Interface for indication and remote control of an unmanned vessel in automatic and manual modes

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Abstract. The article proposes a method for organizing the communication interface of an unmanned vessel and its operator. The interface contains manual controls for the course and speed of the vessel by regulating the angle of the rudder blade shift and the speed of rotation of the propeller shaft, an automatic system for keeping the vessel on a given trajectory for the purpose of navigating the vessel in automatic and manual modes. The interface comprises a system for obtaining filtration, storing the required kinematic and navigation data for identifying mathematical models of the vessel’s movement and the functioning of the autopilot. The interface allows adjusting the PID controller for automatic guidance of the vessel along the trajectory in real time to optimize automatic control, to correct the readings of the GPS and the Earth’s magnetic field sensors, to calibrate the Earth’s magnetic field sensor. The interface includes graphic and digital fields for displaying kinematic and navigation data on the vessel, autopilot and information on the operation of the operator-vessel complex. The interface allows the exchange of data between the operator and the vessel by means of a data transfer protocol via TCP-IP stack protocols on the radio frequencies of public Wi-Fi networks. The interface is created by means of appdesigner tools on the MATLAB platform.

1. Introduction
Due to the concept of e-navigation defined by IMO, the shipping industry needs research in intelligent systems for automatic control of the vessel’s movement and indication of the vessel's navigation parameters, its environment and objects, aimed at gradually strengthening the intellectual support for actions of the human operator in the navigational guidance process [1]. A small-sized experimental vessel was created, equipped with a communication system, receiving data of control actions, collecting and transmitting navigation and kinematic data of the vessel based on the Arduino microcontroller. The interface for the operator’s console of the vessel was written in MATLAB using the appdesigner tools based on devices running the Windows operating system. [2]. The interface allows the operator to visually perceive the navigation information on the vessel, to run in manual mode, assess the vessel control quality in automatic mode, set the parameters of the controller in real time, determine and consider the magnetic declination in the readings of the vessel's magnetic compass, correct in the received GPS coordinates, save and analyze vessel data in order to develop its mathematical models of movement, and set and mend the vessel’s program trajectory [3].
2. Interface organization

Figures 1-3 show a graphical representation of the proposed interface being able to operate independently of the MATLAB environment in the Windows operating system. The sequential numbering by callouts of key control and indication panels is made in the figures, each description is presented below.

Interface bookmarks panel (Callout No. 1, Fig. 1). It contains 3 bookmarks: “Conning”, “Plots” and “Advanced.” “Conning” comprises controls and indication of the vessel’s movement. “Plots” has a field for displaying graphs of changes in vessel’s kinematic parameters being available for measurement. “Advanced” maintains controls for extensive interface and autopilot settings.

Toggle switch for activating the platform connection where the interface to the vessel is installed through the TCP-IP protocol (No. 2, Fig. 1). The indicator changes color to green when the connection is successful.

Toggle switch for reswitching control modes from manual to automatic and vice versa (No. 3, Fig. 1). The indicator changes color to green when the “Autopilot” mode is on.

Toggle switch of on/off recording of all measurable data on the vessel, interface and autopilot (No. 4, Fig. 1). The indicator changes color to green when the “DataRec” mode is on.

Toggle switch turns on and off the synchronous control of the propulsion steering units (PSU) of the vessel, if there is more than one unit (No. 5, Fig. 1) [4]. The indicator changes color to green when the “ConnSync” mode is on.

Indication panel of basic kinematic parameters of the vessel (No. 6, Fig. 1):

- RPM-P – number of revolutions per minute of the left or single engine shaft;
- RPM-S – number of revolutions per minute of the engine right shaft;
- RUDD_P – position of the left or single rudder blade in degrees;
- RUDD_S – position of the right rudder blade in degrees;
- ROT – vessel’s angular speed per minute in degrees;
- MC – magnetic course value in degrees;
- SOG – ground coat speed value per second in meters;
- COG – course over the ground in degrees;
- GYRO – gyrocompass course value in degrees.

![Figure 1. Control interface](image-url)
Graphic field for displaying the vessel’s speed vector; specified and executed trajectories of the vessel’s movement (No. 7, Fig. 1). The drop-down list for the “Duration” values makes it possible to change the number of displayed points of the executed trajectory depending on the time. It can take values of 10, 50, 100 seconds. The drop-down list for the “VectorLength” values allows changing the length of the displayed vessel vector depending on time. It can take on values corresponding to the distance that the vessel will cover in 6, 12, 30, 60 seconds.

Manual control panel for the left or single PSU of the vessel (No. 8, Fig. 1). It includes a rotary “knob” regulator with a range from -35 to 35 degrees to control the position of the rudder blade. The rotary toggle switch “discretetknob” has the values of FAS, HAS, SAS, STOP, SAH, HAH, FAH, corresponding to the vessel’s engine operating modes, respectively: fast astern, half speed astern, small astern, stop, fast aheading, half speed aheading, small aheading. The indicator changes color from green to red in case of a discrepancy between the set value of the rudder blade position and the one worked off on the vessel. The rotary knob switches to the indication mode and shows the value of the rudder blade worked off on the vessel in the case of automatic control. The indicator color changes to red in case of a discrepancy between the program value of the rudder blade position set by the autopilot (“Pr. Rudder”, No. 10).

Manual control panel for the right propulsion steering unit (PSU) of the vessel (No. 9, Fig. 1). It is arranged similarly to panel No. 8, except for the presence of a checkbox the setting of which activates the panel and means that the vessel has two PSUs.

Indication panel of basic parameters of automatic vessel control (No. 10, Fig. 1):
- Dist to NW – distance to the next waypoint of the trajectory in meters;
- CrstoNW – course to next track waypoint in degrees;
- NextCOG – course on the next leg of the trajectory in degrees;
- NextWP – next waypoint number;
- XTE – deviation of the vessel’s position from the current trajectory leg in meters;
- DTG – distance along a given trajectory from the vessel’s position to the last point of a given trajectory in meters;
- Pr. Rudder – program value of the position of the vessel’s rudder blade generated by the autopilot.

“SKIPWP” button makes it possible to manually switch the next waypoint to one ahead.

Panel for loading and entering coordinates of the vessel’s given trajectory (No. 11, Fig. 1). The drop-down list allows selecting one of the preset trajectories or choosing the “Custom” item which activates the corresponding field for entering coordinates from the keyboard.

System information display panel (No. 12, Fig. 1):
- “BufferOverflow: Flush” – flushing the stack buffer due to overflow;
- “REOPEN TCPIP: ServerTimeOut” – reopening the connection due to lack of server response;
- “REOPENTCPIP: ClosedbyServer” - connection reopening by the server;
- “SELECT TRACK” – an error occurs when the autopilot is turned on without a selected movement trajectory;
- “INPUT TRACK” – an error occurs when the autopilot is turned on without a manually set trajectory when the “Custom” item is selected in the drop-down list of loaded trajectories.

Selection panel by setting the corresponding checkboxes of the kinematic parameters of the vessel displayed the graphical mapping field No. 14 (No. 13, Fig. 2). Individual display scale can be assigned to the values of each parameter. The panel contains the following parameters in addition to No. 6 and No. 10:
- Roll – rolling angle values in degrees;
- Pitch - pitching angle values in degrees;
- Yaw - yaw angle values in degrees.
Figure 2. Interface for displaying kinematic parameters.

Graphic field for displaying kinematic and navigational parameters of the vessel selected in No. 13 on a given scale in time (No. 14, Fig. 2). The drop-down list “Duration” allows setting the time period which data will be displayed in the field. It can accept the following values: 10, 50, 100, 500, 1000 seconds.

Indication panel of data received from the GPS transceiver and its state (No. 15, Fig. 3). The following data are displayed in addition to No. 6:

- **HDOP** - Horizontal Dilution of Precision, accuracy decrease in the obtained coordinates of the vessel’s position in the horizontal plane. Depending on the value, the “SignalQuality” indicator changes its color to red, yellow, blue, which corresponds to unsatisfactory, satisfactory and excellent quality of accuracy;
- **Sat. Num** – number of satellites, the data from which are the basis for calculating the location coordinates;
- **LAT** – accepted latitude of the vessel in degrees and degrees-minutes-seconds;
- **LON** – receivable longitude of the vessel in degrees and degrees-minutes-seconds.

Figure 3. Advanced settings interface
Panel for entering the correction into the coordinates' received data of the vessel's position in degrees (No. 16, Fig. 3).

Indication panel for data received from the module containing gyroscopic, inertial sensors and a sensor of the Earth's magnetic field (No. 17, Fig. 3). Data are displayed in addition to No. 6 and No. 13:

- ax, ay, az – longitudinal acceleration along the corresponding axes. Thus, the “x” axis is co-directed with the longitudinal axis of the vessel from the stern to the tank, the “y” axis is directed to the left of the vessel’s diametrical plane, the “z” axis is directed upward;
- magX, magY, magZ – constituents of the Earth’s magnetic field along the corresponding axes. The axes are directed as in No. 18.
- quatR, quatI, quatJ, quatK – constituents of the quaternion describing the orientation of the vessel in space.

Panel for initializing synchronization of the vessel's yaw angle with the values of the magnetic or true (obtained from GPS) vessel courses to obtain the gyrocompass heading (No. 18, Fig. 3).

Panel for entering corrections into the values of the horizontal constituents of the Earth's magnetic field to compensate for the local magnetic declination in millitesla (No. 19, Fig. 3).

Graphical display field of the deviation pattern of the Earth's magnetic field sensor in millitesla (No. 20, Fig. 3). It is designed for detecting and eliminating the influence of magnetic declination.

Panel for inputting parameters of the autopilot constituent by the course (No. 21, Fig. 3) [5]:

- P, I, D – coefficients of proportional, integral and differential terms, respectively;
- Fd – moving average filter parameter.

Panel for parameters input of the autopilot constituent along the trajectory similar to No. 21 (No. 22, Fig. 3).

Panel for parameters input of the vessel and communication module (No. 23, Fig. 3):

- TurnRadius – radius of steady circulation of the vessel;
- TrendDist – distance to the trajectory final point at which it is required to stop the vessel’s engine during automatic control;
- Buffersize – communication buffer size in bytes;
- TimeOut – time of response lack of the server after which the connection is reopened;
- SendRate – frequency of sending data to the vessel per second.

Indication panel of communication data (No. 24, Fig. 3):

- Bytesavailable – number of available data in the buffer in bytes;
- LengthRX – length of available data string in number of symbols;
- TX – string of data transmitted to the vessel;
- Clock – duration of uninterrupted connection in minutes-seconds;
- TimeOut – time of response lack of the server in seconds;
- StringRX – data string received from the vessel.

3. Conclusion

The proposed method for organizing the interface for displaying and controlling the movement of an unmanned vessel allows you to work out the principles of organizing the interaction between the vessel and the operator. It ensures the required navigation information on the vessel for successful pilotage, makes it possible to correct the operation of the automatic control system and sensors in real time, set and edit the given trajectories of automatic movement vessel, providing the operator with full control over the vessel movement. The method can be used to study the principles of construction and identification of mathematical models of vessel movement.
References

[1] Popov AN, Zaslonov VV, Golovina AA 2020 Creating a crewless ship in the framework of the technological paradigm of the Russian Federation Conference proceedings, *Industry competitiveness digitalization, management and integration*, vol. 1, pp. 468-474.

[2] Mathews JG, Fink KD 2002 *Numerical methods using MATLAB.* (Prentice Hall: Williams).

[3] Hasegava K Knowledge-based automatic navigation system for harbor maneuvering *Proc. 10-th Ship control symposium*, 2, 67–90.

[4] Fossen T2011 *Handbook of Marine Craft Hydrodynamics and Motion Control* (Chichester: John Wiley & Sons Ltd).

[5] Hammoud S 2012 Ship motion control using multi-controller structure *Journal of maritime research*.1, 45–52.