Online Consequence Analysis of Situational Awareness for Autonomous Vessels

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Objectives and Scope

The primary research question is to investigate the possibilities and propose a method for an online consequence analysis (OCA) for use as supervision to human operators, or as a decision making tool for autonomous vessels. The proposed method should be in accordance to industry definitions of levels of autonomy (LoA). Lastly, the OCA should be simulated through a simulation study, and relevant results from the analysis should be presented.

Introduction

As the maritime industry is subject to a transitions towards increased level of autonomy enabling for lower manning or unmanned vessels, the need for robust systems providing increased situational awareness becomes evident.

The thesis investigates how different industries view autonomy, especially industry specific LoA taxonomies. It investigates different sensors and techniques for achieving situational awareness, it proposes a method for use of an online consequence analysis (OCA), lastly it proposes a method for an online risk indicator based on the latter.

The OCA's main purpose is to increase the situational awareness of a vessel during transit. The increased situational awareness will be crucial in the industry's pursue towards highly autonomous vehicles that operate without human interaction. As a first step, this may be used as an online supervisor for manned vessels, but is expected to take active part in decision making regarding optimal route- and power system redundancy planning in the future.

Main contributions:

- Comparison between industry LoA definitions (Not covered on poster).
- Literature review regarding sensors and techniques needed for the Online Consequence Analysis (Not covered on poster).
- Proposed method for online consequence analysis, used on surface vessels. Manned or unmanned.
- Proposed method for online risk indicator based on results from the OCA.
- Useful simulation techniques for further work.
- Simulation study of online- consequence analysis and risk indicator.

Conclusion

A method for increasing vessel situational awareness was proposed in for of an online consequence analysis. The OCA is able to simulate vessel- and failure modes dynamics, calculate the associated consequence analysis and risk level online.

The method increases the situational awareness of the vessel, and can contribute to better decision making for humans or unmanned vehicles.

Supervisors

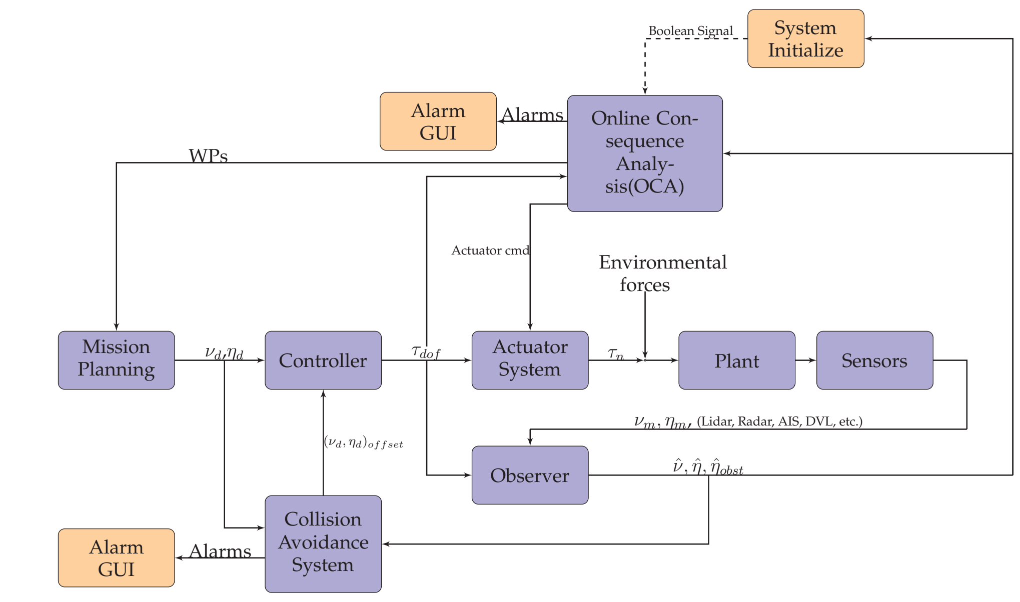
- Main supervisor: Professor Asgeir Johan Sørensen
- Co-supervisor 1: Professor Ingrid Bouwer Utne
- Co-supervisor 2: Post-doctoral Fellow Børge Rokseth

References

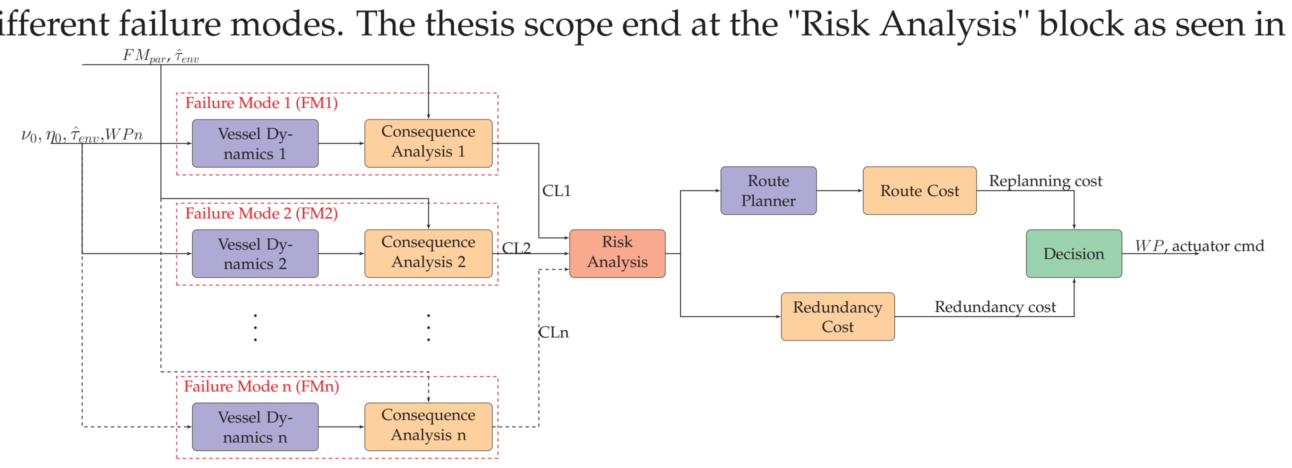
1. IMO 1972, Convention on the International Regulations for Preventing Collisions at Sea, International Maritime Organization.
2. Fossen 2011, Handbook of Marine Craft Hydrodynamics and Motion Control, Wiley.

Method

The following figure shows a system overview of a typical marine control system, with the exception of the collision avoidance system and the online consequence analysis. The CAS is not covered, but illustrates its dominant position compared to the OCA, in terms of control architecture, as it influences the system dynamics at a lower control level. The OCA gathers info from the system observer and power system, as well as information about environmental forces acting on the vessel.



The figure below illustrates the inside of the OCA, where an arbitrary number of failure modes is simulated based on gathered info. The simulated vessel paths as a results of the different failure modes is then distance checked against relevant surrounding obstacles, before calculating consequence level based on radial distance from the relevant obstacles. The consequence level for each failure mode is then used to calculate the associated risk, based on assumed probabilities of occurrence for the different failure modes. The thesis scope end at the "Risk Analysis" block as seen in the figure below.



Further work is proposed to evaluate the online risk indicator, and if violation of a risk threshold occurs, replan the initially planned mission in terms of evaluating the cost of a new route with lower risk, and the cost of increasing redundancy, thus lowering the risk of failure. The cost may represent fuel efficiency, time, weather avoidance and more. Lastly the lowest cost option is then returned to the control system.

Simulation Study

The simulated scenario is the vessel navigating through a narrow channel, while environmental forces act along the positive east axis. The environmental forces in form of current, is exaggerated for illustration purposes and proof of concept. The narrow channel is used to prove the systems enhanced situational awareness w.r.t. IMO COLREGs.

The top left and right (zoomed) plot shows the simulated vessel in north-east position. The plot also shows a selection of the four failure modes simulated from the OCA, point of system recovery, as well as the obstacle distance levels used to calculate the consequence levels. The lower left plot shows a risk matrix scaled from 0 to 1 of each OCA with corresponding numbering. Lastly the lower right plot shows the consequence level v.s. time that's provided online during the simulation run. Each spike represents the consequence level for the different failure modes. If the analysis does not show violation of an obstacle level, it returns -1 for visual representation, but is considered equal to zero.