Laser docking system integrated with Pilot Navigation Support System. Background to high precision, fast and reliable vessel docking.

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Abstract

Docking of vessel as a part of sea voyage requires high precision of positioning, reliability of solution, independent architecture and a great knowledge of operator. In 2006 Pilot Navigation Support System has been build, nowadays combination of this system with Laser Docking System is emerging. Article presents assumptions of integrated system consisting of Laser Measurement System and high precision DGPS System developed for accurate docking/mooring of vessel. Distances and positions must be measured with precision up to 20cm and position must be provided with 2Hz rate to end user. Apart from lasers some FMCW radar sensors will be applied for verification and provision of measurement when meteo conditions (heavy rain/snow) will disable laser measurement. Whole system has an augmented architecture that will increase reliability and availability. End user uses specialized Pilot Navigation Support System with ENC charting type system. On the other hand users will have access to non specialized application for handheld devices, like cell phones, made in JAVA and available through public service of GSM.

1 IDEA OF DOCKING SUPPORT SYSTEMS

The idea behind the construction of a docking system is to facilitate berthing and unberthing of an LNG carrier or any other large vessel by an accurate determination of ship hull position relative to the berth and equally accurate relative speed of the ship. Its main advantage is the identification / determination of ship's distance to the quay independent of ship positioning systems as well as the measurement of hull transverse speed relative to the quay. In this article following nomenclature has been stated: 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 in the A.915 document sets out the following accuracy levels for each type of navigation:

IMO navigation requirements	Accuracy [m]	Integrity		Continuity	Availability	
		Alert limit [m]	Time to alert [s]	Integrity risk [$^{-5}$]	over 3 hours [%]	per 30 days [%]
Ocean and coastal	10	25	10	10	N/A	99.8
Port approach	10	25	10	10	99.97	99.8
Port navigation	1	2.5	10	10	99.97	99.8
Automatic docking	0.1	0.25	10	10	99.97	99.8

The accuracy of 0.1 m for docking can be ensured by satellite positioning receivers working with an external system source, such as the RTK system. Similar accuracy is yielded by a laser system operating on the quay, which to its advantage, is independent of external factors affecting the position received via a satellite system. Although IMO does not precisely state purpose of automatic docking – automation here is more a key word to Dynamic Positioning of vessels and as such does not apply for docking in port.

Idea of building PNDS is providing solution for pilot or vessel captain of following parameters:

- 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 SYSTEMS AVAILABLE ON THE MAREKET

In chapter comparison of different systems available on market are presented. The laser docking system for LNG vessels consists of the following components:

– 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)

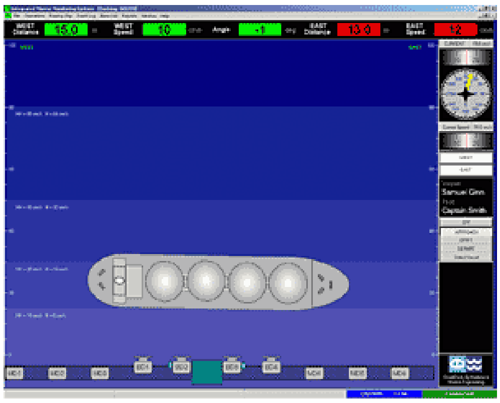

Fig. 2. Portable display of the SmartDock system (Trelleborg www)

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. Figure 3 shows three different displays of 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. The visualization on a portable display takes account of the ship type and terminal design (Fig. 4).

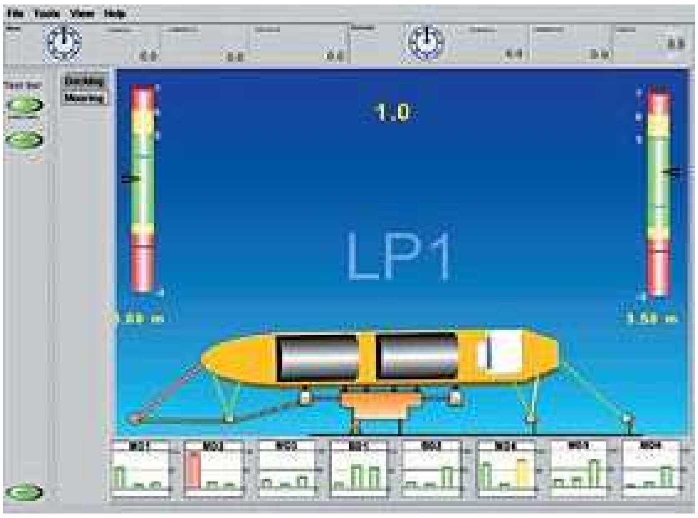

Fig. 4. Portable display of the BAS Marimatech system (Marimetech www)

3 SOLUTION PROPOSED

Project PNDS conducted in Maritime University of Szczecin is based on measurement of distance to vessels hull in relation to shore. At contrary to available systems, effort has been taken to develop more flexible and reliable systems. Main objectives taken into account for the guidelines in the PNDS project are:

- 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),

3.1 *General idea*

Main scope during design time is finding optimal laser head and following parameters were verified while project was running:

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

Except commercially available laser modules, especially designed heads for the purpose of project, were verified. As a main factor influencing laser efficiency internal software if regarded as critical one. It could not be stated that class of optics is crucial due to fact that it is impossible to disassembly laser module and test it without destroying it permanently.

During project realization several solutions from field of electronics has been tested to find optimal solution. For construction fast and ‘low power’ embedded computers were chosen, basing on ARM Cortex M3 solution with nested communication peripherals: (Serial, GPIO - general purpose I/O, CAN, Ethernet). Modular development has been applied as one that brings more scalable output. Modular development is not always best solution - in this case disadvantages were quite slow time related to development progress; although this fact was not critical. As a output laser head presented at fig. 5 has been outlined.

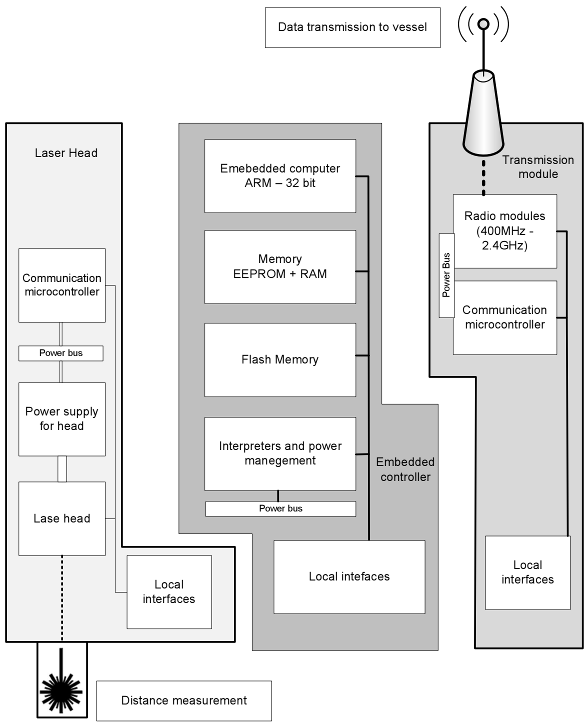

Fig. 5 Internal diagram of single laser head

3.2 *Transmission*

One of factors that led a light to this subject is problems of transmission. Currently build docking support systems are mainly constructed on basis of field bus connecting stations to main controller and then via wireless module to mobile subsystems. It must be stated that distances between laser heads could be around 250 meters in extremely harsh electromagnetic polluting environment (power cables, pipes, constructions etc). It could look like an anachronism – nowadays self organizing wireless networks with redundant transmission channel and dynamic frequency hopping of several or hundreds of stations are nothing extraordinary in automation. Failure of one controlling module cannot lead to break down of whole system – proposed solution can work in two stages centralized with wireless inter head communication and decentralized where one head is connecting to dynamically to mobile unit. Situation were presented at fig 6 (decentralized) and 7 (centralized). Failure of mobile unit (PNDS) is here out of scope and in further study should be estimated. 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.

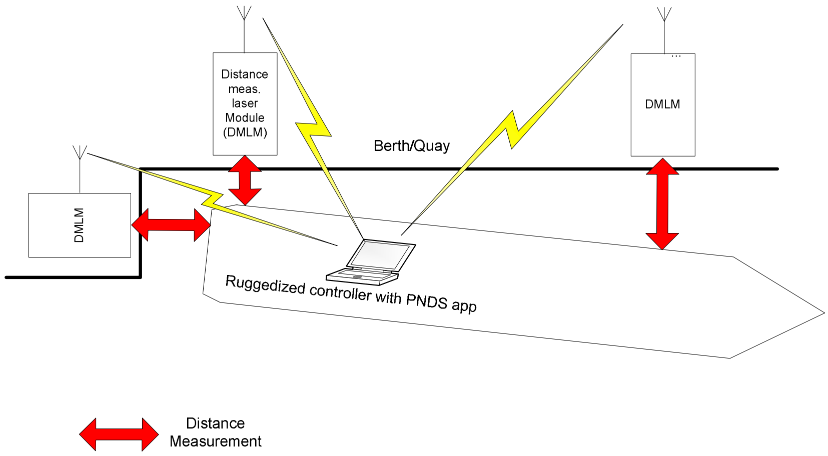

Fig. 6 Measurement in decentralized system (every laser DMLM computes own solution and sends independently to PNDS)

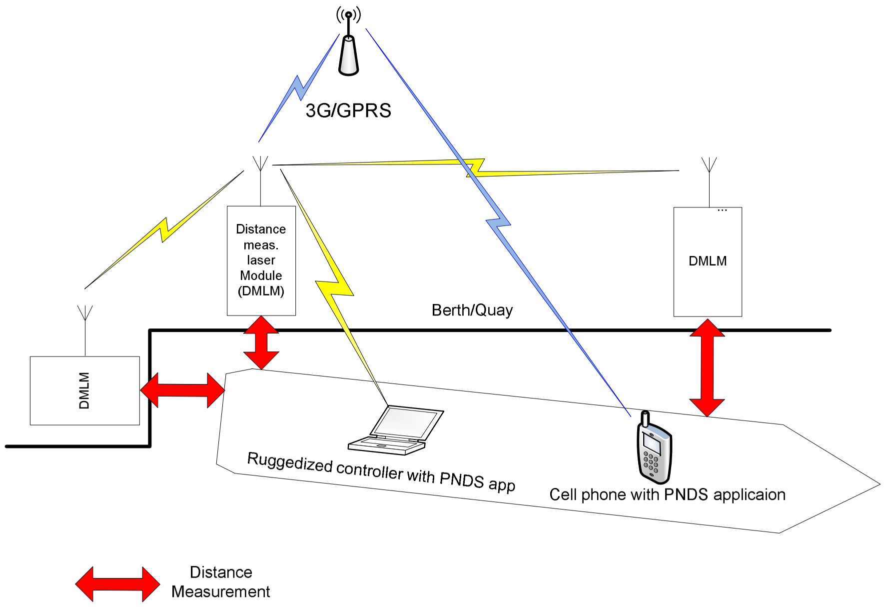

Fig. 7 Measurement in centralized system (every laser DMLM sends to main processing unit at quay and then to PNDS)

3.3 *Access Scheme*

Typical access scheme for ad hoc wireless networks is Time Division Multiple Access (TDMA), in which the transmission in a given radio frequency is divided into time slots. Every unit DMLM may transmit in one or several time slots depending on quantity of data. This method is used in variety of application to mention GSM as first and most popular.

In general TDMA technique generates two kind of problems. Problem of battery powered stations is energy consumption; switching to off-radio state is not always best solution (time lag). Second problem that can be encountered, is a short time of data collection. TDMA can save energy by eliminating collisions as well as entering inactive states until their allocated time slots. Both of this problem might be potentially resolved in PNDS project during real time measurements using this technique.

3.4 *Error correction*

Typically for error correction following methods can be applied:

- BTMA (busy tone multiple access) – two channels are utilized – one for data and one for validation of busy channel. Three types of messages are proposed here: RTS: ready-to-send, CTS: clear- to-send - busy-tone channel. This method is good only for simple wireless networks due to fact that hidden (unwanted) station can easily interrupt communication.
- MACA (multiple access with collision avoidance) additionally handshake mechanism is used here – hidden station cannot start transmission. Frames RTS and CTS are used here in one channel. Each station that receives RTS frame locks its transmissions until CTS will arrive. Simple ISM (Industrial Scientific Medical Band) modems are working with this method.
- DFWMAC (distributed foundation wireless medium access control) is based on MACA and is a primary method for wireless IEEE 802.11 networks. More sophisticated modems are using this as well.

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)

4 ALGORITHM OF DISTNACE 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.

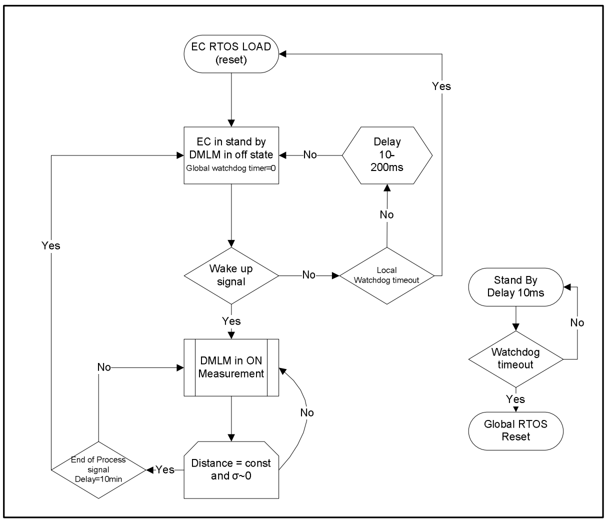

Fig 8. Main program algorithm. EC is embedded computer DMDL is distance measurement laser module, RTOS is Real time operating system, σ – variance of last 10 measurements.

It is important to write program in safe mode thus at least two watchdogs must be used. Timeouts are verified in real conditions and varies from 10 to 200 ms. Another problem is proper initialization of laser modules – powering up and sending initiation commands are provided by solid state relays on FET transistors. When laser module responds with ID and manufacturer sign it must be recognized (at least 4 different types of laser heads could be used in one distance module), and properly initialized (sending data bus parameters, speed of repetition etc). Measurement can be commenced in this point. Suspension of measurement is performed when distance stops changing and variation is around 0. Additional time is given for possible interruptions. Operator on vessel can manually stop this operation, shut down laser heads and set system to stand by.

5 DESIGN OF PORTABLE UNIT

Portable unit of PNDS is taken by pilot to the vessel that is to be moored, and as such must be maximally rugged, lightweight and hand helded as possible. System must be also extremely robust and easy to fix in all conditions of weather. Portable system consists of two modules: PNDS – specialized computer with proper software and radiomodem, and GPS unit mounted outside the bridge (usually wing or monkey deck). Functional diagram is presented at fig 9. Functions that has to be provided to pilot 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). Diagram for integration INS/GPS is presented at fig 9.
- operating time without charging 10h (Li-Ion technology).
- charge time in 80% discharge - 1h.

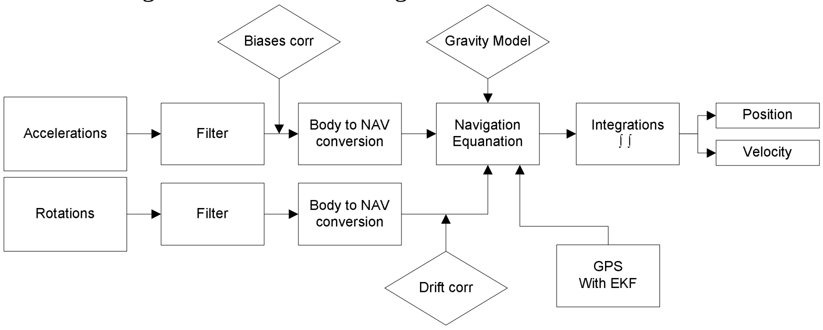

Fig 9. Diagram of integration process in PNDS module (INS/GPS)

Figure 10 presents complete layout of PNDS module (both mobile and shore based). 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.

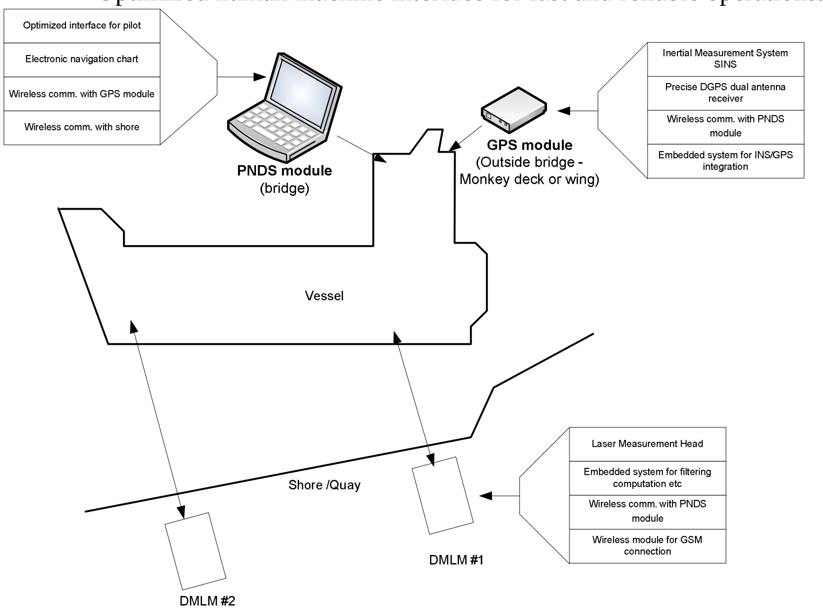

Fig 10 Diagram of PNDS construction

For construction advanced electronics has been designed together with leading manufacturers components. PCB (printed circuit board) were designed in multilayer and components were used in SMD version. Housing and construction has been optimized using fast prototyping techniques and especially Selective Laser Sintering (SLS) has proven to be useful. Some parts were prepared in CNC techniques (computed numerically controlled). Main applications of used SLS method are:

- Slightly less detailed parts and models for fit & form testing compared to photopolymer-based methods using engineering plastics
- Rapid manufacturing of parts, including larger items such as air ducts
- Parts with snap-fits & living hinges
- Parts which are durable and provide the
- Patterns for investment casting

Materials that can be used in SLS:

- Nylon, including flame-retardant, glass-, aluminum-, carbon-filled and others providing increased strength and other properties
- Polystyrene (PS)
- Elastomeric
- Steel and stainless steel alloys
- Bronze alloy
- Cobalt-chrome alloy
- Titanium

Housing and electronics is presented at fig. 11. This module is under sea trials and any changes occurring after that will also be made in fast prototyping techniques.

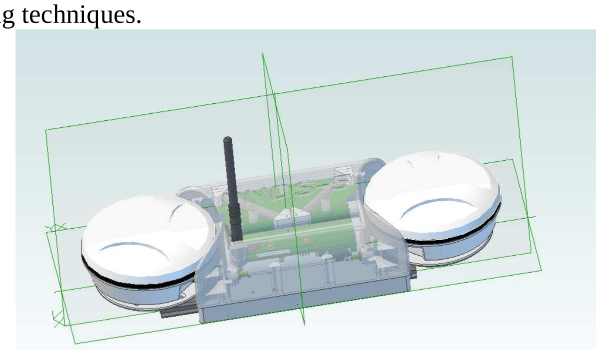

Fig 11.PNDS housing and electronics designed in MUS

CONCLUSIONS

In article main features and concepts of PNDS develeopemnt 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.

ACKNOWLEDGEMENTS

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