Simulation vertical sensing of the water environment hydrophysical fields

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Abstract. Classes of objects that form the information system structure for monitoring the water environment hydrophysical fields have been developed. Class descriptions include object parameters that affect the composition and operation of the system, and methods that define actions with class instances. Additional control classes are proposed for describing the interaction of objects and simulating the sensing process.

1. Analysis of the literature and the problem statement
Monitoring of the water spaces’ hydrophysical fields refers to monitoring of natural environments and covers the ocean, rivers, and inland water bodies. Given the multiparametric and variable nature of physical processes occurring in the ocean, modern hydrophysical experiments usually require an integrated approach. In modern Oceanography, the main research tools are automated systems for collecting, transmitting, processing, and storing observations [1]. Currently, oceanographers and hydrophysicists are armed with a large Arsenal various types of measuring hydrophysical systems: probed [2,3], towed [4], and Autonomous multi-channel [5,6].

According to the methods of application, the systems are divided into vertical-sounding, horizontal-sounding and placed on underwater vehicles, buoys. However, for the most part, they are necessarily equipped with channels for measuring the main hydrophysical parameters – temperature, specific or relative electrical conductivity, speed and hydrophysical pressure. The most urgent task is not just to perform measurements, but to obtain information about changes in hydrophysical fields to areas of the water environment characterized by the presence of turbulent disturbances. Therefore, it is necessary that information and measurement systems allow measurements to be made with the required spatial and temporal resolution.

2. Purpose of article
The object-evolution model [7] the monitoring system for inhomogeneities of the water environment hydrophysical fields describes all the structural elements that form such a system and allow for the entire process of measuring hydrophysical parameters’ vertical profiles. This model includes all necessary elements for system’s realization:

- Movement Means;
- Measuring Means;
- Means Transformations;
and hierarchical transformation of information from the measured value to the intramachine information.

The purpose of this work is to develop a class diagram based on this model and an algorithm for simulating the vertical sensing process, which will allow us to develop the basics of structural and algorithmic organization of information and measurement monitoring systems.

3. Developing a class diagram

Based on the object-evolution model, classes of objects that form the structure of an information monitoring system have been developed. Class descriptions include object parameters that affect the composition and functioning of the system, and methods that define actions with class instances [8]. All model objects that the evolving objects depend on [7] are described by the corresponding classes.

The class diagram is shown in figure 2. The SystemItem class is basic and defines some abstract device with a set of characteristics (the Character property) and a cost. The following parameters are accepted as characteristics of class instances that affect the functioning of the system (figure 1).

- “Measuring Means” – the class DATCHIK: the inertia of the sensor in milliseconds, the coefficients of the calibration characteristics;
- “Movement Means” – the class DVIG: the discreteness of the speed change in cm, which also determines the minimum possible speed, and this value can be used to determine the possibility of speed control (if the discreteness is 0, the engine has a constant speed set by parameter V);
- “Means Transformations” – the class ACP: number of multiplexer channels, range of input converted analog signal, ADC digit capacity;
- “RAM” - the class OZU: the amount of memory in MB;
- “Communication Channel” – the class KANAL: data transfer rate, KB/s.

The "Measured parameter" object is described by the PARAMETR class, which sets the measured profile to simulate the process of measuring hydrophysical parameters. The description of other evolving objects, as well as objects of action and behavior, is included in the above classes, namely:

- the "Analog signal" and "Measurement" objects are represented in the DATCHIK class by the Get_P function, which converts the measured hydrophysical parameter to an analog value using the calibration characteristic of the sensor and transmits the received values via the function parameters;
- the "Digital code" and "Conversion" objects are represented in the ACP class by the Get_P function, in which an analog signal is converted to a digital code by a quantization operation. The resulting digital code is passed using the function parameters;
- the "Buffered information" and "Save" objects are represented in the OZU class by a multidimensional array of P values and the Set_P function that implements the recording of the received values;
- the "Intamachine information" and "information Transfer" objects are represented in the KANAL class by the stream variable f and the send function.

To measure the same hydrophysical parameter in order to increase the depth resolution, it is proposed to use a set of similar sensors located at a certain distance from each other and United in a separate GREBENKA class. This class contains as a parameter a reference to an instance of the PARAMETR class to simulate the measurement process using a set of sensors. The GREBENKA class has time parameters that ensure the discreteness of sensor polling at a specified interval.

The EPURA class provides information about the model of turbulate layers location in the water environment under study, based on which the sensor survey mode is determined.
Figure 1. Diagram of classes of information and measurement monitoring system.

The main functions of the system are implemented by control classes:

- the "Menedger_move" class simulates the probing process using the Move function, which is expressed in changing the current depth value by the value $V \cdot dt$, where $V$ is the parameter of the Dvig object, and $dt$ is the time interval set in the system. Using the Set_dt function, the layer
type is determined based on the received depth value and the data from the Epura object. Then
the new movement speed and the intervals of measuring devices survey are calculate:
• the "Menedger_Izmer" class contains functions for getting information about hydrophysical
fields with a specified depth resolution.

To determine the optimal structure of the measurement system, it is necessary to: set a criterion for
the effectiveness of the system; perform a simulation of the measurement process in order to obtain the
values of the efficiency criterion; compare the characteristics of various system's structures.

4. Simulation the measurement process
Simulation the measurement process consists of the following sequence of actions:

Step 1. Initialization of parameters all structural elements of the system:

1. The researcher determines the list of the measured hydrophysical parameters N. As a result, the
corresponding number of PARAMETR objects is formed, initialization of which consists in
selecting files with vertical profiles; information is read from the selected files to arrays of
PARAMETR objects; the number of objects GREBENKA class is formed based on the number
of measured values;
2. Definition the number sensors \( K \) for measuring each hydrophysical parameter; based on this,
the required number objects the DATCHIK class is formed, the gain the output signal
the measuring device is determined, and the distance between the sensors on the object the
GREBENKA class;
3. Each object DATCHIK has the number channel to the multiplexer, the coefficients of the
calibration characteristics \((a \text{ and } b)\), the inertia and cost; the corresponding values object of class
PARAMETR calculated at the output of the sensor by the formula (1).

\[
P = a \cdot Zn + b
\]

where \( Zn \) is the value of the measured hydrophysical parameter for depth \( h=0 \);

4. Parameters of class objects are Initialized:
• ACP: digit capacity; range of input converted analog signal; cost; number of KolK channels that
meet the conditions

\[
\begin{align*}
\text{KolK} & \geq \sum_{i=1}^{N} k_i, \\
\text{KolK} & = 2^{L}, \quad \text{where} \quad L \geq \log_{2} \sum_{i=1}^{N} k_i;
\end{align*}
\]
• DVIG: discreteness of speed change; cost; depth equal to 0;
• OZU: cost; the bit depth of data arrays \( M \) is calculated using the formula, memory is allocated
for arrays of the specified length, and the array of positions in these arrays is reset to zero;
• KANAL: transfer speed; cost; the amount of information transmitted is 0; is opened the stream
for information output;
• Menedger_Izmer: is initialized an array of numbers measurement channels, so the Kol
parameter equal to the total number of sensors; are reset the current time and measurement error.

5. Based on the vertical temperature's profile and the model the vertical structure of the turbulate
layers [9], an object the EPURA class is created that describes the depth distribution of the
turbulate layers.

6. Appropriate system's objects are initialized for objects of the governing class.
7. Knowing the values of the current depth and the data of the object EPURA class, the type of the sounded layer (laminar or turbulent) and its thickness are determined. This makes it possible to calculate the discreteness of polling by depth for each type of sensor, the time intervals for polling the sensors (if the system has a variable motor, then the parameters of both the sensing speed and the sampling frequency are selected). The lower boundary values of the parameters of the system elements are taken into account: the minimum permissible sensing speed and the minimum inertia of the sensors.

Step 2. Sensor polling cycle, which includes:

- Receiving data from the sensor. To do this, call the Set_Koef function of the ACP class, to which the value sensor readings gain is passed, and then the Set_P function the ACP class to save the sensor readings in the object of the class.
- The new moment of polling of this sensor is calculated. The obtained values are converted by the Get_P function the ACP class into a quantized signal corresponding to the measured value.
- Conversion to physical values is performed using a calibration characteristic.
- The Set_P function the OZU class is executed to save the results in the corresponding data array, while the array pointer is shifted by 2. If the array is full, the Send function the KANAL class is called.
- Move to next sensor.

Step 3. Moving sensors using the engine by depth is implemented by the Move function the Menedger_Move class, which provides for:

- calculation of the current time and depth;
- determination the layer type using the Get_tip function the EPURA class; if the layer type has changed, then it is necessary to change the values of the sensor polling intervals and/or the sounding speed. For this, from the objects of the PARAMETR class, a value is selected that corresponds to the discreteness of the parameter measurement in depth in a given layer and, based on the value of the engine speed, the time interval for polling the sensors is determined;
- according to vertical profiles for the current depth, the readings of the corresponding sensors are calculated using the Get_Par function the PARAMETR class.

Step 4. Steps 2 and 3 are repeated until the specified sounding depth is reached.

Step 5. Determination of the experiment time and measurement error.

- When the specified sounding depth is reached, it is necessary to call the Select function the Menedger_send class to transmit the residual information from the RAM via the communication channel.
- The current time plus the transmission time the last data block will correspond to the time the experiment.
- The accuracy measurement of hydrophysical parameters is calculated by comparing the initial and resulting files of vertical profiles.
- The amount information received is calculated as the sum the transmitted data buffers.
- The cost the system is the total cost of all structural elements plus the cost the experiment.

5. Conclusions
Based on the object-evolutionary model the information-measuring system described in the article, a class diagram has been developed that contains a description all objects that determine the structure such...
a system. Additional control classes are proposed to describe the interaction objects and simulate the sensing process. An algorithm for imitation modeling vertical sounding of the aquatic environment is proposed. Thus, an interrelated description the information system has been obtained, which makes it possible to compare various configurations of monitoring systems.

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