A PLAN FOR THE DEVELOPMENT OF A DEEP-SEA UNMANNED UNDERWATER VEHICLE

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Abstract

In May 2000, the Korean government has established a basic plan for ocean exploitation, Ocean Korea 21 (OK21) including the development of oceanic resources, and deep-sea scientific intervention. According to this plan, the Korea Research Institute of Ships and Ocean Engineering (KRISO) proposed a program for the development of a deep-sea unmanned underwater vehicle (UUV) to explore deep sea for scientific purpose. KRISO has launched a project in May 2001 under the support of the Ministry of Maritime Affairs and Fisheries (MOMAF) of Korea. This paper introduces the project in view of background, objectives, functions and constitution of the deep-sea unmanned underwater vehicle. R&D topics of the plan are described as well.

Introduction

Recently, KRISO, an ocean engineering branch of the Korea Ocean Development and Research Institute (KORDI), has performed a feasibility study for the development of a deep-sea unmanned underwater vehicle that is capable of surveying the whole ocean near 6,000m depth rates [1]. KRISO has derived a five-year proposal from the feasibility study, which was started in May 8, 2001.

The deep-sea unmanned underwater vehicle will be applied to scientific researches in deep-sea as well as in shallow water. For operation of underwater vehicles in shallow water near the Korean Peninsula, a special design is required because of strong tidal current. In addition, MOMAF requires the vehicle to be designed for the purpose of long range survey, a long-term observation, and precise works in a specific area. Thus, KRISO has planned to design the system with the functional combination of both ROV and AUV.

Figure 1 shows the conceptual diagram of the deep-sea UUV. The vehicle system will be composed of three types of vehicle, i.e., a launcher, an ROV and an AUV. The vehicle will mostly be operated in ROV mode in general. The AUV will be launched in particular situation, such as when long-range survey is required simultaneously while the ROV is in operation in deep-sea. The launcher will be connected to a support vessel with a cable, and the ROV will be released from the launcher. The launcher will be equipped with a drum being capable of managing the tether cable for the ROV.

Additionally, the launcher will be equipped with docking and homing devices for the AUV. The AUV will be launched and docked with the launcher in deep water for long range survey. The AUV will be able to be re-launched in deep-sea after recharging the power

Fig. 1. Conceptual figure of the deep-sea unmanned underwater vehicle.

and saving the data or reloading control programs. The deep-sea unmanned underwater vehicle, therefore, will be a multiple vehicle system accompanied with the launcher, the ROV and the AUV for multidisciplinary researches in both shallow and deep-sea environments.

This paper briefly presents the background of the R&D program, the objectives, functions and constitution of the deep-sea unmanned underwater vehicle, and R&D topics of the plan.

Background

The Korean government established a basic plan - new visions and strategies - in the field of maritime affairs and fisheries in 1996 [2]. We must constantly cope with changes in general maritime affairs and fisheries, such as information-oriented globalization. This will take place in the 21st century where (1) rapid changes in the ocean, (2) intensification of competition for extending the ocean economic realm, (3) increase of demands for exploiting ocean resources, (4) the harmony of environment and development, etc. Therefore, the necessity for developing definite and practical strategies of being aware of the ocean as a nation has reached its climax according to the change of internal and external variables.

In accordance with this situation, MOMAF has extensively revised the basic plan for ocean exploitation to the new change of variables, internally and externally. It was recreated into a new plan for ocean exploitation, Ocean Korea 21 (OK21), in May 2000 [3,4].

OK21, as a master plan on the maritime affairs and fisheries, prepares basic principle to develop, utilize, and preserve the ocean. OK21 is a basic national plan for realizing Korea as an ocean-rich country in the 21st century, including proposing basic courses to establish and carry out the policies of maritime affairs and fisheries.

The development of a deep-sea unmanned underwater vehicle is one of the programs in OK21. A deep-sea unmanned underwater vehicle is a fundamental piece of equipment for ocean exploration and oceanographic research, which is applicable to installing underwater structures, surveying deep-sea ecosystem and geology, probing thermal vents, inspecting deep-sea resources, and monitoring sea-bed.

According to this plan, KRISO has done a feasibility study on the development of a deep-sea robotic vehicle [1], and established a 5-year program to develop a deep-sea unmanned underwater vehicle to probe the deep-sea for the purpose of scientific research.

KRISO has done a key role in the field of underwater technologies in Korea. KRISO developed a 250m rated manned submersible for scientific research, a 300m rated ROV CROV300 for underwater monitoring in 1993, a 200m test-bed AUV VORAM in 1997 [5,6]. KRISO has also designed a basic system for a heavy-duty ROV since 1997, and is under developing a semi-autonomous underwater vehicle equipped with an electric motor-driven manipulator [5,6]. In addition, KRISO has several test facilities, such as a ocean basin, a towing tank, and an acoustic tank, etc. Therefore, MOMAF grants that KRISO organizes the R&D program based on its experiences and facilities.

Objectives

The objectives for the development of a deep-sea UUV is as follows:

– Establishment of an infrastructure for sampling and acquiring oceanographic data and ocean resources
– Development of a deep-sea probe for ocean exploration
– Development of the core technologies of UUV; design, operation, autonomous navigation and control
– Stimulating Korean ocean industries and scientific research in ocean development
– Development of the navigation and control technologies and of the underwater docking technology for multiple underwater vehicles

Final goal is the development of a 6,000m depth rated deep-sea unmanned underwater vehicle.

Missions and Functions

The main mission of the deep-sea UUV is data acquisition for research on deep-sea oceanography. MOMAF has requested the deep-sea UUV should be applied to scientific research in shallow water as well as deep sea. And additional requirement is the vehicle has to survey long ranges of deep sea and conduct precise works in a specific area such as sampling and coring at sea bed.

The missions of the vehicle are as follows:

– Data acquisition for deep-sea oceanography
    • Deep-sea sampling, monitoring and inspection
    • Hydrothermal bent probing and research on deep-sea ecosystem and biological oceanography
    • Scientific research on submarine volcanoes

and marine geoscience

- Scientific research and applications in shallow water
  - Monitoring, sampling, and inspection in shallow water
  - Inspection of sunken ships and light works

Functional requirements of the vehicle to conduct the missions are precise navigation, acoustic communication and reliable operation in deep-sea without disturbing ocean environment.

- Precise navigation in deep-sea and shallow water
- Precise work with manipulators
  - Inspection, sampling, coring, and maintenance of underwater structure
- Underwater communication and control
- Sea-bed inspection with optic and acoustic equipment
- Low noise operation

Constitutions of the UUV

The vehicle should be designed with special features to cope with the requirements of MOMAF. The environment of shallow water near the Korean peninsula is very severe because of strong tidal current and high turbidity. Thus a depressor is needed to compensate current-generated external disturbances acting on the cable and vehicle. In general, ROVs are suitable for underwater works with manipulators, and AUVs are compatible for long range survey.

Since the design philosophy of underwater vehicles depends on operating depth and missions, KRISO has proposed a multi-vehicle system composed of an ROV, an AUV and a launcher. The ROV will be equipped with additional thrusters to improve the maneuvering performance of the vehicle in strong current, and the launcher, as a role of depressor of the UUV, has deep-sea launching and recovering devices for the ROV and the AUV. The AUV will be designed as small as possible to minimize the size of the launching device. KRISO also considered the possibility for the ROV autonomously doing light works without cable connection in future applications.

The launcher is connected to a support vessel with a cable, and the ROV is released from the launcher and recovered, which is similar to KAIKO of JAMSTEC or JASON of WHOI [7,8]. The launcher will be equipped with a drum being capable of managing the tether cable and a docking device for the ROV.

The small AUV also is launched from the launcher in particular situation, such as, when long-range survey is required simultaneously while the ROV is in operation in deep-sea. The launcher will be equipped with additional homing and docking devices for the AUV. A special homing and docking device will be designed for autonomous reliable navigation, control and docking. The AUV will be able to be re-launched in deep-sea after recharging the power, saving the data and reloading control programs.

For multidisciplinary researches in both shallow and deep sea, therefore, the UUV is composed of multiple vehicles: the deep-sea launcher, the ROV and the small AUV.

- Deep-sea launcher
  - Launching and recovering system for the ROV and the small AUV in deep-sea
  - Heading control for docking with the ROV and the AUV
  - Localization with an LBL system
- ROV
  - 6 d.o.f. motion control equipped with mission packages
  - Navigation and control with a SSBL system
  - ROV mode: normal works with cameras, manipulators and samplers
  - AUV mode: untethered UUV for future applications
  - Two layered buoyancy materials: variable buoyancy, payload and propulsion
- Small AUV
  - Long range survey in deep-sea
  - Equipped with a small and reliable navigation system for underwater launching and docking
  - Acoustic communication with the launcher

Main Equipment

Main equipment for the UUV is as follows:

- Two hydraulic manipulators and water samplers
- Underwater cameras and lights, acoustic image systems
- Acoustic communication system for the small AUV
- Underwater homing/docking system for the ROV and the small AUV
- Navigation Sensors: LBL, SBL (or SSBL), gyro, compass, doppler log
- Tether management system: cable length: 8,000m, tether : 200m
- Sensors: depth, attitude, altitude, OAS, SSS, FLS, CTD, etc.
- Extra work package interfaces for other scientific

equipment

– Emergency devices: a cable cutter, weight drops, and power control devices

Related Research Topics

There are several unproven systems in the multidisciplinary UUV system. KRISO has to refine and redesign the conceptual system through basic researches specified as follows:

– Design philosophy for multi-purpose underwater vehicles - trade off with cost
– Special design consideration for deep-sea vehicles - pressure vessel, sensors, cables, communication, navigation, etc.
– Hydrodynamic modeling of the vehicles including cable dynamics
– Interactive control of manipulators with the motion of the underwater platform
– Multiple vehicle dynamics for cooperative operation
– Underwater homing and docking of the small AUV - navigation, sensors, control algorithm, data transfer, power transmission etc.
– Real-time control of the small AUV by acoustic telemetry in deep sea
– High density power source for AUV
– Operational consideration for the launcher, the ROV, and the small AUV

A docking system for the small AUV is a typical example of research topics. Figure 2 depicts a possible docking system for the AUV, which is similar to those of REMUS AUV of WHOI [9].

The AUV could come to a way point for the first step in approaching to the launcher, and keep a straight tracking line to get into the dock. In this kind of docking system, the AUV should track the dock within a circle of docking window. However, it is difficult to get exact docking without failure because the launcher will slowly move due to external forces exerted by current and cable disturbance induced by transmission of a surface ship's motion. Although a lateral thruster of the launcher could control its heading, the launcher could not regulate the vertical and horizontal motion. We plan to attenuate the vertical motion of the launcher passively, make a predictive model for the motion of the launcher including cable dynamics, and control the AUV to track an estimated path. The AUV will be docked with reducing forward speed to minimize impact force. Thus a precise dynamic modeling of the vehicles is fundamental for the predictive docking system as well as advanced control algorithms. In addition, an acoustic communication system and a reliable small navigation system between the launcher and the AUV are needed to transmit motion and command data and to measure the relative

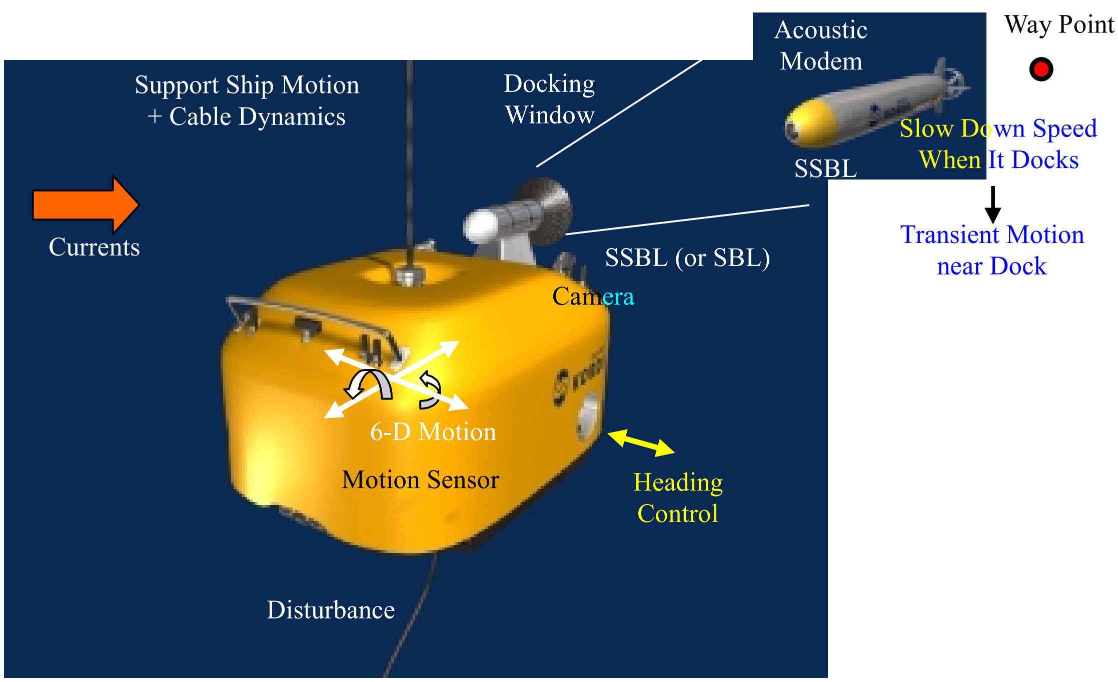

Fig. 2 Conceptual diagram for a deep-sea docking system for the small AUV.

position of the vehicles.

Among the above research fields, KRISO will especially concentrates its efforts on the following advanced research topics:

- Modeling and simulation - underwater systems and components
- Advanced control – underwater vehicles and underwater manipulator systems
- Communication and control of cooperating AUV's
- Navigation, homing, and docking challenges
- Advanced acoustic communication and control in high density media

Organization for the Program

KRISO has been leading the research program with the help of several academic institutes of Korea. Industrial companies will join after producing a basic and detail design of the UUV. KRISO set up the concept of the UUV and defined the functions and specification of it last year. A technical committee has been monitoring and consulting the program. KRISO has to lead the program effectively and develop advanced technologies under limited funds. Therefore, international cooperation is needed to make successful progress in the advanced research topics and to minimize the trial and errors in design, manufacture and operation. Figure 3 shows the organization and process for the development of the deep-sea UUV.

Concluding Remarks and Acknowledgement

This paper briefly introduces the plan for the development of a deep-sea unmanned underwater vehicle in Korea. KRISO is leading the 1st year program under the support of the Ministries of Maritime Affairs and Fisheries (MOMAF). International cooperation will be expected in the research topics of the advanced navigation, control, acoustic communication, homing and docking technologies.

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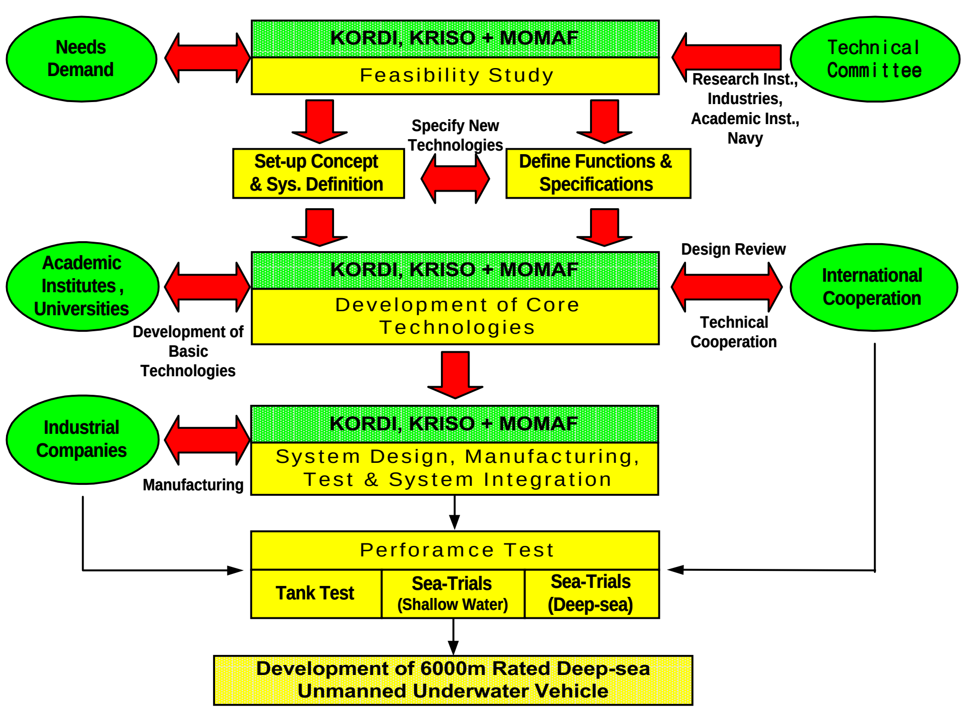

Fig. 3 Organization and process for the R&D of the deep-sea UUV.

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