Construction of a micro sense of force feedback and vision for micro-objects: development of a haptic device

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Abstract

The purpose of this research was to develop a combined sense system that uses both force feedback and visual feedback to determine the shape of the microscopic features of a sample. We constructed a haptic device that gives a sense of that force to the operator when touching the sample. We recreated touch of salmon roe as one of minute samples this time.

Keywords: force feedback, haptic interface, simulation.

1. Introduction

Technologies that can accurately perform minute work are now being sought for medical treatment and in the field of manufacturing semiconductors. Such minute work is improved by using micromanipulators, but their operation is difficult because the operator has no sense of force; he or she relies only on sight through a microscope. As a result, a person skilled in the use of this technology is needed for all minute work. The efficiency of minute work would be improved if the operator were able to have a sense of force while using a manipulator.

Here we describe the development of a more efficient system for minute operations. Our aim was to develop a system using not only the sense of sight through a microscope but also a sense of force from the manipulator. For this fundamental research, a system was created to assess the reaction force when a minute sample was touched. A cantilever was used to touch the sample, and the reaction force was obtained from the degree to which the sample bent. In addition, we used a haptic device and amplified the force feedback from a minute sample of a virtual object.

2. System Structure

The system structure is shown in Fig. 1. This system consists of a microscope with an automatic x-y stage, a piezo stage, a feedback stage controller to control the x-y stage, a piezo stage controller, a haptic device for transmitting force feedback, a cantilever, and a PC via which the user can control and operate these components. The sample was fixed on the x-y stage by an injector and a holding pipette. When the cantilever, which was fixed to the piezo stage, touched the sample, the operator could maintain the cantilever's position by obtaining the value of the reaction force through the interface. The resolution of the piezo stage is 1 nm.

Fig. 2 provides a diagram of the haptic device. It consists primarily of a rotor, a laser, and a position-sensitive device (PSD). We installed a coil on the rotor with a polarity magnet, which generated electromagnetic induction by an electric current and a magnetic force. The angle of the rotor can be measured by the laser and the PSD. The rotor was able to follow any input waveform.

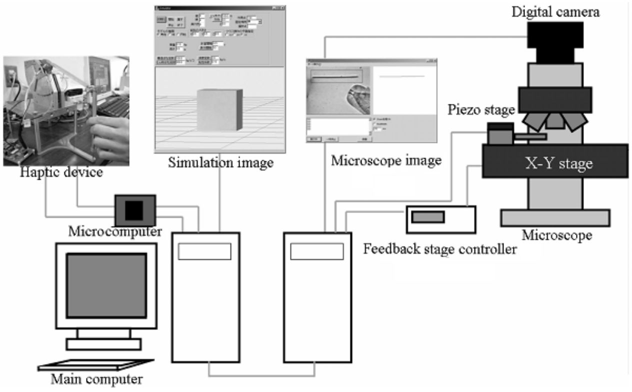


Fig.1. Photograph of the system structure.

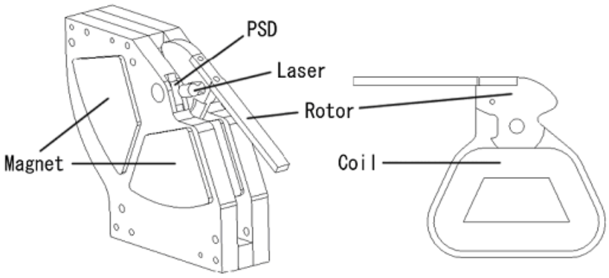


Fig.2. Diagram of the haptic device.

The actuator is controlled by a servomechanism on the actuator. The system driving the actuator therefore consisted of four actuators: a microcomputer, an inputting AD/DA port, an outputting microcomputer, and a PC outputting order value. The system controls the actuator during each part of the process. Fig. 3 shows the structure of the haptic device.

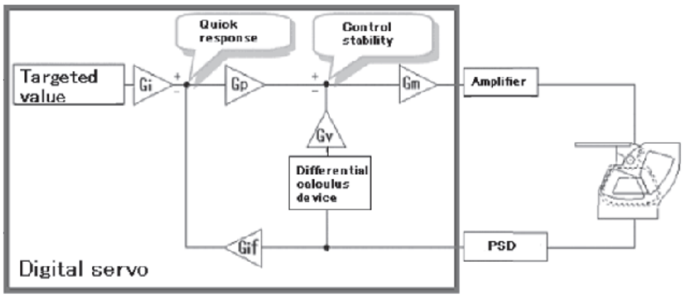


Fig.3. Structure of the haptic device.

The actuator, whose actions are governed by the PD control, is operated through a digital differential calculus device. A transfer function for the quadratic function system shown in Fig. 4 is provided for the actuator servo system. The role of each parameter of the control system is to adjust the total offset to a master in Gi/Gif, to regulate the item viscosity/resonance point in Gp/Gv, and to regulate the total gain in Gm.

Table 1 provides a list of the control parameters of the servomechanism system.

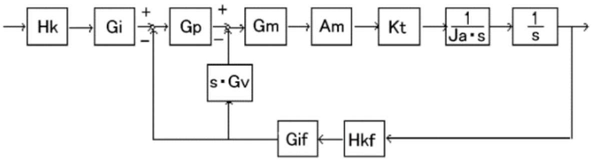


Fig.4. Block diagram of the servomechanism system.

3. Measuring the reaction force

The reaction force was used to calculate the force applied by the minute object. In this experiment, we touched the minute object with the cantilever, and the reaction force was obtained based on the degree of bend of the cantilever. The environment of the experiment is shown in Figs. 5. Based on this experiment, we were able to determine the reaction force applied by the minute object.

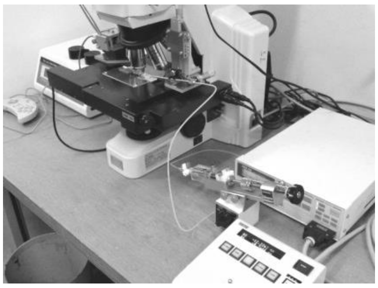


Fig.5. Environment of the experiment.

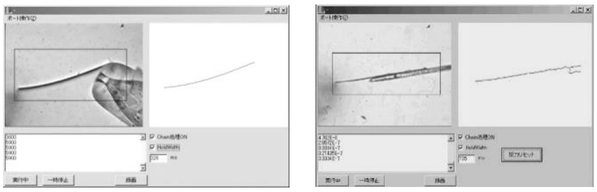


Fig.6. The cantilever moving

Left of the figure 6 shows the cantilever touching the tip of the holding pipette. Right of the figure 6 shows the experiment that measures the reaction force of the downy hair. The image-processing speed of the cantilever was improved by the tracking process. The bend of the cantilever is assumed to be linear-elastic so that Hooke’s law may be applied. The restoring force, F, of the bend of the cantilever is given by

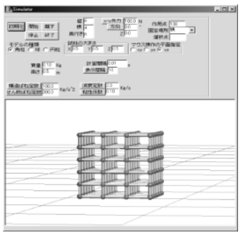
$$F = kx \qquad (1)$$

where x is the compression distance from the equilibrium position, and k is the spring constant.

4. Deforming the sample in simulation

In this study, we attempted to build a working system using a microscope, a haptic device, and a simulation. A fundamental element was simulating the deformation of a minute object. Figure 7 shows the graphical user interface (GUI) of the simulator. A graphic tool was created using OpenGL to draw the object and to choose the shape of the sample, for instance, a cube or sphere. The dynamic model of the sample consisted of a spring-mass array of mass points in both the vertical and horizontal directions. An example of the arrangement of mass points is shown in Fig. 8. When a force was applied at a mass point, the simulation calculated the speed of all mass points that had been affected. The image was renewed after every ten calculations.

We defined a spring as having a size but no weight, and a mass point as having a size, a weight, and a rigid body. An arbitrary mass object can be placed on a spring on a bitmap (Fig. 9). In addition, a sample can be seen from various viewpoints, and the deformation of the sample, which is impossible to observe by microscope, can be checked. The shape of this object can be either a cube or a sphere, and any point may be selected as a fixed point or an operating point.



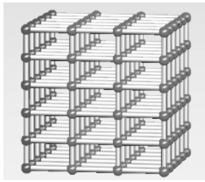


Fig.7. Simulator. **Fig.8.**Arrangement of mass points

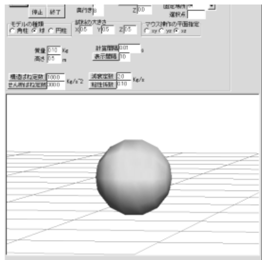


Fig.9. Placing an arbitrary object on a bitmap.

5. Characteristic measurements and a reappearance experiment for an object

Dynamic characteristics of the object were measured and then recreated using the haptic device. The object used this time was salmon roe. We measured response of salmon roe and showed the displacement of its surface a figure. Fig. 10 shows the response of the salmon roe.

Salmon roe is 6 millimeters in diameter and we cannot precisely feel the sense of touch. Hence values in the figure are multiplied by 68 so that human can feel the sense of salmon roe's touch. Fig. 11 shows that response of the salmon roe and haptic device. Table1 shows the frequency, constant of spring, and damping coefficient in each ectopic focus.

In this experiment, there was a tendency for a touch feeling close to that of real and big salmon roe to be created when characteristic was recreated.

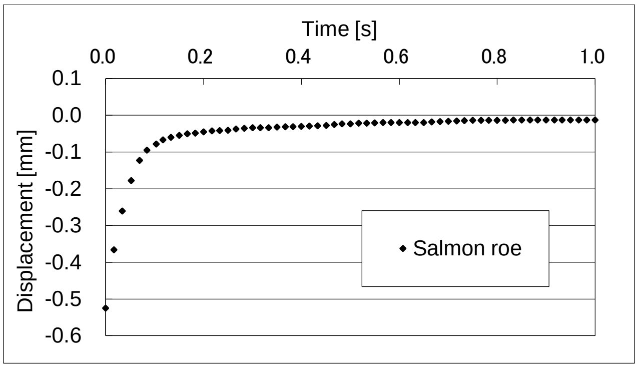


Fig.10. Time response of Salmon roe

Table1. Haptic device parameter of dynamic characteristic

Displa cement [mm]	Frequency [Hz]	Spring constant [N/mm]	Damping ratio
0～6	6	0.072	2.6
6～35	6	0.072	1.0

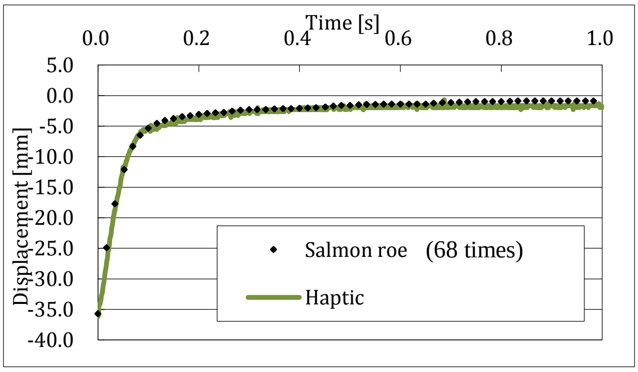


Fig.11. Time response of Salmon roe and Haptic device

6. Conclusion

In the present study the characteristics of salmon roe were measured and recreated, the evaluations also were carried out with regard to response and sense of force using a haptic device. The characteristics of various objects will be measured in the future, and the characteristics should recreate.

Future research should focus on building a system that allows a reaction force to be detected and shown more precisely. Such a system would make it possible to test smaller samples.

7. Acknowledgement

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8. References

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