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A Novel Control Architecture for Mission Re-Planning of AUV

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Abstract

A hierarchical control architecture for mission re-planning of autonomous underwater vehicle (AUV) navigating in uncertain ocean environment is presented in this paper. The proposed component-oriented control architecture structured is made of three parts: situation reasoning, re-planning trigger and hierarchical re-planning layer. Situation reasoning using the unstructured real-word information obtained by sorts of sensor detectes and recognizes uncertain event.The re-planning trigger decides the re-planning level by the event types and influence degree. Hierarchical re-planning layer contains mission re-planning, task re-planning and behavior re-planning. Different re-planning level depends on the result of re-planning trigger. Preliminary versions of the architecture have been integrated and tested in a simulation environment. Experiment indicates that the novel control architecture can implement mission re-planning steady and safty.

Keywords: *autonomous underwater vehicle, control architecture, mission re-planning*

1. Introduction

Developments in Autonomous Underwater Vehicle (AUV) have been of great interest to many researchers, engineers and scientist [1-3]. The capabilities of AUVs as well as their mission requirements have been increased. Recent advances in autonomous underwater vehicle technology have led to their use in a number of military and civilian applications including anti-submarine warfare, oil field surveys, oceanographic research or maintenance/monitoring of underwater structures among others underwater scenarios

Research on autonomous underwater vehicle own the common control problem with other air, land and sea surface unmanned vehicle because of the dynamic and uncertain environment. But in marine environment, besides requiring high-dimensional and computationally intensive sensory data for real-world mission execution, stability of sonar and random occurrence is make it more difficult to develop control architecture for AUV.

We present a hybrid, hierarchical architecture for mission re-planning of autonomous underwater vehicle. Our goal is to develop novel control architecture to realize the mission re-planning when the previous mission plan cannot execute correctly. Through the situation reasoning perceive abnormal events and the re-planning trigger decides the re-planning level

2. An Overview of Control Architecture

A control architecture [4] is the part of the robot control system which makes the decisions. The first attempt at building control architecture for autonomous underwater vehicle began around 1990s. Traditional architecture relied on a centralized world model for verifying sensory information and generating actions in the world model, following the sense, plan, and act patter. The design of the classical control architecture was based on a top-down structure [5]. The sequence of phase in traditional deliberative control architecture is shown in Figure 1. The common problems for this architecture are that the integration representation of the real world is extremely difficult and the sensor data can only uses during the world model and not during the plan execution. It is dangerous in dynamic marine environment.

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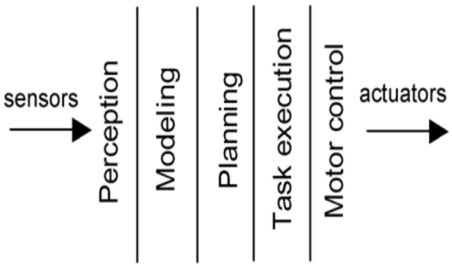

Figure 1. Phase of Traditional Control Architecture

The behavior-based architecture used a set of parallel behaviors which reacted to the world environment suggesting the response the robot should take to finish the behavior (see as Figure 2). The behavior-based architecture is fast and reactive and solves the problem with world modeling or real time process. However when trying to carry out long-range missions, there are so much limitations and it is difficult to optimize the robot behaviors.

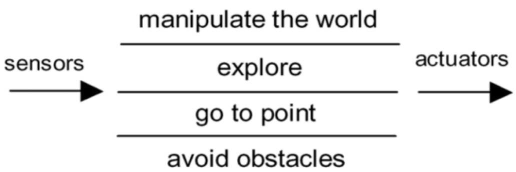

Figure 2. Behavior-base Control Architecture

Most of today's architecture for autonomous robotics is hybrid and structured in three layers: the reactive layer, the control execution layer, and the deliberative layer (see as Fig. 3). It integrate the advantages of previous two, but it is complex to handle dynamic and uncertain environment and mission re-planning.

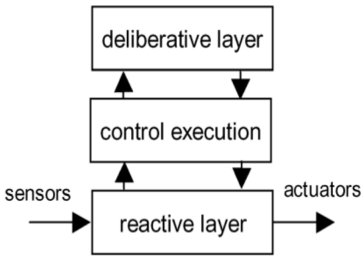

Figure 3. The Hybrid Control Architecture

3. Our Proposal

In order to solve above problems mentioned in previous section.We propose a noval control architecture for mission planning of autonomous underwater vehicle. It is a hybird and hierarchical framework (see as Figure 4). The proposal framwork contain three layers: situation reasoning layer, re-planning trigger and hierarchical re-planning layer. Situation reasoning layer using the unstructured real-word information obtained by sensors detectes and recognizes uncertain event. According the event types and influence degree, the re-planning trigger decides the re-planning level. Hierarchical re-planning layer contains mission re-planning, task re-planning and behavior re-planning. According the re-planning level generated from re-planning trigger, hierarchical re-planning layer will select corresponding re-planning layer.

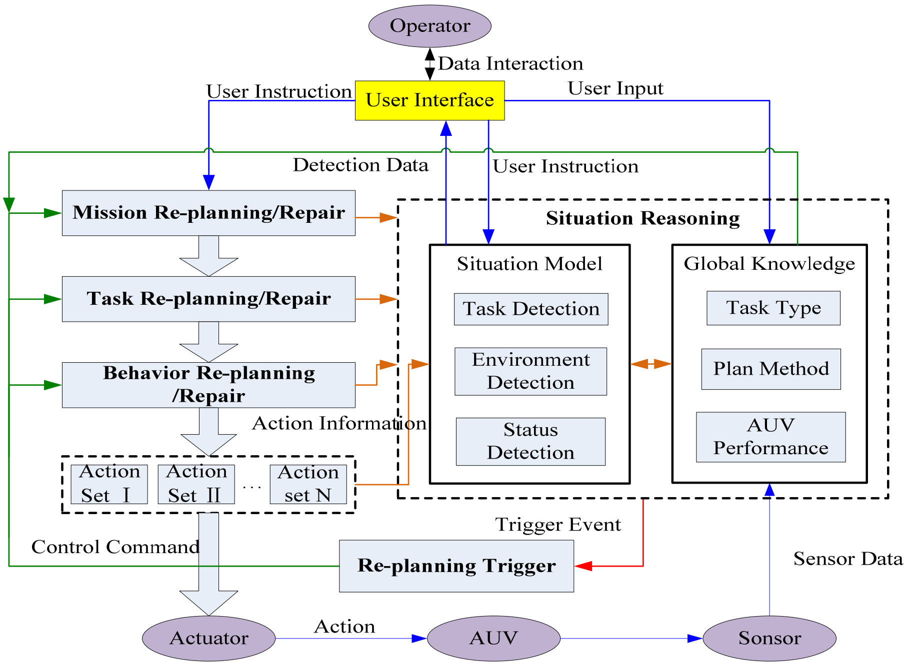

Figure 4. Our Proposal Control Architecture for Mission Re-plannin

3.1. Situation Reasoning

Situation Reasoning is one of the most core part in the proposal control architecture [6]. This layer generates the influence degree of events according user input, environment sensor data and global knowledge such as task type executing, database of plan method and AUV performance which usually never changed. The result of this layer, influence degree of events, is sent to the re-planning trigger.

Situation Model receives the uncertain information from task execution information, internal state data of AUV and environment sensor data to modeled uncertain events according to their priority and their nature. Task event detection detects the implementation and progress of the AUV task. Environment event detection percepts the environment relative to the assigned mission, including the environmental status, attributes, and dynamics. State event detection delete faults of AUV various sensors.

Detecte part including Task detection, Environment detection and State detection, is used to handle with the uncertain event information and be able to predict the influence degree of event for completion of the task.

Combine with global knowledge, the input of uncertain event see as Table 1 and Ithe output of situation reasoning contains event type, probability and Influence degree on the task, see as Table 2:

Table 1, Input of Uncertain Event

Task information	Status information of AUV	Environment
Task type Position of target Planning information	Cabin leaks Battery compartment leaks Fault of low voltage Low voltage is low Fault of high voltage Fault of depth gauge Etc...	Status information of AUV Obstacle (statics or dynamics, more or less) target information

Table 2. Output of Situation Reasoning

Event type	Event name	Event Probability	Influence degree on task
	Random object	0~1	0~1
Ocean environment	Target unachieved	0~1	0~1
	Off Route	0~1	0~1
	Target Lost	0~1	0~1
	Energy shortage	0~1	0~1
AUV status	GPS correction	0~1	0 or1
	Fault of propeller	0~1	0~1
	Task parameters changed	0~1	0 or 1
Uncertain task	Task types changed	0~1	0 or 1

Re-planning trigger receives the result of situation reasoning. When the following four sorts event (not limited) happened, the re-planning trigger will be trigged. First one is that the planning monitoring observe the plan progress has large deviation with the original plan; the second one is that the external encironmment or task target has changed; the third one is that the internal status of AUV change a lot, the task can implement anymore; the last one is any unpredictable events happened.

3.2. Hierarchical Re-planning Layer

Mission re-planning is implemented mainly because the mission target has changed which may caused by operators through the user interface also because that the planning monitoring module found the status of AUV has different with the original and then determine if mission re-planning should be implemented. Besides above, when the environment which the planning relies on has been changed, mission re-planning will also be executed. New mission planning can improve AUV’s efficiency.

Task re-planning is carried out mainly because the mission re-planning. But mission re-planning will spent much times and energy. In order to improve system flexibility and reaction speed, task re-planning lower than mission re-planning is also needed. When the status of AUV or environment changes a little, task re-planning is enough.

Behavior re-planning is the lowest level for re-planning. When it receive the command from mission re-planning and task re-planning. It will adjust the behavior or action sequence to finish new task. Another situation is that when implementing the original action with no change cannot finish the sub-task, the behavior re-planning will also start

4. Experiment

The experiment is used to demonstrates the advantage from proposed control architecture. Experiments include common navigation, navigaiton in current, static obstacle avoidance and target unreach. A contrast experiment is also implemented.

Navigation in uncertain underwater environment is familiar. The Figure 5 show the AUV’s navigation without uncertain events.

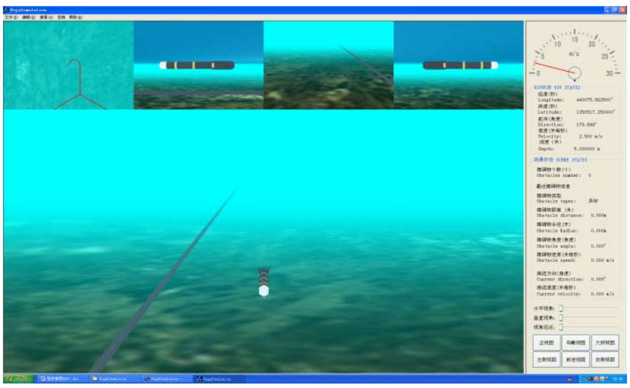

Figure 5. AUV’s Navigation in Underwater Environment

When there are obstacles. The control architecture will start the mission re-planning and carry out the obstacle avoidance, at the same times the AUV deviates from the predetermined route and farther away, see as Figure 6.

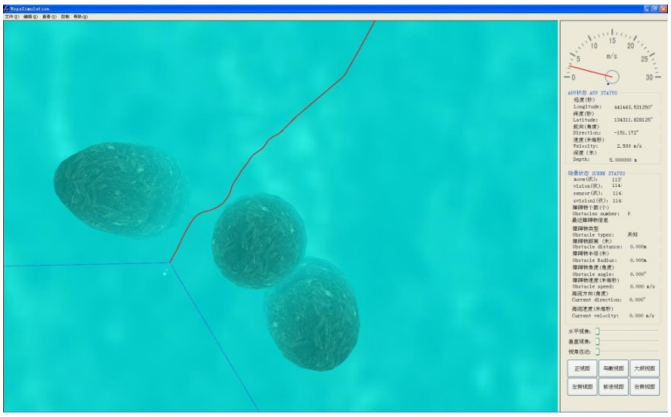

Figure 6. AUV Obstacle Avoidance

A contrast navigation experiment is alos proposed in Figure 7. The left one is used the control architecture presented in the paper for mission re-planning.

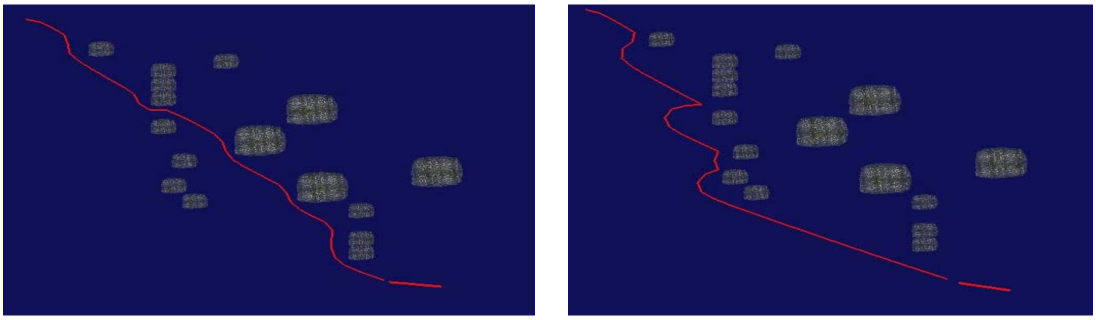

Figure 7. Contrast Navigation Experiment

Navigation in current is shown in Figure 8. The control architecture will carry out the mission re-planning.

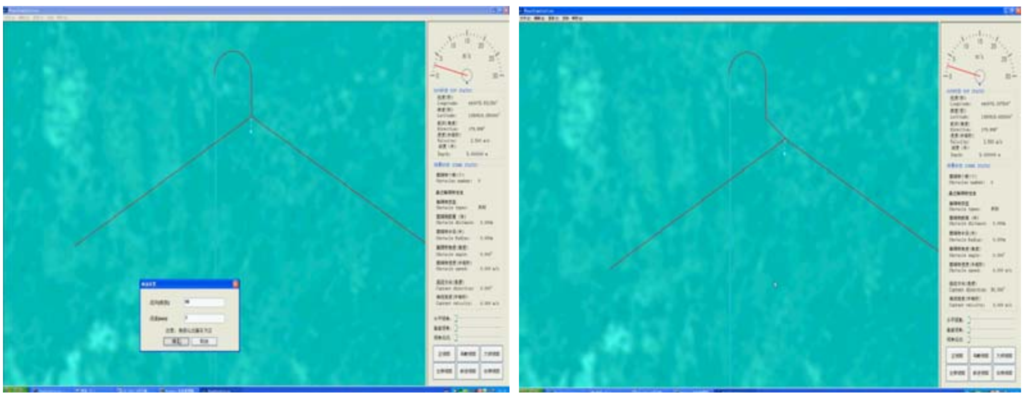

Figure 8. Navigation in Current

Random obstacles appeared event indicates the distances from obstacles is less than safe distance, which is threat toAUV. AUV is more closer to obstacles, the higher the probability of random obstacles appeared event happened is. The control architecture detectes the event and triggets mission re-planning, see as Figure 9.

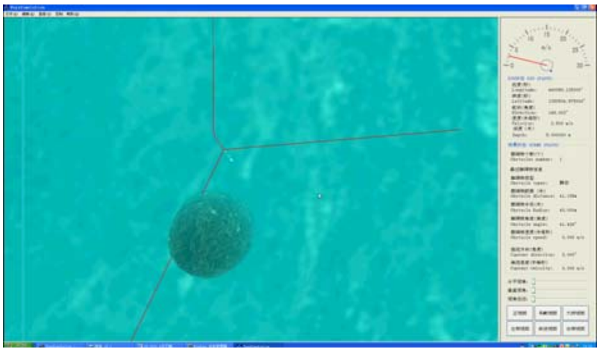

Figure 9. Random Obstacles Appeared Event

Key point unreached event means that AUV can not reach the target point which is covered by obstacles, or invalid planning actions. It will generate uncertain event and touch off the mission re-planning, and re-plan another plan to achieve other target, see as Figure 10.

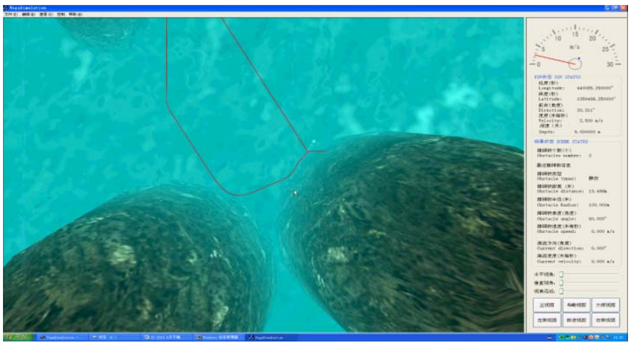

Figure 10. Key Point Unreached Event

5. Conclusion

In the paper, we present novel control architecture for re-planning of autonomous underwater vehicle. Preliminary versions of the architecture have been integrated and analysis in a marine simulation environment. The result demonstrates the benefits of the control architecture with re-planning feature. Future work will focus on the real marine environment to verify the practicality and efficiency of this proposed control architecture.

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