Re-creation of a membrane puncture’s sense of an object constituted of liquid and an outer membrane by a haptic device and a deformation simulation of the virtual objects

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Abstract

The purpose of this research is to develop a combined sense system that uses both force feedback and visual feedback on a deformation simulation. We constructed a haptic device that gives a sense of that force to the operator when touching the sample on a computer. We focused on a way to recreate a membrane puncture’s sense of salmon roes.

Keywords: force feedback, haptic interface, simulation

1. Introduction

Technologies that can accurately perform minute work are now being sought for medical treatment and bio technology field. 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 is 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 is 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 research, focus on to recreate reaction force of puncture against an object which constituted of liquid and an outer membrane. Among them, salmon rows were handled in this research.

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1. System Structure

The system structure is shown in Fig. 1. This system consists of the haptic device for generating reaction force, a microcomputer for controlling the haptic device, simulation for showing virtual objects and microscope for measuring dynamic characteristics.

Fig. 2 provides a diagram of the haptic device. It consists primarily of a rotor, a laser, and a position-sensitive detector (PSD). The angle of the rotor can be measured by the laser and the PSD. The haptic device has a coil on the rotor with a polarity magnet. When current flows through the coil, the coil experiences a force (Lorentz force) perpendicular both external magnetic field and to the direction of the current flow. The rotor is able to stable follow an input waveform less than the frequency 36 Hz.

Fig. 3 shows the connection between the haptic device and a microcomputer. The haptic device is controlled by command signals from the microcomputer process.

2. Force modeling for sensing a membrane puncture.

This section describes the modeling of a membrane puncture’s sense of an object constituted of liquid and an outer membrane. The object is assumed salmon rows. Because salmon rows are easy to get and tractable.

Fig. 4 shows the relation between the pushing amount of needle and the reaction force. The reaction force by deformation before puncture is modeled by the Voigt’s model. When the pushing amount exceeds the puncture point, Transition to Maxwell’s model that is expressed as a viscous resistance of a liquid. At this moment, operators can feel the puncture sense by caused the sudden fall of the reaction force. Fig. 5 shows each model, and Table. 1 shows characteristics of each model.
Table 1. Characteristics of each model.

<table>
<thead>
<tr>
<th>Item</th>
<th>Maxwell’s model</th>
<th>Voigt’s model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combination of spring and damper</td>
<td>Serial</td>
<td>Parallel</td>
</tr>
<tr>
<td>Viscoelasticity</td>
<td>Liquid-like</td>
<td>Solid-like</td>
</tr>
<tr>
<td>Step input of stress</td>
<td>A moment elasticity</td>
<td>Stress relaxation</td>
</tr>
<tr>
<td>Step input of stress</td>
<td>A delay elasticity</td>
<td>Creep</td>
</tr>
</tbody>
</table>

3. 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. Fig. 6 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. 7 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. 8). 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. 6. Simulator.](image)

![Fig. 7. Arrangement of mass points.](image)

4. Characteristic measurements and a reappearance experiment for an object

Dynamic characteristics of the object were measured and then recreated using the haptic device as reaction force before puncture. The object used this time was salmon roe. We measured the response of salmon roe and showed the displacement of its surface a figure. Fig. 9 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. 10 shows that response of the salmon roe and haptic device. Table 2 shows the frequency, constant of spring, and damping coefficient in each ectopic focus.

In this experiment, there was a tendency to create a touch feeling that resembles a real and big salmon roe when characteristic was recreated.

![Fig. 8. Placing an arbitrary object on a bitmap.](image)

![Fig. 9. Time response of Salmon roe.](image)

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Next, a viscosity was measured in order to recreate the liquid viscosity of salmon rows. Fig.11 shows the conditions of an experiment. The moving part of the haptic device was sunk and then the moving part was vibrated constant parameters. Then, the vibration was damped to compare the case of not touched liquid because of viscosity. The damping difference between touched liquid and not.

In this experiment, Sodium alginate aqueous solution 1% weight ratio was used. Because the viscosity of liquid is similar to salmon rows and also use in artificial salmon rows.

Fig.12 shows the relation between the difference of damping ratio and lateral area of under the liquid. As a result, the bigger the lateral area of under the liquid of moving part, result in the bigger the damping ratio.

5. Conclusion

The reaction force from puncturing an object which consists of the liquid and an outer membrane was recreated by Voigt model and Maxwell model. Operators can feel the puncture sense by caused the sudden fall of the reaction force when changing the controlling model. 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.

6. Acknowledgement

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7. References
