A Proposal Towards an Unmanned Ship Code

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http://appmech.aalto.fi/en/research/marine_technology
Background

Unmanned ships operated from a Shore Control Centre

• May enable safe, cost-efficient and environmentally friendly maritime transport
• Thought in principle technically feasible
  - Regulatory challenge: existing maritime rules and regulations assume as default that a ship is manned → Do not therefore provide a path towards their regulatory approval
• To address this issue, to enable unmanned ship operations, and to ensure that they are at least as safe as conventional ship operations, we propose to determine an Unmanned Ship Code (USC)
Polar Code

Our proposed USC is determined along the lines of the recently introduced Polar Code

- First IMO regulatory framework addressing Arctic shipping risks
  - Supplements existing requirements (e.g. SOLAS and MARPOL) in order to take into account Arctic specific hazards
  - Goal-based: determines mandatory provisions in terms of goals, functional requirements FR(s), and regulations that meet those

Approval principle of the Polar Code

- Goal(s)
- FR(s)
- OR
- e.g. Polar Class (PC) standards
- Regulations to meet the FR(s)
- Performance assessment
- Prescriptive (standard) design
- Equivalent or alternative design
Polar Code

• A design is approved either as a
  - *Prescriptive design*
    • Meets all regulations associated with the FRs
  - *Alternative design*
    • Meets the intent of the goal and FR(s) concerned and provide an equivalent level of safety as the prescriptive design

• To prove equivalency, a design should be analysed, evaluated, and approved on the basis of IMO guidelines

• Polar Code approval → *Polar Ship Certificate*
  - Determines detailed operational limits

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8. e.g. Polar Class (PC) standards
Regulatory challenges for unmanned ships

Existing regulatory challenges relate with obligatory crew functions

• COLREGs, Rule 5:
  - A ship must always maintain a proper lookout by sight and hearing as well as by all available means appropriate in the prevailing circumstances and conditions to make a full appraisal of the situation and of the risk of collision

• STCW, Ch. VIII, Reg. VIII/2:
  - Officers in charge of the navigational watch must be physically present on the navigating bridge or in a directly associated location at all times.

• SOLAS, Reg. 24:
  - The on-board track control system (autopilot) must enable an immediate switch from automatic to manual control

• SOLAS, Reg. 33:
  - The master of a ship is required to assist persons in distress at sea
Unmanned Ship Code (USC)

Similarly to the Polar Code, the USC is

• Performance-driven and goal-based, and supplements existing rules and regulations
  - Because it may be difficult to demonstrate compliance with all relevant FRs, the USC would also include references to new and established industry standards as well as ‘common interpretations’ of existing rules for manned ships
• Suggests that a ship is issued an “Unmanned Ship Certificate” that determines a ship’s operational limitations

In contrary to the Polar Code, the USC not only supplement but also replace existing regulations, especially those that define obligatory crew functions
The “Unmanned Ship Certificate” could specify the permitted operational conditions in terms of:

- Type of fairway
- Traffic density
- Prevailing weather conditions

Whenever a ship encounters a situation exceeding the operational limitations, she would need to operate at a lower level of autonomy → Increased involvement by the Shore Control Centre.

### Autonomy Levels (AL) as determined by Loyd’s Register

<table>
<thead>
<tr>
<th>AL</th>
<th>Description</th>
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<tbody>
<tr>
<td>AL0</td>
<td>No autonomous functions. All operations are manual</td>
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<tr>
<td>AL1</td>
<td>On-ship decision support. Data will be available to Crew</td>
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<tr>
<td>AL2</td>
<td>Off-ship decision support. Shore monitoring</td>
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<tr>
<td>AL3</td>
<td>Active human-in-the-loop. Semi autonomous ship. Crew can intervene.</td>
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<tr>
<td>AL4</td>
<td>Human-on-the-loop. Ship operates autonomously with human supervision.</td>
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<tr>
<td>AL5</td>
<td>Fully autonomous ship. There is a means of human control.</td>
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<tr>
<td>AL6</td>
<td>Fully autonomous ship that has no need for any human intervention.</td>
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The general approach to reduce the level of autonomy in challenging situations should not be based on the assumption that human involvement is always safer. Instead, it should be determined to maximise safety, considering the strengths and weaknesses of both technical systems and human operators.

As last resort, each safety critical system would require an integrated ‘fail-to-safe’ function.

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Towards its aims, USC addressees the following functions

- Look-out
- Collision avoidance
- Search and Rescue (SAR)
- Cybersecurity
- Technical reliability
- Fire protection
- Physical security

• Each of these functions is to be provided by a specific system
The goal of the unmanned look-out system is to provide a function equivalent to the function of an on-board human look-out

- FRs should therefore be determined both with regards to visual detection of objects (‘sight’), and the detection of sounds (‘hearing’)
- Naturally, the performance of the system determines the allowed level of autonomy
  - For remote control: it is enough that the system transfers sufficient visual and sound data to the Shore Control Centre
  - For higher level of autonomy: the system must also be able to identify objects and sounds
- The performance of the system could be tested and validated using ‘test tracks’, along which an system’s ability to detect various objects could be measured
The goal of the unmanned collision avoidance system is to replace the collision avoidance actions normally taken by the crew

- This means that it must be able to plan and execute proper collision avoidance manoeuvres
  - Only needed for autonomous operations

Comment: Depends on input from the look-out system
The goal of the Unmanned Search and Rescue (SAR) system is to provide assistance to persons in distress at sea

- The system is expected to be able to
  - Contact and inform SAR services
  - Lower life rafts or lifeboats
- Functions provided by manned ships that are difficult to enable
  - Recovery of persons from the water or lifeboats
  - Provision of shelter and first aid to recovered persons
The goal of the unmanned cybersecurity system is to provide protection against all types of cyber hazards

- This could be ensured by prescribing a specific cybersecurity standard, combined with appropriate FRs
  - *These could include “penetration tests” during which human testers try to exploit all the vulnerabilities of a system*

**Comment:** Cyber security is already an issue for conventional ships and the IMO recently issued guidelines on maritime cyber risk management
The goal of the Unmanned Technical Reliability system is to ensure sufficient technical reliability

- Obviously, without an on-board crew, any technical failure - however minor - may lead to serious consequences
- FRs that may help to avoid this include:
  - Condition monitoring devices that enable addressing technical issues before the occurrence of failures
  - Inbuilt technical resilience systems that may limit the consequences of technical failures
  - Backup systems
  - Fail-to-safe functions incorporated into safety critical systems as last resort
The goal of the unmanned fire protection system is to ensure a sufficient level of fire protection
- Because the fire protection system would only need to protect the ship and her cargo, and not persons, it could apply highly efficient fire fighting methods such as CO2

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The goal of the unmanned physical security system is to ensure a sufficient security for the ship and her cargo

- This can be achieved partially by other means as those used on manned ships
  - *E.g. on an unmanned ship, the access to the ship and her cargo can be made significantly more difficult by passive means such as locks and other protective physical barriers*
  - *Possible additional active measures include remotely controllable anti-piracy ‘weapons’ (e.g. long range acoustic devices, anti-piracy laser and water cannons)*
Additional systems required for continuous autonomous operations include:

- An operational and strategic decision-making system
  - Safe weather routing
  - Planning of complex manoeuvres such as entering/leaving port
  - Determination of safe speed margins that consider prevailing operational conditions

Comment: State-of-the-art technology is not able deal with such tasks (MUNIN)
Summary and discussion

The goal of the USC is to enable unmanned ship operations and to ensure that unmanned ship operations are at least as safe as conventional ship operations

• To this end, it is determined along the lines of the recently enforced Polar Code, meaning that it is fundamentally goal-based, but include also references to new and existing technical standards → multiple paths to regulatory approval

The societal acceptance is higher for accidents caused by humans than for accidents caused by machines → applied technical solutions must be robust and real-world testing is needed

Next steps: definition of goals and FRs + testing standards for the safe operation of unmanned ship systems

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https://www.dimecc.com/dimecc-services/d4v/

This research is carried out within the frame of the DIMECC project D4VALUE (Design for Value - Value driven ecosystem for digitally disrupting supply chain).

Thank you for your attention!

Will be presented at imdc2018.aalto.fi/