Making of a Japanese Traditional Automation, Namely Renrigaeri, and its Application to Education

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1. Introduction

Karakuri dolls are Japanese traditional automata. They move with spiral springs or gravity forces instead of electric motors or fuel engines. Therefore, in a view of energy consumption, the movements have been applied to many manufacturing factories in Japan.

For example, a Karakuri doll called Chahakobi ningyo carries a cup of tea, and goes back as a result of complex mechanisms with many parts such as gears. The movement was applied to machines which carries automobile parts. The machines have brought cost down of electric power and contributed prevention of global warming (Ikeda 2011).

Thus, Karakuri dolls are not only interesting but also important for students who study technologies to understand their mechanisms.

Our college of technology accepts junior high school graduates and educates students on technologies for five years to become researchers or engineers who will contribute to the development of industrial technologies. The fifth year students research themes about technologies for graduation.

On the other hand, our college has implemented public relations such as science classes for junior high school students or elementary school students in order to increase the number of applicants for entrance to our college. It has been said that one of serious problems in Japan is children's phobias about technologies or science (Ogura 2013).

Thus, we adopted reproduction of Karakuri dolls as themes which the fifth year students researched for graduation, and as teaching materials in science classes for the fourth, fifth, and sixth year pupils in elementary school. It is difficult to reproduce Karakuri dolls because of the complex mechanisms. So, we selected Renrigaeri which seemed to have simplest mechanism.

2. Renrigaeri models

We made Renrigaeri models which were different a little from original Renrigaeri. Figure 1 shows original Renrigaeri produced by Hosokawa in the Edo era (Tachikawa 2002). The original Renrigaeri, hereafter we call it Renrigaeri, consists of two puppets, two wooden cylinders into which an amount of mercury is put, and stairs. The puppets continue to go down the stairs by force moments on a basis of weight of mercury; the upper puppet jumps over the lower one and lands the stairs. By far, many Renrigaeri models have been reproduced by many people. Because the mercury was harmful, metal balls have been often used in them (Suzuki 1994). So, we also used metal balls. The balls rolled in two plastic straws used as cylinders.

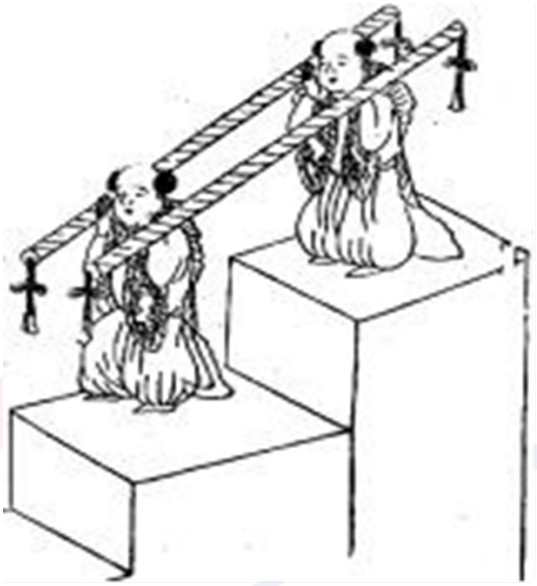


Figure 1 Renrigaeri (Tachikawa 2002)

Photo 1 shows our Renrigaeri model. The metal balls move in the cylinders, the upper puppet jumps over the lower one and lands the stairs. The action is repeated.

Photo 1 Renrigaeri model: two puppets continue to go down stairs as shown in the left, the middle, and the right.

Photo 2 shows puppets. The puppet was assembled from these parts made of Balsa woods. Balsa wood was very light. The parts were cut by a laser cutting machine. The cutting machine facilitated that the puppets were almost the same in size.

Photo 2 Puppet: parts (left) and whole (right)

Photo 3 shows cylinders. The cylinders were made of straws, nylon cramps, caps, and metal balls. They were commercially available.

Photo 3 Cylinders: parts (left) and whole (right)

Photo 4 shows stairs. Parts of stairs were made of middle density fiberboard. They were cut with a laser cutting machine. The fiberboard was hard and suitable as a material of stairs. The laser cutting machine facilitated that the pitch of the stairs was almost the same in length.

Photo 4 Stairs: parts (left) and whole (right)

By assembling the parts, we made a Renrigaeri model as shown in Photo 5. Some know-how was required to move the model smoothly. The two cylinders and the two rotating axes were parallel, respectively. Furthermore, the lengths from ends of cylinders to nylon clamps were the most crucial. When they were too short or too long, the model did not move at all or failed to jump or failed to land.

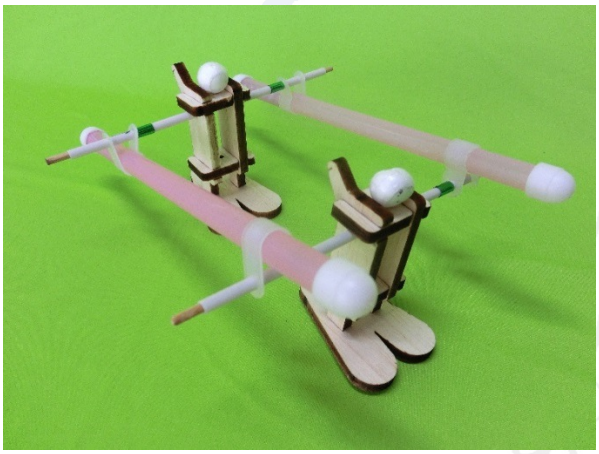


Photo 5 Pair of puppets having two cylinders

3. Science class

In a science class, we decided that the number of pupils was 20 at most. Therefore, we prepared 20 sets of manuals and parts. Furthermore, we collected staff to help us and trained the staff so that the staff could assemble the parts. We prepared time schedule, too.

In a manual, we used many photos and little sentences so that pupils were not frustrated.

As staff, we collected about 10 students in our department. On the basis of the manuals, the staff assembled the parts and moved the Renrigaeri models in advance. It was important for them to understand how to move the Renrigaeri models smoothly.

About 20 pupils participated in a science class which had four hours. They were eager to move the models smoothly as if they played with toys. Table 1 shows results of questions to pupils. Good results were obtained.

Table 1 Results of questions to 20 pupils

Questions	Results
Could you assemble Renrigaeri?	Yes 100% No 0%
Could you move Renrigaeri?	Yes 100% No 0%
Could you understand manual?	Yes 100% No 0%
Could you feel that staff was kind?	Yes 100% No 0%
Was staff's explanation good?	Yes 100% No 0%

4. Theme for graduation

In our department, the fifth year students research themes about mechanical engineering for a year.

In a theme, improvements of Renrigaeri models and understanding of their mechanisms have been carried out. Figure 2 shows a mechanism to move Renrigaeri models. M1 and M2 are force moments. Counterclockwise moment, M1 is caused by weights, while clockwise moment, M2 is by that of the upper puppet. When an angle θ between the ground and the upper puppet is achieved, M1 becomes larger than M2, and the model starts to move. The mechanism is similar to that of a seesaw.

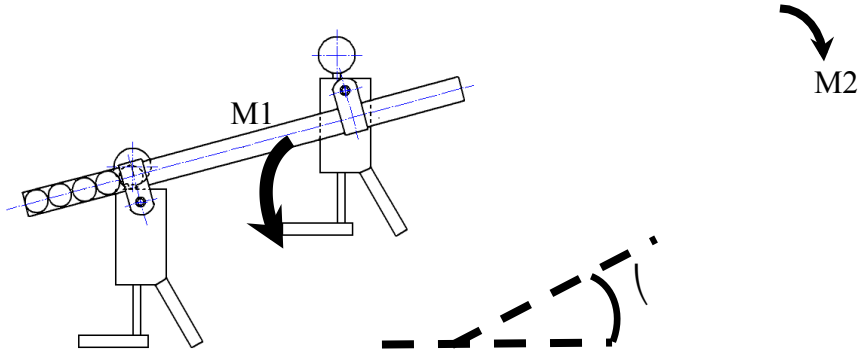
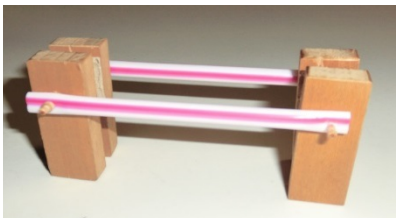
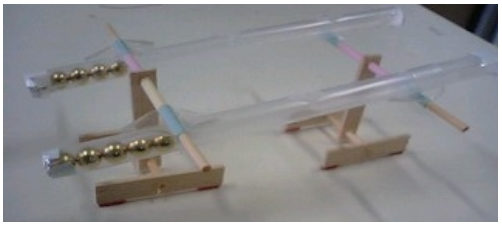


Figure 2 Mechanism of Renrigaeri models: M1 > M2 at θ

The mechanism and the know-how described in previous section (see Photo 5) could be understood by many trials and errors of models. Photo 6 shows models made from 2009 to 2012. The first model in 2009 could not be moved. But we could understand how to move Renrigaeri. This model was important. The 2nd model in the same year could be moved and used for a science class in the year. In the third model in 2010, the puppet was hand-made, and we knew that two puppets should have the same size. In the 4th model, the puppets were made with a laser cutting machine so that they had the same size. Thus, models developed with year by many trials and errors including analyses of results of the trials.

(a) First model in 2009 (b) Second model in 2009





(c) Third model in 2010 (d) Fourth model in 2011

Photo 6 Evolution of Renrigaeri models from 2009 to 2011

5. Conclusion

Renrigaeri models were reproduced as themes for the fifth year students to graduate and made for science classes to pupils in elementary schools. The models were suitable teaching materials for the pupils. Many trials and errors including analyses of results of the trials were indispensable to evolution of the models.

References

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