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Study of autonomous work control for multiple limbs underwater robot

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Abstract: In this study, we put the focus on stabilizing the position and posture of the underwater working robot, which has 4 legs of 3 joints for walk and two 6D.O.F manipulators for work with autonomous control of legs. In the underwater working by such kinds of robot, stability would decrease by buoyancy effect comparing to on- land work and becomes easy to have an influence with reaction force of the work of robot or current flow. I is necessary to change the corresponding control method according to environment, such as sea floor topography and geology. Therefore, in this research, the target condition and contents of operation should be autonomously defined by conditional branch processing like IF-THEN method. And under this target condition, position and posture control is accomplished as the hybrid system with force control. We confirmed this control method with facility, which is constructed of Stewart type parallel mechanism and 7D.O.F manipulator.

Keywords: Underwater work robot, Autonomous control

I. INTRODUCTION

In those days, the requirement for under water robot becomes higher and higher with a progress of robotic technology. In former 20 years, under water robot was used as explorer. So it was designed to have a shape of submarine and to move under neutral buoyancy. For those type of robot, it is impossible to complete even a light work such as maintenance of under water facility. In Japan, JAMSTEC which has a lot of experience in the field of deep sea science and technology is planning to develop a new concept of robot. It is not floating but moving on a sea floor has an ability to handle a heavy objects. On those backgrounds, the authors started to develop a underwater work robot which has manipulators for hand work and walks on a sea floor with four legs. For this robot, of course, ework control is the most important subject, but stabilizing arm base in the heavy disturbance is a same level of important subject. In this study, we put our mind on a autonomous control of platform state under a reverse force from object, disturbance from tidal flow or wave.

II. UNDER WATER WORK ROBOT

1. Concept

Basic requirements for under water work robot are mobility and activity. It should move to work place quickly and achieve the work perfectly. For a mobility, robot should have neutral buoyancy, but for a work it should have a body stiffness and fix himself to the work place. Considering these requir ements, we chose four legs moving mechanism. Thi s robot equips two manipulator and hand system fo r work. We will show the image of this robot in F ig. 1.

Fig.1 Feature of under water work robot

2. Under water work

The robot will be carried between sea surface and sea floor with submergible carrying vessel. Wh en it arrives to work place, it should fix himself to sea floor. In case of unstable work place, the foot hands grasp something to fix his body. Under thes e conditions, robot starts work with using arm and hand system. In this operation, it will have a eacti on force from object through the work and another force from tidal flow or wave, and should keep h and position and posture for precise work in such kind of circumstance. In the water, there are many kind of work. Making a base for machine or facility, settling them, constructing plants or building, connecting utilities to them, their maintenance or repairing work, removing or cleaning are just small example. Under water work robot should accept all kind of requirement, make judgment by himself and complete the task.

III. CONTROL SYSTEM

1. Control subject

As mentioned before, under water work robot is not so powerful, big and heavy because he must sometimes use neutral buoyancy in its motion. However their task sometimes requires high accuracy, high skill, high power, high speed or wide activity. Before thinking about control, we should classify the works which robot meets in the water from the point of robot situation. The item becomes as follows.

(1) Standing work
(2) Holding work
(3) Floating work
(4) Laying work
(5) Cooperating work

(1) Standing work is a normal style for the robot. When the reaction force or external force is not so strong, the robot can accomplish his task with standing on a sea floor. In this case, power joint of each leg should keep plat home position and posture at initial situation.

(2) Holding work is used in the situation where reaction force or external force is a little stronger to keep plat home condition and foot finger attached on each leg grasp something on the sea floor. Then power joint of legs absorbs the displacement.

(3) Floating work is a special case. Of course there exist a work at higher position from sea floor. At that time robot uses neutral buoyancy and goes up to work position. Of course, holding work is available. And this work is similar to the work in space.

(4) Laying work is used under very strong external force such as wave. In this case, robot lay down on a sea floor like a crab. Sometimes foot finger grasp something not to move.

(5) Cooperation work is used when he must handle a heavy or large object. At that time, he communicate to other robots and handle it under cooperation. When many robots are working in the same place, it is a kind of cooperation work and they need leader in the work group. We show image figures for those works from Fig.2 to Fig. 6.

Fig. 2 Standing work

Fig.3 Holding work

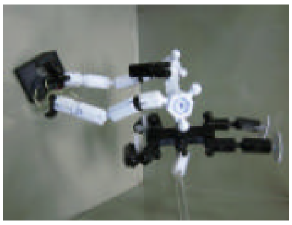


Fig.4 Floating work

Fig.5 Laying work

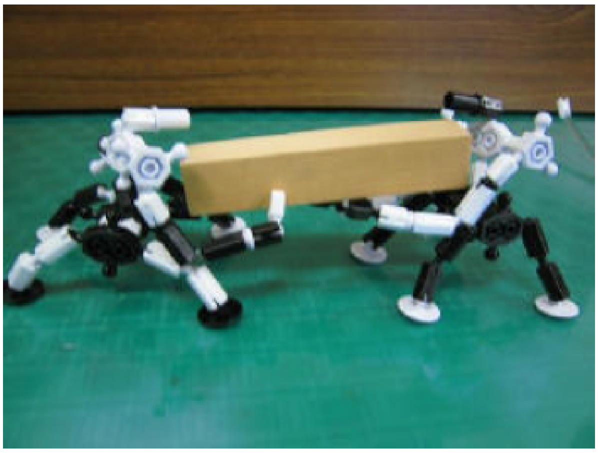


Fig.6 Cooperation work

2. Control method

This type of under water work robot is consisted of multi links and joints mechanism and having excess degree of freedom for the work with hand and arm system under strong external force. In this system it is available to control all joints for the work but it is very difficult to select effective joint and assign effective torque for the work. So, in our study, we divided the control loop into two functions. One is work control with hand and arm system. Another is body control with leg and foot finger system. With this method, the degree of freedom is decreased and control becomes easy. The former is discussing in the study by Yamanashi et al. In this paper, we show the detail of latter control.

As mentioned before, there are many kinds of work style for body control and they must keep body condition to constant while robot is working. So in this control there are also two control functions. One is work style classifying and another is body control under classified body style. The former is designed as autonomous function and considering all kind of work condition, most effective style is selected when the work is practicable for robot. But at impracticable situation, robot takes contact to human supervisor.

The latter is designed to keep the style, and position and posture of plat home with feedback control We show the concept of this control method in Fig. 7 and detail of body control in Fig. 8..

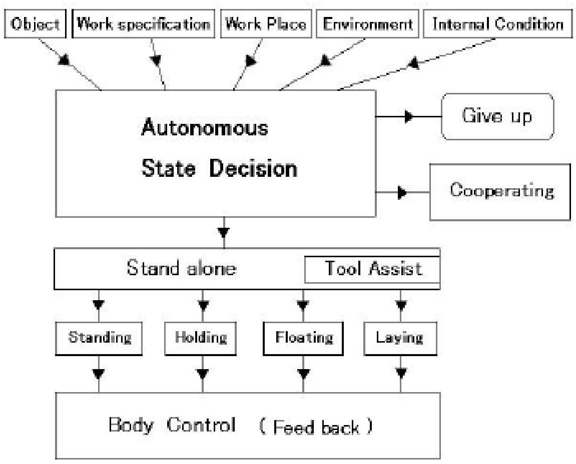


Fig. 7 Concept of control method

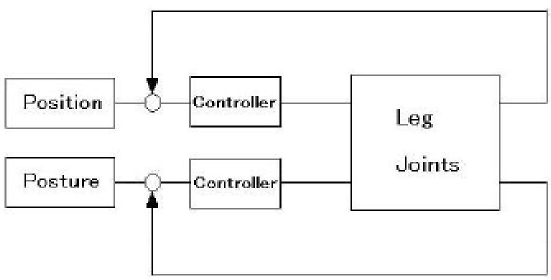


Fig.8 Body Control

IV. AUTONOMOUS CONTROL

In this section, we introduce the detail of autonomous style selection method.

1. Concept

There has been many kinds of technology advocated as an autonomous algorithm and they are mainly depending on a intelligent method such as artificial intelligence or genetic algorithm. And one of them is a compact size of program but takes longtime for decision, another needs a large size of database. Considering those experience and practicability, we adopted logical decision method.

2. Logical decision method

We must set check fields and items as input from view points of what, where, who, when and how for logical decision. Considering the application to under water work, we chose following fields and items, and set three decision levels for each item, that is, handling impossible, self handling impossible, self handling possible.

(1)Object: the information of work object is most important and we set following items in this field

① Size: Extra Large? Large? Possible

② Weight: Extra heavy? Heavy? Possible

(2)Work specification

① Accuracy: Extra precise? Precise? Possible

② Required Power: Extra strong? Strong? Possible

③ Process: Extra complex? Complex? Possible

(3)Work Place

① Ground Condition: Impossible? Possible

② Depth : Extra deep? Deep? Possible

③ Work Space:Extra narrow? Narrow? Possible

(4)Environment

① External Force: Extra strong? Strong? Possible

② Transparency : Extra Dirty? Dirty? Possible

(5)Internal Condition

③ Motor Torque: Extra High? High? Possible

④ Stress: Extra High? High? Possible

⑤ Mechanism: Impossible? Possible

To those Items of the field, we check the level sequentially. The output of this process is as follows.

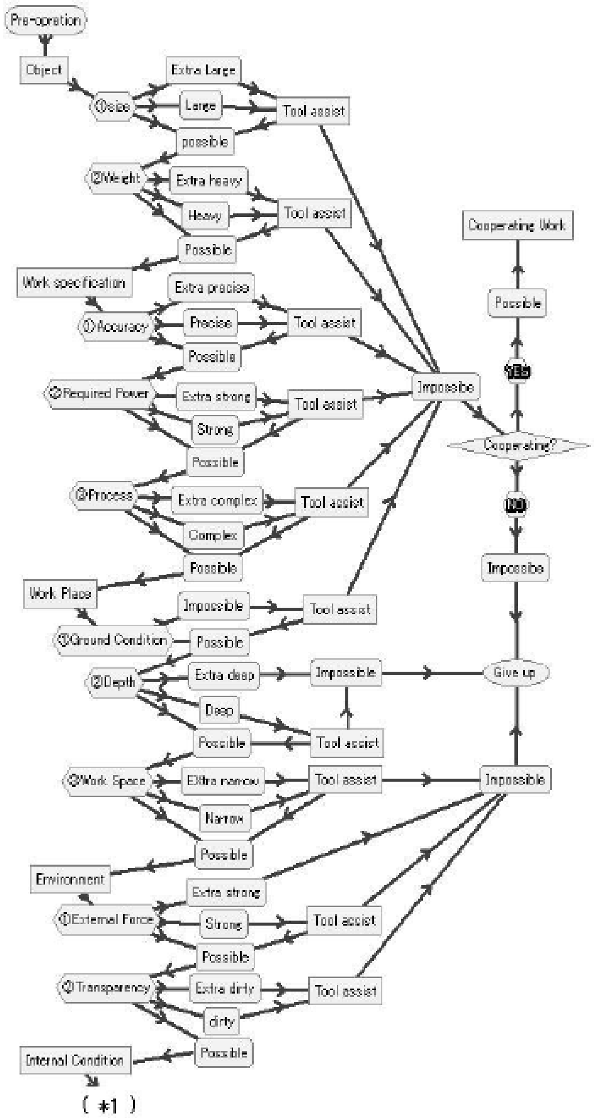
(1)Stop Work: When there is at least one item that is over impossible level, robot cannot complete the work and send the information to supervisor.

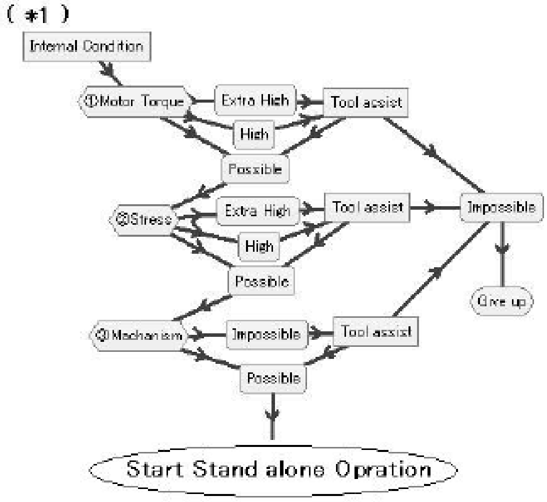
(2)Cooperation: When there is an item that is self handling impossible, the robot send a signal to call another robot for help.

(3)Tool Assist: When there is an item that is requiring special tool, the robot send a signal to another robot to carry the special tool.

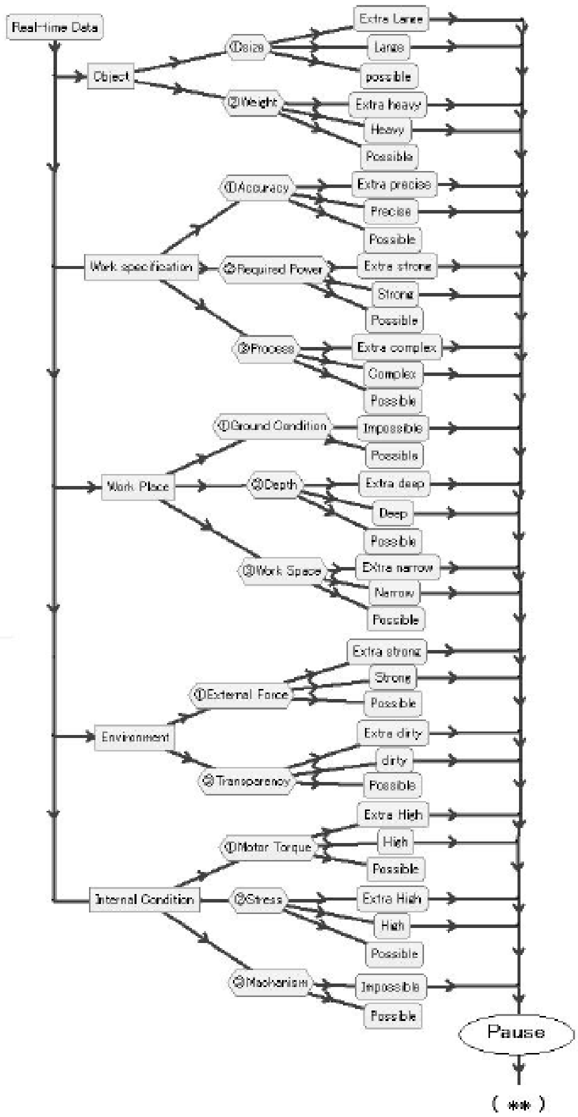
(4)Change Posture: Internal condition comes to high level, the robot should search the availability for decreasing the level with changing posture. However, manipulator should change the posture simultaneously in this case. So, he should check both availability.

(5)Continue Work: When every check item is cleared, robot can complete the work. After this decision, we must select the work style depending above mentioned criteria. We show this algorithm in Fig. 9 with flow diagram.





Working state



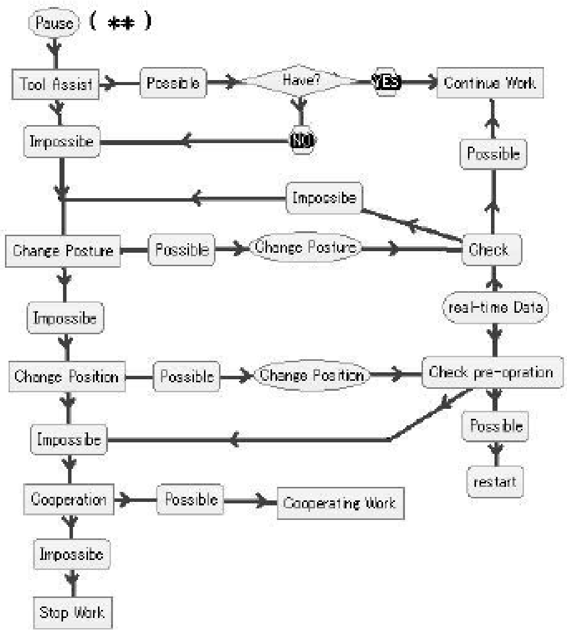


Fig. 9 Algorithm for autonomous control

V. CONFIRMATION OF FUNCTION

This algorithm is constructed with very simple structure. But it requires many kind of threshold value and it is another problem how to decide it. Including this problem, we are thinking to confirm the suitability of this algorithm is most urgent matter. We have prepared a experiment system consisted with parallel mechanism and 7 DOF manipulator (PA-10 7C). For these equipments, we can give a reaction force with pushing manipulator and external force with pushing or pulling manipulator attached base of parallel mechanism. Now we are in the experiment and going to show the result in the symposium.

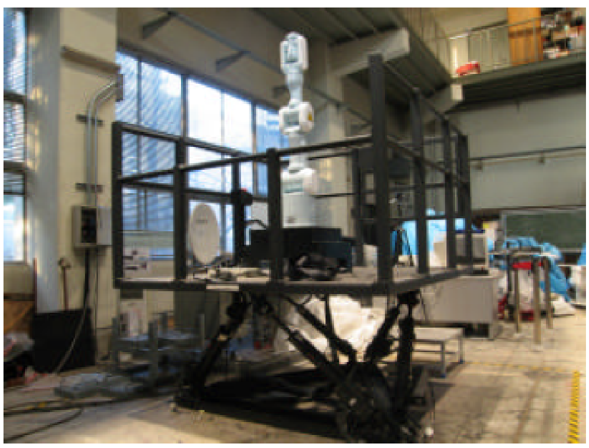


Fig.10. Experimental equipment

VI. CONCLUSION

In this study we discussed autonomous control for under water work robot. There are many kinds of work in the water and some of them requires heavy machine. However we are proposing a rather light robot with four legs and two hands. We are thinking this type of robot has higher availability than humanoid type or heavy machine type and arranged autonomous work control method for it. The algorithm is a combination of logical decision method and feedback control. We are thinking it has enough practicability for this type of robot.

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