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Issues on Application of Portable Pilot Units

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Abstract

Portable Pilot Units (PPU) play an important role in modern pilotage. With more than 20 years' PPU development and practice, a comprehensive data analysis is conducted in this paper. The reliabilities and accuracy of different sensors are compared. Finally, the risk of PPU piloting and the corresponding countermeasures is discussed.

Keywords: PPU; Data Sources; Accuracy; Reliability

1 INTRODUCTION

Portable Pilot Units (PPU) can perform continuous monitoring and tracking of both own and target ships. It can offer various information related to pilotage, such as tides, dynamic schedules and so on. Pilots would improve their situation awareness substantially by using PPU. Meanwhile, safety of pilotage operation under situations of confined waters, heavy weather and poor visibility can be promoted. PPU can help maritime pilot extend his view, enhances situational awareness, supports pilot decision making, increases safe berthing operations, enables optimisation of fairway use and used for evaluation and training purposes, as shown in Figure 1. With widely applications, design of PPU has attracted many attentions. IMPA (International Maritime Pilots' Association) promulgated the Guidelines on the design and use of Portable Pilot Units in 2009 [1]. The guidelines indicate that although PPU are not able to meet all the requirements of SOLAS on ECDIS (Electronic Chart Display and Information System), the hardware portability, electromagnetic compatibility and safe bridge design were recommended to satisfy relevant requirements. In recent years, meeting point, ship's position prediction, berthing auxiliary have been introduced into PPU. With the development of intelligent computation service, critical data push, and paperless signing, PPU have become more accurate, automatic and intelligent.

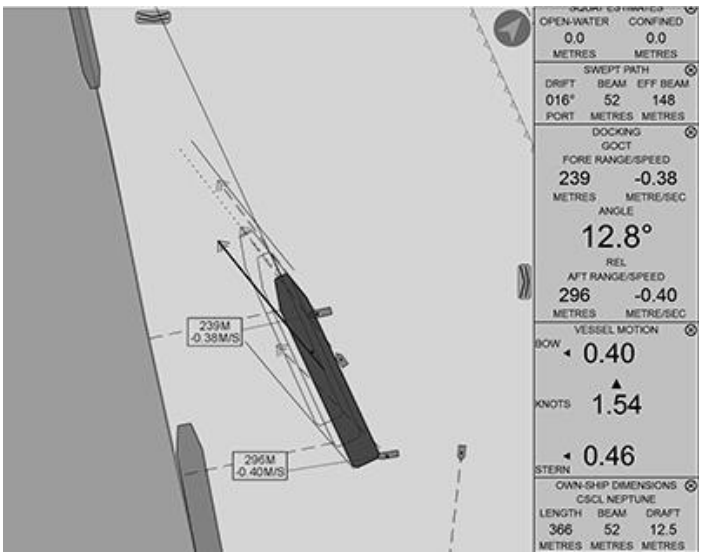

FIG. 1 PPU USED TO INCREASES SAFE BERTHING OPERATIONS

The guidance also suggested that the possible problem and defect of data sources be recognized while using PPU. PPU consist of display terminal, data sources (sensors), software and communication links. When they were applied to navigation or decision-assisting, the accuracy and reliability of data sources should be the most fundamental

consideration. It requires that a pilot should have sufficient understanding so as to avoid adverse effects caused by blind relaying on PPU.

2 DATA SOURCES OF PPU

2.1 Primary Data and Sources

PPU's functions of ship's position monitoring and decision-assisting are based on the accuracy of position, HDG (heading), COG (course over ground), SOG (speed over ground), ROT (rate of turn), antenna's location. The way to access these data includes:

- AIVDO (AIS VHF Data-link Own vessel report) of AIS message, the accuracy depends on the sensors which connected to the AIS transponder and correct static information.
- Using portable GPS receiver and e-compass sensor, the accuracy depends on operational environment of devices.

2.2 Access and Transfer Mode

The current data access mode adopts AIS Pilot Plugs adapter to connect pilot plug, to read and transfer AIS data. The adapter is in charge of transferring AIS data to destination node. Devices with AIS, GPS receiver and e-compass can provide data such as position, HDG, ROT, rolling and pitching.

Transfer mode can be divided into two kinds of wired and wireless. Since there are no unitary specifications in AIS pilot plug installation, the pilot plug of some ships is not installed at the bridge front beside the window, which has led inconvenient when PPU adopt wired connection [2]. Aiming at this, a wireless transfer AIS pilot plug is designed. In December 2015, a PPU, which consists of this equipment (Cenkin COE-BT-485 9) and SevenCs ORCA Pilot G2, Panasonic FZ-G1, had obtained Type approval of DNV GL group.

3 ACCURACY OF DATA SOURCES AND APPLICATION RISK ANALYSIS

3.1 Accuracy of Data Sources

3.1.1 Accuracy of GPS

The error from GPS will lead accuracy degradation of ship's position, COG and SOG that are transferred to PPU. There are geometric error and pseud-orange error in GPS. In 2000, the US announced to shut down SA (Selective Availability). After that, positioning accuracy of GPS reaches about 20 m, and stabilizes at 5~30 m. Nonetheless, the accuracy of GPS will increase with the GDOP (Geometric Dilution of Precision) in high latitude area and PDOP (Position Dilution of Precision) in middle and low latitude area [3]. It is obvious that the accuracy is not enough for berthing and ship's position prediction calculation.

Positioning accuracy of GPS is greatly improved by DGPS (Differential Global Positioning System). The differential positioning technology with meter-scale accuracy has already satisfied requirements of navigation positioning accuracy. RTK (Real-time kinematic) technology can make positioning accuracy into centimeter-scale. But it has not been applied in navigation.

3.1.2 Accuracy of HDG

Ship's gyrocompass is accurate and reliable. It has latitude error, speed error, ballistic error, swing error and head marker error [4]. According to resolution MSC.116(73), the accuracy of THDs (Transmit Heading Devices) should meet the following requirements: transfer resolution error less than ±0.2°, static error less than ±1.0°, dynamic error less than ±1.5°, following error less than ±1.5°.

IMO (International Maritime Organization) resolution A.956(23) prescribed that the ships of 500 gross tonnages and above should equip with a gyrocompass. HDG is obtained by a connected gyrocompass or converter. According to ITU-R M.1371-5 [5], the range of HDG transferred by AIS message is 0°~359°.

3.1.3 Accuracy of ROT

According to IMO resolution A.526(13), the error of ship's ROT sensor should be less than 0.5°/min of the actual rate of course change plus 5% of heading rate of indicated value change. Currently, the majority of ships are not equipped with ROT sensor, so the ROT data cannot be obtained by PPU. As supplementary, PPU use two methods to get additional sense data:

- Software internal calculation. ROT is estimated by analyzing AIS message and change of HDG. This method is limited by update rate of AIS data. The error will increase with insufficient sampling.
- Obtained by external sensor. The external electronic magnetic compass sensor will bring error because of incorrect compensation influenced by hull. Meanwhile, the error will increase with poor reception of external GPS compass.

3.1.4 Smoothing Calculation of GPS Drift

GPS position is drifting because of GPS error. Therefore, ship's position, COG and SOG will have a continuous fluctuation in PPU even the ship is stationary. GPS receiver will use smoothing calculation to ensure an optimum state. The time interval of smoothing calculation is 2~30s, decided by users. Smoothing calculation will make ship's position, COG and SOG to have a certain degree of delay. Pilot should pay attention to the fact that the delay of ship's position will lead to a few hundred meters' error in extreme circumstance.

3.1.5 Factors that Influence Accuracy of PPU

Accuracy of PPU is influenced by coordinate error, ENC (Electronic Navigation Charts) unit error and data sources error.

- Coordinate error. The display mode of ECDIS is restricted by S-52 standard [6] (established by IHO). When geographic coordinate is converted to plane coordinate, the fast Mercator projection transformation is adopted to satisfy accuracy requirements. When plane coordinate is converted to screen coordinate, the error can decrease by increasing screen resolution, so the error produced by coordinate conversion is negligible [7].
- ENC unit error consists of error introduced by ECDIS production and ECDIS seamless splicing technology. The error will be diminished with technology development.
- Access data source error contains insufficient accuracy of sensor and low reliability, which are the main error sources. Besides, corresponding mathematical models should be established for ship's position prediction, meeting point and berthing parameter calculation. The accuracy is also influenced by practicability of these mathematical models.

3.2 Data Reliability Analysis of Different Access and Transfer

3.2.1 Reliability of Data from AIS

Pilot prefers to use AIS Pilot Plugs adapter because this device is portative and convenient. The reliability of AIS data is related to reliability of information offered by access sensors. Besides, AIS' monitoring on target depends on AIS configuration of target ship, normal operation of sensor and data accuracy [8]. According to ITU-R M.1371-5, accurate information provided by AIS message and RAIM (Receiver Autonomous Integrity Monitoring) message can help user recognize accuracy and reliability.

With the improvement of SBAS (Satellite-Based Augmentation System) and recognition of importance of position accuracy in navigation safety, more and more merchant ship introduced DGPS or DGNSS (Differential Global Navigation Satellite System) to increase positioning accuracy and reliability. According to the 73rd meeting of IMO on SOLAS Convention Chapter 5, ships over 50,000 gross tonnages built after July 1, 2002 must be installed with rate of turning indicator. Ships over 100, 000 gross tonnages and were built after September 1, 1984 also must be installed with ROT indicator. More comprehensive, accurate and reliable ship's dynamic information can be obtained on AIS.

3.2.2 Reliability of Data from Independent Sensors

Independent sensor can fully or partially provide data of ship's position, COG, SOG, HDG, ROT as requested. Although advanced DGPS and DGNSS receiver, electronic compass or GPS compass and AIS receiver module have been integrated, the performance cannot be satisfied since influence of the hull, reflection of the chimney and masts, obscuration and restriction of receiving antenna. Only when the antenna is situated at the best location with no interference, reliability can be guaranteed. Ideal location of the receiving antenna should be as high as possible [9], which is difficult for a portable AIS receiver. Thus the data plausibility, validity, latency and integrity is influenced by this limited reception environment.

3.2.3 Reliability of Different Data Transfer Format

1) Internet Transfer

Shore-based AIS obtains ship's dynamic information and transfers it to PPU through internet. The transmission link is easily affected by network coverage status and environment in the operation area. And data originates dynamic information of own ship broadcast but not Parsing AIVDO messages, it cannot obtain real-time position, SOG and COG because of influenced by AIS reporting interval and network latency. It should be prudent when using internet data as sources of PPU.

2) Cable Transfer

Wired transmission is the most stable data transfer. It has advantages of interference-free and long distance transmission. But it is not convenient. It is restricted by location Pilot plug and cable length.

3) Wi-Fi AIS Pilot Plugs Transfer

It will be blocked and disconnected if interfered by other high power Wi-Fi signals. Some devices use UDP (User Datagram Protocol) protocol, as UDP provides connectionless (no handshake) communication, the data packet cannot be assured to transfer to destination address. The real-time performance of reliability of data transfer will reduce with the loss, repetition and random order of packet [10].

4) Bluetooth AIS Pilot Plugs Transfer

Bluetooth has the advantages of PPP (Point to Point Protocol) Protocol, automatic matching and linking, stable data transmission, low power consumption and high reliability. The transmission distance of Bluetooth can reach 100 meters for Class 1. In addition, the external communication port of the terminal will not be occupied. Therefore, Bluetooth is widely used for PPU data communication.

3.3 Application Risk

The dynamic information obtained by PPU will have a certain error because of transmission delay. The precision of ship's position monitoring and prediction will be influenced. If analysis and verifications are not conducted, it would cause accident provided PPU is blindly trusted and relied on.

On the foggy January 25th, 2014, the ship of "CAP BLANCHE", which was piloted by a pilot from Canada Pacific pilotage organization, was grounding at FRAZIER River around the S10 Buoy. According to the accident report of Transportation Safety Board of Canada, the PPU pilot used is connected to a portable ROT sensor and an AIS Pilot Plugs. ship's position prediction was enabled. Because of poor visibility, the ship motion trend was lack of reference and verification. The pilot had to use PPU to estimate ship's position. When the ship was at the turning of STEVESTON BEND channel, ship's position prediction was wrong because of error of ROT sensor and GPS. Then the ship deviated from the center of the channel and was grounding at the south side. The reasons caused "CAP BLANCHE" grounding was the lack of information exchange of captain and pilot, the lack of utilization of bridge resource, and poor visibility. But the most important reason was improper use of PPU. The report indicated that the actual ROT reached twice times the average of ROT sensor. But the pilot did not perceive [11], as shown in Figure 2.

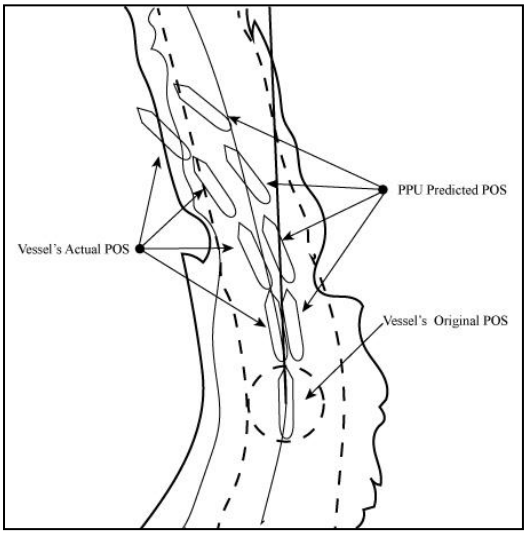

FIG. 2 MV. CAP BLANCHE GROUNDED IN THE STEVESTON BEND

4 COUNTERMEASURES

4.1 Standardization of AIS Device Installation, Setting and Utilization

AIS device installation, setting and utilization should be standardized. Ship-borne AIS device should be surveyed by qualified inspectors from service organizations strictly according to the SOLAS V/18. PSC (Port State Control) should have a carefully examination on AIS device setting and utilization.

Lu Yueming, who is from China Maritime Pilots Association, presented that AIS device installation, setting and utilization should be formulated by the authority, so as to standardize corresponding behaviors. If there are two GPS receivers on board, the one with higher accuracy should be connected to AIS. If there is a DGPS receiver on board, the DGPS should be connected to AIS. If there is ROT indicator on board, it is also should be connected to AIS [12]. Thus pilot can obtain accurate and reliable dynamic and static data from AIS device. Meanwhile, professional check and inspection should be performed to assure a good operation condition for AIS.

4.2 Source Control by Pilot Organization

An overall plan should be taken for pilot organization development and deployment of PPU. The plan's standard should be formed according to requirements of PPU design and utilization guidance, give full consideration to the portability, reliability, operability and compatibility to multisource data.

The detail measurements include:

- Type approved device and high accuracy position and THD sensor are adopted to strengthen reliability and data accuracy. When involved position sensor, besides GPS, GNSS (Global Navigation Satellite System) with GALILEO, GLONASS, BEIDOU should be considered to avoid political risk and to improve positioning resources;
- High resolution display terminals should be used to ensure the resolution of ECDIS display;
- Software development should support bENC (bathymetric ENC), so that the newest hydrographic data can be overlaid and ECDIS can be updated without delay;
- DGPS and RTK base station should be established in port, so as to promote high precision ship navigation guidance;
- Optimize port network coverage, strengthening interconnection with private network ability.

Pilots special training is the key of PPU deployment. When US Navy was implementing advanced ECDIS-N system, themselves and civil marine accident analysis was carried out. They found that it had great risk to have overly

believe in ECDIS guidance. If training work was ignored, crew members could not have a good proficiency to the operate the system well. In that case, an advanced system was more dangerous than a traditional navigation system [13]. Pilot organization should take special training to improve pilot's recognition of PPU's limitations and analysis ability of sensor's error and precision. Meanwhile, current deficiency of PPU should be recognized. The performances of the Display terminal, sensors, software and communication link should be constantly improved. Thus accident potentially brought by PPU limitations could be largely avoided.

4.3 Terminal Control by Pilot

The use of PPU has additional requirements for pilots, which include the following aspects:

- Principles, specifications, and functions of various sensors of PPU should be understood. And limitations should be fully aware of;
- Position data and navigation parameter should be analyzed; Cross check for multiple data sources and proper assessment for positioning accuracy of sensors should be known well;
- Operations of simple, convenient and effective verification of landmark and radar position should be proficient.

It should also be noted that there would be some errors with position reference point and ship dimensions from AIS message. So Pilot Card should be used to check AIS message for correction on PPU. It must input correct location when use external sensor. To adopt converter to provide actual heading for the AIS should check whether the ship's initialization has been done before sailing.

Errors of dynamic and static information of AIS report would also exist on target ship. Thus calculation of meeting point will bring system errors, especially in heavy traffic density areas. When data link is busy, some devices will automatically stop data sending, which would result in that dynamic information of PPU can't be updated in time. Therefore, pilot need to use radar to conduct verification for collision avoidance.

4.4 Utilization of Current AIS Base Station

PPU should fully utilize current AIS base station in device improvement in the future. According to ITU-R M.1371-5, AIS base stations can improve position accuracy by DGNSS differential correction signal of No.17 message. The function has been verified and put into practice in Shanghai port. It will be gradually extended to other port in the near future. Base on this function, ship at port can obtain high reliable navigation information and promote port pilotage comprehensively.

5 CONCLUSION

Pilots should have a comprehensive understanding for PPU's function and their application. The limitation of PPU and error of sensors should be fully considered to avoid potential risks. Meanwhile, proper look-out and information that are independent of PPU should be utilized to confirm the plausibility and validity of data sources. Under such condition, the PPU can function more properly. As the International Regulations for Preventing Collisions at Sea on radar usage: Assumptions (Collision risk) shall not be made on the basis of scanty information, especially scanty radar information. Therefore, pilots should make decision according to actual situation and fully usage of bridge resource, but rather rely on single navigation aids exclusively [14]. Only in this way, safety of piloting can be guaranteed.

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