An underwater research drone for the Yenisei

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Abstract. The study of the rivers and lakes of Eastern Siberia has its own peculiarities. Fast currents, small depths, silt, algae, and the abundance of small non-ferrous artifacts on the riverbed are all factors, which make such investigations complicated. In this report, the authors discuss a software and hardware complex for a proposed remotely operated underwater vehicle, which is specially developed for operating in the rivers of northern Siberia.

1. Introduction

The structure of a modern integrated geographic information system (GIS) of a fast-moving river cannot consist exclusively from aerial and acoustic imaging data. An important addition to the counters of the water bodies is data collected within the course of special investigations performed with the help of unmanned underwater vehicles. The need for novel principles in the design of such devices arises from the fact that existing mass-produced apparatuses are designed for operating in marine coastal environments and in still water reservoirs or those with slow current. Therefore, they cannot be deployed in large fast-moving rivers, such as the Yenisei. Furthermore, the operators of remotely operated underwater vehicles (ROVs) often face a number of challenges associated with visual fatigue. In addition, the operator has to divert his or her attention to maintaining the ROV on course. Therefore, there is always a risk of missing an important underwater feature.

In order to solve this problem, we propose to design a set of programs such as a neural network that will be able to: (1) identify targeted objects; (2) improve visualization quality; (3) classify objects; and (4) reconstruct the event.

2. Proposed design of the ROV

As aforementioned, aerial data does not provide the operator with sufficient information on the hydrography of a waterway. Existing acoustic imaging systems, such as the side scan sonar (SSS), also leave large white spots due to their inability to identify certain objects and determine the nature of the image, which is not optical, and therefore, is often difficult to interpret. This suggests a return to traditional optical imaging systems, which feature moving platforms with video and photographic cameras. There has been a long and successful tradition in using such systems for various kinds of underwater research, including underwater archaeology, zoology, and other areas of Earth and environmental sciences. In this report, we provides an overview of existing technical solutions for the design of miniature ROVs, suitable for use in the proposed study area.

The vast majority of professionally manufactured ROV, available on the market, are designed for marine and lake environments. The water here usually has a sufficient visibility degree (for instance, in the Sea of Azov, visibility ranges from 1 to 1.8 m [1]). The operational depths of ROV working in marine environments range from 100 to 3000 m, with speeds ranging from 1.5 to 2 kn (0.77–1.02 m/s) [2, 3, 4].

Structurally, commercial ROVs can be subdivided into two groups:
1. Quadcopter configurations with radial drivers for four to eight propellers.
2. Frame configuration with rotary reverse propellers and auxiliary stationary vertical displacement fans.

The light source for most models comes from powerful light-emitting diodes (LED).

The use of these ROVs can be complicated in fast-moving rivers (current speeds of up to 7 km/h) with high sediment rates, and low (2–20 m) depths. Thus, (1) currents of up to 1 m/s (3.6 km/h) will reduce the maneuverability of the ROV and waste precious electrical energy; (2) the propellers of the ROV are susceptible to clogging with algae; (3) vertical flows from motionless fixed propellers will raise sediments, further complicating visualization and negatively affecting the orientation of the apparatus.

Powerful LED backlights can reduce visibility if sedimentation rates are high.

The proposed solution consists of the following principles:
1. The design of the body of the ROV should exclude protruding components, such as masts, braces, and gratings that increase drag. A more preferable shape is streamlined having a circular or ellipsoidal cross-section.
with elongated, torpedo-shaped outlines. The design should be monolithic, smooth, and sustainable to viscous and friction resistance.

2. Vertical fans and propellers should be eliminated. Vertical movements should be executed with special rudders, or by reverse movement of pairs of horizontal propellers.

3. Protection of the propellers from algae is necessary.

4. The light source should be a combination of conventional LEDs and red or infrared emitters that will significantly increase visibility range in turbid water.

3. Neural networks for underwater object recognition

The effectiveness of the ROV operator depends on his or her concentration. When observing a monotonous image, a person’s attentiveness decreases after about 15 minutes. As visual fatigue accumulates, the operator can miss an important object that briefly got caught by the camera. Moreover, the operator can be distracted and fail to notice an interesting underwater feature. Most often, this problem is solved using an onboard computer equipped with artificial intelligence (AI) programs operating on the principle of an organized mathematical model of an artificial neural network.

An example of a popular open source cross-platform is the YOLO [5] complex developed on the basis of TensorFlow[6]. In its basic form the neural network is presented along with the training models (training coefficients). However, they are suitable only for solving the simplest problems, such as searching for missing persons, vehicles, vessels, and managing agricultural activities and forestry.

In order to identify and classify more complex objects, it is necessary to use machine learning based on neural network. Examples of such programs are MXNet and Scikit-Learn [7, 8]. Due to the fact that high performance is required from the computer, the use of an external server or a cluster of such servers is advisable. Once the data is collected, the next step is bringing the images to a standard dataset. This is typically a symmetrical matrix with fixed sizes of 1024×1024 pixels and a gray gradient of 256 shades. For this purpose, the EBImage program [9] (distributed under a free license) can be used.

The normalized graphical objects are proposed to be processed through deep learning algorithms and then transferred into the input of a convolutional neural network (CNN). This technology is widely used. For instance, Amazon Information Service automatically generates contextual advertising of goods and services; Google can search through images; Instagram and Pinterest can personalize the personal pages of its users. The technical implementation of CNN is presented in the program ADVENTURES-IN-ML-CODE [6], which is integrated with the PyTorch and TensorFlow frameworks.

The last component of the software package will be implemented directly to the ROV and respond to events and objects appearing in the video stream.

The hardware of the complex should include the following parameters: (1) a 48 core CPU, with a frequency of at least 2.1 GHz; (2) a level 3 cache of at least 22 MB; (3) a memory capacity of at least 4 TB.

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References
[1] Goptareva N P (ed) 1991 Girometeorologia i gidrokhimiia morei SSSR. T. 5: Azovskoe more [The Hydrometeorology and Hydrochemistry of the Seas of the USSR (St Petersburg)]
[2] Small-sized remote-controlled unmanned underwater vehicles JSC “Tethys Pro” (available at http://www.tetis-pro.ru/catalog/332/)
[3] Marine Geo Service (available at http://marinegeoservice.ru/ROVs.html)
[4] Cable tracking ROV / ECA Group (available at https://www.ecagroup.com/en/solutions/cable-tracking-rov)
[5] YOLO: Real-Time Object Detection (available at https://pjreddie.com/darknet/yolo/)
[6] API Documentation. Tensor Flow (available at https://www.tensorflow.org/api_docs/)
[7] MXNet Architecture (available at http://mxnet.incubator.apache.org/versions/master/architecture/index.html)
[8] Sci Learn | Project Description. PyPi (available at https://pypi.org/project/scikit-learn/)
[9] Bioconductor – EBImage. Image processing and analysis toolbox for R (available at https://bioconductor.org/packages/release/bioc/html/EBImage.html)