USAGE OF THE DISTRIBUTED COMPUTING SYSTEM IN THE RECOVERY OF THE SPECTRAL DENSITY OF SEA WAVES

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This article presents a task of the recovery of the spectral density of sea waves in the linear case. Creation of the onboard ship system giving the current information about sea state and weather forecast in the navigation area is one of the most urgent problem. Weather forecast can be based on the analysis of the sea waves spectral density change. Evaluation of the sea wave spectral density is solved on the basis of indirect dynamic measurements of vibrational motion of the marine dynamic object in a seaway. The first researcher to raise the wave parameter identification problem on the basis of object behavior was Y. Nechayev. Over the past fifteen years, this problem has become rather popular and the works of Nielsen U.D., Simons A.N., Pascoal R. and others are of the most significance. Nevertheless, despite of researches large number it is still impossible to speak of an acceptable effective solution to this problem. The recovery of the sea waves on the basis of the behavior of the marine dynamic object requires the analysis and processing of large amounts of information. To improve the accuracy of identification requires using different algorithm of recovery and a large number of test calculations. The calculations should be made in real time. The system should also store processed data and provide access at any time. The software should have the fault-tolerance property, i.e. the software should continue to work in the case of failure of one of the parts. All these requirements and features make us to use distributed computing system for developing software of the solution of the problem.

Keywords: the distributed computing system, the recovery of the spectral density, the wave parameter identification.

1. Introduction

Creation of the onboard ship system giving the current information about sea state and weather forecast in the navigation area is one of the most urgent problem. Weather forecast can be based on an analysis of sea waves spectral density change. Evaluation of sea wave spectral density is solved on the basis of indirect dynamic measurements of vibrational motion of the marine dynamic object in a seaway. The first researcher to raise the wave parameter identification problem on the basis of object behavior was Y. Nechaev (Nechaev, 1990, 1996) [1, 2]. Over the past fifteen years, this problem has become rather popular and the works of Nielsen, Simons, Pascoal and others are of the most significance [3-8]. Nevertheless, despite of researches large number it is still impossible to speak of an acceptable effective solution to this problem. Therefore, in this paper an improvement of the available methods for the sea waves parameters identification when a ship is used as a buoy is offered.

2. The problem

2.1. The formulation of the problem

At the moment the methods and the analysis is developed only for a linear case. In the linear case the oscillation equation is represented as:

$$y''(t) + a \cdot y'(t) + b \cdot y(t) = \zeta(t), \tag{1}$$

where a is a damping factor, b is a parameter that characterizes the frequency of the ship's own oscillations, $\xi(t)$ describes disturbance caused by sea waves. It is known by Khinchin theorem [9] that in the linear case relation between the input and output spectral densities to restore the wave parameters is represented as:

$$S_y = \left|\Phi_{xy}(\omega)\right|^2 S_x, \tag{2}$$

where S_x is a spectral density of the input process that can be associated with the disturbance, i.e. sea waves; S_y is a spectral density of the output process, i.e. the registered process of ship vibrations caused by waves; $\Phi_{xy}(\omega)$ is a transfer function of the linear system.

2.2. The solution of the problem

An algorithm for solving the sea wave parameters identification problem in the linear case is proposed. The algorithm is based on the iterative algorithm of adaptive identification and use the concept of “climatic spectrum” [10]. The steps of the solution are the following:

1. Read the acceleration data on the sides and determine the linearity of the process.
2. Read the data of different types of pitching.
3. Calculate the spectral density of the output stream.
4. Calculate a possible set of the input stream spectral densities. The example of such recovered spectral densities is shown in the pic. 1.
5. Find the best solution using “climatic spectrum” and the values of parameters a and b from eq. (1).

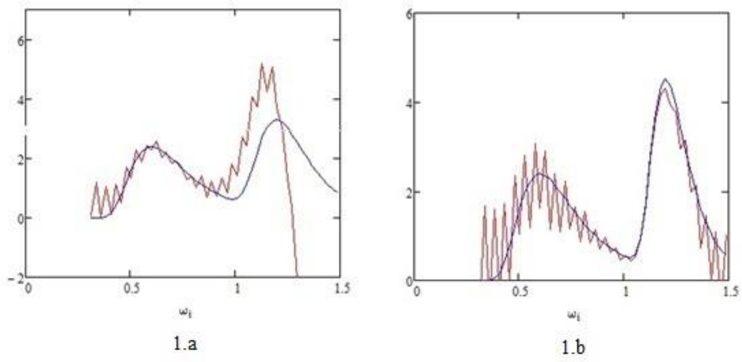

Figure 1: 1.a) the recovery of the roll spectral density, 2.b) the recovery of the pitch spectral density

2.3. The issues of the problem

The formulation of the problem in a detailed form you can see in [11-14]. It should be noted briefly that there are the following main issues:

1. Read sensor data.
2. Calculate the linearity of the pitch.
3. Calculate the spectral density of the output and the possible set of the input stream spectral densities.
4. Find the best solution from the set and the values of the parameters of eq. (1).
5. Calculate weather forecast and display it for a user.
6. Storage and backup storage of all data.
7. The requirement to perform all calculations in real time.
8. Requirement of fault tolerance of one of the nodes.

3. The software structure

The software structure satisfying the requirements of paragraph 2.3, can be implemented as a distributed computing system. The solution of the sea wave parameter identification problem has four loosely coupled tasks. Each of these tasks has his own features regarding to a hardware:

1. Reading, processing and sending sensor data to the storage. It has no complex calculations, has no power consumption. It should work permanently and it should have a special hardware in connection with sensors.
2. Long-term storage of information, the ability to backup and simultaneously transfer data to multiple nodes.
3. Parallel calculations of the set of possible solutions of the equation (1) and comparison with the data of the “climatic spectrum” in real time. It requires a multiprocessor hardware.
4. Displaying the forecast on the user's screen and the ability to configure and work with the system.

A schematic representation of such structure is shown in Figure 2.

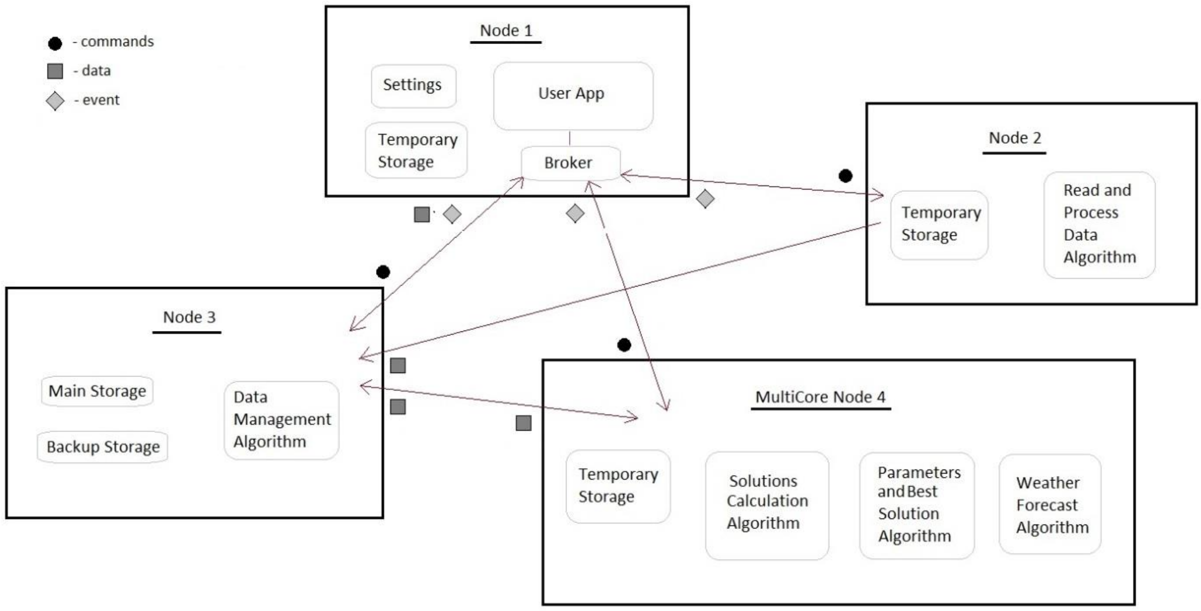

Figure 2. The hardware structure

Thus, the software is divided into four hardware nodes, each of which is designed to perform its individual tasks:

1. Node 1 is designed to display all information for the user. This node is main node in the system. It knows everything about the location and settings of the system and other nodes. Communication with other nodes is carried out according to its own protocol through a separate dedicated module “broker”.
2. Node 2 reads data from sensors, performs their “rough” processing and conversion to the required format and sends it to the storage.
3. Node 3 is designed to store all recorded data during the navigation of the ship. These data, recorded over a year or more, can be used for programs adjusting the weather map in sea navigation regions by other services.
4. Node 4 is designed for calculations. After the data window is read and stored on the node 3, this node receives the necessary information to calculate the weather forecast. Since model parameters (1) are not exactly known, but have limitations, then the calculated set of possible solutions will be quite large. This set of solutions should be compared with the set of possible spectral densities from the “climatic spectrum” characteristic of the given navigation area and find the best match. The data reading window on node 2 is sliding. Therefore, this node should be well designed to perform parallel computing both in terms of hardware and software.

It should be noted that “Solutions Calculation Algorithm” can be applied only in the case of the linear impact on the ship. So the linearity of the process should be verified before the solutions can be calculated. In the case of the nonlinear process the linearity can be reached using methods of statistical linearization proposed by Kazakov I.E. [9] or changing navigation conditions. When the methods of the statistical linearization can’t be applied the system will inform the user to change navigation conditions and it will show influence of these changes to change the linearity.

4. Conclusion

The article presents the sea waves spectral density identification problem in the linear case and the software and hardware structure proposed to make a solution. The solution of the problem has a range of features that can be divided into four separate loosely coupled tasks: sensor data reading and processing, data storage, parallel calculations and a user application. These features impose on the construction of software and hardware solutions: they have different calculation complexity, different construction of the hardware, different power consumption, etc. The most appropriate solution in this case is the solution developed as a distributed computing system.

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