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Is COLREG enough? Interaction between manned and unmanned ships

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ABSTRACT: In recent years, there has been a growing interest for autonomous unmanned shipping. Both from research and industry. Between 2013-2015 the EU-project MUNIN investigated the feasibility of trans-ocean unmanned shipping. While trans-ocean drones could be expected to seldom encounter other ships, short-sea shipping would mean intense interaction with other manned SOLAS and non-SOLAS vessels. This rises some serious questions. How can we expect watch keepers on other SOLAS vessels, fishing boats and unexperienced leisure boat skippers to react when they meet an unmanned vessel? Will they behave in the same way as with manned ships today? Is there a need for the unmanned vessel to communicate intentions in different ways than today? Is there a need for humans to know that they are detected by the autonomous vessel, or is enough that they know the drone will adhere to COLREG? Is there a need to designate separate fairways for unmanned vessels? This is a discussion paper pointing to pending research needs relating to interaction between manned and autonomous vessels.

1 INTRODUCTION

1.1 *The MUNIN project*

In recent years, there has been a growing interest in unmanned, autonomous shipping. A number of projects and conferences has attracted interests from stakeholder all over the world.

One such project was the EU 7th Framework project MUNIN (Maritime Unmanned Navigation through Intelligence in Networks, 2013-15).

The objective of the MUNIN project was to show the feasibility of unmanned, autonomous merchant shipping. The ships would be under control of on-board crew approaching and leaving a harbor, being autonomous and unmanned only from pilot drop-off point to pilot pick-up point. However, there might be maintenance teams on-board if necessary. The goal was also that the ship would be under autonomous control during the main part of the ocean voyage, remotely monitored from the Shore Control Center. Only in exceptional cases was the shore control center expected to actually maneuver the ship remotely.

Limited tests were successfully conducted in a simulator environment before the project ended in 2015.

1.2 *Collision avoidance*

The proposal from the MUNIN project was that a ship during the major part of the unmanned deep sea voyage should proceed in an “autonomous execution” mode. This meant that the ship’s autopilot should follow the pre-programmed voyage plan in track-following mode. This is just as ordinary ships do today: a voyage plan is programmed into the navigation system, which the autopilot follows. Sometimes the operator has to acknowledge a change of course at a waypoint, but the autopilot can also do this automatically.

The MUNIN project also designed an Autonomous Navigation System, which based on information from the onboard sensor system, the nautical chart, and the uploaded voyage plan automatically could detect obstacles and conduct evasive maneuvers if no intervention from the Shore Control Center was made. If the obstacles was identified as other ships, collision avoidance should be made according to the rules of the road, the International Regulations for Preventing Collisions at Sea (COLREGS). The ship could also be remotely maneuvered from the shore control center using radar and cameras. As a last resort, if e.g. radio communication were lost, the ship would go into a “fail to safe” mode, drifting or hovering on its station (assuming dynamic positioning capabilities).

An autonomous ship on the high seas, conducting a weather-routed voyage somewhat on the side of the shipping corridors would not meet many other vessels. The technical challenge as far as interaction with other ships would therefore be limited. Instead the problem would be to conduct testing on international waters in absence of legislation from the IMO.

However, both Norway, Finland (LVM, 2016) and the United Kingdom (DfT, 2016) has declared that they want to be the first nations conducting autonomous shipping. If approved by national authorities testing can be done on national waters, and e.g. in 2016 the Norwegian Maritime Authority and the Norwegian Coastal Administration signed an agreement, which allows for testing of autonomous ships in the Trondheim fjord in the middle of Norway (NMA, 2016). Tests with smaller crafts has already been conducted here and the first tests with larger ships are already being planned, see Figure 1.

Figure 1. Kongsberg will together with British Automated Ships Ltd build the first full scale autonomous ship to be tested in the Trondheims fjord in 2018 (Kongsberg, 2016).

Testing autonomous navigation in national waters means coastal and inshore navigation. This is an altogether different challenge than ocean navigation.

2 UNMANNED INSHORE NAVIGATION

2.1 *Challenges for coastal and inshore navigation*

Navigation in confined waters means increased difficulties that needs to be tackled by the autonomous systems onboard, even if the vessel is remotely monitored by a shore control center. I will in the following assume that autonomous systems will conduct all but exceptional emergency handling. I will discuss three types of problems: (a) navigation in narrows and in proximity of land and shallow water, (b) interaction with SOLAS vessels, and (c) interaction with non-SOLAS vessels, such as leisure crafts, small fishing boats and kajaks.

2.2 *Navigation in confined waters*

Navigation in close proximity to land and shallow water will require good precision by the onboard positioning systems, good nautical charts, and good maneuvering capabilities by the autonomous vessel.

Precise positioning will be fundamental and will be based on Global Navigation Satellite Systems (GNSS). Apart from the American GPS, the Russian GLONASS, the European Galilei and the Chinese BeiDou is under (re-)construction so in the future redundant satellite coverage of high precision can be expected. The passenger ferries on the Hurtigruten, which traffic the narrow inshore fairways of Norway from Bergen to Kirkenes every day, the whole year around, already today conduct most of the voyage with the autopilot in track-following mode based on GNSS data. However, GNSS is vulnerable to intentional interference due to weak signal strength. Thus, the GNSS signal must be crosschecked by independent systems such as radar and/or LIDAR systems comparing satellite positions with positions derived from radar maps and 3D terrain models.

One might also speculate on the needs to install new aids to navigation in narrow and tricky fairways. For instance, automatic positioning based bearing and distance to the new type of e-RACONS, which transmits a unique identification code. Maybe also electronic leading lines, which giver very high precise cross track position like an airport ILS.

Equally important will be good nautical charts based on high-resolution bathymetrical surveys. The resolutions must be good enough to allow back-up systems like radar, LIDAR and echo sounder to crosscheck and verify chart data from the satellite position with independent measures from the onboard instruments. For radar and LIDAR the nautical chart needs to have terrain elevation features also for the land areas. Many nations are already collecting this kind of data (e.g. Kartverket, 2015).

Together with good positioning and good maps, the maneuvering properties of the autonomous vessel needs to be good. Winds, waves and currents will pose a great challenge for autonomous navigation in areas like the Norwegian west coast. It will be difficult to replicate the ship handling skills of experienced mariners, instead an autonomous vessel will need dynamic positioning capabilities allowing it to hover on a set position and translate in any direction.

2.3 *Interaction with SOLAS vessels*

If close proximity to land and shallows constitute one problem of inshore navigation, high traffic density and interactions with other ships, constitute the other. In this text, I have assumed that the autonomous vessel is a SOLAS vessel carrying stipulated equipment like an AIS transponder, transmitting position, course and speed to other SOLAS vessels in the vicinity. Relying on radar, AIS and that all ships obey COLREG, one could assume that the problem of collision avoidance would be solved. However, COLREG does not unambiguously define which ship should give way and which should stand on. For instance, there are no precise definition of the terms “restricted visibility”, “safe distance” or “safe speed”. For instance, ships should give way for other ships on their starboard side (rule 15), but ships should also cross a traffic separation scheme “on a heading as nearly as practicable at right angles to the general direction of traffic flow" (rule 10). Conflicting opinions on which of these two rules are most important has caused incidents in the past (Lee & Parker, 2007).

Ship Traffic Management is a new paradigm of route exchange that has been, and is, investigated by the MONALISA (SMA, 2014), the STM (STM, 2017) and SESAME Straight (Kongsberg, 2014) projects. Briefly, the meaning is that ships send their voyage plans to a coordination center that coordinates all plans to make sure no two ship are at the same place at the same time. The coordination center will also coordinate the arrival time to an available port slot by recommending speed changes. Because ships might not be able to precisely follow preset plans due to influence of currents and weather, the routes need to be updated at regular intervals and the automatic coordination mechanism needs to constantly update recommendations for course and speed to keep the separation between ships. For the shipping industry, the benefit is more efficient voyages arriving just in time to an allocated port slot with a minimum of fuel consumption. For the interaction between manned and autonomous vessels, this means that collision avoidance can be done in advance by the coordination center. (Although sensors and collision avoidance algorithms will still be needed, e.g. in cases where ships maneuverability breaks down.)

However, there remains an even bigger problem: the interaction between autonomous ships and non-SOLAS vessels.

2.4 *Interaction with non-SOLAS vessels*

The International Convention for the Safety of Life at Sea (SOLAS) is a maritime treaty, which requires flag states to ensure that ships flagged by them comply with minimum safety standards in construction, equipment and operation. Most bigger ships are SOLAS vessels while smaller crafts like leisure and small fishing boats are not. That also means that they mostly lack stipulated equipment like AIS transponders and receivers, ECDIS and radars displaying AIS targets, and for the future, abilities to do route exchange and participate in a Ship Traffic Management regime that coordinates traffic, and ensure separation.

One of the biggest challenges as far as the interaction between manned and autonomous ships will involve non-SOLAS crafts. Because they normally do not have an AIS transponder, they do not automatically exist in the internal representation of the world in the Automatic Navigation System of the autonomous ship. Instead, they have to be detected by the autonomous ship's sensors (radar, infrared or daylight cameras or LIDAR). Tests done during the MUNIN project with fused radar and infrared data showed that objects with a size down to a bath-ball could be detected in calm weather with no sea state. In reality, small boats and kayaks will be difficult to detect among the waves of an open inlet – just as they might be for the naked eye. Technology will no doubt improve within this field, but the problem remains: the sensor systems of the autonomous ship sees what it sees, and how can the fisherman or leisure boat skipper know that they are detected by the autonomous vessel? If a fisher, laying still, pulling up lobsterpots observes an autonomous ship coming in his direction, how can he know whether it will turn, or run maybe him down? Or a slender kajak crossing the fairway?

Probably there will be a need for new technical solutions here. With mobile coverage in the coastal areas, a smartphone could act as an AIS transponder/receiver (see Figure 2).

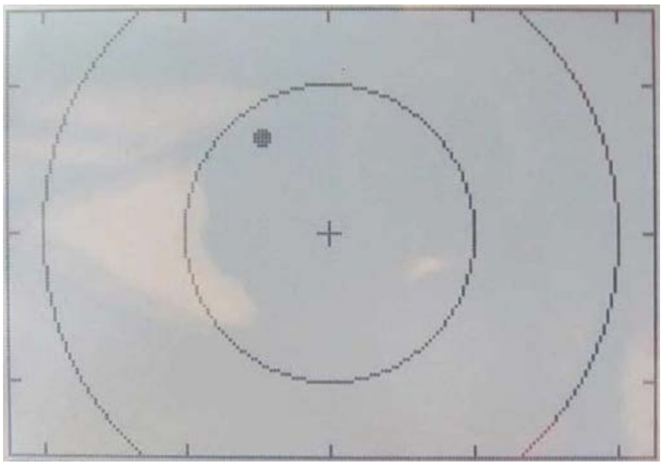

Figure 2: The interface of an AIS receiver. The own boat is in the center and the circles depicts a range of 2 and 4 nautical miles. In this case, an AIS target is approaching from the northwest. Source: ATSB (2013).

The application should also be able to verify that the phone (and the boat it is in) exists on the map of the autonomous vessel. In addition, it might be beneficial if the autonomous vessel was able to communicate its intentions to the small boat as to whether it will change course or if the small boat will have to move away, and in what direction. The lobster fisher might get an alarm on his phone that an autonomous vessel will pass over his position in 5 minutes. Such an app would also be beneficial also in today's traffic environment. In the foggy waters of South Korea several small fishing boats is every year run down by commercial ships while fishing in the approach fairways to major ports (e.g. Maritime Herald, 2016).

3 CONCLUSION

As the technical development of systems for autonomous ships ramps up, it will be necessary to find answers to the questions from the public on issues that may seem scary or dangerous. Therefore, research is needed in issues relating to maritime human factors and the man-machine interaction realized when we now will encounter and must interact with drone ships. In Scandinavian waters thousands of leisure crafts, every summer invades the fairways and port approaches. They are problems for manned commercial shipping today, what about tomorrow.

GLOSSARY

AIS, Automatic Identification System
COLREG, The International Regulations for Preventing Collisions at Sea
ILS, Instrument Landing System
LIDAR, Light detection and ranging
RACON, Radar beacon
SOLAS, The International Convention for the Safety of Life at Sea

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