

Simulation of the communication system between an AUV group and a surface station

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Abstract. An object model for simulation of the communications system of an autonomous underwater vehicles (AUV) group with a surface station is proposed in the paper. Implementation of the model is made on the basis of the software package “Object Distribution Simulation”. All structural relationships and behavior details are described. The application was developed on the basis of the proposed model and is now used for computational experiments on the simulation of the communications system between the autonomous underwater vehicles group and a surface station.

1. Introduction

The World Ocean covers about 70% of the earth surface. However, according to various sources, its depths are studied for 2%–7%. In order to increase this percentage, mankind is constantly inventing new equipment. In that way, the first autonomous underwater vehicle (AUV) called "Special Purpose Underwater Research Vehicle" was invented in 1957 at the University of Washington [1].

AUV is a robot which outwardly resembles a torpedo and moves under water without any human assistance with the purpose of obtaining information on bottom configuration and the presence of any objects or obstacles there. The vehicle is capable of reaching the depth of up to 6 km, moving along the programmed trajectory, carrying out the required work and returning to the surface station after the program completion. The surface station is a watercraft or a shore base carrying out control and receiving messages from AUV. More detailed information about AUV can be obtained in [2–4].

AUV operates autonomously underwater without any connecting cable. Transmission of commands aboard the vehicle and telecommunication back is carried out with the help of the hydroacoustic communication system. Application of the hydroacoustic channel imposes certain restrictions on the communications system. The point is that AUV is usually applied not one at a time, but in groups. Accordingly, a rather low rate of transmitting information along the hydroacoustic channel (at present time, it is not more than 50 kilobits per second [5, 6]) is supplemented by the restriction on the number of concurrent communication sessions. More specifically, the number of such sessions at a time point must be equal to 1, while, otherwise, several sessions can initiate critical destructive interference for each other.

Consequently, there arises a timely scientific task to analyze and optimize the operation of the AUV group and a surface station communication network. The apparatus of the Queuing Theory [7, 8] is the most suitable for handling the above stated task. In terms of the Queuing Theory, such communications systems are simulated as cyclic systems (also called polling systems) [9–11]. Quite a



lot of analytical findings (see, for instance, review [11]) have been obtained in this sphere; however, no success has been achieved yet in obtaining analytical findings with regard to the majority models of arbitrary service, correlated arrivals, server connection random disciplines. In such a case, it is possible to apply simulation methods [12, 13], enabling to obtain results for a system of almost any configuration.

The objective of the given research is to build applications for simulating communications system between AUV and a surface station.

Paragraph 2 presents the subject area description made in terms of the Queuing Theory. This part of the paper is also devoted to the description of basic discrete event approach principles to simulating.

Paragraph 3 describes the simulation software package “ODIS” (Object Distributed Simulation) [16, 17] used as a platform for the application under development. A major simulation algorithm, stepwise simulation organization and basic system objects are also presented.

Paragraph 4 deals with the description of the application developed for the simulation of the AUV group and a surface station communication network. The application specifications, object model and primary events description are presented as well.

2. Queuing models and their simulations

In the paper, the communications system between the AUV and a surface station is presented in the form of a single-server queuing system (Figure 1). The terms above are the terms belonging to the Queuing Theory, below there are the subject area related terms.

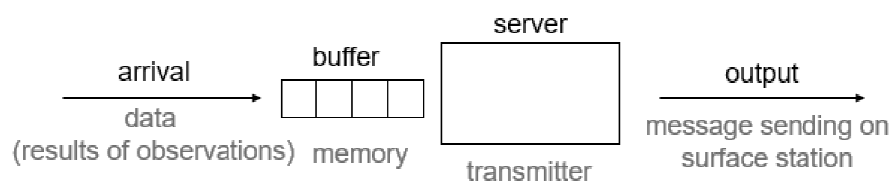


Figure 1. An AUV model in the form of the single-server queuing system.

- Data are the messages generated by AUV sensors. It can be a photo, a video or information taken from measuring equipment; the information is further converted into a text file.
- Memory is a queue of messages being further transmitted to the surface station. The server memory is limited, thus, if it is filled up, the new incoming data cannot be stored and should be lost.
- A transmitter is a device which transmits messages to the surface station.

The given work applies a discrete-event approach to simulation [14]. It is used to build the model which reflects the system evolving through time, when variables' states change at specific points in time. Events happening at such time points signal system state transition.

As it was mentioned above, AUV operates in a group, connected to a certain surface station. Typically, they fluctuate at a certain distance from each other, moving in one direction. The connection between an AUV and a surface station is performed with the help of a hydroacoustic communication system via the cycling protocol. In other words, each server allocates a certain time interval for transmitting all the information accumulated. During the period of communication between one server and a surface station the other devices are in the peace and quiet order.

While all servers are similar, in the Queuing Theory such protocols are simulated with the aid of one queuing system with server vacation [15]. In the present case, server vacation is the time between the termination of a certain server communication period and beginning of a new communication period for the same server. It is possible for simulation to use “server vacation technology” and simulate only one server from the group or the whole group of servers. Simulation of the whole group is more flexible, i.e. it enables to set random disciplines and laws for service, arrivals, communication periods,

buffer sizes and message transmission rate for various servers. Precisely, this approach is being applied in the present paper for implementing a simulation model of the communications system connecting AUV and a surface station.

We have used a software package of queuing systems simulation named ODIS as a platform for the goal application implementation. More detailed information about ODIS can be obtained in [16, 17].

3. Development of an application for simulating the communications system between AUV and a surface station

The design of the application under development resulted in the introduction of the following objects (Fig. 2).

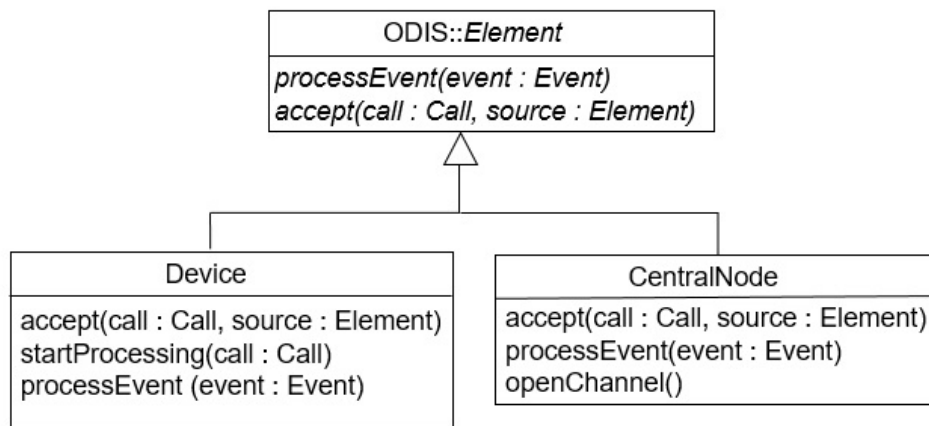


Figure 2. The elements of the communications system AUV model.

Object Device simulates AUV. In the method “accept(...)”, it accepts the request, and on condition that at the moment the server is at the state of transmitting data to the surface station and there is no queue, this request transfer immediately starts (method startProcessing(...)). If at least one condition is violated, the request gets to the buffer.

Object CentralNode is the object, simulating a surface station. Its method accept(...) is not used now and generates an exception. Method processEvent(...) is used to finish a communication with the current device. Then it switches to another device using the method “openChannel()”.

The class diagram in Figure 3 presents the structural bonds of AUV objects. Class CentralNode possesses the nested object of the Device type, called deviceOnAir. This object is the server participating in a communication period at the moment, i.e. this pointer constantly toggles from one Device object to another.

Figure 4 shows an AUV vehicle in terms of an object model. Each AUV (class Device) has an object of the Message type called procMess, which is a message being transmitted at the moment (if there is such a message).

The main events for simulating the communications system of an AUV group are the following:

1. Arrival of the message.
2. Start of the communication period.
3. Finish of the message transfer.
4. End of the communication period.

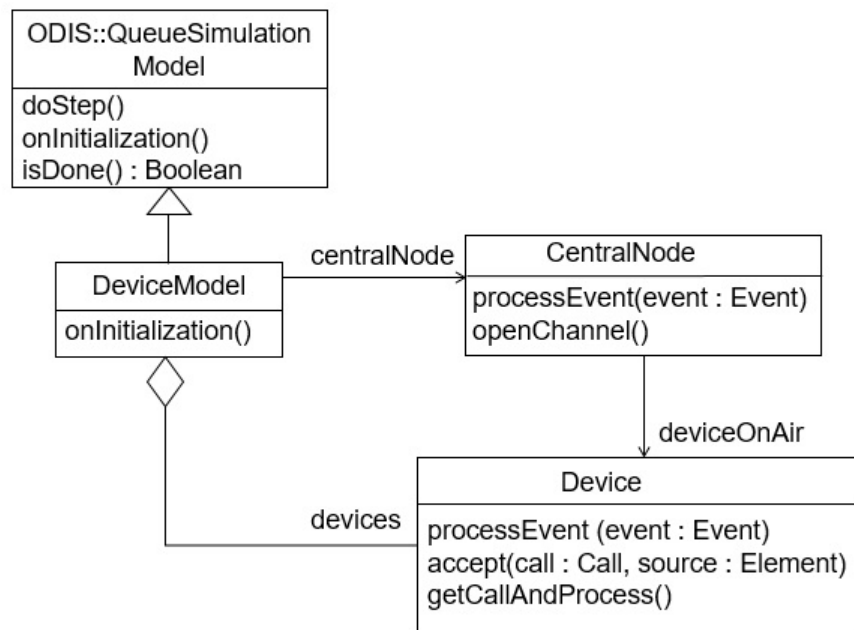


Figure 3. AUV objects structural relationships.

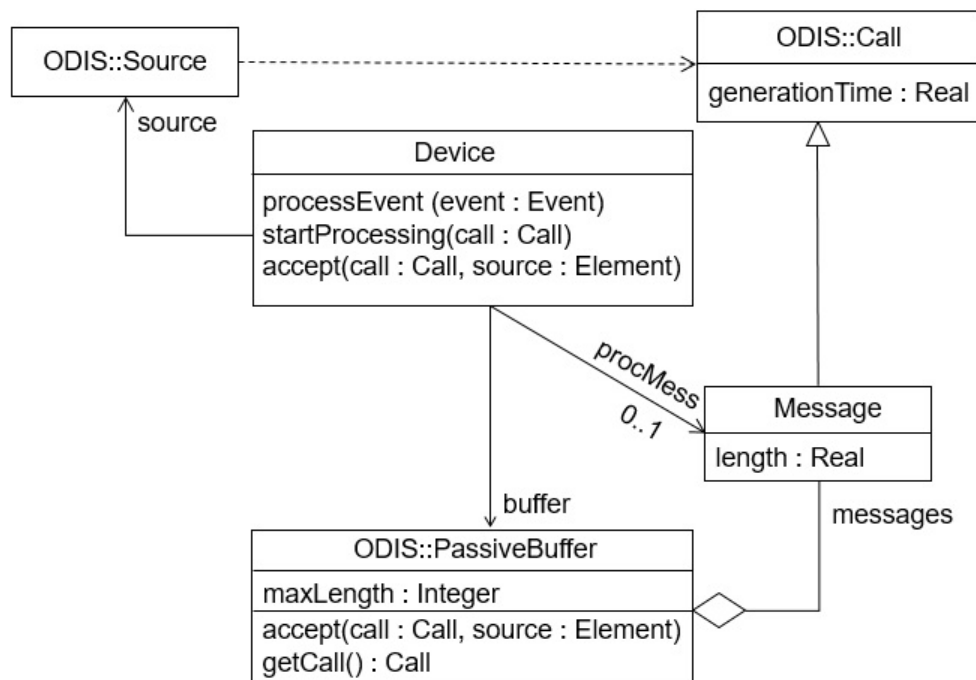


Figure 4. An AUV vehicle in terms of the object model.

The process of messages arrivals implies their creation and forwarding to the server, which is made by class Source (Fig. 5). The device object, in its turn, forwards the request to the buffer. Then the condition is checked: whether there is a place in a buffer for the request or not. If there is enough place in the buffer, the request gets in a queue. If the buffer is full up, the request leaves the system.

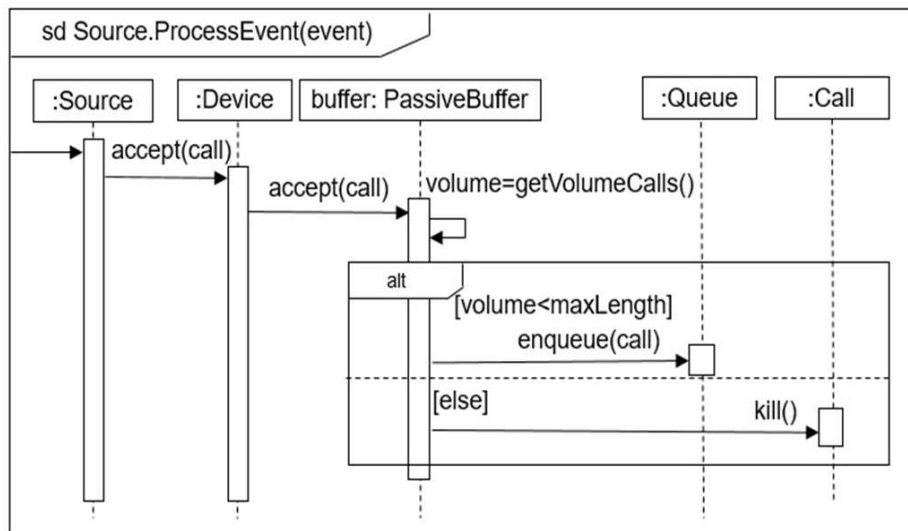


Figure 5. The event of a message arrival.

The beginning of the communication period is determined by a surface station (Fig. 6). It starts the communications period with one of the AUVs. Then, an object of the Device type calls method getCallAndProcess(), where the server gets the request from the buffer and starts its processing.

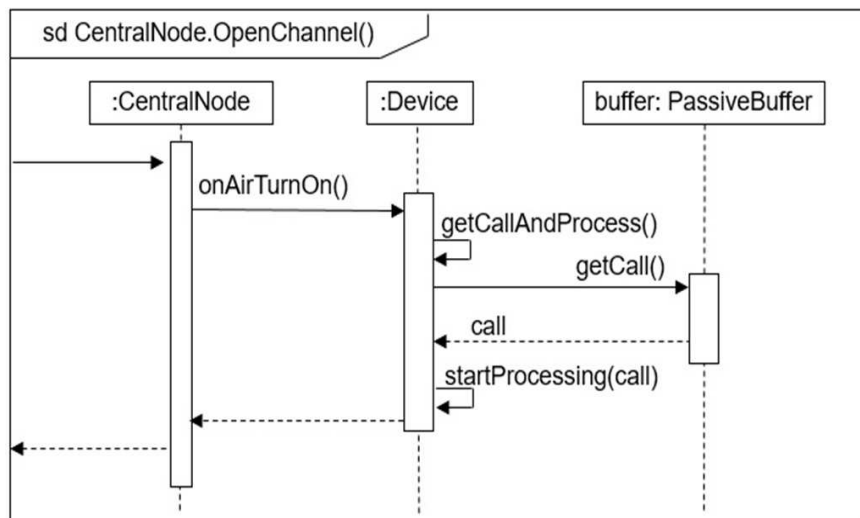


Figure 6. The event of the communication period starting.

An object of the AUV class completes processing of one message; it happens in its method ProcessEvent(...) (Fig. 7). When one message processing is complete, processing of the next one starts.

A surface station is responsible for finishing a communication period with each AUV (Fig. 8). If at the moment of communication period termination a message was being sent, it gets back to the buffer and the event of this message transfer is deleted.

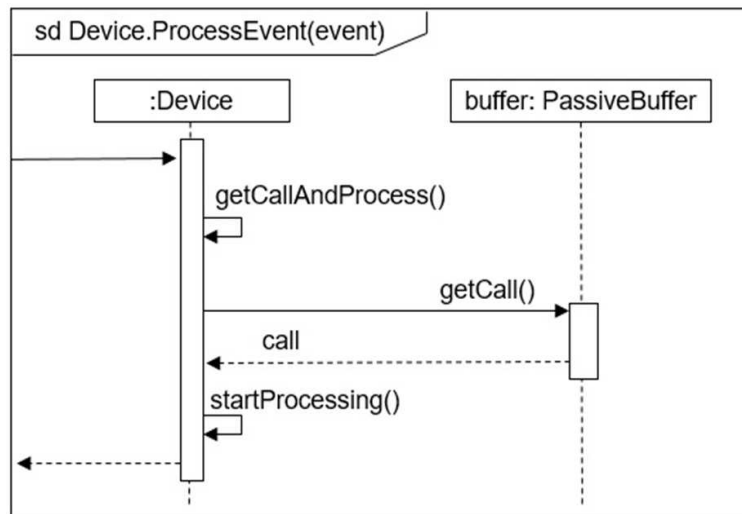


Figure 7. The event of a single message transfer finishing.

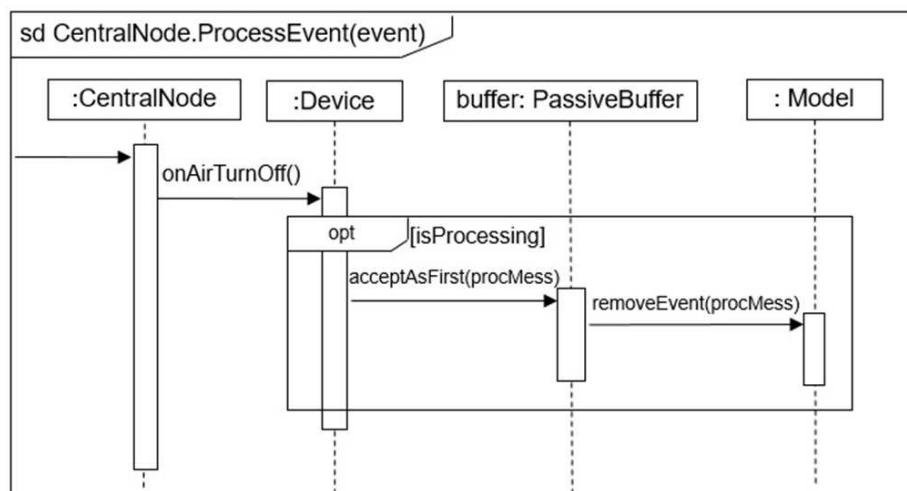


Figure 8. The event of communication period ending.

The proposed approach can be used for visualization of the underwater environment [18] and other applications [19-22].

4. Conclusion

The paper introduces a realization of the design of an application for simulating the communications system between an AUV group and a surface station. All the necessary classes and interactions between them are described. As a consequence, the application was developed and is now used for conducting computational experiments on the simulation of communications system between an AUV group and a surface station.

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References

- [1] Widditsch H R 1973 *SPURV – The First Decade* (University of Washington, Appl. Phys. Lab.,

- APL-UW 7215)
- [2] Ervin W P, Madden J P and Pollitt G W 2014 *Unmanned Underwater Vehicle Independent Test and Evaluation* (Johns Hopkins APL Technical Digest, V. 32 (5)) pp 752–761
 - [3] Griffiths G 2002 *Technology and Applications of Autonomous Underwater Vehicles* (Taylor & Francis)
 - [4] Wadoo S and Kachroo P. 2010 *Autonomous Underwater Vehicles: Modeling, Control Design and Simulation* (Taylor & Francis)
 - [5] Wang J, Li D, Zhou M and Ghosal D 2008 Data collection with multiple mobile actors in underwater sensor networks *Proc. 28th Int. Conf. on Distributed Computing Systems Workshops (Beijing)* (IEEE) pp 216–221
 - [6] Toso G, Masiero R, Casari P, Kebkal O, Komar M and Zorzi M. 2012 *Field experiments for dynamic source routing: S2C EvoLogics modems run the SUN protocol using the DESERT Underwater libraries* (Oceans) pp 1–10
 - [7] Sztrik J 2011 *Basic Queueing Theory* (University of Debrecen)
 - [8] Cooper R B 1981 *Introduction to queueing theory* (New York: Elsevier North Holland)
 - [9] Borst S C 1996 *Polling systems* (Amsterdam: Stichting Mathematisch Centrum)
 - [10] Takagi H 2000 *Analysis and applications of polling models / Performance Evaluat: Origins and Directions* (Ed. Haring G., Lindemann Ch. and Reiser M. Lecture Notes Comput. Sci. 2000. V. 1769) pp 423–442
 - [11] Vishnevskii V M and Semenova O V 2006 Mathematical methods to study the polling systems *Automation and Remote Control* **67(2)** 173–220
 - [12] Law A and Kelton D 2000 *Simulation modeling and analysis* (3rd ed. Mc Graw Hill: Boston)
 - [13] Byrski A, Oplatková Z, Carvalho M and Kisiel-Dorohinicki M. (Eds.) 2012 *Advances in Intelligent Modelling and Simulation. Simulation Tools and Applications* (Springer)
 - [14] Bangsow S (Ed.) 2012 *Use Cases of Discrete Event Simulation* (Springer)
 - [15] Nazarov A and Paul S 2016 A Number of Customers in the System with Server Vacations *Communications in Computer and Information Science* **601** 334–343
 - [16] Meshcheryakov R V, Moiseev A N, Demin A Yu, Dorofeev V A and Matveev S A 2015 Using Parallel Computing in Queueing Network Simulation *Bulletin of the Tomsk Polytechnic University* **325(5)** 99–109
 - [17] Moiseev A, Demin A, Dorofeev V and Sorokin V 2016 Discrete-event approach to simulation of queueing networks *Key Engineering Materials* **685** 939–942
 - [18] Demin A Yu, Sorokin V A and Khasaeva D Z 2014 Three-dimensional visualization of the underwater environment using graphical library “3D bodies” *Proc. of the Int. Conf. Mechanical Engineering, Automation and Control Systems (MEACS) (Tomsk)* (IEEE) arnumber 6986895
 - [19] Pogrebnoy V K and Pogrebnoy A V 2004 *Proc. 8th Korean-Russian International Symposium on Science and Technology (KORUS-2004) (Tomsk)*, Vol. 1, pp 137–141
 - [20] Botygin I A , Popov V N , Tartakovsky V A and Sherstnev V S 2015 *Proc. SPIE 21st Int. Symp. Atmospheric and Ocean Optics: Atmospheric Physics* **9680** 1–4
 - [21] Popov V N, Botygin I A and Koshelev N V 2016 *Key Engineering Materials* **685** 925–929
 - [22] Avdeeva D K, Kazakov V Y, Natalinova N M, Ivanov M L, Yuzhakova M A and Turushev N V 2014 *European Journal of Physical and Health Education* 6 Article number BM-015-14