A low-cost universal feeder

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Construction of a universal feeder for a cost of less than \$200 is described. The feeder consists of two plywood panels, the first of which is circular and has grooves cut around its margin to hold reinforcers. This circular panel is secured to the second, rectangular panel so that it is free to rotate. A brush fixed onto the axle of a stepper motor above the circular panel sweeps the reinforcers away from the circular panel. Another stepper motor rotates the circular panel after each delivery to prepare the next reinforcer for delivery.

A universal feeder is useful when irregular-sized reinforcers, such as raisins, cookies, or candies, are used. The present paper describes the steps that I followed in constructing an inexpensive universal feeder.

A schematic diagram for construction is shown in Figure 1. A rectangular base, 600 mm wide and 700 mm long, was cut from 12-mm-thick flat plywood. A long nail (70 mm) was hammered midway along the 600-mm width, so that about 58 mm of the nail was left protruding from the plywood. Three small ball bearings (8 mm high) were fixed onto the base in a triangular pattern, each 200 mm equidistant from the nail. A circular panel, 600 mm in diameter, was then cut, and 64 rectangular grooves (2 mm deep, 10 mm wide, and 25 mm long) were chiseled along its margin (spaced about 28.2 mm center to center), in which reinforcers were to be placed. Woodworking putty was used to make the beds of the grooves arciform so that the reinforcers could be delivered smoothly. Sixty-four nails (35 mm long) were driven centripetally into the circular panel's curved edge (see Figure 1), so that they protruded about 22 mm. The nails were positioned between the chiseled grooves so that reinforcers could be swept from the panel without colliding with surrounding nails. A small hole was drilled in the center of the circular panel, and it was then fixed to the rectangular base over the long nail already placed as a "spit." The circular panel could be rotated by pushing the surrounding nails with a little force.

A motor stand was constructed, using a long piece of lumber (27 mm high, 45 mm wide, and 380 mm long) as an arm and a small piece of lumber (40 mm high, 45 mm wide, and 150 mm long) as a base. On the tip of the arm

was set a stepper motor (Sanyo, 103-770-3), which was positioned above one of the grooves on the circular panel. A paintbrush (20 mm wide, 4 mm thick, and 80 mm long) was then fixed to an axle of the motor with small bolts and nuts (see Figure 1). The stand was then fastened to a corner of the rectangular base. When the motor rotates 360°, the brush will sweep a reinforcer in the groove away from the circular panel. Once the reinforcer is swept from the circular panel, it will drop into a funnel-shaped pipe that is connected to a tray, a food cup, a well, and so on. The position of the motor stand and the length of the brush should be adjusted so that each reinforcer is swept away uniformly.

Another stepper motor (Sanyo, 103-770-3) was fixed onto another piece of small lumber (35 mm high, 55 mm wide, and 50 mm thick), which was fitted onto an adjacent corner of the base. Two aluminum plates (12 mm wide and 102 mm long) were fastened with small bolts and nuts to the axle of the motor from opposite sides, forming a flat propeller (see Figure 1). The "propeller-rotating" unit should be placed so that the blades overlap one of the 64 edge nails by 4 mm. When the motor rotates 180°, the propeller will push the nail so that the circular panel rotates 5.625° (1/64th of a revolution—an angle that corresponds to an interval of two neighboring nails around the circular panel). The position of the motor, the length of the aluminum plates, the initial position of the propeller, and the positions of the 64 nails should be adjusted so that the propeller pushes the nails regularly.

There are many commercially available boards to drive stepper motors (see, e.g., Moore, Broekhoven, Lederman, & Ulug, 1991). Let us assume that each motor is connected to a circuit, making the motor rotate one step (0.9°) counterclockwise as a pulse is sent from a computer. In order to dispense reinforcers quickly, controlling software should make the brush-rotating motor rotate first and then make the propeller-rotating motor rotate. We have used a BASIC program that first sends 200 pulses to the circuit for the brush-rotating motor so that the motor rotates 180° and the brush sweeps a reinforcer. Then, 200 additional pulses are sent to both circuits. These pulses make the brush-rotating

The research reported in this paper was supported by Grants 60790004, 63710032, 01710032, 02710030, 03710019, 04710026, 05710037, and 06710030 to M. T. from the Ministry of Education, Science, and Culture of Japan. The author is indebted to N. Kikkawa, S. Sakatani, T. Shimizu, and S. Suzuki for trustworthy assistance in the construction of the feeder, and to K. Fuji for helpful suggestions. Requests for reprints should be sent to M. Takahashi, Department of Behavioral Science, Faculty of Letters, Hokkaido University, Kita-10, Nishi-7, Kita-ku, Sapporo 060, Japan (e-mail: takam@hubs.hokudai.ac.jp).

motor rotate another 180° so that the brush returns to its initial position. At the same time, the propeller-rotating motor rotates 180° and the propeller makes the circular panel rotate one step (1/64th of a revolution), so that the next reinforcer is prepared for delivery under the brush.

The stepping rates of these two motors can be controlled by the rates of the pulses.

There are several commercially available universal feeders (Model UF-100, Davis Scientific Instruments; Model S-100, Sanso-seisakusho; Model-70, Model-120,

Gerbrands). Compared with the commercial units, the present feeder seems to require slightly more room for its operation. Moreover, the present feeder can hold only 64 reinforcers, whereas the commercial feeders can hold 70–120 reinforcers. However, the present feeder has the advantage of being easy to maintain (e.g., it can be disassembled quickly for cleaning without the use of tools). In addition, it can be made at an extremely low cost. Commercial units cost more than \$2,857 in Japan, but the present feeder can be constructed for less than \$200 per system (less than \$100 for plywood, about \$50 for two motors, and about \$50 for two circuits). In other words, the present feeder costs less than one fourteenth of the commercially available ones. This is a specific advantage of the present feeder, particularly when there is a need for a large number of units.

Two feeders have already been made according to the proposed design and have been used successfully in experiments with monkeys for several years (see Takahashi, 1991, 1993, 1994). The feeders are reliable and, as noted above, easy to maintain. However, if the propeller-rotating motor rotates too fast, the circular panel will rotate more than 5.625° ($1/64$ th of a revolution), so that the next reinforcer to be delivered will not be exactly under the brush. When this happens, the following deliveries sometimes fail. Therefore, the rotating speed of the motor needs to be adjusted so that the circular panel rotates slowly. Using wider brushes is also effective in preventing such failures. A second difficulty occurs if the panel-rotating motor fails to rotate the circular panel properly (one of the two feeders made in our laboratory showed this problem). The propeller might sometimes hook the nails around the circular panel and

the motor momentarily goes out of control (i.e., “loss of steps” occurs). However, it is easy to eliminate this problem as well. For example, waxing the propeller and the nails reduces the frequency of hooking. If that does not work well, a microswitch can be attached to the motor in order to detect every 180° rotation of the propeller. By connecting its output to the input of parallel digital I/O, the software could continue to produce additional pulses until the propeller succeeds in rotating 180° (such a “home” switch might also be useful for proper synchronization of the brush-rotating motor). Finally, although I constructed my feeders from plywood, Plexiglas might be a better material. Plywood eventually might warp, and this could likely contribute to the failure of the device.

In summary, the universal feeder described in the present paper is easy to build and operates well after being properly adjusted. Construction is inexpensive, providing an advantage over commercially available feeders.

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(Manuscript received February 9, 1994;
revision accepted for publication June 23, 1994.)