In the groove

Designing an unusual type of cam

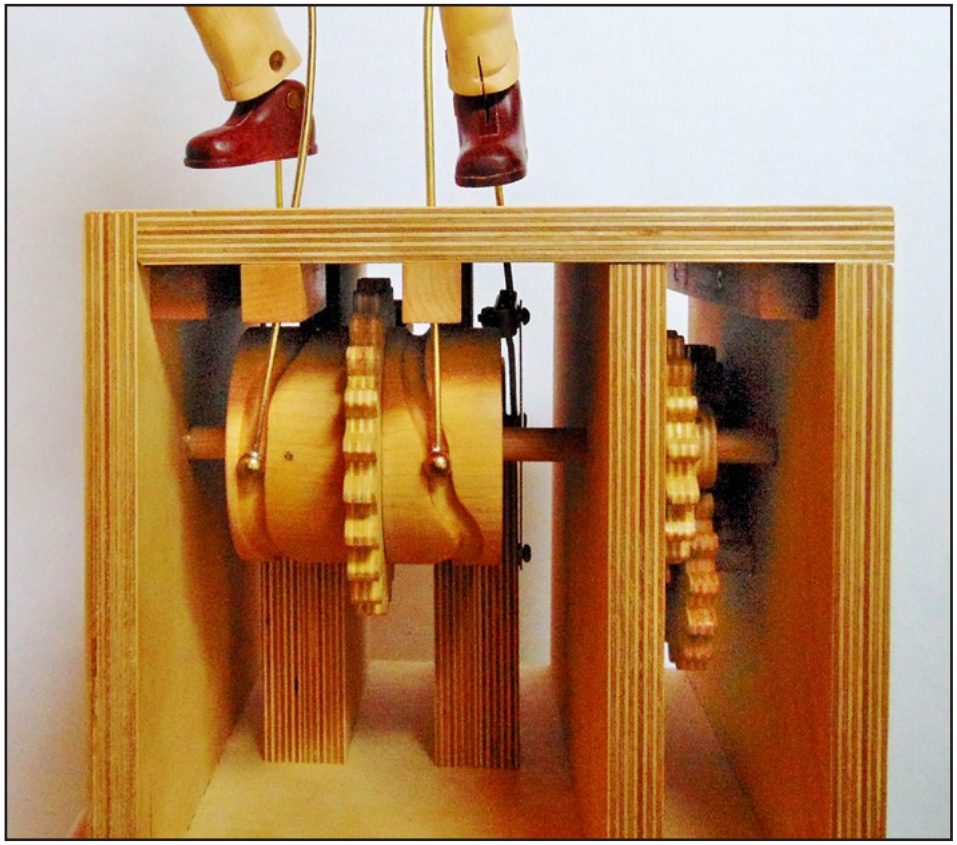
by Chris Hughes • Owen Sound, Ontario, Canada • Photos and drawing by the author

I am pleased to share the design and construction of the grooved-drum cams that I use to provide movement to the arms of my automaton, *The Swordsman*. The challenge was to provide independent sideways motion to each arm while the figure's legs moved forward and backwards.

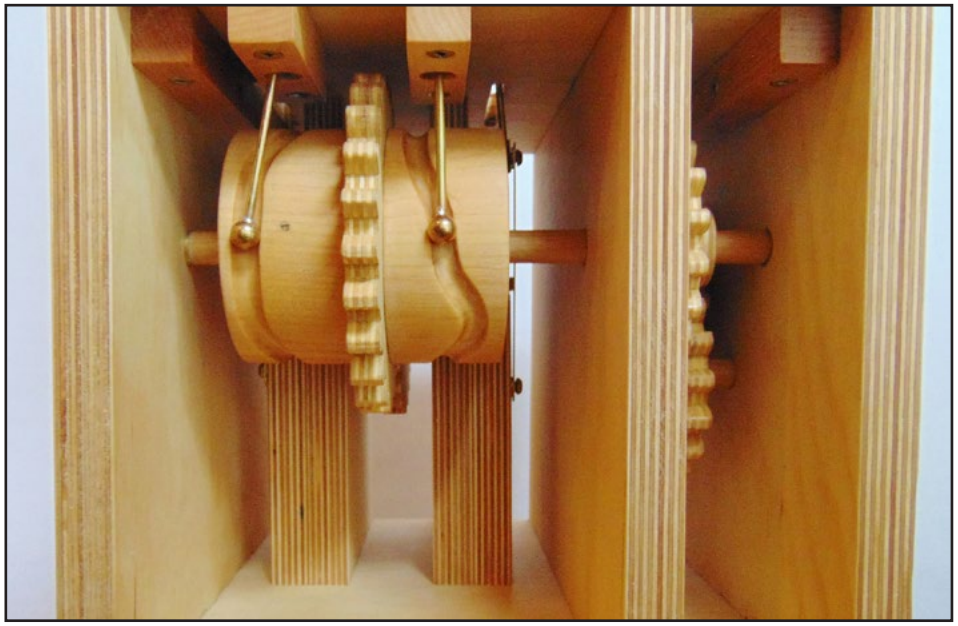
The inspiration for the grooved-drum cams probably came from mechanism 167 in the online version of *507 Mechanical Movements* (*AM* book review, March-April 2020, page 50). I used a pivoting follower rather than the linear one shown in the book. I had previously used a similar follower to move the arm with the coffee cup in my *Morning Walk* automaton.

The Swordsman was actually conceived as a tai chi master doing an approximation of a move called Grasp Bird's Tail. However, once it was completed, I didn't find it as compelling as I thought I would. So, with a new hand, a sword, a vest, and an optional eyepatch,

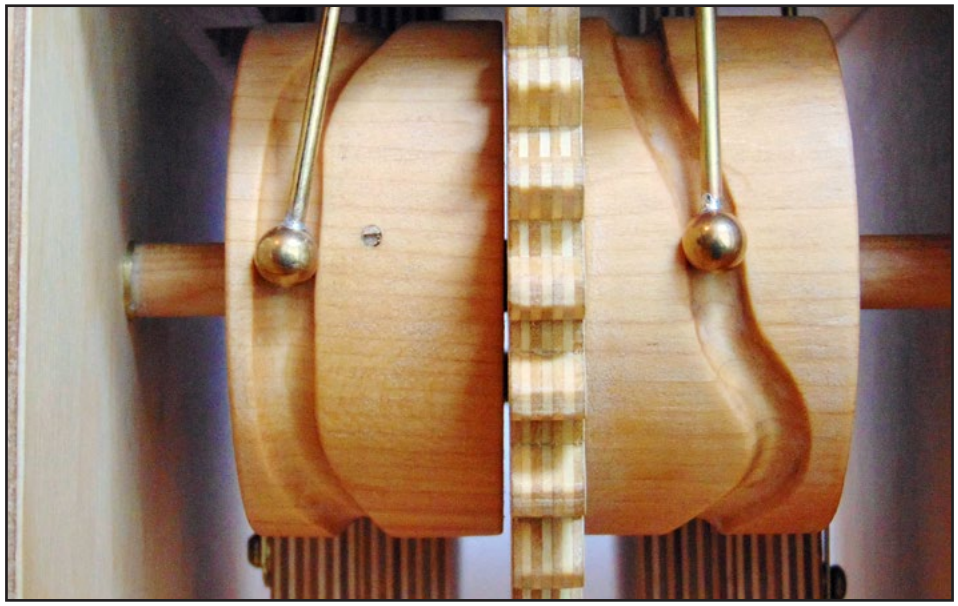
1, 2. *The Swordsman* with arms open and closed. The grooved-drum mechanisms cause each arm to swing left and right independently of the other. Note that the arm control rods can move only side to side, while the leg rods can move only fore and aft.



3. The grooved drums, positioned immediately below the figure. Here you can see how the followers interact with the arms.



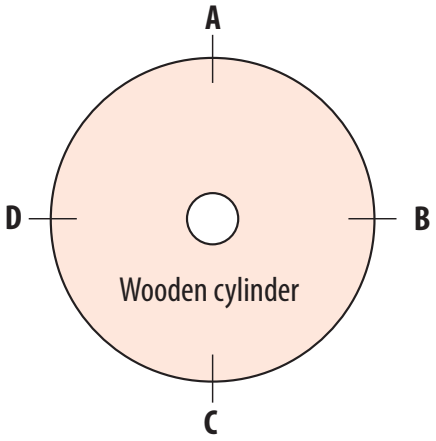
4. The arm mechanism. Pivots for the followers are housed in the hardwood pieces screwed to the bottom of the deck.



5. Close up of the drums and followers. The brass balls make for low-friction followers.

the *Tai Chi Master* became *The Swordsman*. Ta da!

The Swordsman's mechanism is made of two basswood drums, 60mm (2.4") across by 40mm (1.6") high, with the wood grain running parallel to the driveshaft. This made the groove easier to carve, as I was cutting across the grain all the way around. I used a bandsaw to round the basswood blocks into the drum shapes, then finished them on a belt sander. Ideally, each drum needed to be as close to round as possible so that the follower maintained an even pressure through the full rotation of the drum. The wooden gear that can be seen between the two drums serves only to drive the mechanism controlling the feet.



Draw the desired track on a paper strip the same length as the circumference of the wooden cylinder used in your mechanism.

The track must start and end at the same point on the top and bottom of the paper strip.

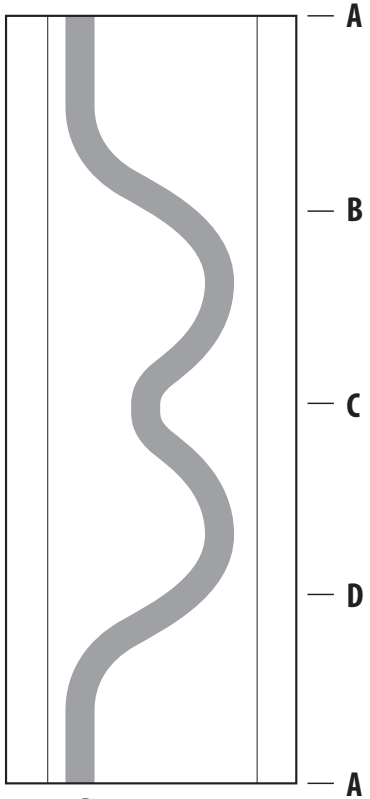
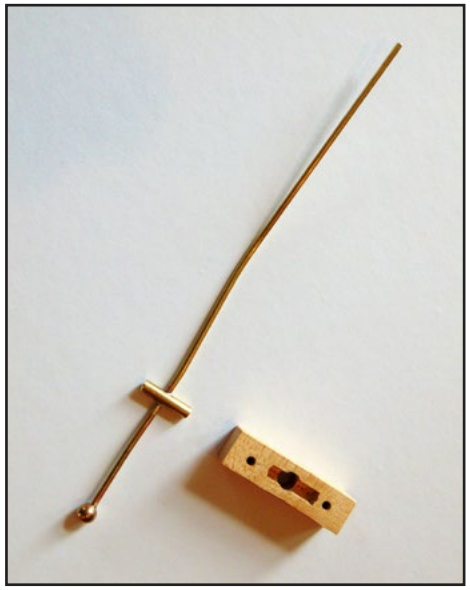


Figure 1—Laying out the cam

Design

The first step of the design was to decide how much movement was desired and how far above the top surface of the box the movement would be happening. On *The Swordsman*, the arms are about 200mm (7.9") above the pivot point of the followers, and the center of the grooved drum is about 70mm (2.8") below it. Therefore, acting as a lever, the end of the rod moves an arm roughly three times the distance that the follower moves left and right in the drum groove.

For Grasp Bird's Tail I wanted each hand to move alternately outward and stay there while the opposite hand made two movements towards it. This was achieved by two mirror-image drums facing each other, but rotationally offset by 180 degrees. Each cam follower would therefore need to start on one side of the drum and swing twice towards the other side before returning to the original side. The movements would need to be centered on opposite sides of the drums in order to be coordinated between the two arms.



6. A cam follower and its support box. The follower and its rod have been removed from the automaton. The entire rod is 270mm (10.6") long. The small horizontal cross piece nests in the box and has limited rotation.

Construction

Once the desired amount of movement was decided upon, the circumference of the drum was measured and a strip of paper the same size was marked out, as shown in **figure 1**. This strip was divided into quarter sections from top to bottom. Starting at the lower-left side of the strip of paper, I drew a single line that crossed to the right side, then made two dips back toward the middle before returning to the left side at the top. The pause on the left side was centered on "A" and the two dips were centered on "C"' on the disk cross-section shown in **figure 1**. The track of the groove must start and end at the same location at "A" at the top and bottom of the strip.

The line was adjusted by eye until I was satisfied that the curves were gradual enough that the follower would stay in the groove. Once the single line was established, two pencils were taped together and the line traced to outline the other side of the groove. A piece of carbon paper was then taped around the drum, and the strip of paper taped over that so that the track could be transferred onto the drum.

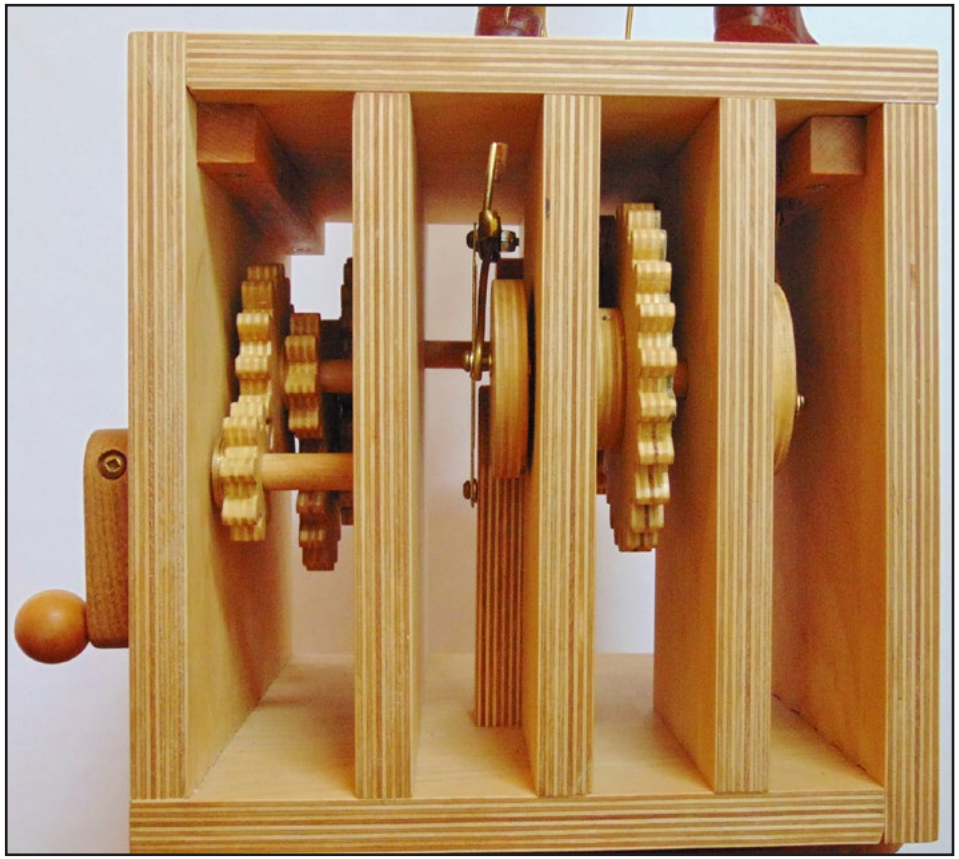
With the drum firmly clamped to my workbench, I first roughed-in the track with a woodcarving gouge. Rocking the tip of the gouge from side to side helped to make a deeper cut with less effort. I considered

starting with a rotary tool but was worried about losing control of it and defacing the area outside of the track.

Once I had the track established all the way around the drum with the gouge, I then used the rotary tool to deepen the track. After that I used a round file and sandpaper to make the track more uniform. My goal was to create a profile that would match the 9.5mm (⅜") diameter of the brass ball-bearing follower as closely as possible.

While setting up the mechanism, I firmly attached one drum but left the other loose to allow for adjustment. I was pleasantly surprised by the amount of variation in movement that was made possible simply by adjusting the relative positions of the two drums. The final configuration for *The Swordsman* has both drums in the same orientation and about a quarter turn offset from each other.

While the prototype figure's torso was supported by a rod, I found that I was able to mount the final figure using just the foot and arm supports. This had the happy result of increasing the motion transferred to the torso by the leg mechanism, but required some extra adjustment of the arms in relation to the legs. The figure is held to the box only by gravity, and I found that if the arm and corresponding leg on either side got too far apart, the arm was liable to pop off the support rod, causing the figure to pitch backwards in an alarming manner.



7. The backside of the box, showing the leg mechanism and wooden reduction gears (three 8-tooth gears and three 16-tooth gears), as well as Chebyshev's Lambda Mechanism that drives each leg.

An internet search told me that the leg mechanisms I used on *The Swordsman* and *Morning Walk* are examples of Chebyshev's Lambda Mechanism. The timing for both the arms and legs is the same—one rotation for eight turns of the hand crank.

The cam followers were made from a length of 3.2mm (⅛") brass rod soldered into a hole drilled in a 9.5mm (⅜") brass ball. The pivot point (or fulcrum) of the lever is made from a short length of 6.4mm (¼") brass rod, drilled through and soldered to the 3.2mm brass rod. The pivot rod is housed in a slot cut in a short length of hardwood screwed to the underside of the deck (**photo 6**). A hole was drilled in the deck and elongated with a small file to allow the rod to swing back and forth.

Advantages of the grooved-drum mechanism are that it offers a wealth of variations, is fairly compact, is relatively easy to construct, can be operated in either direction, and is an interesting and attractive alternative to the traditional cam. A disadvantage is that the follower will readily jump out of the track if the other end of the lever meets too much resistance. I'm curious to see what other applications can be made for this mechanism.

Links

The Swordsman: *https://youtu.be/nZt5Wa5Z0Os*
A Man and his Dog (not using drum cams): *https://youtu.be/sVkBQfqFBG0*
To see all of this issue's videos in one place, click *here*.