing that tiny part, in that specific color.

**Teun:** Ha, ha. Apart from the CAD work, it seems that we work in very much the same, intuitive way. And yes, what you call "the state of flow" is an amazing but indescribable feeling. What makes LEGO your weapon of choice? What do you consider the main advantages and/or disadvantages of working with LEGO parts, as opposed to other materials?

**Daniele:** From time to time, I resort to 3D printing and custom electronic components, especially for commissioned works that can be hybrid, because the clients just want a machine that's robust and durable with a LEGO finish. Otherwise, for all the rest, I try my best to stick to the pure LEGO medium for many reasons. First, I like to work within the constraints of the LEGO building system. Second, over time, I grew to strongly believe that if I did the same things with 3D-printed parts, metal, or wood, few people would be interested in them. When I see some marvelous automaton carved in wood, I appreciate the artwork, but I see it distant from my skills. Seeing something incredible built with LEGO conveys the idea that something magic has been done with mere toys. Children and older kids think, "I could do that too!"

However, in the end, it's just a matter of personal taste. I would not like to showcase a Timberkits or UGears model at home, but a colorful LEGO automaton on my cupboard? Surely, yes!

**Teun:** You are incredibly diverse and productive. What have you been building lately?

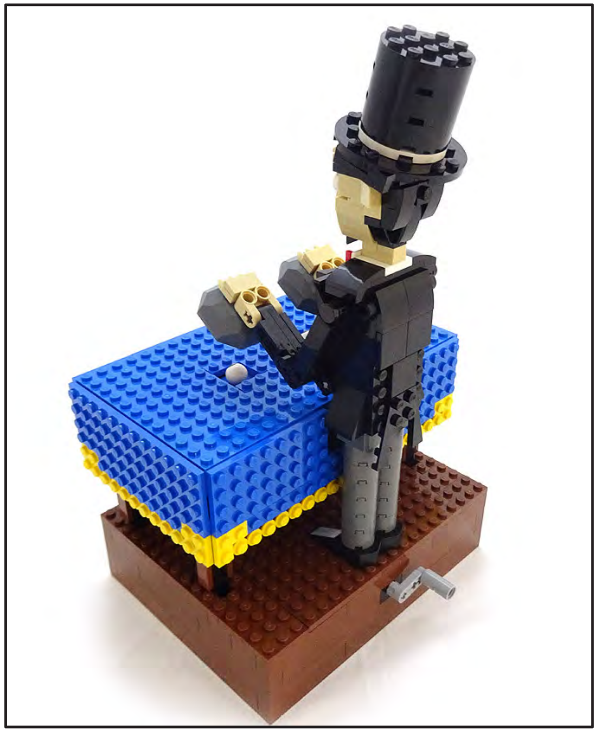
(Text continued on page 50)

*AT-ST* automaton. After LEGO acquired the rights to produce Star Wars sets, the world was also flooded with Star Wars fan models. Sadly, they are hardly ever animated, but Benedettelli used the Force to build this AT-ST scouting robot. It not only turns its armored body, but also sways from side to side while walking, and that adds a lot of gusto to its stride.

LEFT: Benedettelli has built Rubik's Cube-solving, walking, shooting, crawling, rolling, car- and duck-building robots, but arguably his most amazing model stems from his early affinity for classic 18th century automata. *LEGONARDO* is a portrayer robot that can be programmed to draw virtually anything (even something as complex as its builder's hairstyle). Benedettelli's custom software makes *LEGONARDO* draw contours first and add shading and details later, making it seem as if we're seeing a true artist at work.

RIGHT: *LEGONARDO* went through various incarnations during its developmental stages, but this much-smaller prototype deserves mention in its own right. This cute yellow robot had great potential as a drawing robot but could only draw small portraits, and Benedettelli found it too slow for live-demonstration purposes.


*Magician 2* automaton. While displaying some of his models in the Museum Speelklok (Utrecht, Netherlands), Benedettelli was allowed a tour of the museum's archive of antique mechanical marvels, which inspired him to build this model of the classic cups-and-balls magician. Note the empty space under the table—no small feat to achieve with LEGO!



4. While playing with his daughter, Benedettelli discovered a DUPLO figure that made a squeaking noise when its head was turned. He used this as the basis for the world's first 100% analog musical LEGO automaton, the *Chirping Bird*. Apart from producing sound, the bird also moves its head, beak, tail, and wings in a lively random fashion, through the clever use of gears.

(Text continued from page 48)

**Daniele:** My last effort (July 2020) was a pure LEGO chirping-bird automaton (**photo 4**), with four movements, and a real chirping sound generated by an old LEGO DUPLO figure. The various movements are periodic and each is repeated after a predictable number of crank turns. But the gears that drive the movements are chosen so that the ratios are coprime. Putting it simply, the exact same combination of movements will repeat only after hundreds of crank turns, resulting in a pseudo-random behavior of the automaton. My next automata on the to-do list are secret (I also have a series in mind), but my time is limited now, as I am working on a new publication based on LEGO products.

**Teun:** One last question: If you had unlimited time and bricks, what would be your ideal LEGO automaton?

**Daniele:** Silly project: I would love to invent an automaton that randomizes and writes funny insults.

Serious project: I would love to design and build a modular symphonic orchestra (1:8 scale), with moving musicians playing in sync. How cool would that be? Any patrons out there wanting to support me? Ciao! AM

## Links

Daniele Benedettelli website and YouTube channel
*https://robotics.benedettelli.com/*
*https://www.youtube.com/c/DanieleBenedettelli/featured*

The Zilotone in action
*https://www.youtube.com/watch?v=CE6Lc7B5b5Y*

State of flow
*https://en.wikipedia.org/wiki/Flow_(psychology)*

# Get Moving

## Spider Roundabout

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

*There was an old spider who lived in quite a stew.*
*She had so many children, she didn't know what to do.*
*So she spun a nice roundabout from silken thread,*
*And whizzed them all around until she put them to bed.*

Mum Spider was worried about the kids just hanging about and wondered what she could do to keep them busy. Then she saw a bare tree and thought it would do nicely. With a little bit of work, there would be room for everyone.

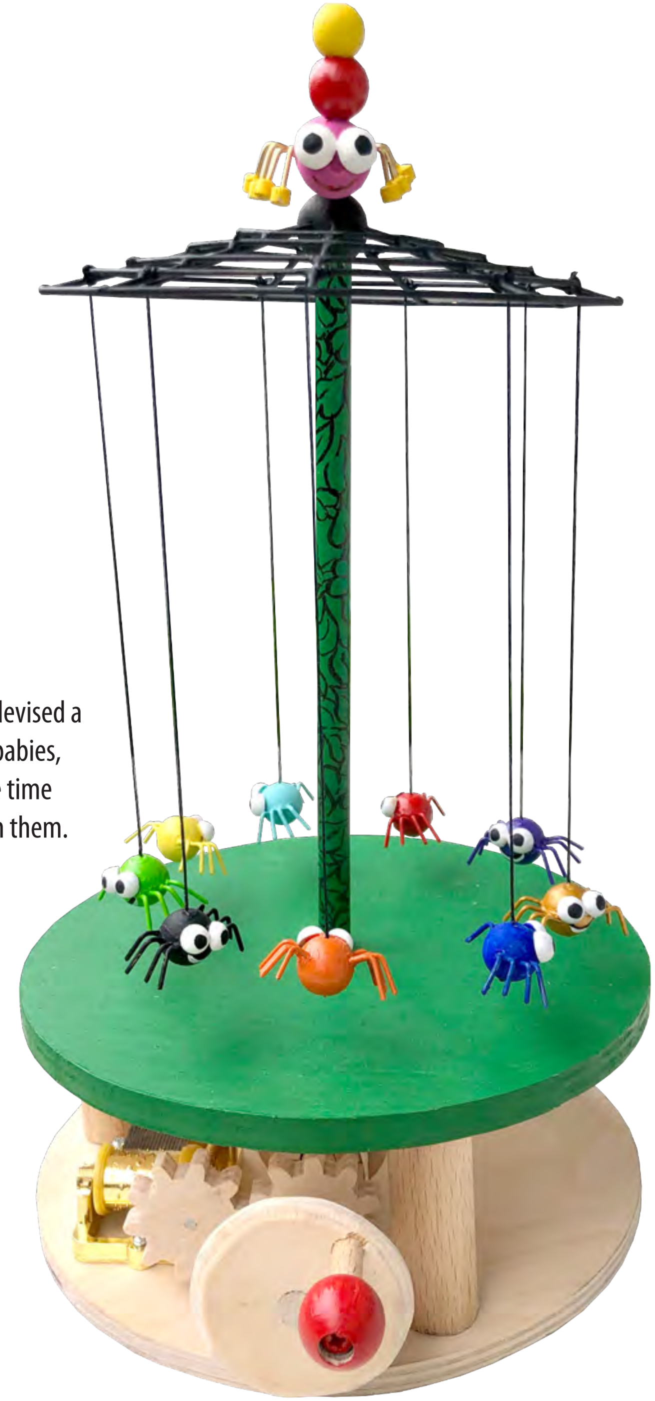
### The technical brief

The mechanism to turn the roundabout needed to be as simple as possible. It also had to drive a small music-box mechanism that plays "Die Berliner Luft," a tune that every Berliner knows, about Berlin's fantastic air.

Spiders can have phenomenally large families, but I decided to go for a token number of nine baby spiders. What was good enough for Queen Victoria and Prince Albert is good enough for me. They had four boys and five girls. I will leave it to the viewer to decide on the sex of the various members of my little family. Brass rods are strong enough to make the web, and wood will do for the rest.

### Making the family

The baby spiders are uncomplicated creatures. They are comprised of a small, pre-drilled wooden ball for the body, two wooden hemispheres for their big, appealing eyes, and a piece of bent brass rod for each of their



Mum Spider has devised a diversion for her babies, while at the same time keeping an eye on them.

eight legs (**photo 1**). For the strand of web from which they dangle, I used a cotton thread glued into the predrilled hole, which I then filled with a piece of 3mm (⅛") dowel (**photo 2**).

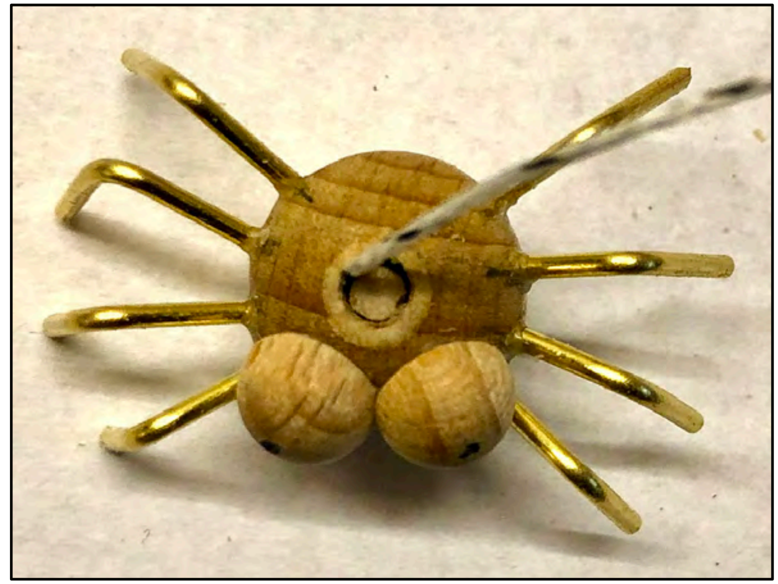
Mum Spider is larger, of course. She has a stylish hairdo and shoes, and a 3mm hole in her underside, for attaching her to the top of the tree (**photo 3**).

As there are nine spider children, the web had to have nine segments. Mum Spider needed a bit of help to make the web, so I used slim brass rods, carefully bent to shape (**photo 4**). I soldered them together, arranging them in a slight umbrella shape.

The web is mounted into a wooden ball that just rests on top of the tree, which has a 3mm dowel set into the center, glued safely in position to hold Mum Spider. The ball is not glued in place—it is turned by friction. This allows mum to jig around and issue instructions to her brood. It also allows the web to coast gracefully to a stop when the tree stops turning.

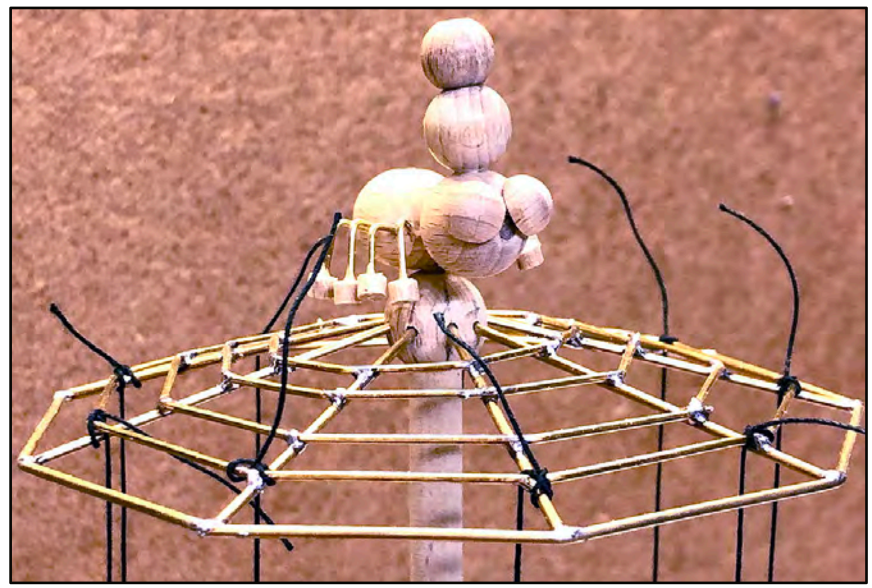
On a circular base, I mounted a small music-box mechanism that I bought for a few euros. After cutting off its bent-metal handle, I could push on a wooden cog,

1. The parts to make a baby spider. The wooden ball that forms the body has been predrilled to accept the legs.



2. A finished baby spider, waiting for its color. Note the small piece of dowel in the hole in its body that retains the string.

3. Fashion-conscious Mum Spider, sporting a fancy hairdo.

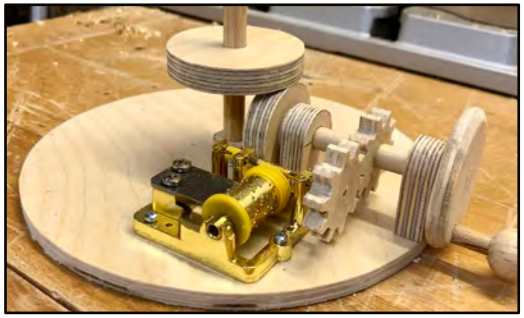


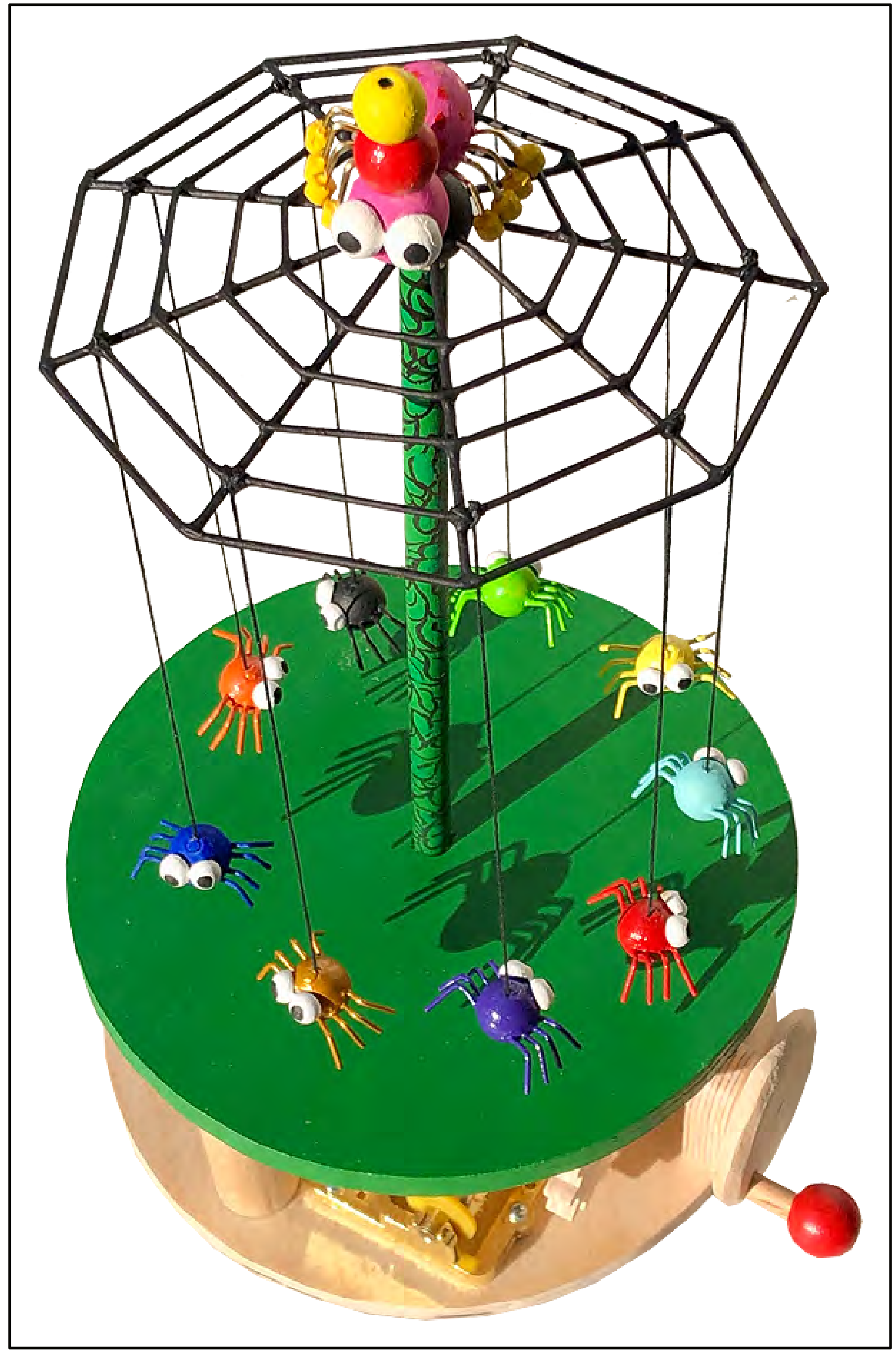
4. The finished web. The web ball on which Mum sits is loose on its spindle. When the tree revolves, so does the web, by friction.

which I cut using my bow saw. An identical cog drives it when the handle is turned (**photo 5**). Fortunately, the music mechanism doesn't mind if you turn it the wrong way. It just goes click, click, instead of playing its merry tune.

Turning the handle also rotates the drive wheel, which is in frictional contact with the larger wheel glued to one end of the vertical tree. This can also be seen in **photo 5**. I added a wooden bearing to the base, through which the tree passes. This, together with the hole in the floor of the base, keeps the tree nicely vertical.

The upper part of the base rests on three fairly chunky pieces of dowel. Careful alignment is required to ensure free rotation of the tree before things are glued together. AM





ABOVE RIGHT: 5. The base mechanics, with the music-box mechanism. Gears were hand cut with a bow saw.
BELOW RIGHT: 6. The assembled roundabout, about to be tested.
FAR RIGHT: This finished roundabout, ready for play.

A video of the *Spider Roundabout* can be seen here: *https://tinyurl.com/SpiderRoundabout*

# BUILDING BLOCKS

## Combinations

**by Paul Giles** •Sun City Center, Florida, USA

Drawings by Marc Horovitz, except where noted

Linkage systems can offer a great number of new motions. Links and pins are also much easier to fabricate than cutting gear teeth or producing cams. But just how do we make a link system from scratch? There is good news—we don't have to reinvent the wheel. Go back to the continuing mantra of this Building Blocks series. Close your eyes and think about the result that you want to achieve, then solve your problem the way that engineers are trained to work: backwards. Look at the end motion that you need for your automaton project. Then figure out how to reach the basic or main part of that motion. This first, coarse motion is often the hardest part, so just study all the building blocks and look for something close, not perfect.

As you move forward to the next design step, you can combine linkage systems with gears, cams, and other building blocks to pause motion, redirect it, or create a flurry of motion. For instance, adding a wedge to the scissors movements in the last article was an easy example of combining two automata tools.

Let's look at just two examples that will get you started on your own projects. First, imagine a champion boxer in the ring. He's waiting for just the right moment to throw his famous knockout punch. The boxer throws a series of left jabs, all the while feinting with his right. He sees an opening, and the fight is over!

To make both of the boxer's arms move, your first thought might be of a six-bar linkage (**figure 1**). The sixth bar in the illustration simply connects to the power input—a rotating wheel. Looking at the motion from this linkage, we can visualize two problems. The motion is a pure left-right-left-right, which can quickly get boring. The second problem is that each punch goes the same distance and at the same speed. A real boxer doesn't move that way.

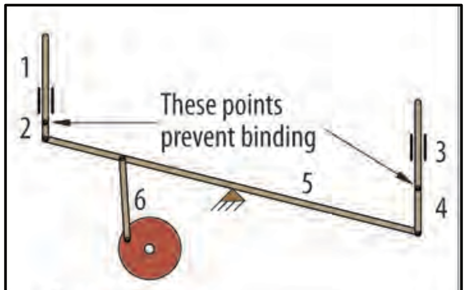



Figure 1

A good second attempt may be to replace the central pivot point with a few gears (**figure 2**). With this approach, more jabs can be thrown with the left than hard right punches. You can pick any ratio of punches that you want by simply changing the gear ratio of the two gears attached to the links.

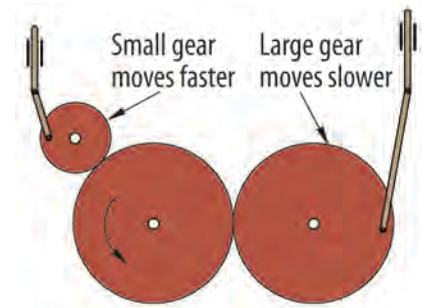



Figure 2

But there are still two problems. The smaller gear that is needed to throw more of the jabs will also throw them faster. Worse, the knockout punch will move at the speed of growing grass—not good news for the champ. What to do? You can consider several tools. Among them may be another gear to increase the speed of his right hand. Other options include a lever or the scissors-and-wedge device, as shown last time. A lever can increase the speed, as well as the distance, if the pivot point is off center (**figure 3**).

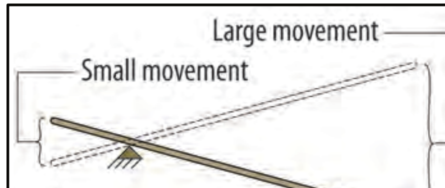



Figure 3

The second problem is a little harder to solve. Even if one hand jabs four times for each punch from the other side, the boxer will also throw his winner at exactly the same moment as that fourth jab. That's just not natural. This time a pair of cams would best solve the problem (**figure 4**).

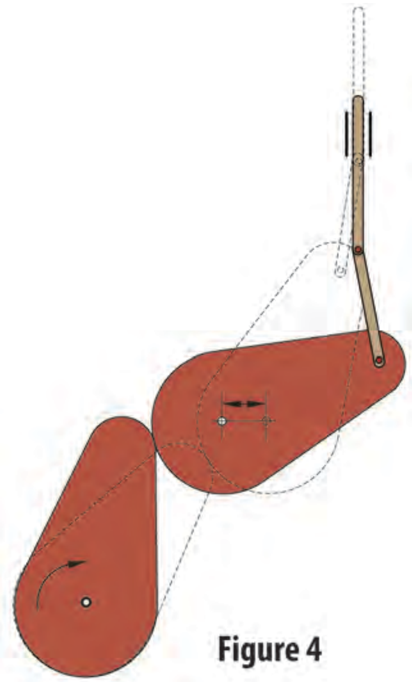


Figure 4

There is a twist, though. One cam is being used to drive another cam for that awesome right. Never limit yourself only to the motions described on so many internet websites. They can only provide you with early inspiration. Methods and combinations are your own design. That is why Building Blocks continually emphasizes the all-important step of closing your eyes and visualizing the motion.

This new cam arrangement could even be used for the left jabs, but there is still work to do to make everything feel natural. Both cams in **figure 4** will always move in a circle. Look first at the left jabs. All that you have to do is to add a few more bumps to the left-side cam, slightly undercut the driving cam, and add a light spring to return the driven cam to its ready position (**figure 5**). You also just solved the gear problem of having the wrong punching speeds.

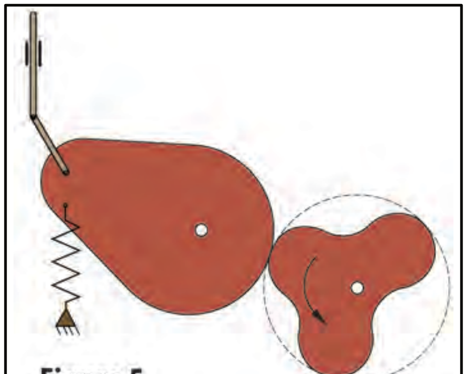


Figure 5

There's now just one last item from our list of wants. The boxer needs to wave his awesome right fist around while landing those jabs. As you get to the end of a challenging design, and if you are working with a good solution, then the final pieces of the puzzle often fall right into place. You simply need to also add a few bumps to that right cam to fake that fist forward. Again, a light-duty spring will then return his fist to the ready position (**figure 6**). Just be sure to slightly undercut the driving cam so that the punch cam will return freely.

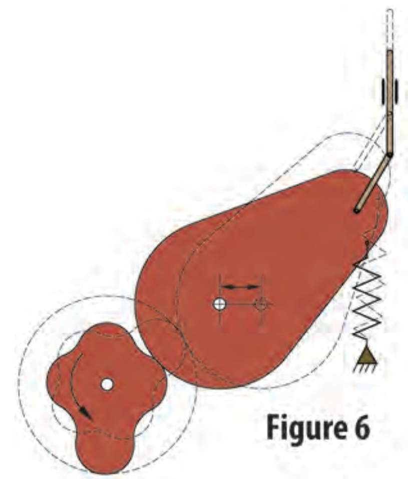


Figure 6

There's one final but easy-to-miss detail left. The timing of the jabs and that big punch must be maintained. If you only use cams for your automata, then after even a dozen or so knockouts, there will be some slippage in the arm movements. This can be fixed forever by putting gears back in. Toothed gears will keep the champ at the top of his game. The gears would only be used to control timing, not speed or movement (**figure 7**).

As a second example, imagine a flock of birds in flight. Some circle left, some right. A few birds fly

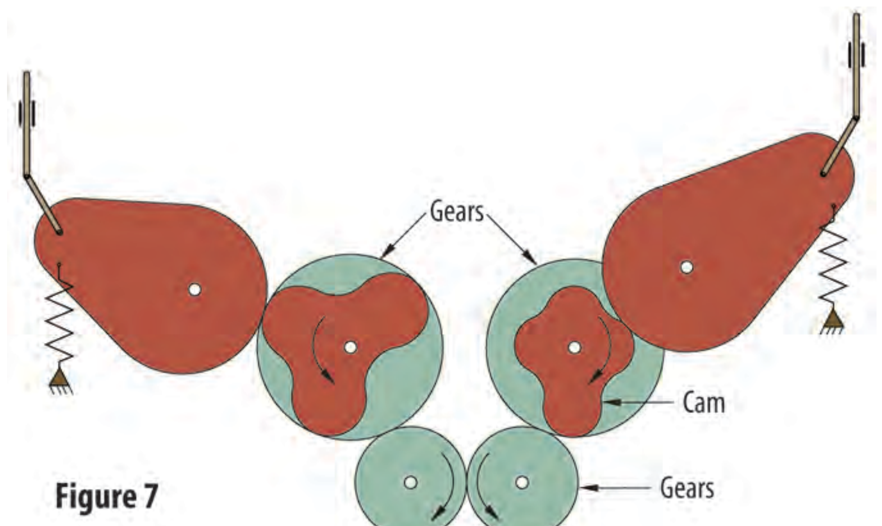



Figure 7

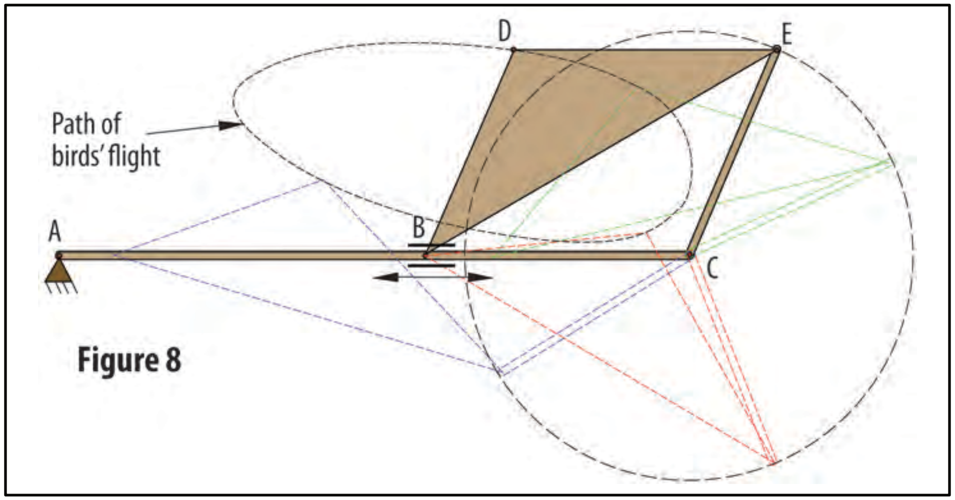


Figure 8

larger circles than others. Those will really not be circles, but more pleasing casual loops. Putting all of the birds on gears would simply make them look like a clock.

The same approach of using several small steps will be used to make those birds fly. A first thought might be to attach each of those birds to a gear and go right into the build. Visualizing their motions again reveals two kinks to work out. Birds on basic gears have all the excitement of watching the second hand move on a watch. The other problem is possible interference of all of those flight paths—there can't be collisions in the skies.

Keeping the design process simple, we can begin with just a single bird, then work upward in complexity. The circular flight path could be changed by using egg-shaped cams rather than round gears but let's try to build some wow-factor into the project. Later, we will also want to slowly move all of those flight paths as a system of birds across the entire sky.

For many of us, the often-hidden portion of an automaton is every bit as exciting as what is outside the box of movements. You can create an impressive-looking oval flight path with a five-bar link system (**figure 8**). These links combine several tricks that were shown in earlier link systems. First, change one link to a slider, then form a rigid triangle with three of the links. The tip of that triangle will create the casual oval movement. Point D will describe a closed flight path for the bird. Adjusting links B-D and/or D-E will alter the shape of the path. Adjusting any of the A, B, C, or E points will alter the location of the closed path.

Now that a fun design for the moving bird has been settled on, it's time to add the next level of difficulty. The automation will feature nine flying birds. We do not want to repeat the link design nine times. There wouldn't be room and we also want to avoid anything that looks too complicated. What can be done is to create three groups, each with three birds. If the single point at the top of the triangle, point D, is replaced by three rigid arms, all nine birds can fly with only three mechanisms. An added benefit is that, by offsetting that triangle top with different arm lengths, each of the three new paths will all be slightly different.

By completing these three identical groups of birds, construction is also greatly simplified. Any guides or templates used for one piece is already in place for the other two. The simplest way to join the three units together is again with a set of gears. If a sun-and-planet gear arrangement (**figure 9**) is chosen, we can take

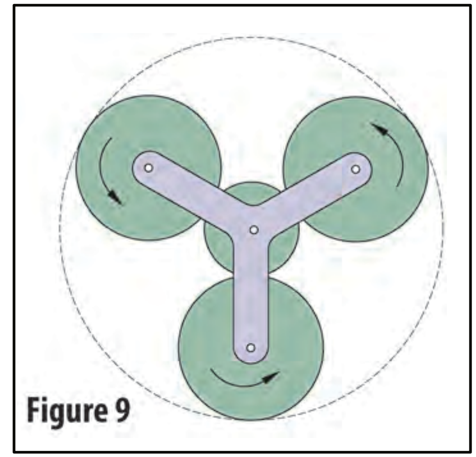


Figure 9

care of two of the three final tasks. We provide efficient power to all three bird units and we also cause all three of the groups to orbit the sky, as the individual birds also fly in their own loops. All that's left is to add one extra gear to one of the planet gears, to reverse the direction of one of the flights of birds (**figure 10**).

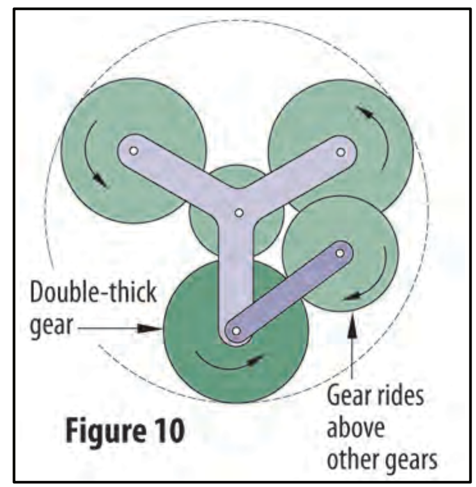


Figure 10

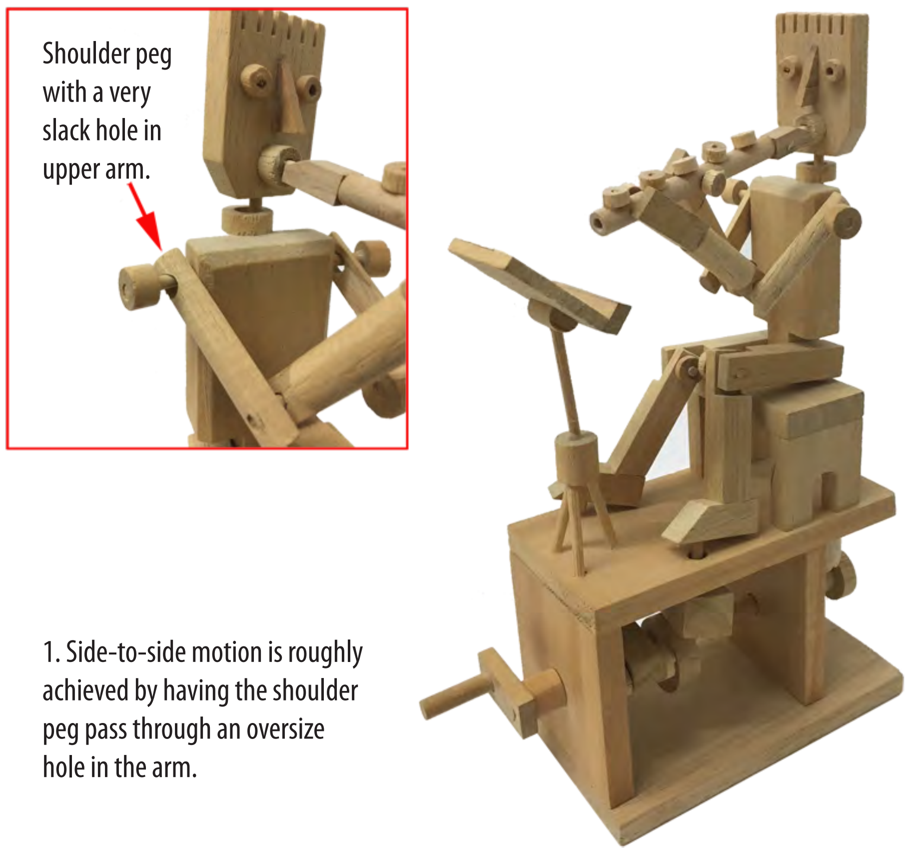
# AUTOMATA FOR BEGINNERS

## Universal or "multiple direction" joints

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

A universal joint—also called a U-joint—is one that allows movement in more than one plane or in a rotary motion. Our shoulders are a sort of universal joint (we can move our arms all around), as opposed to our knees, which can only bend backward and forward. Different materials allow for different sorts of universal joints. Metal and plastic U-joints can mimic the skeletal ball-and-socket joint, but with wood, we have to take a different approach.

This challenge has been much on my mind recently, because we at Timberkits are in the process of designing a series of woodwind- and brass-instrument players, and we want their arms to be able to hold and move a range of instruments in different ways—to lift them up and down, sway them from side to side, etc. I will start by exploring these shoulder issues and then look at some other forms of universal joints.

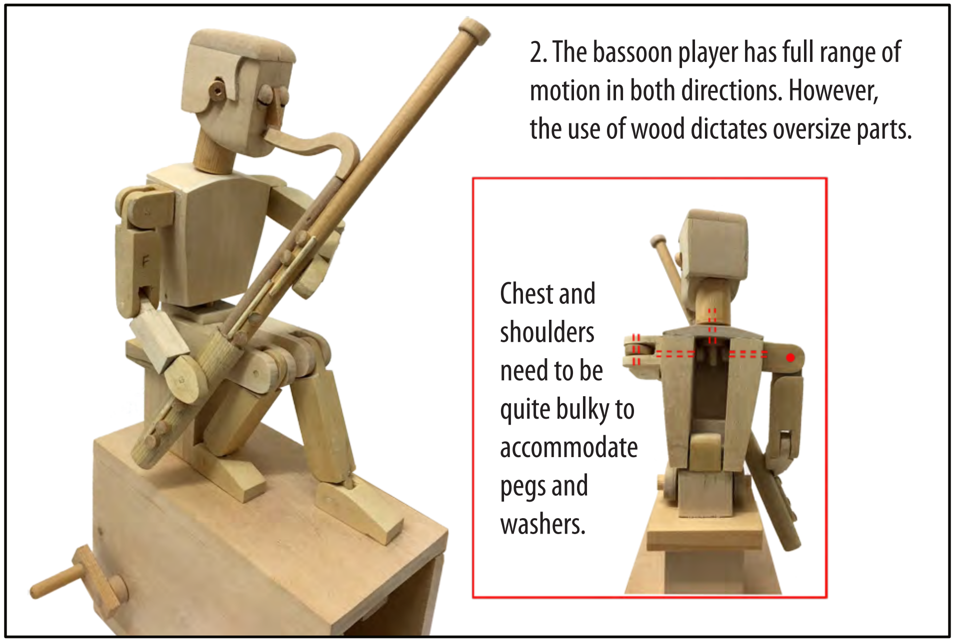



1. Side-to-side motion is roughly achieved by having the shoulder peg pass through an oversize hole in the arm.

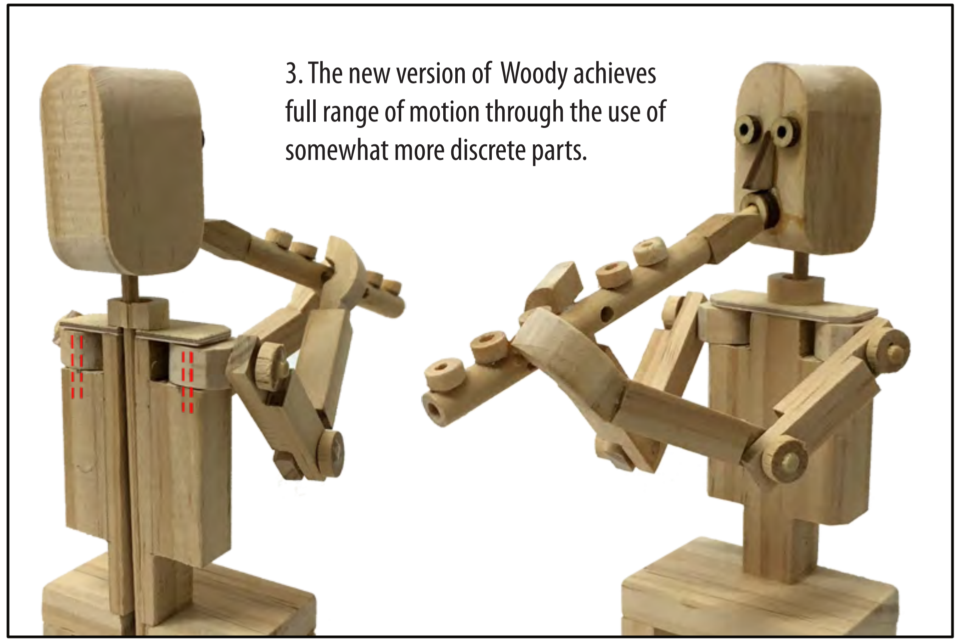
The first woodwind musician made by Timberkits was Woody Blues (p**hoto 1**), many years ago, when our design and construction techniques were more rudimentary. His shoulders were not made as true universal joints. They allowed for up-and-down movement because of the pin through a hole in his upper arm. However, limited side-to-side movement was only enabled by a lot of built-in slack. It did the job but left the shoulders looking a bit…peggy!

**Photo 2** shows a much more substantial model, with shoulder sockets that rotate with upper arms jointed into them, that can extend the range of movement. Both arms and neck are pegged into the body and held in the central cavity by little washers. This allows a very good range of movement but has the disadvantage of making the shoulders bulky and extended.

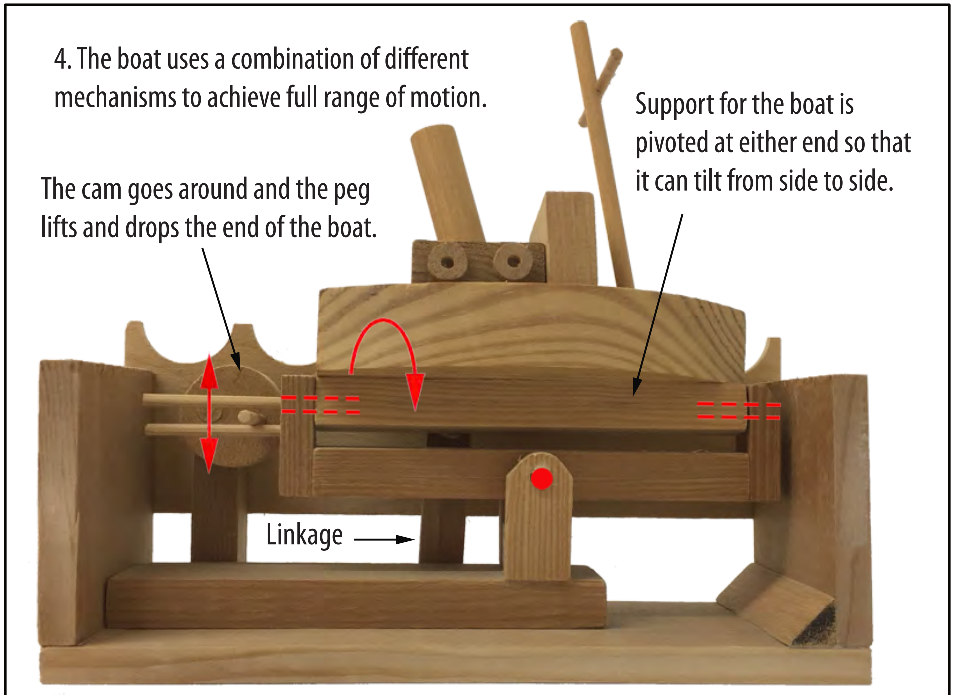
**Photo 3** shows another approach. This involves sections pegged into the body to allow the arms to move backward and for-




2. The bassoon player has full range of motion in both directions. However, the use of wood dictates oversize parts.



3. The new version of Woody achieves full range of motion through the use of somewhat more discrete parts.




4. The boat uses a combination of different mechanisms to achieve full range of motion.

ward, and then pegged into the shoulders, allowing the arms to move up and down.

One of the problems with wood is that intricate components have to have enough “meat” to have strength. Plastic and metal allow for finer detail and structure without compromising strength. As a result, what works on a chunky scale might not work on a smaller scale.

Shifting away from the figurative, **photo 4** shows an example of a multidirectional mechanism for a boat. I have taken the side off of the automaton to photograph it, so you can see its workings. This is beautifully simple.

By far the cleverest way of achieving movement in all directions is a Hooke joint. As you can see in **figure 1**, the section of the material used is thin, which is difficult to achieve in wood. It is effectively a two-way hinge but can also accommodate rotation via the shafts.

I normally try to illustrate these articles with our simpler models, as they are aimed at beginners. However, I am going to lapse here and show you a gorgeous bit of engineering in our Traction Engine (**photo 5**), which is the most elaborate Timberkits product to

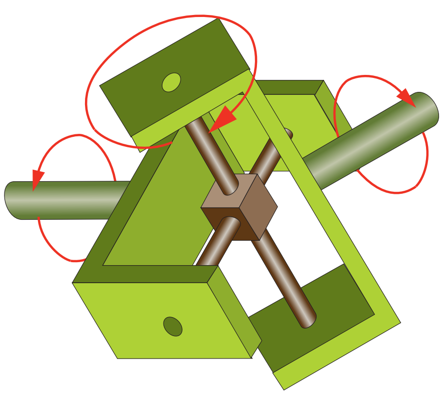
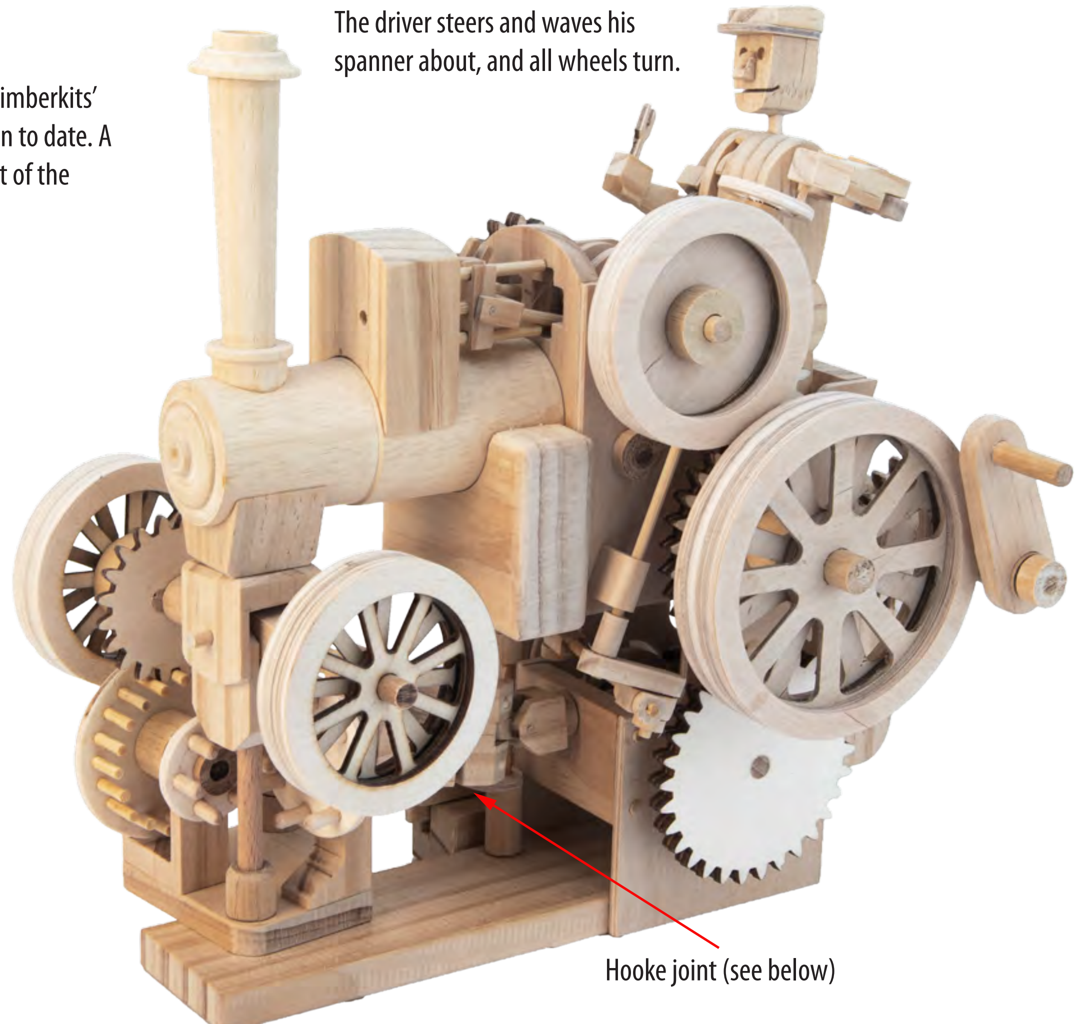


**Figure 1—Hooke joint**

date. I simply can't resist because it is so superb. Not only does it employ a wooden Hooke joint to allow the two ends to rotate and hinge at the same time, but it also allows the joint to open and close as its connection to the front axle moves backwards and forwards.

Building mechanical models is a bit like learning a language. The basic mechanical principles that I have been illustrating in my articles here are your vocabulary or phrase book. How do I make something go up and down? How do I tilt an object? How do I make it wave, wiggle, or twist? If you combine these "phrases" into more complex compositions, you will begin to master the wonderful world of automata motion. Go on—have a go! ◼

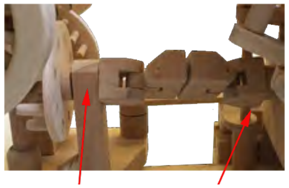
5. The Traction Engine is Timberkits' most elaborate automaton to date. A Hooke joint is used as part of the transmission.



The driver steers and waves his spanner about, and all wheels turn.

The front axle tilts from side to side, as if going over bumpy ground, and can rotate laterally for steering.

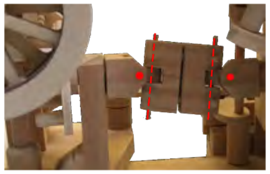
Hooke joint (see below)



Front axle connection

Driveshaft connection

See the joint opening up as the front axle connection moves away from the driveshaft.



Notice how the different parts of the joint can twist and turn at different angles to each other.

# The End