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PILOT DOCKING SYSTEM – NEW TOOL FOR SAFE MARITIME OPERATION

Abstract: Docking of vessel as a part of sea voyage requires high precision of positioning, reliability of solution, independent architecture and a operator's knowledge. Article presents integrated system consisting of Laser Measurement System and high precision DGPS System developed for accurate docking of vessel. Whole system has an augmented architecture that will increase reliability and availability
Keywords: piloting of vessel, docking system, navigation support

1. IDEA OF DOCKING SUPPORT SYSTEMS

The concept of the construction of a docking system is to facilitate berthing of a large vessel by an accurate determination of ship hull position in relation to the berth. Comparing to satellite positioning systems its main advantage is the identification of ship's distance to the quay independently, as well as the measurement of hull transverse speed relative to the quay. Article presents: PNDS – pilot navigation docking system as main system and its sub systems: PNSS – pilot navigation support system, LDS – laser docking system

For comparison standards of accuracy, continuity and a availability must be presented, main source of its is IMO (International Maritime Organization) in the A.915 document sets out the accuracy level for each type of navigation and for automated docking its at level of 0.1m. This value can be ensured by satellite positioning receivers working with an external system source, such as the RTK (Real Time Kinematic) system. Accuracy at this

level is granted by a laser distance meter operating on the quay, independently from external factors affecting the position received via a satellite system.

Concept of building PNDS is providing solution for pilot following data (Gucma et al, 2010):

- providing accurate position in relation to shore (accuracies of 0.1 m must be acquired in time to readout of 1s)
- multiple laser modules for different type of vessels (ferries, LNG etc.)
- portable display that can be taken into vessel with additional DGPS/SINS module for port passage and berthing
- optimized electronic chart at mobile module
- dynamic ship/shore transmission network and protocols
- possibility of mobile applications for cell phones/smart phones etc.

2. COMERCIALLY AVAILABLE SYSTEMS

Comparison of different systems available on market is presented. Laser docking system for large vessels consists of the following components (Trelleborg www):

- external sensors – at least two per quay – laser or radar sensors;
- control system located at the operator's room on the quay;
- readout system, which may have different options, based on:
  - large display located on the quay
  - light on the quay signaling that safe movement parameters have been exceeded,
  - remote transmission, using portable receivers, mainly laptops or dedicated palmtops.

The systems which present information on mobile displays turn out to be better than boards in poor visibility. Such systems replace systems based on large display located on the quay, and additionally can be integrated with pilot navigation systems. Besides, remote systems can be used by skippers of tugs participating in un/berthing manoeuvres.

2.1. Smart Dock

Example of a docking system is SmartDock made by the Trelleborg Harbour Marine. This laser system is based on remote data transmission. Its external sensors are shown in Fig. 1, while Fig. 2 depicts its portable display.

Fig. 1. External sensors of the SmartDock Harbour Marine-made system (Trelleborg www)

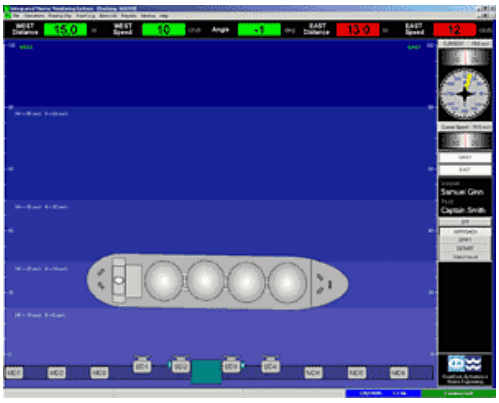

Fig. 2. Portable display of the SmartDock system (Trelleborg www)

2.2. BAS

A similar solution is offered by Marimatech, a company that produces docking systems with a large display mounted on the quay and mobile displays. Fig. 3 shows three different types of displays for the docking system BAS (Berthing Aid System) made by Marimatech.

Fig. 3. A large display and mobile displays of the BAS system by Marimatech (Marimetech www)

The docking BAS Marimatech system, with a range of 300 m from the quay, delivers data on the distance to the quay and transverse speed (Marimetech www). The visualization on a portable display takes account of the ship type and terminal design (Fig. 4).

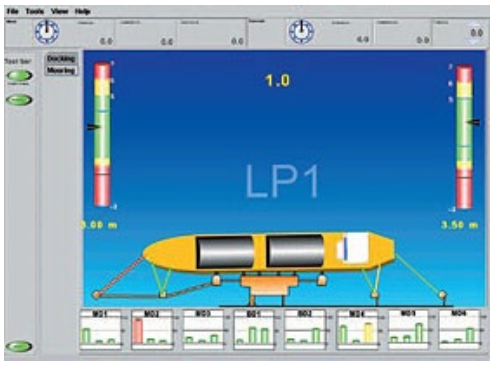

Fig. 4. Portable display of the BAS Marimatech system (Marimetech www)

3. PNDS SOLUTION

Project PNDS conducted in Maritime University of Szczecin is based on impulse laser and FMCW (frequency modulated continuous wave) radar heads. Effort has been taken to develop flexible and reliable system. Main cope of PNDS project are (Gucma et.al., 2010):

- •possibility of wireless transmission to vessel without any additional devices,
- •optimized presentation of measurement for sea pilot,
- •redundant transmission features and multiplexing of channels (ISM+GPRS),
- •'intelligent' transmission take over in case of one or more laser heads went down,
- •fast interchanging of laser heads,
- •possibility of FMCW radar heads application,
- •variety of end user applications and platforms (usage of JAVA techniques).

Both PNSS – pilot navigation support system, LDS – laser docking system will be discussed in following sub chapters.

3.1. Overview of LDS

Laser head is especially designed and evaluated subsystem - diagram of LDS is presented at fig. 5. Design process let to find optimal laser head and following parameters that will be verified while project is running:

- •laser wavelength,
- •divergence of laser beam,
- •laser repetition frequency,
- •distance solution measurement time,
- •statistical computation made in laser head.

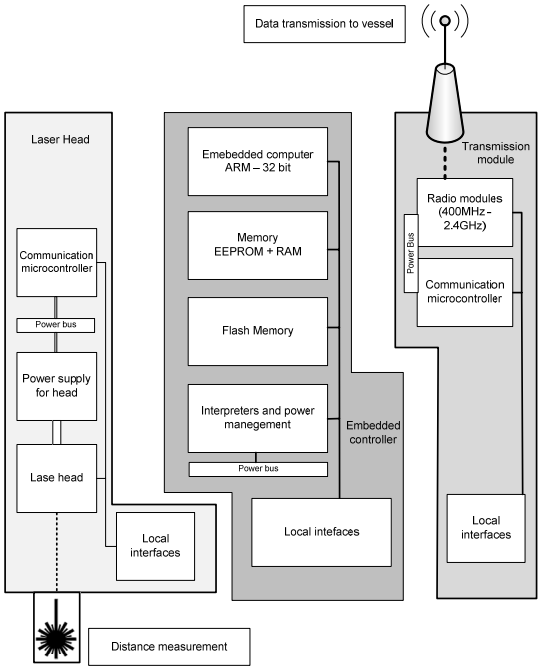

Fig. 5. Internal diagram of single laser head in LDS

Except commercially available laser modules, especially designed heads for the purpose of project, are tested. Several solutions from field of electronics has been tested to obtain optimal solution. For construction fast and 'low power' embedded computers were chosen, basing on ARM Cortex M3 microcontroller, solution with on board communication peripherals: (Serial, GPIO - general purpose I/O, CAN, Ethernet etc).

3.2. PNSS

Portable unit of PNDS is taken by pilot to the vessel at the roads of port. PNSS must be maximally rugged, lightweight and handy. System must also let to be fixed in all conditions of weather. Portable system consists of two modules: Bridge – computer with software and radiomodem, GPS unit mounted outside the bridge (usually wing or monkey deck) (Gucma et. al. 2010). Diagram is presented at fig 10. Functionality provided to pilot/captain covers:

- precise positioning.
  - in navigation mode - accuracy: 2m,
  - in docking mode - accuracy: 2 cm,
- heading independent from ships gyro with accuracy of 0.5 deg.
  heading and position availability after GPS signal is lost (SINS – strapdown inertial navigation system).
- operating time without charging - 10h (Li-Ion technology).
- charging time (in 80% discharge) - 1h.

From view point of software following functionality is implemented:

- Detailed bathymetry over ENC charts.
- Compatibility with S57 standard (official marine electronic charts).
- Optimized human machine interface for fast and reliable operations.

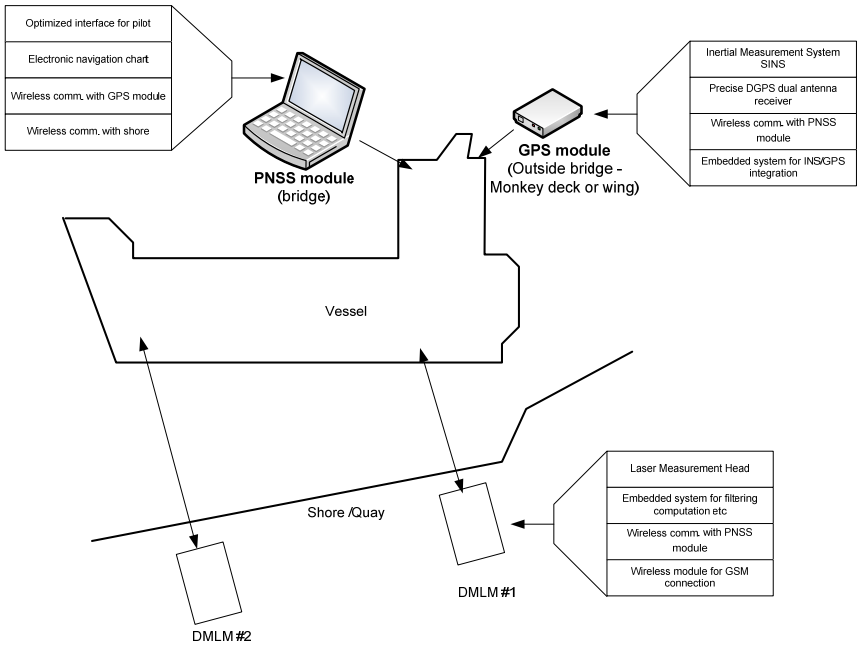

Fig 10 Diagram of PNDS

3.3. Transmission between LDS and PNSS

Commercially build docking support systems are mainly constructed on basis of field bus connecting stations to main controller and then presenting output on large display or transmitting to pilot via VHF link (Marimatech www). Distances between laser modules could be around 250 meters in presence of harsh electromagnetic environment (power cables, pipes, constructions etc). Two types of systems were validated: presented at Fig. 6 (decentralized system) and fig. 7 (centralized system). Malfunction of PNSS unit is here out of scope and in further study should be done. Additionally centralized system – here treated as working in normal conditions can be connected to GPRS station and as such be operating at mobile devices without specialized interfaces – only with designed for it application (Gucma et. al 2010).

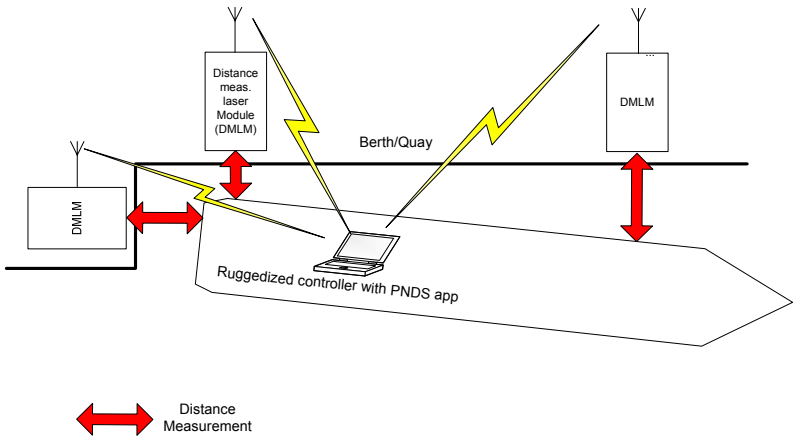

Fig. 6 Measurement in decentralized system (every laser DMLM computes own solution and sends independently to PNSS)

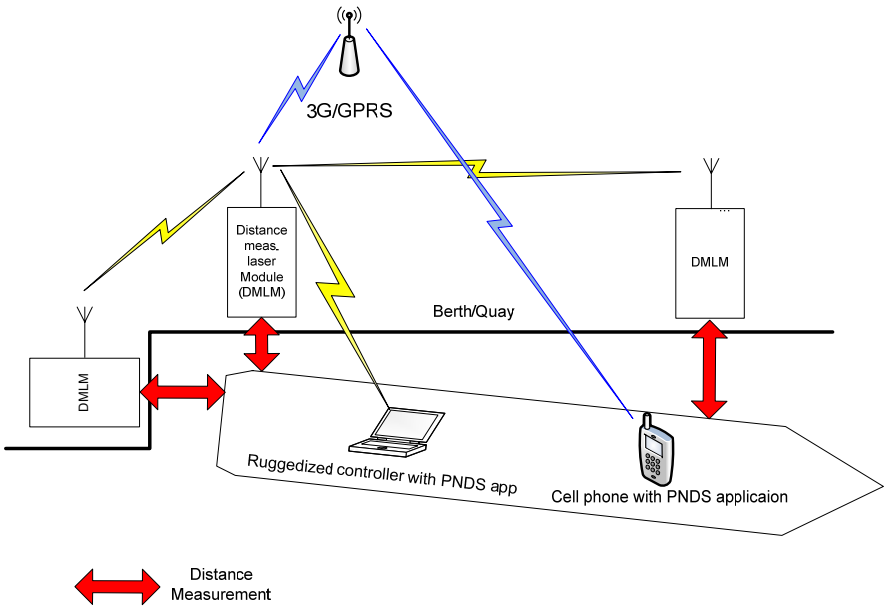

Fig. 7. Measurement in centralized system (every laser DMLM sends to main processing unit at quay and then to PNSS)

Access scheme for PNDS system is typical TDMA and problems of error correction in TDMA networks were taken in many scientific discussions just to mention: (Ergen, S.C. Varaiya, P. 2005) or (Jolly, G. Younis, M. 2005)

3.4. Algorithm of distance measurement

Distance measurement is defined as a readout of value in meters from shore base point to object – vessel that is approaching. Its required to held system in standby – where no laser is operating (due to limited life cycle of laser) and embedded microcontrollers are polling for start signal periodically (usually every 100ms). This state can achieve very low

power consumption and battery operation is possible. Wake up signal is send from vessel to main controller and algorithm of this state is presented at Fig. 8. (Gucma et.al. 2010)

Program is written in safe mode - two watchdogs are used. Timeouts for this watch dogs are verified in real conditions and varies from 10 to 200 ms. Suspension of measurement is performed when distance stops changing. Timeout is given for possible interruptions. Operator on vessel can manually stop this operation, shut down laser heads and set system to stand by.

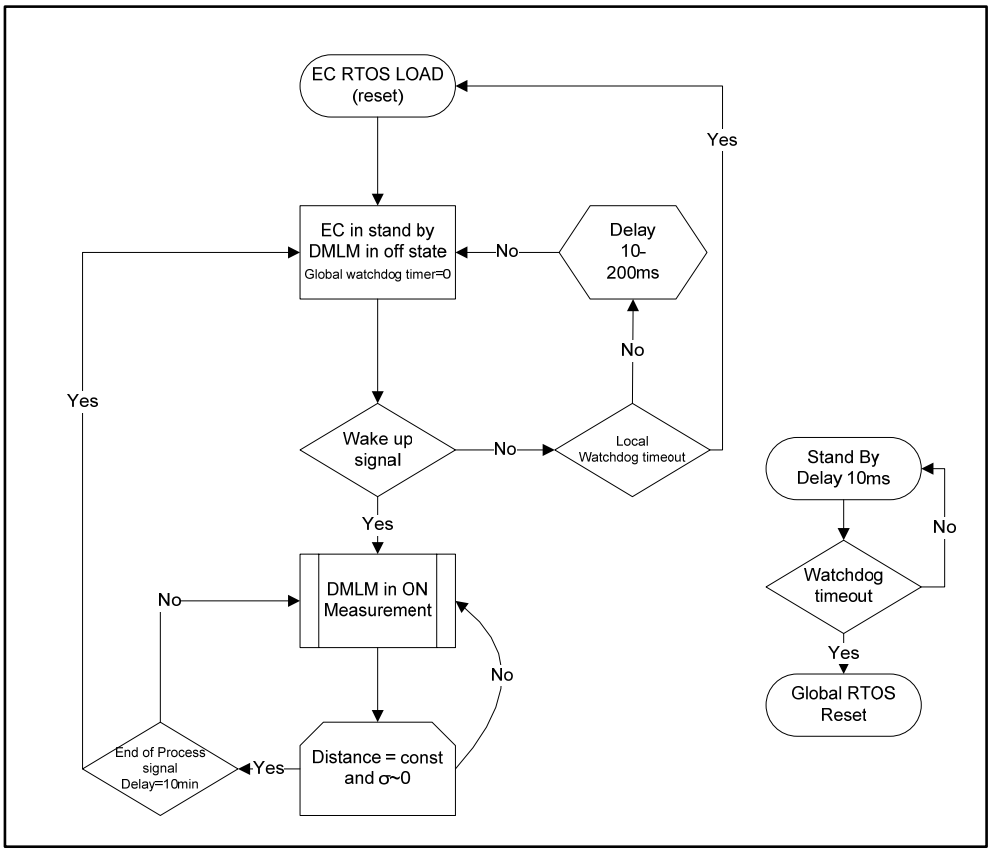

Fig. 8. Main program algorithm. EC is embedded computer DMDL is distance measurement laser module, RTOS is Real time operating system, σ – variance of last 10 measurements.

3.5. Simulations

At first stage to build laser docking system it is necessary to evaluate all potential threats. Simulators are very effective and relatively cheap to perform this tasks. The main problem to solve is to develop the system as much reliable as possible. In Marine Traffic Engineering Institute in Maritime University of Szczecin many simulators were built so far – and as such needed experience has been gathered. As a base of new laser docking simulator the previous one, pilot navigation system simulator, was the starting point [Fig. 9.].

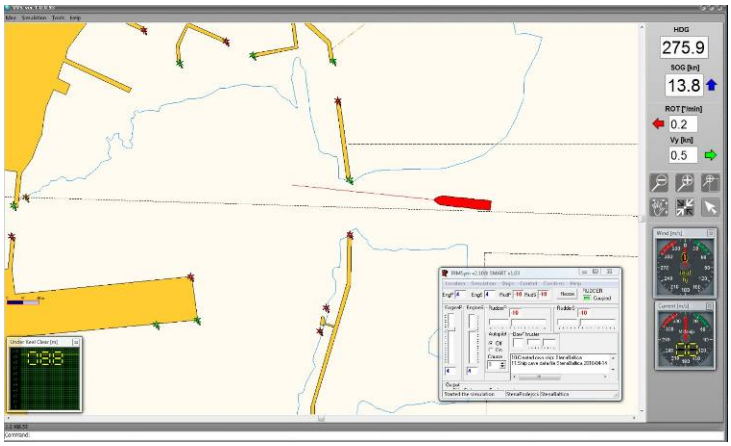

Fig. 9. Pilot Navigation System simulator

To make new simulator usable, new laser docking module was implemented. It allows to define up to five laser sensors in any place of the chart in any moment [Fig. 10]. The measurement method of laser sensor is performed strictly in the same way as real one. It means the laser sensors show the distance in defined direction up to their maximum range, which is also defined during placing it on the chart [Fig. 11].

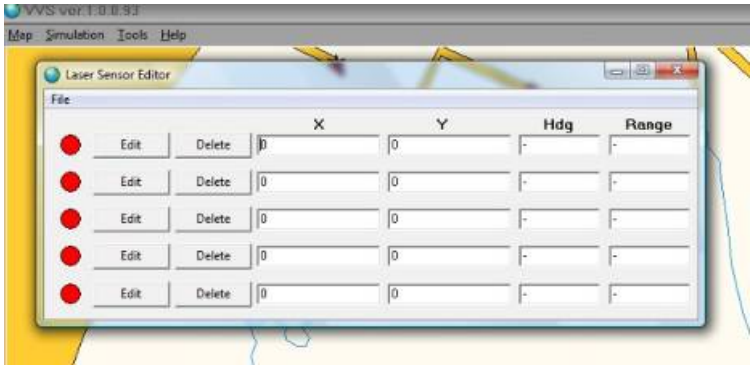

Fig. 10. Pilot Navigation Docking System simulator - laser sensor module setup window

As sensors can be defined at any place it is possible to monitor any other distances during approaching the vessel. It could be crucial especially in restricted visibility. Our research and performed simulations had to find the answers for many important questions.

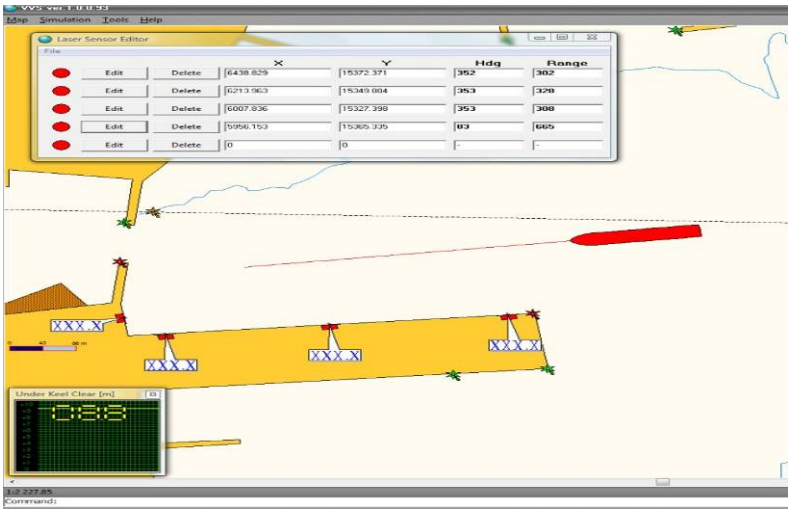

Fig. 11. Pilot Navigation Docking System simulator - laser sensor module – single laser adding to chart

The first one, the most important, is: What should be the best sensors configuration along the quay in order to give very accurate, reliable and useful information? The other one concerns the user interface. How to show the information in the most convenient way? After many of simulations the answers will be ready and the results will be implemented in the real system which the first version is already prepared to utilize the conclusions [Fig 12].

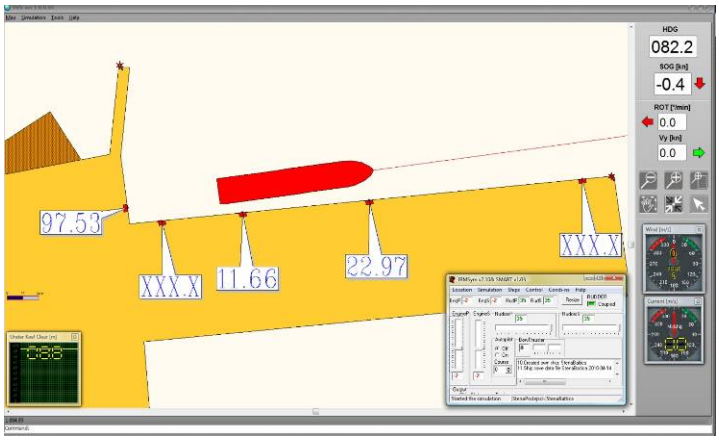

Fig. 12. Pilot Navigation Docking System simulator – distances during mooring operations

4. CONCLUSIONS

In article main features and concepts of PNDS development are presented. Whole process of design will be completed on pre-prototype building in the middle of 2010 year. After this stage performance tests can be done, and changes in algorithm. Transmission and visualization will be tested both by experts methods as well as a real tests. Simulations

at properly build simulator will let the experts to asses layout of laser module at quay and overall functionality of system.

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SYSTEM PILOTOWO DOKINGOWY – NOWE NARZĘDZIE ZABEZPIECZENIA OPERACJI MORSKICH

Streszczenie: Dokowanie statków jest jednym z etapów podróży a jego przeprowadzenie wymaga od operatora (najczęściej pilota) dużego doświadczenia oraz dokładnych informacji o pozycji. Artykuł prezentuje założenia budowy systemu pilotowo dokującego dla wspierania operacji cumowania dużych statków. System opiera się na pomiarze odległości od kei do statku z wykorzystaniem laserowego dalmierza impulsowego. Takie systemy są budowane obecnie ale ich funkcje nie zawierają wszystkich niezbędnych właściwości. Proponowane narzędzie jest zaawansowanym układem do niezawodnego pozycjonowania statku w trakcie operacji cumowania.
Słowa kluczowe: nawigacja morska, pilotaż statku, system dokingowy