A - MAST 2015

International Conference of Advanced Intelligent Maritime Safety and Technology

Original article

Human-machine interaction between unmanned, autonomous, ships and manned non-SOLAS vessels in confined and inshore waters: research needs

Thomas PORATHE

Dept.of Product Design, Norwegian University of Scince and Technology, Trondheim, Norway, thomas.porathe@ntnu.no

Abstract

Many bridge officers of large commercial ships have experienced unpredictable behavior on the part of small leisure or fishing vessels that appear e.g. in the fairway in to a port. Often the big ship has restricted maneuverability due to inertia and deep draught while the small vessels has fewer maneuverability restrictions. In some cases, the smaller vessels will make an evasive maneuver that will bring them into the course line of the ship. In rare cases, this leads to accidents. The problem is that the small non-SOLAS vessels might not be aware of the intentions of an approaching ship, of the limitations on the big ship's maneuverability, and whether or not the ship is able or willing to comply with the rules of the road. This is a problem today in the interaction between manned ships. However, because several international research projects now investigates the use of autonomous unmanned ships, this might be an even bigger problem in the future.

This paper proposes to discuss Human Factor issues involved in the interaction between SOLAS and non-SOLAS vessels and possible solutions and suggestions that should be investigated through research. For instance, use of special fairways, special ship marking, use of physical signals from ship – e.g. turn signals, use of electronic signaling through e.g. smart phones, etc..

Keywords: Sample paper, MS Word (no more than 6 keywords)

I. Introduction

As research on the technical feasibility of autonomous unmanned vessels continues to attract funding, now it is also high time to look into the human factors aspects of autonomous unmanned shipping.

In the research project MUNIN (Maritime Unmanned Navigation through Intelligence in Networks) large autonomous unmanned cargo vessels was investigated. They were envisioned to be unmanned on the open ocean, from pilot drop-off to pilot pick-up points (MUNIN, 2015). Detection and collision avoidance with other large SOLAS vessels was thought to be relatively straightforward using radar, AIS and COLREG based algorithms. However, this poses two problems: first the detection of small crafts, and secondly, the problem of manned vessels not following COLREGS.

Detection of objects like small sailing and fishing boats or rafts will be a problem with today's technology, particularly in bad weather with high sea state. Small crafts are not conspicuous radar targets and may not be equipped with AIS transponders. Image recognition from infrared or daylight camera is a possibility. In the meantime one should consider a strategy that is usefull also in the interaction with large, manned ships: to stay out of large ship's way.

In brief, a SOLAS vessel is a ship above 500 gross tons on international voyage or any passenger ship with more than 12 passengers on international voyage. Non-SOLAS vessels are any other vessels, e.g. small cargo ships, fishing boats, tugs, leisure crafts, etc.).

I.I. Interaction between manned ships and small crafts

In May 2012 the 190 meters long bulk carrier *Furness Melbourne* collided with the sailing yacht *Riga II* in the charted "preferred route" off the coast of Queensland in north eastern Australia. It was dark and the bulker did not see the 13 meters long sailing boat on her radar, which had not been properly tuned and set. Although the lookout reported having seen the lights of the yacht, the officer of the watch dismissed the sightings as the light from a distant lighthouse. The accident board concluded that there had been a lack of proper lookout on both vessels before the collision (Australian Transport Safety Bureau, 2013).

This is not unusual that large ships collide with small boats. Large ships has a limited possibility to do evasive manoeuvres, both due to large inertia and slow response time, and in confined waters due to narrow channels with limited water depth. Leisure boat skippers, often with limited training and experience, may have difficulties judging the speed and manoeuvrability of large ships. According to rule 9b of the Convention on the International Regulations for Preventing Collisions at Sea, abbreviated COLREG (1972) "a vessel of less than 20 meters in length or a sailing vessel shall not impede the passage of a vessel which can safely navigate only within a narrow channel or fairway".

The Australian Transport Safety Bureau (2013) wrote in the above mentioned accident investigation report: "In the past 25 years the ATSB and its predecessor have investigated 39 collisions between trading ships and smaller vessels on the Australian coast. These investigations have all concluded that there was a failure of the watchkeepers on board one or both vessels to keep a proper lookout and that there was an absence of early and appropriate action to avoid the collision" (p. 15).

Hemlin and Torge, two final-year cadets at the Maritime Academy at Chalmers University of Technology, Sweden, in 2012 did an interview study on interference between commercial traffic and leisure crafts in the approach to the port of Gothenburg, which is the largest port in Scandinavia with around 11,000 berthing's in 2011. They found out that interference by small leisure craft summer time in the approach was considered a large problem by the officers interviewed. The captain's guild of the Stena Line ferry company in 2004 wrote a letter to the Swedish Maritime Administration requesting that something had to be done about the situation with small leisure crafts passing the approach fairways during summertime. "Problems often arising by navigating the boats in the middle of the fairway, sometimes in flotillas, crossing the fairway in an improper manner, misjudging the speed of the ferries and thereby putting us and themselves in dangerous close quarter situations" (Hemlin and Torge, 2012, p. 41).

The problem will be amplified in restricted visibility. In many parts of the world, fog is prevailing during large parts of the year. Collisions between small fishing boats and commercial traffic is a constant hazard in coastal waters. Commercial vessels will use radar in restricted visibility, but like in the accident described above radar is no guarantee that small bats will be detected.

II. Possible solutions

II.I. Interaction between autonomous, unmanned vessels and SOLAS vessels

Algorithms for making autonomous unmanned vessels do collision avoidance according to the COLREGS are being developed in many projects, (e.g. Naeem, Irwin, & Yang, 2012; MUNIN, 2015). Given the progress of *e-Navigation* and *route exchange* (e.g. Porathe, et al., 2015) one may envision that a "slot-paradigm", equal to the one used in aviation, will support separation between ships participating in such a future system. Such route exchange systems are currently investigated in e.g. the MONALISA (2015) and SESAME Straits (2015) projects.

The MUNIN project also envisioned that autonomous unmanned vessels, although in automatic "track-following" mode, or autonomous "self-deciding", mode most of the time, also would be monitored by a Shore Control Centre which had the ability to take over and remote-control the vessels, given that necessary communication links was available (MUNIN, 2015; Porathe, 2014). Route exchange with ships sending their "intended route" to autonomous unmanned vessels will make it possible for SOLAS ships to avoid entering into close quarters situation where the COLREG is needed. However, for small crafts the situation will be different.

II.II. Interaction between autonomous, unmanned vessels and small crafts

If we now have accidents with large manned ships failing to detect small crafts or having problems avoiding colliding with them in confined waters, what can we then expect the day we will have autonomous vessels?

First, we must not assume that unmanned vessels are blind because there is no one onboard. Although it remains to be proven, the MUNIN project proposed that autonomous unmanned vessels would even be more vigilant than manned vessels. The example above with the collision between *Furness Melbourne* and *Riga II* certainly opens up for such claims.

Using fused sensor information from radar, AIS, night, and day vision cameras, which never asleep may certainly challenge human vigilance and attention. But there is a limitation to the situations that can be foreseen by programmers. However, there will probably remain situations needing human interpretation for times to come (albeit the progress of machine learning). It will therefore be necessary to investigate other solutions which involves actions that must be taken by skippers of small fishing boats and leisure crafts.

One of the problems with this target group is that they are not as well defined as the bridge officers certified according to the international, mandatory STCW code used for training of ship officers. They also have wide range of different backgrounds from very experienced, to novices with very few hours on the sea.

In the study by Hemlin and Torge (2012), mentioned above, a common mistake by unexperienced leisure craft skippers was to underestimate the speed of large vessels proceeding in the fairway, leading to unnecessary and risky situations; and this was in the normally good visibility of a Swedish summer. The problem might be amplified in restricted visibility.

So, if research is needed on the technical development of sensors and sensor fusion to develop the autonomous decision-making, there also is a need for solutions and provisions from the point of view of the small non-SOLAS vessels.

III. Research needs

III.I. Traffic separation

We can assume that the public in the beginning will be sceptic to autonomous unmanned ships. They will not trust them and rather stay out of their way than testing their collision avoidance algorithms. An obvious first step until we can be assure that the sensor technology of the autonomous unmanned vessels are reliable are to separate the manned and the unmanned traffic. This can be done by clearly marking the autonomous ships and by creating dedicated traffic lanes for unmanned vessels. Small craft skipper will then know where they might risk meeting an autonomous unmanned ship, and where the autonomous ships do not go. In Figure 1 is an example of an "autonomous ship lane" marked on a chart over Gothenburg, Sweden (left) and a "waiting area for crossing" marked in the chart, according to a suggestion by one of the respondents in the study by Hemlin and Torgne (2012).

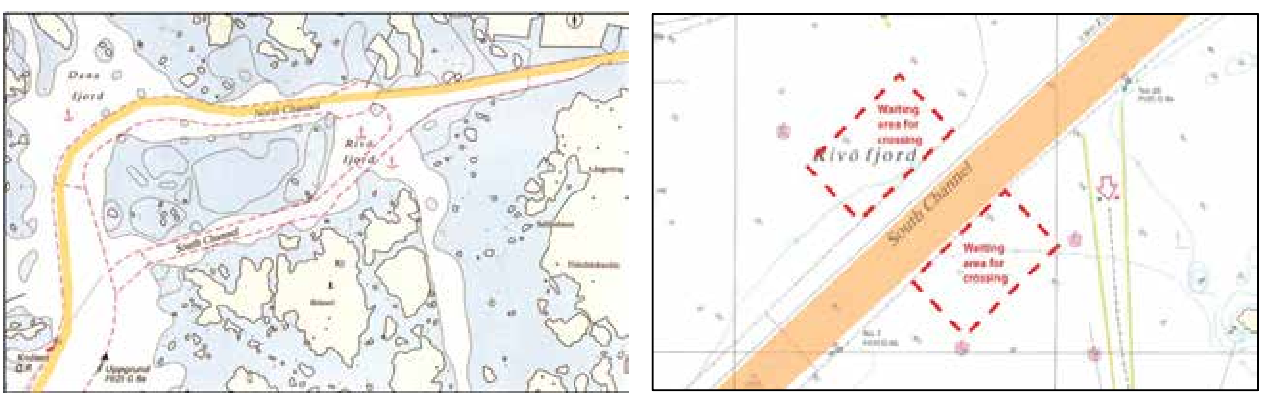

Figure 1: By constraining autonomous unmanned ships to designated traffic separation lanes (orange area) manned traffic can stay out of their way until trust in the autonomous decision-making arise. Left, an example suggestion for the approach to Port of Gothenburg, Sweden. Right, a suggested small craft crossing from Hemlin and Torge (2012),

Source: Chart underlays, Swedish Maritime Administration.

III.II. Physical signals from ship

Rule 34 of the COLREGS stipulates the use of sound signals to indicate maneuvers – one short blast means I am altering course to starboard; two short blasts meant that I am altering my course to port; and three short blasts, I am operating astern propulsion. These sound signals may be accompanied by similar light signals. However these signals are to be given at the point in time when the maneuver is just about to commence, and cannot be used to signal future intentions. Showing intentions in ECDIS is something that has been investigated in the ACCSEAS project (2015; Porathe, Lutzhoft, and Praetorius, 2013). However, for small crafts that may not have immediate access to an electronic chart system there might be a need for some alternative method of showing intentions. One example of such a situation for manned ships was mentioned in the study by Hemlin and Torge (2012). In this situation, a small craft is approaching a large ship but does not know which way the large ship intends to go (see Figure 2). The same problem will be valid for a small craft encounter with an autonomous ship if there is no way for the unmanned ship to show its intentions. In this particular situation even a flashing direction indicator, like on a car, could be valid.

Other examples of signaling is from European inland canal shipping where "blue boarding", showing a blue, square sign, signals that I request to pass starboard-to-starboard. Experiments with physical, intention signaling might be very valuable, particularly for interaction and communication with very small crafts without any onboard navigation equipment.

Figure 2: A small eastbound craft (in the red circle) would need to know the intentions of the autonomous unmanned westbound vessel A: will it continued straight, or turn port for the South Channel?
Source: Hemlin and Torge (2012), adapted by the author. Chart underlays, Swedish Maritime Administration.

Figure 3: Restricted visibility outside the port of Yeosu in South Korea in April 2014.
Source: Photo by the author.

Visual signals might be possible in good visibility; however, in many part of the world, foggy conditions are often prevailing (see Figure 3) and will require alternative solutions.

III.III. Mobile phone app

Today, when a smartphone is in everyone's pocket, apps could serve as communication platforms between an autonomous unmanned ship and vessels and interacting small crafts. It could be to warn of their presence, or to communicate intentions. Given that the phone app would have satellite position, and the app could pick up the intended route of the autonomous unmanned ship, the app could warn the owner of the phone of an upcoming close quarters situation. Sending an alarm to get out of the way. A simple interface of an AIS receiver is shown in Figure 4. The "own boat" is in the centre, and there is a ship approaching from NW.

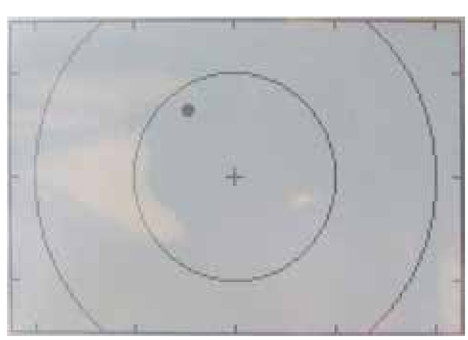

Figure 4: The interface of an AIS receiver. The own boat is in the center and the circles depicts a range of 2 and 4 nautical miles. In this case, an AIS target is approaching from the North West.
Source: ATSB report 295-MO-2012-006

Such an interface can be extended with many features showing the intentions of the approaching vessel as well as giving suggestions for an evacuation direction based on the intentions of the autonomous unmanned vessel.

IV. Conclusions

This paper suggests a number of research needs for human-machine interaction between unmanned autonomous ships and manned non-SOLAS vessels in confined and inshore waters. If these situations can be solved for the most complicated case in inshore areas, a solution will be possible for oceans as well. Both in European and South Korean waters a large amount of small fishing and leisure crafts will need to feel confident in knowing the intentions of future autonomous ships. A sketch for a joint research project looking into behavior of untrained, non-certified skippers, building trust in the interaction with autonomous ships, might be a vise investment. Collaboration with coastal and maritime administrations regarding design of traffic separations, and rules and regulations, as well as with fishermen and boat owners will be necessary. Solutions can be tested in simulator environments as well as in the sea.

The European Union has recently opened some calls within the Horizon 2020 research agenda that possibly could be of interest.

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