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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, w e considered a dynamic model of undulatory fins and it has been used to construct the dynamic model of pr opulsion and control system and analyze its motion velocity, and propulsion efficiency. We proposed and desi gned the corresponding control algorithms to generate appropriate thrust force and to decrease disadvantatageo us influences of the interference of flutter kick. We can realize free posture control and get various motion f orms.

Keywords: Humanoid, Underwater Robot

I. INTRODUCTION

With the great development of science, the robot technology has been experiencing rapid advancement .As the intercrossed subject of under water engineering and robot technology, under water robot s are among current interest all over the world. However the research on underwater humanoid robot has not been particularly investigated. 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 situations, the authors are putting the focus on developing Underwater Humanoid Robot.

II.DESIGN OF ROBOT

In this section, we briefly present a design of underwater humanoid robot prototype, describing its propulsive mechanism and mechatronics design.

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.

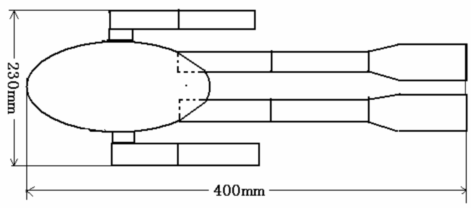

Fig.1 Image of Underwater Humanoid Robot

Fig.2 Underwater Humanoid Robot

Fig. 2 shows prototype of radio-controlled underwater humanoid robot. 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. Forces on the system

Given the composition of this robot, the set of external forces on this robot is lift and drag from the legs, lift and drag from the body, lift and drag from the arms, the force of buoyancy, the force of gravity, and the moments resulting from these forces. These forces are shown in Fig.3.

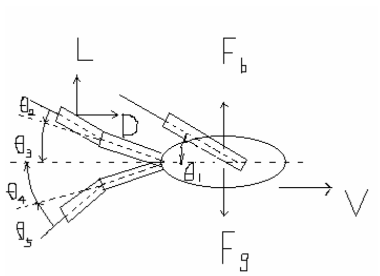

Fig.3 modeled forces

2. Unforced equations of motion

The position and orientation of the body segment of the robot are denote by g which can be written in homogeneous matrix notation as

$$g = \begin{bmatrix} R & x \\ 0 & 1 \end{bmatrix} \quad (1)$$

Where R is the orientation of the body, and x is the position of center of mass of the body, both relative to a fixed inertial reference frame .the longitudinal axis of the body is taken to be x axis, the lateral axis is to be y axis, and z axis to be positive upward. The body-fixed translational and angular velocities are denoted by the vectors V and Ω. The velocity of the body is given by

$$\dot{R} = R\hat{\Omega}$$
$$\dot{x} = RV$$

$$\hat{\Omega} = \begin{bmatrix} 0 & -\omega_3 & -\omega_2 \\ \omega_3 & 0 & -\omega_1 \\ -\omega_2 & \omega_1 & 0 \end{bmatrix} \quad (2)$$

where ω_i is the joint angular rotation rate.

In order to calculate the moment of inertia and added mass simplicity, we approximating the body as an ellipsoid, the arms and legs as columns.

3. Potential forces

The robot is assumed to be neutral buoyancy with centers of buoyancy and gravity that are noncoincident but are collocates along an axis parallel to the z axis. By the effect of gravity and buoyancy we can get a torque.

$$T = -\frac{1}{2} m\gamma R^T k \times r_b$$
$$k = \begin{bmatrix} 0 & 0 & -1 \end{bmatrix}^T \quad (3)$$
$$r_b = \begin{bmatrix} 0 & 0 & h \end{bmatrix}^T$$

here γ is the magnitude of the gravitational force, h is length from the center of mass to the center of buoyancy.

4. Forces on legs

To simulate the dynamics of the swimming, we simply considered an equation of force with flutter kick. It includes the lift and drag on the legs.

$$L = \frac{1}{2}\rho c_l A(v_1^2 + v_2^2)\cos(\frac{\pi}{2} - \psi)$$
$$D = \frac{1}{2}\rho c_d A(v_1^2 + v_2^2)\sin(\frac{\pi}{2} - \psi) \quad (4)$$

where L is Lift force, D is Drag force, ρ is density of fluid, c_l and c_d are the lift and drag coefficients, A is the planform area of the leg in the x-y plane, v_1 is tangential velocity, v_2 is normal velocity, ψ is the angle between leg and body. As the influences of the interference of flutter kick is very complex, we use the approximation and calculate under ideal condition in this paper.

5. Forces on the body and arms

We assume the shape of body is not plate but a n ellipsoid, and then the resistance force on the bo dy is assumed to be generated in the usual steady flow. Under this assumption, the drag and lift force becomes as follows

$$\begin{aligned} D_b &= \frac{1}{2} c_{db} \alpha \rho S v^2 \\ D_a &= \frac{1}{2} c_{da} (\alpha + \theta) \rho S v^2 \\ L_b &= \frac{1}{2} c_{lb} \alpha \rho S v^2 \\ L_a &= \frac{1}{2} c_{la} (\alpha + \theta) \rho S v^2 \end{aligned} \qquad (5)$$

where v is velocity of the body, c_{Db} and c_{Da} are the drag coefficients of the body and arms, c_{lb} a nd c_{la} are the lift coefficients of the body arms, α is attack angle, s is projected area of body in th e y--z plane, θ is the angle between body and arms.

6. Force Equations of motion

For systems such as this one where forces on the system are independent of the body position and orientation, Lagrange equation can be used to describe the system dynamics. A mechanical system of the type considered here can be described by the states of the body g, termed group states, in combination with the values of the states that describe the relative placement of moving components to the body, denoted R and termed the shape states. The shape state states R are the joint angles of legs and arms.

The Lagrangian for this robot with states $r, g, \dot{r}, \dot{g}$ can be written as

$$L(r, g, \dot{r}, \dot{g}) = \frac{1}{2} [\dot{r} \quad \dot{g}] M(r, g) \begin{bmatrix} \dot{r} \\ \dot{g} \end{bmatrix} - U(r, g)$$

$$r = \begin{bmatrix} \theta_1 \\ \theta_2 \\ \theta_3 \end{bmatrix} \qquad (6)$$

Where $U(r, g)$ is potential energy, and V and M correspond to the body-fixed velocity and mass matrix in the robot system. r is the matrix of the joint angles of arms and legs.

IV. CONTROL

In order to evaluate the validity of the model in t he previous section to actual robot, we must determ ine the control method that will generate desired m otion primitives.

1. Forward locomotion

Since the robot moving in straight course is described as a posteriorly propagating wave, the desired motion for the robot links is expected to approximate the wave to generate forward thrust, the desired motion can be expressed as

$$\mathrm{f}(\mathrm{x}, \mathrm{t}) = \left(c_1 \frac{x}{l} + c_2 \left(\frac{x}{l} \right)^2 \right) \sin\left(k \frac{x}{l} + \varpi t \right) l \qquad (7)$$

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. In order to generate the body wave, we set the joint angles as fallows

$$\begin{aligned} &\theta_1 = 0, \theta_2 = \theta_0 \sin(\omega t), \\ &\theta_3 = \theta_0 \sin(\omega t - \varphi) \end{aligned} \qquad (8)$$

We can achieved the forward locomotion, here θ_0 is amplitude. φ is the phase difference. Using the analysis results, we can get the relationship between velocity and frequency of flutter kick. Then with changing flattering frequency, we can get a desired swimming speed.

2. Turning

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

$$F = \frac{1}{2} m \omega^2 D \qquad (9)$$

If we set the robot arms making angle between body as θ, we can get the centripetal force from thrust force and resistance force. Using the analysis results we can get the relationship between θ and w.

V. SIMULATION

In order to evaluate the applicability and capabilities of humanoid robot, we made simulations study with using developed model. The results of simulation for forward swimming and turning are shown in Fig.4 and Fig.5. 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

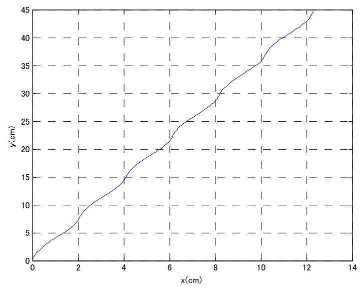

Fig.4 simulation result for forward swimming

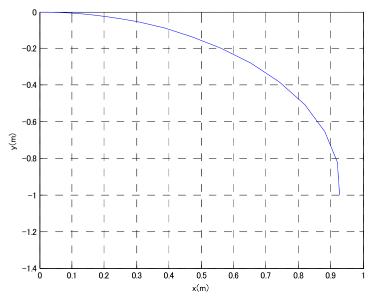

Fig.5 simulation result for turning

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. The photograph of is shown in Fig.6. This robot was tested in the water tank in our laboratory.

Base robot Controller Waterproof suit

Fig. 6 Robot System for Experiment

2. Experiment Results

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

VI. CONCLUSION

In this paper, we considered a dynamics model and control method. Concretely, 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 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. Of course, more accurate parameters remains to be seen, and we would like to develop the system to higher level.

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