The Innovation in the Model of Interaction of the Sea and the Ship and Parallel and Distributed Computing

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ABSTRACT

Ensuring safety of a ship is one of the most important and urgent problems. This is achieved by improving the ship characteristics and identification of the sea waves parameters in the navigation area. The paper is about the second way and possibility of weather forecast in the navigation area through information about the current state and prehistory. There are two approaches to solve this problem: meteorological and instrumental. Both of them have many implementations, but there is no final solution. The reason is that all solutions have quite significant shortcomings. The paper is about the "instrumental" approach, where the ship is considered as a buoy in the model of interaction between ship and waves. The difference between the presented model and the others in this approach is that it uses additional information, called the "climatic spectrum". The "climatic spectrum" is the result of building of the weather model in a particular sea region. This innovation allows us to resolve a number of serious shortcomings of other models. Considering the ship as a buoy has a long history, but the improvement of the model based on information from other areas is applied for the first time. The paper shows how such addition in the model of interaction between waves and ship changes the algorithm of sea waves parameters identification, and how, in this case the ship control algorithm is changed. The main advantage of using the weather model "climatic spectrum" is a more accurate solution to the problem of sea waves parameters identification and ability of weather forecast in the navigation area. The software solution is built on distributed computing system. The calculation block of the system uses parallel computing.

Keywords

Distributed computing system, recovery of spectral density, 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 problems. 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 a large number of studies 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. 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:

$$\ddot{y}(t) + a \cdot \dot{y}(t) + b \cdot y(t) = \zeta(t), \tag{1}$$

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

$$S_y(\omega) = |F_{xy}(i\omega)|^2 \cdot S_x(\omega), \tag{2}$$

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

At the moment there is a solution only for the linear case. The proposed algorithm is based on the iterative algorithm of adaptive identification and use the concept of "climatic spectrum" [10]. This innovation improves the existing control algorithms of management of the vessel. This also builds the solution of the identification problem based on retrospective, current and expert information. The steps of the solution are the following:

- Read the acceleration data on the sides and determine the linearity of the process
- Read the data of different types of pitching
- Calculate the spectral density of the output stream
- Calculate a possible set of the input stream spectral densities. The example of such recovered spectral densities is shown in Fig. 1
- Find the best solution using climatic spectrum and

the values of parameters a and b from eq. (1)

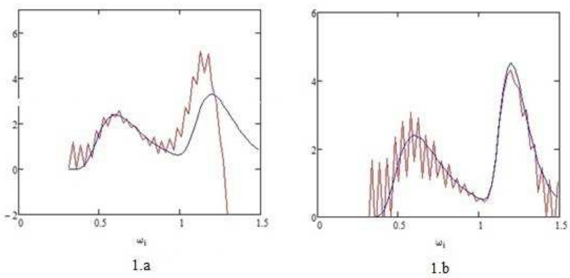

Figure 1: 1.a) the recovery of the roll spectral density, 2.b) the recovery of the pitch spectral density

Calculation of the possible set of input spectral densities and determination the best solution is a parallel part of the identification algorithm. It is shown in Fig. 2:

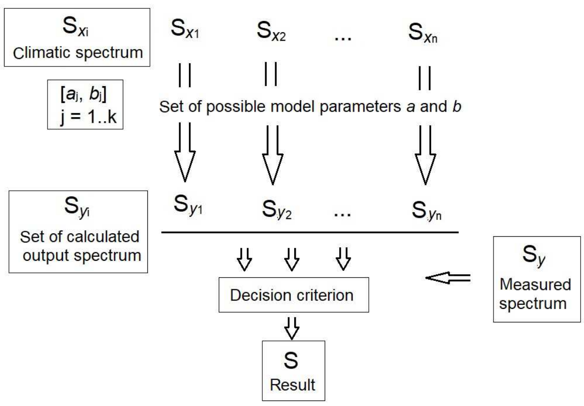

Figure 2: Parallel calculations in the identification algorithm

In the first step, possible spectra can be taken from the "climatic spectrum" [10], and using the parameter model selection algorithm, possible output solutions are calculated. The second step is a selection of the best similarity of the calculated results and measured by sensor data spectrum. This part is implemented on different nodes as parallel calculations. The result is one of the "climatic spectrum" that showed the closest result to the measurement of sensor data.

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:

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

The existing solutions of the problem do not use any additional information from other areas. It complicates obtaining accurate knowledge of sea weather and does not allow obtaining such results as a sea wave spectral density form and weather forecast. The proposed innovation model allows to get all of it, but requires a more complex software and hardware structure.

3. SOFTWARE AND HARDWARE

The software structure satisfying the requirements of paragraph 2, 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 its own features regarding hardware:

• Reading, processing and sending sensor data to the storage. It has no complex calculations, has no power consumption. It should work permanently and have a special hardware in connection with sensors
• Long-term storage of information, the ability to backup and simultaneously transfer data to multiple nodes
• 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
• 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 Fig. 3:

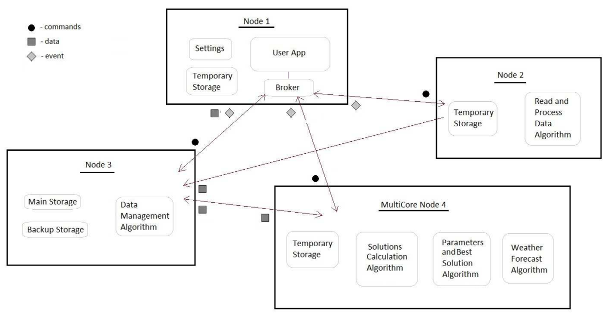

Figure 3: The software and hardware structure of the proposed solution

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

• Node 1 is designed to display all information for the user. This node is the 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
• Node 2 reads data from sensors, performs their rough processing and conversion to the required format and sends it to the storage
• 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
• 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 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 statistical linearization cannot be applied, the system will inform the user to change navigation conditions, and it will show the influence of these changes to change the linearity.

4. CONCLUSION

The article presents the innovation model in the sea waves spectral density identification problem in the linear case and the software and hardware structure proposed to make a solution. This innovation improves the existing control algorithms of management of the vessel. This also builds the solution of the identification problem based on retrospective, current and expert information. The solution of the problem has parallel calculations and its software and hardware is developed as a distributed computing system.

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