Artificial Insemination System by Male and Female Micro Robots

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1.Introduction

In the biomedical field, the precise operation is required to achieve cell injection and genome analysis. To enhance these technologies, the special instrument with higher accuracy can provide the solution to these requirement. Several sophisticated instruments have been developed and some of them are equipped with the advanced sensor and actuator. In the meantime, the micro robotics has the potential application to many fields such the biomedical engineering as well as micro-engineering. For these years, our group have developed many small robots for the application to the precision engineering[1),2),3)].

In this report, the unique artificial insemination system operated by male and female micro robots is proposed and the successful experimental results are described. The small robot, which is approximately 1 cubic inch, is composed of piezo element and electromagnet to move precisely with the manner of an inch worm[4)]. And one small robot has the micro pipette actuated by the micro pump while another one has the special micro capillary which can incubate the fertilized egg. In the experiment, the egg and the spermatozoon of fish are implemented into the micro injector and the micro incubator on these small robots. Two small robots can navigate each other to inseminate by using acoustic, optical and mechanical touch trigger switch sensors and reactive based sequential manner. And the fertilized egg in the micro incubator was successfully hatched after two weeks later under the temperature and water condition control instrument.

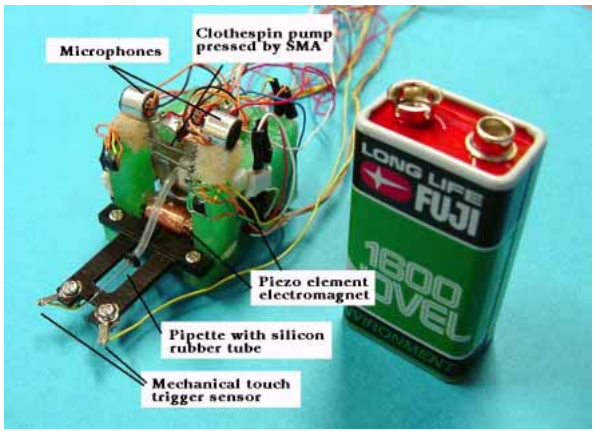


Fig.1 Male micro robot with a pipette, a pump and three range sensors for autonavigation to the female robot

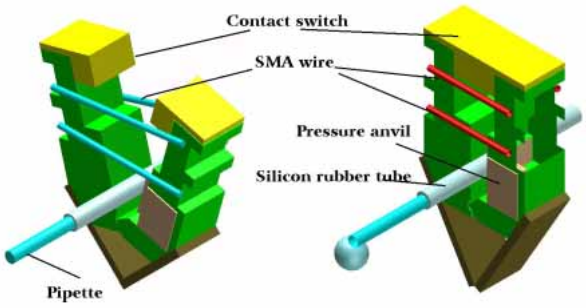


Fig.2 Illustration of the one-shot clothespin pump pressed by the SMA wire

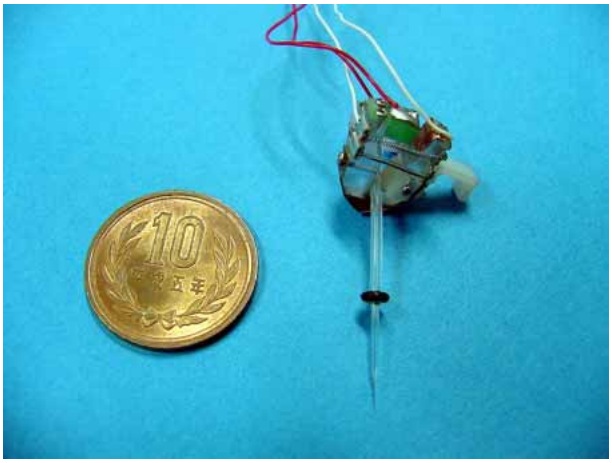


Fig.3 Photograph of the simple active pipette and clothespin pump

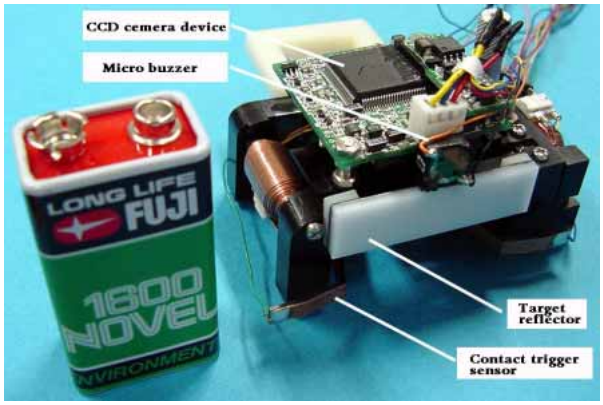


Fig.4 Female small robot with CCD image device and capillary incubator.

2. System Configuration

2.1 Male Micro Robot

The small male robot with a micro pipette, a micro pump as well as several sensory elements is shown in Fig.1. It has piezo elements and electromagnet legs to provide an inchworm step locomotion although the electricity and control signal are still supplied via several wires.

For the male to head, approach and align to the female one, three kinds of range sensors are implemented on the small robot. A pair of microphones is used to detect the direction of acoustic source on the female robot. Twin micro infrared optical sensors can measure the approaching angle and the mechanical touch sensor on the feeler can contact with the guide bar of the female robot. The component of a pipette with a one-shot SMA driven clothespin pump which is incorporated with the male robot is developed as shown in Fig.2 and Fig.3. The silicon rubber tube is connected with the end of the pipette and can be compressed by the clothespin actuated by SMA wire. Then the small amount of the liquid in the tube can be easily pushed out by the simple electric signal while the higher resolution can not be expected.

2.2 Female Micro Robot

Female micro robot with a micro capillary incubator, a CCD camera element, a target reflector and a small buzzer as an acoustic invitation signal is shown in Fig. 4. As shown in Fig.5, the unique micro capillary which is equipped with the optical infrared sensor for checking the egg movement, the thermistor and heater coil for controlling the temperature is fixed at the center of body to incubate and the focus point of CCD image device is set at the end of capillary to monitor the egg status visually after the insemination.

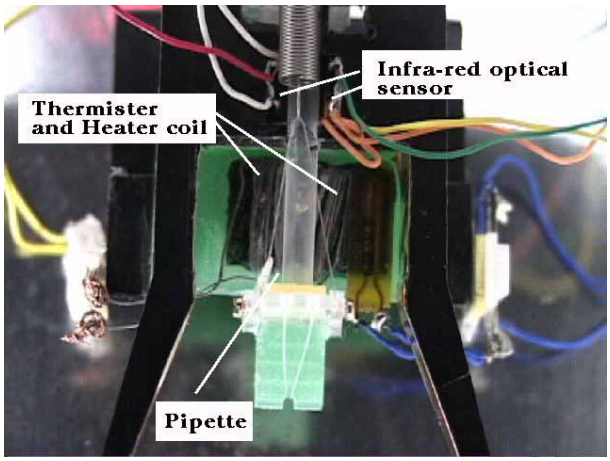
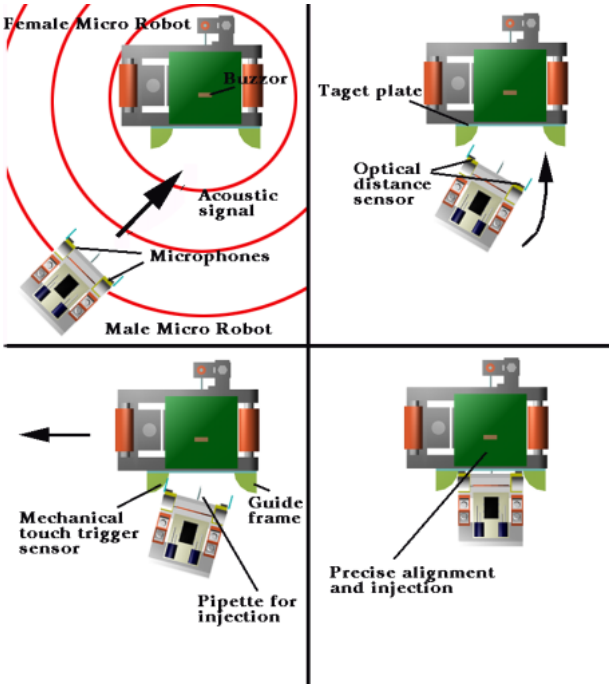


Fig.5 Close up view of small incubator with sensor, heater and shutter.

3. Precise Navigation for Insemination

As shown in Fig.6, the sequence of insemination is illustrated. At first, a pair of microphones on the male robot can detect the



direction of acoustic source generated by the buzzer on the female robot. The differential amplitude of detected signals causes the alternative activation of piezo elements to head itself to the signal source. When the male robot comes to close the female one, twin micro infrared optical sensors can measure its approaching angle to keep itself at right angle to the female one. At last the mechanical touch trigger sensor on the feeler can contact with the guide bar of the female robot to generate the control signal that causes the female one to move forward or backward to align the micro pipette into the incubation capillary precisely. Then the spermatozoon in the male small robot can be injected into the egg of female robot. This precise rendezvous action is based on "insect like behavior" rather than engineering procedure with global positioning system.

Fig.6 Sequence of two robots navigation

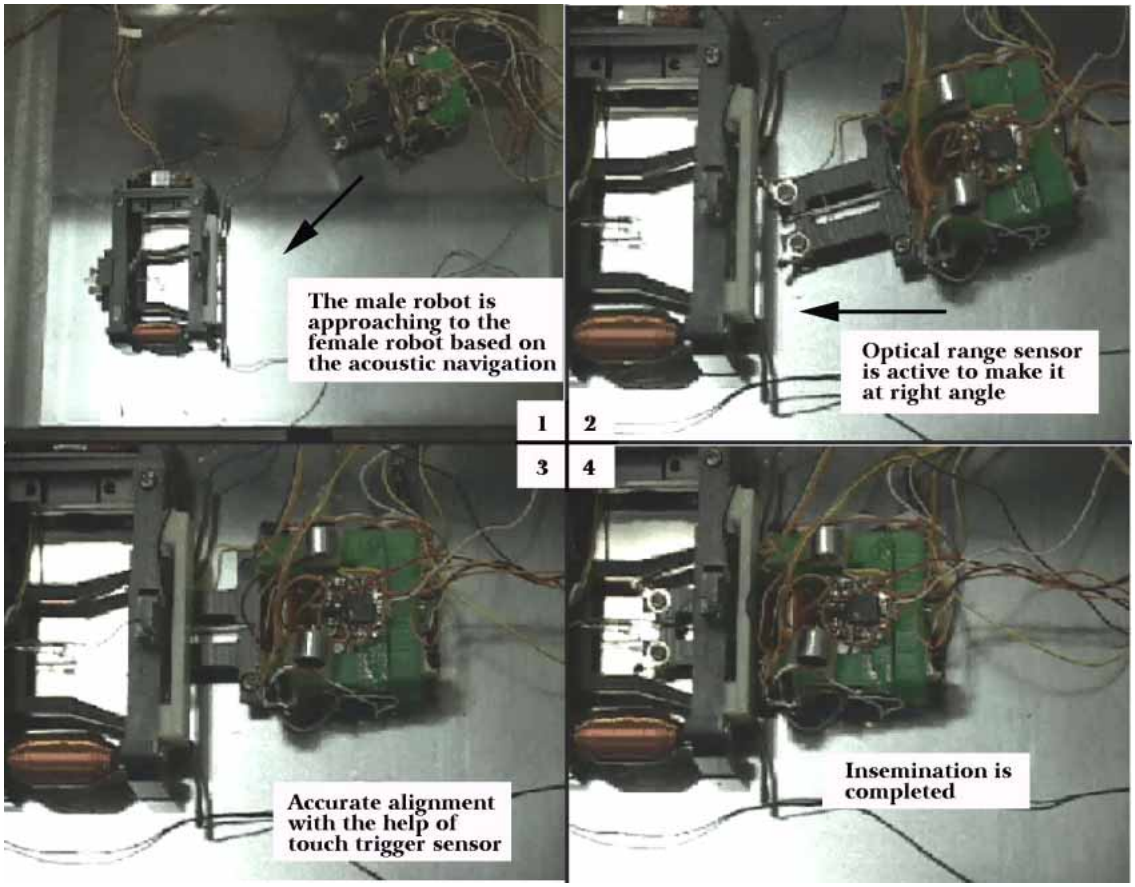


Fig.7 Expermental result of automatic navigation for insemination performed by two small robots.

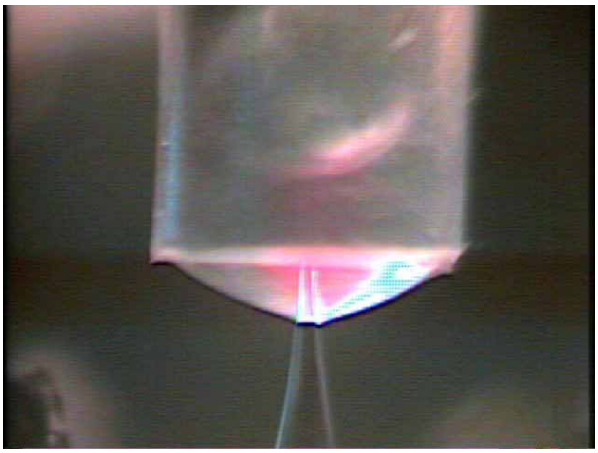


Fig.8 Close up view of precise injection to the egg in the tube on the female robot

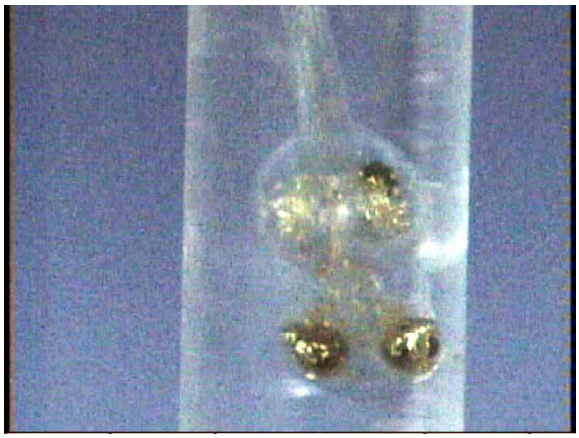


Fig.9 A tiny fry succeeded in hatching after 12 days

4. Experiment of Insemination and Incubation

The sequential photo of the actual experiment is shown in Fig.7 as well as the close up view of injection is in Fig.8. In this experiment, the egg and the spermatozoon of killifish are used for artificial insemination. This active pipette pumped by the SMA driven clothespin can control of the small amount of the liquid at the resolution of 0.35 microliter The two small robots succeeded in approaching each other automatically and making fine positioning based on three range sensors with the repeatability of 20 micron. After the tool alignment is completed, the spermatozoon was injected into the egg cell. In the female small robot, the fertilized egg can be incubated under the temperature control system and water monitoring instrument. As shown in Fig.9, the tiny fry succeeded in hatching in the tube after12 days later when the water temperature is kept at 25 degree.

5. Conclusions

In this report, an artificial insemination system performed by the piezo drive micro robots. These robots can navigate automatically each other by using acoustic, optical and touch trigger sensors to make accurate alignment and injection. As the primary experiment, the artificial insemination was successfully conducted by using the egg and the spermatozoon of killifish.

References

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