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Development of under water use humanoid robot

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Abstract: In this research, we have developed a swimming robot with flutter kick of two legs, which can swim freely both on the surface of water and in the water, and established the control method for all kinds of motion of this robot, such as straight swimming, turning, down going or up going. Furthermore, with optimizing the three-dimensional action of underwater robot, we can expect improvement of the performance of underwater robot for complex work.

Keywords: Humanoid, Underwater Robot,

I. INTRODUCTION

With the development of science and technology, robot has been experienced surprising rapid advancement. Particularly, the research on humanoid robot becomes very high level and its motion is improving day by day. The authors think that the humanoid type underwater robot is convenient for underwater works as on the ground. The underwater environment is so dangerous for human, that many kinds of robot have been extensively used for underwater work, such as underwater resources exploration, oceanographic mapping, undersea wreckage salvage, ocean engineering survey, dam security inspection, and so on. However, there has been no underwater robot which can take the place of the diver by now. Considering those situation, the authors are putting the focus on developing Underwater Humanoid Robot.

II.DESIGN OF ROBOT

As illustrated in Fig.1, the propulsive structure treated here is a free-swimming humanoid robot. It is composed of three parts: a body with two arms and two legs. Each of the legs is composed of two links and one oscillating fin. The robot is wearing a waterproof suit on the body. And it is designed to get neutral buoyancy also.

The neutral buoyancy is the condition that the gravity equal to buoyancy. And the center of buoyancy and gravity are arranged to be collinear along the body z-ax

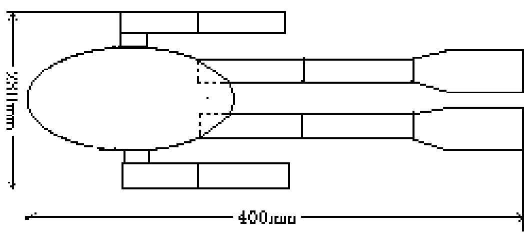
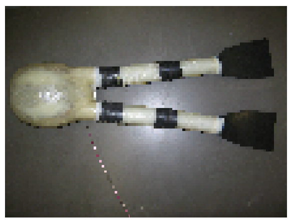


Fig.1 Image of Underwater Humanoid Robot

Humanoid-1



Humanoid-2

Humanoid-3

Fig.2 Example of Underwater Humanoid Robot

Fig. 2 shows prototypes of radio-controlled underwater humanoid robot. They have been developed in our laboratory. The mechanical device used in this paper is humanoid-3. The body of the robot is wrapped with gum. In the body, following devices are installed in a water shielded package. 1)Microcontroller board: Motion Greator for TTL and PS/2 Bluetooth controller, 2)Communication devices: Parani ESD-200 Bluetooth Serial Adapter, 3)Arm servo motors, 4)Batteries and 5)Underwater camera. The total weight is approximately 1.5 kg. And the length is 400mm. We can control the swim of robot with wireless communication. Its speed is adjusted with frequency and amplitude of oscillating signal, and its turning motion is controlled with arm motion.

III.MOTION ANALYSIS

In this section, the authors built the dynamic model on the basis of undulated fins and the drag model in fluid mechanics. The dynamic model of undulated fins can make clear the relation between the forces/moments and propulsive wave parameters, geometric parameters as well as swimming velocity. We can study about the motion of the robot, control method and efficiency of propulsion. This dynamic model for undulated fin has been validated with experimental tests in thrust, and propulsive velocity of the underwater robot.

1. Basic motion of straight swimming

When the robot is swimming on a straight course, the desired motion can be expressed as

$$f(x,t)=\left(c_1\frac{x}{l}+c_2\left(\frac{x}{l}\right)^2\right)sin\left(k\frac{x}{l}+\varpi t\right)l \qquad (1)$$

where f is transverse displacement of the body, x is displacement along the main axis. t is time, k is body wave number, ϖ is body wave frequency, l is length of the robot.

2. Thrust force

To simulate the dynamics of the swimming, we simply considered a equation of thrust force with flutter kick.

$$p=\rho s\,cos[\alpha_0\,cos(2\pi ft-\phi)]\,c$$
$$\left\{h_0 2\pi f\,sin(2\pi ft)-tan[\alpha\,cos(2\pi ft-\varphi)]\frac{2fh_0}{s'_t}\right\}$$
$$2h_0\pi\,sin(2\pi t) \qquad (2)$$

$$s'_t=\frac{fh}{2v}$$

where p is thrust force, ρ is density of fluid, α_0 is the maximum attack angle, f is the frequency, v is velocity of robot, φ is phase difference and c is coefficient of interference between two legs. As the influences of the interference of flutter kick is very complex, we use the approximation and calculate under ideal condition in this paper.

3. Resistance force

We assume the shape of body is not plate but an ellipsoid, then the resistance force on the body is assumed to be generated in the usual steady flow. Under this assumption, the resistance force becomes as follows

$$R=\frac{1}{2}c_D\alpha\rho Sv^2 \qquad (3)$$

where v is velocity of the body, c_D is resistance coefficients, α is attack angle, s is projected area of body and arms in the x-y plane.

4. Dynamic equation of straight swimming

When robot is swimming in the water, buoyancy is equal to gravity of robot. Then the equation of dynamics can be written as

$$m\frac{dv}{dt}=p-R \qquad (4)$$

where m is mass of the robot.

IV. CONTROL

1. Turning control

When the robot is required to turn uniformly with given angular velocity w and turning diameter D, a centripetal force F and a turning moment T should be offered as

$$F = \frac{1}{2} m \omega^2 D \qquad (5)$$

$$T = \frac{1}{4} m \frac{d\omega}{dt} D^2 \qquad (6)$$

If we set the robot arms making angle between body as θ, we can get the centripetal force from thrust force and resistance force. It makes possible to change direction and continuous direction change becomes turning. Confirming the motion, we applied data table looking up control method, which is determining θ from data table between θ and w.

2. Speed control

From the equation (2) (3) (4), we can get the relationship between velocity and frequency of flutter kick. Then with changing flattering frequency, we can get a desired swimming speed, As a note, the phase difference φ is set at 80°, because it is evaluated that we can get the best thrust force.

V. SIMULATION

In order to evaluate the applicability and capabilities of humanoid robot, we made simulations study with using developed model. From Fig.3 to Fig.6 we will show the results of simulation for swimming start mode as an example. The condition for simulation is shown in Table 1.

Table 1 Condition of Simulation

Dimension of Robot:
Body Width ;23cm, Body Length;40cm
Body Depth; 11cm, Leg Length;20cm
Fin Size; 10cm*6cm
Weight; 1.5kg
Frequency of Leg Motion; 2Hz

The coefficients of resistance of the body were calculated with approximating the body as ellipsoid and arms as columns.

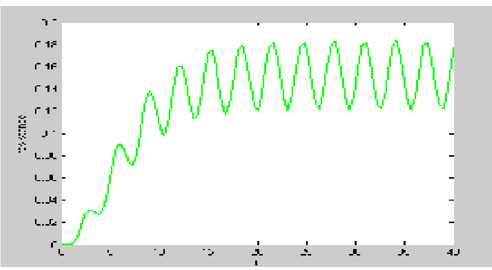


Fig.3 Resistance

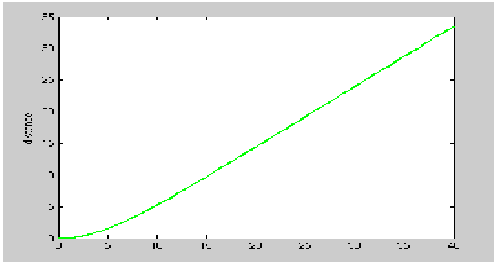


Fig.4 Moved Distance

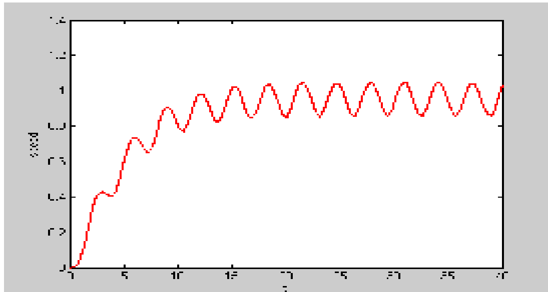


Fig.5 Moving Speed

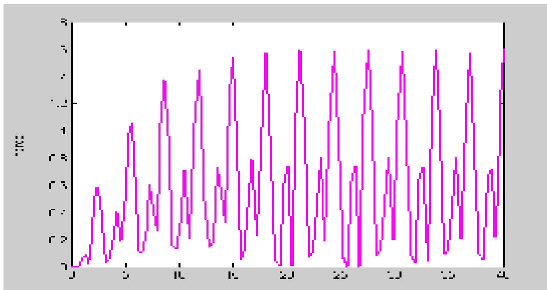


Fig.6 Thrust Force

VI. EXPERIMENT

For the confirmation of the simulation results and further study, we made experiments with actual robot.

1. Experiment system

In this experiment, we used a high performance humanoid robot as a base machine and covered it with waterproof suit. It can be controlled with game controller remotely or with program autonomously. It equips an underwater camera on a body. The photograph of shown in Fig.7. This robot was tested in the water tank of 2m × 2m × 1m (length × width × height) in our laboratory. Fig. 8 shows the shape of the tank.

Table 2 Specification of Humanoid Robot

Servo motor: ROBOTIS Dynamixel AX-12+
Number of AXIS:10
Computer: Motion Greator for TTL(Atmel ATMEG A128)
Wireless: Parani ESD-200 Bluetooth Serial Adapter
Controller: PS/2 Bluetooth controller

Base robot Controller Waterproof suit

Fig. 7 Robot System for Experiment

Fig.8 Water Tank

2. Experiment Resuluts

We would like to report those results on the symp osiun as much as possible.

VI. CONCLUSION

Here we proposed a humanoid type underwater robot. Through the basic study, we are thinking that this type of robot has higher performance than conventional underwater robot and can accomplish higher level of work instead of diver. In this paper, we introduced mainly the propulsion system, such as principal, the structural design or control algorithms to generate appropriate thrust force. This mechanism has a disadvantage that the flutter kick of both leg interfere each other. We found the method to decrease the influence and to satisfy manipulation requirements. This propulsion system can also generate turning moment, upward going moment or downward going moment adding thrust force with selecting angular velocity of fluttering and center angle of fluttering. And with integrating basic control to cooperated control, we can realize free posture control and get various kind of motion.

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