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Review and Classification of The Modern ROV

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Overview

With unmanned ground chariot, unmanned aircraft and unmanned ships gradually on the battlefield to show higher and higher operation effectiveness, Unmanned operation platform will play an important role in the future modernization war. Unmanned Underwater Vehicles (UUV) is an important development direction of unmanned platform. Accelerate the development of UUV, occupy the strategic high ground, the future of resource exploration, military development, ecological research and many other aspects is essential.

1. Classification of modern ROV

Unmanned underwater vehicle(UUV), is a diving equipment which takes submarine or surface vessels as an operating platform, and capable of navigating underwater and undertaking underwater target searching, survey, identification and salvage tasks. According to the different contact ways with the water surface support platform, it can be divided into Remote Operated Vehicle (ROV) and Autonomous Underwater Vehicle (AUV). Depending on the purpose of use, it can be divided into operation type and Search type.

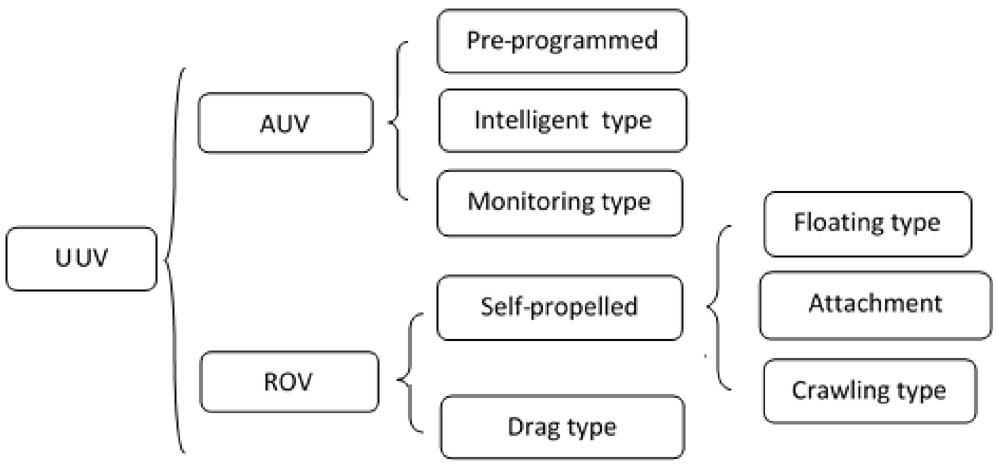

Figure 1. Types of Underwater Robots

Like space rockets to explore space, an underwater robot is an important high-tech device in the field of ocean exploration, development and utilization. Underwater robots involve many disciplines as fluid mechanics, anti-corrosion, mechanical, acoustics, electronic information, optics, guidance and control, navigation, computer science, sensor technology.

ROV can accept relatively large data transmission and longer underwater operating time, because of connected with surface ship through the umbilical cable. It can accept relatively large data transmission and longer underwater operating time, also can support complex operating equipment and large electricity load. To compare with other type of unmanned underwater vehicle, ROV possess flexible, dynamic, high operating depth, strong endurance and environmental adaptability and many other characteristics.

The type of modern ROV system can be divided by size, drive form, power and dive depth.

Table 1. The type of modern ROV

type	capability	power /kW
Small (electric)	Observation (< 300 meters)	Less than (7.4)
Large (electric)	Observation / minor operation (<3000 m)	Less than (14.7)
Extremely deep (electric)	Observation / data acquisition (>3000 m)	Less than (18.4)
Medium (electric / hydraulic)	Slight / moderate intensity operation (<2000 m)	Less than (73.6)
Large (electric / hydraulic)	High strength / large load (< 3000 meters)	Less than (220.7)
Extremely deep (electric / hydraulic)	High strength / large load (> 3000 meters)	Less than (88.3)

2. Development status and scientific research achievements of ROV

Researchers of United States have sealed the camera to the sea bottom, a cable-type underwater robot shape was born in 20th 50s. The world's first real sense of the ROV is developed in the United States in 1960, "CURVE". January of 1966, the United States use "CURVE" in the Atlantic Ocean from the sea recovered from a bomber crash lost hydrogen bomb. Since then people attach importance to ROV technology research.

The Nereus is a novel operational under water vehicle designed to perform scientific survey and sampling to the full depth of the ocean of 11,000 meters—almost twice the depth of any present-day operational vehicle. The goal of the Nereus project is to provide the U.S. oceanographic community with the first capable and cost-effective vehicle for routine access to the world's oceans to 11,000 meters.

The world's most famous scientific operating ROV is the United States *Jason* series, it is a dual ROV system which consisting of a relay station and ROV noumenon. The first generation of *Jason-1* serviced in 1988 which the maximum dive depth about 6000m. During the service, it completed hundreds of dives in the Pacific, Atlantic and Indian Ocean. The longest dive time is 100h and on average is 21h. In 2002, the second generation of *Jason* series *Jason-2* ROV has serviced. Its structure is more solid, technology is more advanced, and the maximum dive depth is even reached 6500m.

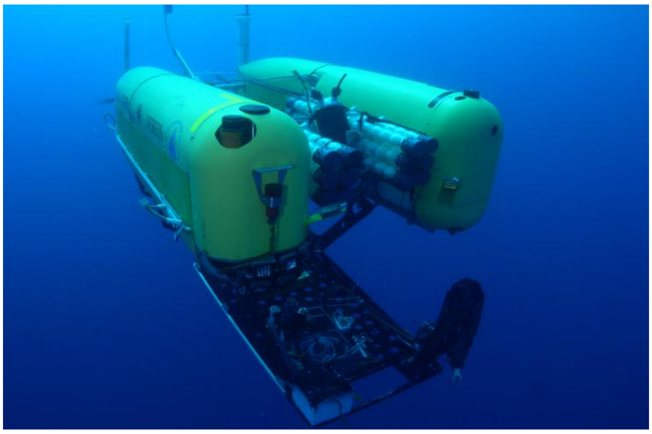

Figure 2. The Nereus

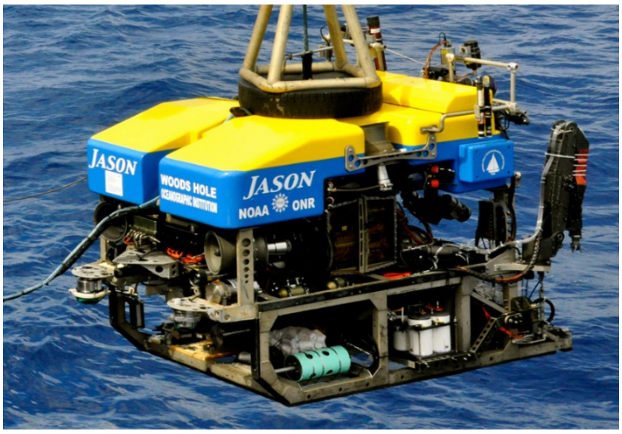

Figure 3. ROV Jason-2

Oceaneering is the world's largest working class ROV operator, and the most important supplier of oil-gas industry ROV. The company on the one hand is the largest ROV operator, the other hand is the world's largest ROV system manufacturer. The ROV range includes a working system with a rated dive depth of 2,500 m to 3,000 m (8,200 ft -9,840 ft), millennium work system with a rated dive depth of 4,000 meters (13,120 ft), and rated diving depth of 8000 meters (26,240 feet) of ultra-deep system.

Divinycell HCP and BTMI synthetic foams (epoxy microbead buoyancy materials) are used on Oceaneering's ROV. Divinycell HCP can be used for a range of 700 meters (2,300 feet) from sea level to underwater and provides very low buoyancy loss and water absorption in long-term load environments. The BTMI Synthetic Foam (Epoxy Microbead Buoyancy Material) has a high unit of buoyancy and can be applied to products of different depth levels up to 10,000 meters (32,800 feet).

3. The composition of ROV control system

In general, ROV control system can be divided into three parts: surface control system, umbilical cable and underwater system.

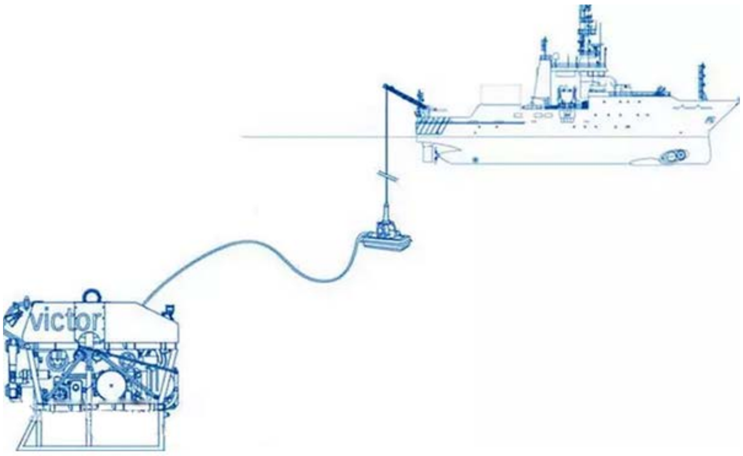

Figure 4. Structure diagram of ROV control system

ROV's surface control system is located on board, or set on a shore-based console, the system is marching with computer, data converter, power supply, control handle, display screen and other equipment. Through the computer and display screen the operator can analyze data or observe the environment where robot located, monitors the robot's live operation, and operating the corresponding motion control of the robot and the speed of it.

Figure 5. Surface control system

In order to safely and quickly dispose of underwater robots, there is a need for a hanging system on the hull, consisting mainly of type A crane and winch.

Figure 6. Hanging system

Through the umbilical cable, the surface console can not only transport power, control signals to the ROV, it also receives the returned information from robot. In shallow water area, a few hundred meters of umbilical cord can be directly from the hull. However，in deep water area, umbilical cable will increase the underwater ROV movement and operation resistance. So，relay (Tether Management System, TMS) was being used.

The ROV noumenon includes sealed and pressure-resistant housing, power system, observation and lighting system, sensor, communication system and control system.

The robot shell is made of carbon fiber, which increases the strength of the shell and reduces the quality of the shell. The electrical system is concentrated in the sealed compartment, enhancing the waterproofing effect, and is easy to disassemble and repair. The skeleton is equipped with a buoyancy material to facilitate the buoyancy ratio.

According to the movement command issued by the control system, ROV can be advance or retreat, floating up or sinking, traverse, horizontal rotation, etc, to achieve six dimensions of movement. The robot moves advance or retreat when longitudinal propeller with the same speed, differential can turn bow movement. Vertical propeller with the same speed can be floating up or sinking, propeller differential rotation can adjust the pitching attitude. Based on Newton 's law of mechanics, the law of conservation of mass and energy, on the viscous incompressible Newtonian fluid to establish continuous equations and equations of motion:

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$$\frac{\partial u_i}{\partial x_i} = 0$$

$$\frac{\partial u_i}{\partial t} + \frac{\partial}{\partial x_i}\left(u_i u_j\right) = \text{I}\frac{1}{\rho}\frac{\partial p}{\partial x_i} + v\frac{\partial}{\partial x_j}\left[\frac{\partial u_i}{\partial x_j} + \frac{\partial u_y}{\partial x_i}\right]$$

Where:

u_i $(i=1,2,3)$ The velocity component in the positive direction of the three axes,

u_j $(j=1,2,3)$ The velocity component in the negative direction of the three axes,

x_i $(i=1,2,3)$ The coordinate component in the positive direction of the three axes,

x_j $(j=1,2,3)$ The coordinate component in the negative direction of the three coordinate axes,

p is the pressure, ρ is the fluid density， v is the kinematic viscosity coefficient of the fluid， t is time.

The resistance of the underwater robot consists of two parts: the robot noumenon movement resistance and the cable resistance. The calculation formula of ROV noumenon movement resistance is:

$$F = \frac{1}{2} C_d \rho V^2 L^2$$

Where: C_d is resistance coefficient, the value is calculated using Fluent V is the speed of robot, ρ / _ ^ _D_Dd_________ﻚﻮ88___________

The resistance to the cable is estimated by the following equation:

$$F = \frac{1}{2} C_d \rho V^2 A$$

Where： C_d is resistance coefficient， V is the speed of robot, ρ ∛ ⁄(density, A is feature area, equal to the cable diameter multiplied by the length perpendicular to the direction of the flow.

Typically, the front end of the operating underwater robot is equipped with two mechanical arms. The starboard mechanical arm is an operating arm, generally 5 to 7 degrees of freedom which is more flexible, high operating accuracy, the control system mainly adopts the master-slave electro-hydraulic servo control; The port side mechanical arm is mainly used as a positioning type arm which is simpler, but powerful, generally have 3 to 5 degrees of freedom, and it can be reliable implementation of ROV suspension positioning function, the control system uses a simple switch control mode.

Depending on the ROV assignment task, the requirements for the job tool can be roughly divided into two categories: To complete the conventional underwater operations tasks, can be equipped with some more standard, common operating tools. Most of these tools have a standard interface that can be purchased or self-developed; To complete some specific job assignments, such as sample collection for various uses. Most of the need to develop the appropriate sampling tools and sample containers, and the need for relevant disciplines of expertise which has a high degree of difficulty.

In order to successfully follow the established trajectory to complete the search mission, navigation and positioning control technology is extremely important when ROV work in the complex underwater environment. Currently widely used navigation systems are acoustic navigation, inertial navigation, GPS navigation, visual navigation, etc.

1. Acoustic navigation is the use of acoustic signals in the water is not easy to decay that can be transmitted remotely from the characteristics of the positioning of the sensor. Attenuation of Electromagnetic Wave in Water . According to the length of the baseline acoustic navigation system is divided into: Short Baseline (SBL), Ultra-Short Baseline (USBL), Long Baseline (LBL).
2. Inertial Navigation According to Newton's theorem, the acceleration of the carrier is measured by the inertial element (accelerometer). After the integral and operation, the carrier speed and position information are obtained. The inertial measurement device includes accelerometer and gyroscope. The three degrees of freedom gyroscope is used to measure the three rotational movements of the carrier, three accelerometers are used to measure the acceleration in the three translation directions of the carrier, the carrier position information is calculated using these six acceleration values.

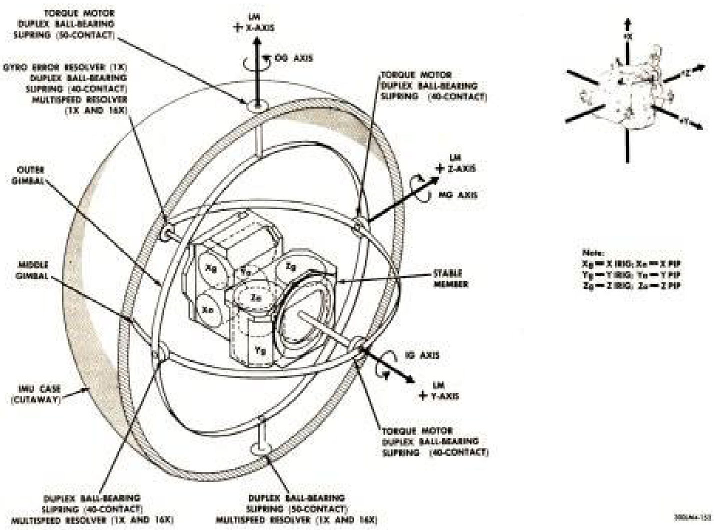

Figure 7. inertial navigation

3. The GPS navigation is based on time and the known position of GPS specialized satellites. The satellites carry very stable atomic clocks that are synchronized with one another and with the ground clocks. GPS satellites continuously transmit data about their current time and position. A GPS receiver monitors multiple satellites and solves equations to determine the precise position of the receiver and its deviation from true time.
4. Visual navigation is a navigation technique that obtains the position of the carrier by processing the image information acquired by the visual sensor. In the past 30 years, due to the autonomy, cheapness and reliability of the navigation method, it has become a hotspot of navigation technology. Visual navigation has the advantages of low cost, small size, high precision, rich information, strong anti-interference ability.

4. Algorithm of ROV motion control

PID controller has been widely used in various industrial process control because of its simple algorithm, easy implementation and strong robustness. PID control is a linear control method for proportional, integral and differential of system deviation.

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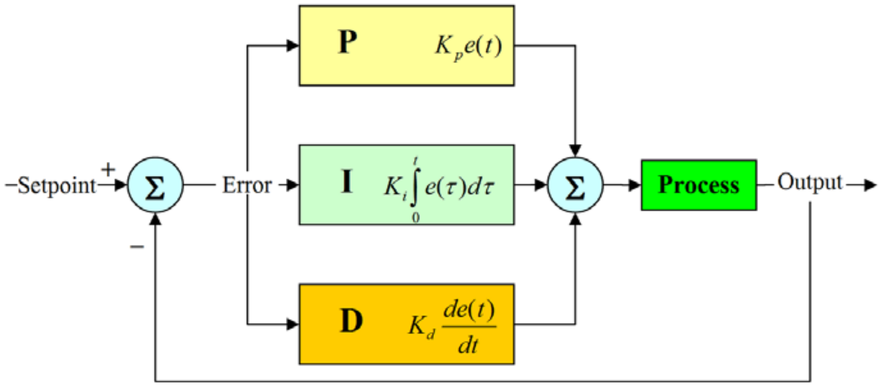

Figure 8. PID control system schematic

The expression of the PID control algorithm is：

The independent PID controller systems in ROV use serial correction, respectively control the depth, bow angle and pitch angle. ROV depth control system through the PID tuning PID simulation results are quite good that can achieve the set target data, but has a certain overshoot, and the response speed is slow; ROV bow angle control system through the PID adjustment can reach the set target data and have better control performance; ROV tilt angle control system through the PID regulator can achieve the set of target data, the response speed is faster, have better control performance.

As the working environment of underwater robots is very bad, in the impact of current and other factors, the traditional PID control in the anti-interference cannot achieve better results. Fuzzy control and classic control theory and modern control theory, its main features are: Is a language controller, easy to control non-linear system; fast response, anti-interference ability, with strong robustness. Fuzzy control theory refers to the concept of fuzzy set based on the basic concept or continuous membership function theory, using language rules to describe knowledge and experience, combined with computer technology, fuzzy reasoning to judge a high-level control strategy.

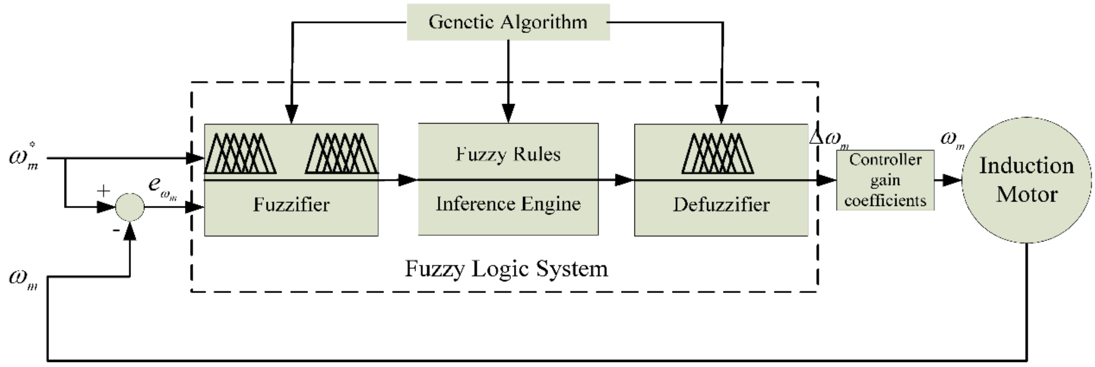

Figure 9. Genetic algorithm for a fuzzy control system

Adaptive control is an important branch of modern control theory and is usually applied to applications where the parameter uncertainty is serious or the parameter changes slowly, but the stability is weak. Adaptive control and conventional feedback control and optimal control, is also a mathematical model based on the control method, the difference is that the prior knowledge of the model and the perturbation based on the adaptive control is relatively small, and it is necessary to constantly extract the information about the model in the course of system operation and make the model gradually improve.

Summary.

There are three technical barriers to intelligent underwater robots to remote development: energy, remote navigation and real-time communication. The development of ROV using solar energy is a very significant research direction.

The water depth over 6000 meters of the ocean area accounted for 97% of the total ocean area in the earth, so many countries to develop 6,000 meters water depth technology an significant goal.

Increasing the intelligence level of underwater robot behavior has always been the goal of national scientists. The development of multi-robot collaborative control technology is also an important aspect of increasing ROV intelligence.