

## Multi-level control system of group motion of autonomous underwater vehicles

**Abstract.** *The features of application of the AUV group are analyzed to improve the performance of underwater search operations for large water areas. The generalized structure of the five-level system of group control of autonomous underwater vehicles is developed, which provides for a consistent spatial motion when performing underwater search operations over uninhabited technologies. Specialization of individual vehicles and separate groups of them is proposed to meet the challenges of underwater search, communication of vehicles between each other and with the base and to ensure the navigational safety for group application of the vehicles.*

**Keywords:** autonomous underwater vehicle, group control, automatic control system

The problem of collective behavior and group management of autonomous underwater vehicles (AUV) demands for a new control paradigm, a new architecture of the control system design, which, in turn, requires the creation of new technologies for synthesis and software implementation of group control systems. This is primarily due to the features of AUV group functioning, which occurs in the presence of uncertainties of the environment, the parameters of objects being searched and specifications of AUVs itself as control objects.

The analysis shows that in such circumstances of AUVs application the following two tasks are the most difficult: ensuring the effective coordination of AUV group behavior, creation of software infrastructure (platform) that supports cooperation of a large number of miscellaneous AUV devices and software.

The control tasks of groups of moving objects are particularly complex when they should coordinate their behavior, for example, to avoid collisions, or to cooperate for solving common tasks.

For these and other similar applications of moving objects group the next common features can be distinguished: network-based information exchange in the AUV group; large number of information sources that generate powerful streams of data that must be stored in a centralized repository of a group; flexibility of communication systems, when the composition of nodes and topology changes constantly, for these reasons in some cases the system architecture of "client-server" will be unable to work; confidentiality of information from some AUVs, because the data may fall under the concept of state secrets or be commercial.

These features are encouraged to consider in design of automatic control system of several AUV groups and it must be synthesized as a layered structure.

The five-level automatic control system is being offered for AUV group control, which contains the levels of mega-, strategic, tactical and local control and also the level of quality control.

The level of mega-control develops an overall organization plan for underwater search missions on unmanned technologies, forms membership of the groups of search AUVs and identifies areas of water for their application, develops how to deploy L AUV

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groups in the areas of water and sets the criteria of quality control  $Q$  of the search operations performed.

The level of strategic control over AUV group is being realized by the AUV-leader of the group and includes the development of strategic behavior of the  $i^{\text{th}}$  group of AUVs: analyzes the given task, formalizes characteristics of objects of underwater search and AUVs-members of the group (energetic, dynamical, communicational, etc.); develops the general plan of the mission for the  $i^{\text{th}}$  group of AUVs; identifies the factors that limit the executive opportunities of the  $i^{\text{th}}$  AUV group (hydroclime data, technical resources, anthropogenic factors, etc.); determines the quality criteria of the accomplished mission for the  $i^{\text{th}}$  group of AUVs.

The level of tactical control of AUV group plans actual implementation and develops search mission tasks for each AUV of the  $i^{\text{th}}$  group. It chooses from the database the laws of safe AUV spatial movement and positioning near the founded underwater object; chooses the laws of identification, inspection of objects and documenting of the results; defines modes and formats of communication for AUVs of the  $i^{\text{th}}$  group between each other, group leader and the level of strategic control.

The level of local control of individual AUV generates information control vector for the local control system of the  $j^{\text{th}}$  AUV, which, in turn, generates control signals for the actuators of the  $j^{\text{th}}$  AUV.

The level of quality control serves as the feedback between individual AUV and appropriate levels of the multilevel system of automatic group control. It forms a set of quality index of group control for each level and provides for control over its fulfillment during the underwater mission.

Analysis of the functioning specifics of search AUV groups made it possible also to formulate the major tasks concerning the organization of automatic control of such groups.

### **Conclusions**

In the present work the generalized structure of the five-level system of AUV group control is developed, which provides for a consistent spatial AUVs motion when performing underwater search operations over uninhabited technologies. The main problems concerning the organization of automatic control of AUV groups are formulated, which include the creation of separate vehicles as simple control objects, formation and support of the spatial group configuration, the flexibility of its structure during the execution of underwater missions, navigational safety of vehicles spatial movement, as well as the reliability of internal communications of AUV group and its search capabilities. Specialization of individual vehicles and separate vehicle groups is proposed to meet the challenges of underwater search operations, vehicles communication between each other and with the base and ensuring navigational safety at AUV group applications.

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