Positioning Control of a Micro Manipulation Robot Based on Voice Command Recognition for the Microscopic Cell Operation

H. Terada, K. Makino, H. Nishizaki, E. Yanase, T. Suzuki and T. Tanzawa

Abstract In the gene manipulation field, to make a genetically-modified mouse, the multi micro manipulation pipettes operation is needed. Especially, to realize more complex cell operations, it is needed that three micro manipulation pipettes are operated simultaneously. Therefore, to realize the simultaneous operation, a micro manipulation robot has been developed. This robot consists of a voice command recognition system and a rectangular-coordinate type structure, and controls the positioning of the third pipette by voice command without manual operations. Then, to eliminate the vibration generated by the feedback loop, a driving actuator uses an oil hydraulic pump which is driven by piezo-electric device to realize the intermediate stop and positioning. Furthermore, it is confirmed that the prototype robot can be driven by voice command recognition.

Keywords Robot · Positioning · Micro manipulation · Voice command recognition · Cell operation

H. Terada (✉) · K. Makino · H. Nishizaki · E. Yanase · T. Suzuki · T. Tanzawa
University of Yamanashi, Yamanashi, Japan
e-mail: terada@yamanashi.ac.jp

K. Makino
e-mail: kohjim@yamanashi.ac.jp

H. Nishizaki
e-mail: hnishi@yamanashi.ac.jp

E. Yanase
e-mail: eririn@alps-lab.org

T. Suzuki
e-mail: t13jm029@yamanashi.ac.jp

T. Tanzawa
e-mail: ttanzawa@yamanashi.ac.jp

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1 Introduction

A progress of the gene manipulation technology requires various micromanipulators. Especially, to make a genetically-modified mouse, the multi pipettes operation is needed [1]. At this case, two micro manipulation pipettes are driven by manual operation using oil hydraulic joysticks at the microscopic cell operation [2], and it is required to operate the third micro manipulation pipette. However, an operator drives two pipettes by both hands and foot pedals. The third pipette cannot be operated simultaneously. Therefore, to realize the simultaneous operation, a micro manipulation robot which is controlled by voice command is required.

On the other hand, when the conventional micro manipulation robot systems are driven by stepping motors or friction drive type piezo actuators, the vibration of the microscopic levels is remained [3, 4]. In this report, a micro manipulation robot based on voice command recognition is designed to solve these problems. Especially, a recognition algorithm is proposed to prevent robot malfunction, and that is compared the detected voice to the pre-learning language database. In addition, a prototype robot is tested to verify the reliability of a microscopic motion.

2 Structure of a Microscopic Cell Operation System with a Micro Manipulation Robot

A structure of a microscopic cell operation system with a micro manipulation robot based on voice command recognition is proposed as shown in Fig. 1. To coincide with a manual operation, this robot system consists of a rectangular coordinate structure which is driven by oil hydraulic pumps. When an operator controls a motion of two manual operation devices using the manual haptic devices, that robot is required to hold and to push the cell simultaneously. However, an operator cannot operate this robot by his/her hand, because both haptic devices are grasped. Therefore, this robot is controlled by voice command recognition. Furthermore, when we use the conventional voice coil type micro manipulator, the resolution of a positioning is restricted to 20 μm [5]. However, in recent cell operation fields, the higher positioning accuracy is required. To realize these requirements, the oil hydraulic pump is driven by the piezoelectric actuator which has a displacement magnifying mechanism. Then, the piezoelectric element is controlled by the displacement feedback. However, to eliminate the vibration caused by the displacement feedback of the piezoelectric element, a structure of the oil hydraulic pump is constructed as shown in Fig. 2. This pump generates an oil hydraulic pressure using the diaphragm deformation, and eliminates the small vibration by the silicon oil viscosity.

When the input motions of a step function and a ramp function are used, the response characteristics of the oil hydraulic actuator on the X-axis are shown in

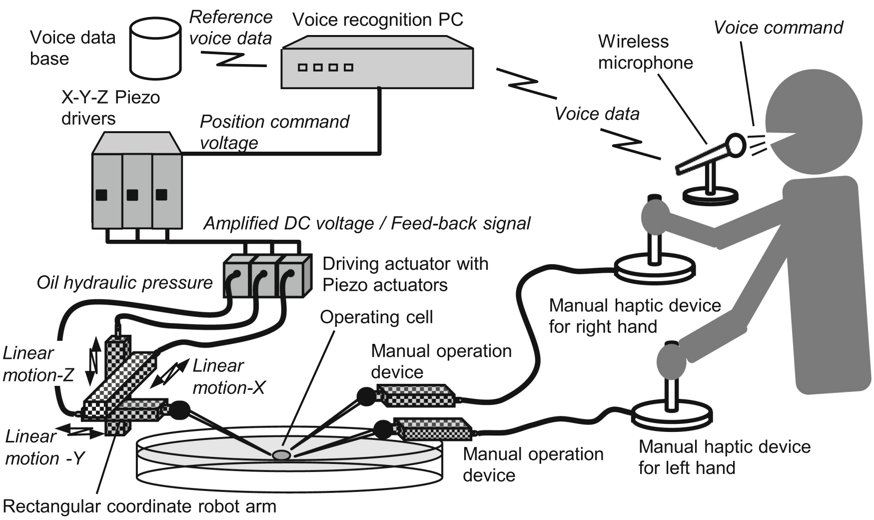


Fig. 1 Microscopic cell operation system with a micro manipulation robot based on voice command recognition

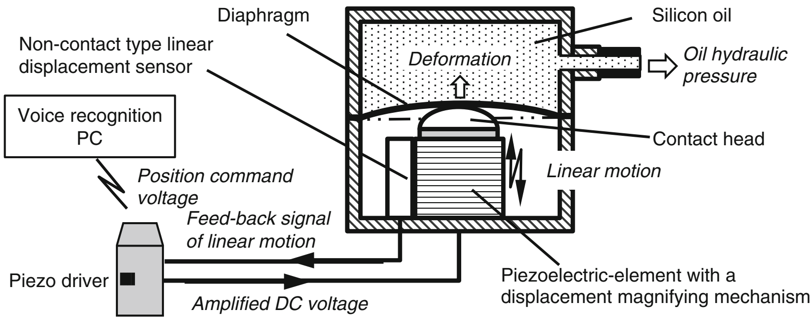
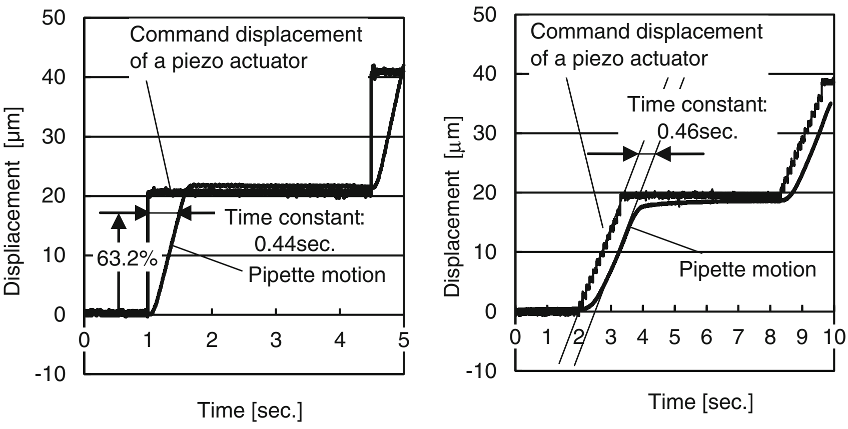


Fig. 2 Structure of an oil hydraulic pump driven by piezo-electric device

Fig. 3. The resolution of an input signal is the 0.7 μm, and the required resolution of an operation is 2.0 μm. In case of a ramp function, the pipette on the X-axis can move very smoothly at 13.0 μm/s, and in case of a step function, the pipette on the X-axis can move very smoothly, too. Then, both time constants are less than 0.5 s; these performances are enough to the human response speed. Furthermore, in cases of the Y-axis and the Z-axis, these response characteristics are the same. However, this motion speed is not enough for the expert operator, so the voice command recognition has to be simplified or to be predicted a command.



a) Input motion of a step function b) Input motion of a ramp function

Fig. 3 Response characteristics of an oil hydraulic actuator. **a** Input motion of a step function. **b** Input motion of a ramp function

3 Algorithm of Voice Command Recognition

Japanese language is a phonogram, and it can be divided to the single set of speech sounds or the small syllable, and this language has a unique grammar. Therefore, other language recognition method which is different from the English recognition has to be investigated. To solve this problem, it is popular that the open-source software of Japanese large vocabulary continuous speech recognition is used for the academic research. This open-source is called as “Julius” [6, 7]. It incorporates major speech recognition techniques, and it can perform a large vocabulary continuous speech recognition task in real-time. The command voice is converted to the feature vectors sequence which is shown Mel-Frequency Cepstrum Coefficient [8]. Then, these vectors are matched with the statistic acoustic models. When the vector is matched with that pattern, the motion signal voltage of the commanded axis direction is output.

A flowchart of the voice command recognition is shown in Fig. 4. Especially, under the microscope, the fundamental motion of a pipette is a rectangular coordinate motion, and the arbitrary direction motion on the horizontal plane to adjust the holding position of the cell is sometimes used. In addition, there is some hysteresis loss of each axis motion, and the motion length needs to be compensated. Therefore, in a magnification adjustment, compared with the direction of previous operation and the next operation, the compensation length and direction are determined. Considering this point, the voice command of a robot arm motion is defined as Table 1. In this case, the arbitrary direction on the horizontal plane is commanded using the clock direction. Especially, considering the resolution of D/A, the motion of diagonal direction is approximated by the pulse ratio of the

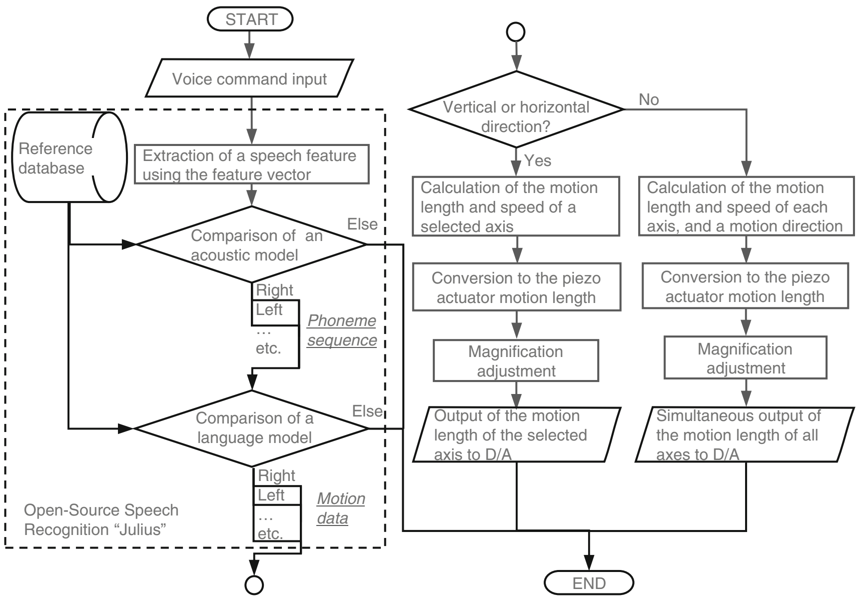
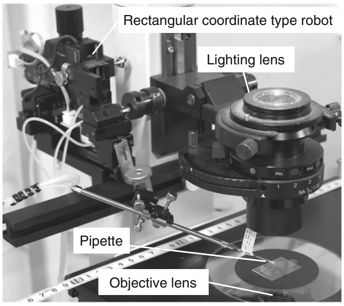


Fig. 4 Flowchart of voice command recognition

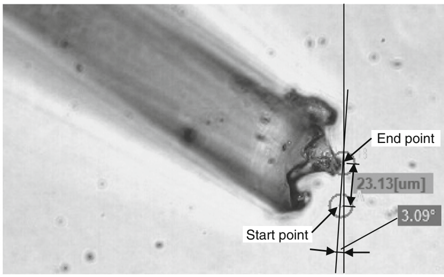
horizontal pulse to the vertical pulse. Furthermore, the correct motion rate of each motion is shown, too. Almost direction commands do not have recognition errors. However, the commands of the speed and the motion range are affected by the word order, and the error rate of voice recognition sometimes increases. It is similar to the individual differences in pronunciation, too. Therefore, another word order has to be investigated.

Table 1 Main command of a robot arm motion and the correct motion rate

Class	Command	Command in Japanese	Correct motion rate (%)	Class	Command	Command in Japanese	Correct motion rate (%)
Speed	Quickly	ha-ya-ku	90.0	Arbitrary horizontal direction	One	hi-to-ji	100.0
	Slowly	yu-q-ku-ri	73.3		Two	fu-ta-ji	100.0
					Three	Sa-N-ji	100.0
Motion range	Larger	mo-q-to	60.0		Four	yo-ji	100.0
	Smaller	su-ko-shi	83.3		Five	go-ji	100.0
					Six	ro-ku-ji	93.3
Direction	Right	mi-gi	86.7		Seven	na-na-ji	100.0
	Left	hi-da-ri	100.0		Eight	ha-chi-ji	100.0
	Up	u-e	100.0		Nine	ku-ji	100.0
	Down	shi-ta	100.0		Ten	ju-ji	100.0
	High	ta-ka-ku	100.0		Eleven	ju-i-chi-ji	100.0
	Low	hi-ku-ku	76.7		Twelve	ju-ni-ji	100.0



a) Rectangular coordinate type robot arm



b) Measurement of a pipette motion on the horizontal plane using the microscopic image processing

Fig. 5 Prototype system. **a** Rectangular coordinate type robot arm. **b** Measurement of a pipette motion on the *horizontal plane* using the microscopic image processing

Then, at microscopic cell operation, the positioning error of an arbitrary direction motion on the horizontal plane is measured to evaluate the usefulness of this type robot arm as shown in Fig. 5a. The positioning repeatability of each axis is tested using the image processing under the microscope as shown in Fig. 5b. Therefore, the positioning error of each axis at 10.0 μm linear motion is less than ±2.0 μm. This performance is enough for the cell holding operations.

4 Conclusions

To realize the multi micro manipulation pipettes operation, the micro manipulation robot based on voice command recognition has been developed. It is con-firmed that the operator can control third pipette by voice command smoothly. In future work, to improve the voice recognition rate and to consider the individual differences in pronunciation, we have to optimize the word order. Then, to realize higher response speed, the voice command recognition has to be simplified.

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