A COLREGs-Compliant Local Guidance System for Unmanned Surface Vehicles based on Hierarchical Task Network

Darlan Alves Jurak
Pontifical Catholic University of Rio Grande do Sul, Brazil
darlan.jurak@gmail.com

Abstract

The current open challenge for Unmanned Surface Vehicle (USV) is the development of reliable, robust and full capable autonomous guidance system. Related to collision avoidance, the non-objectiveness of the rules of the road for marine craft point out the need of a suitable planning strategy. This work proposes the use of Hierarchical Task Network planning for modeling USV collision avoidance guidance system.

1 Introduction

Driven by military, scientific and commercial interests, the development of USVs systems has become a strong current demand [Liu et al.2016]. By definition USVs are marine crafts without a crew that are capable of perform tasks on the surface of the water.

The practical meaning of USV **autonomy** is related to its ability to interact with the real world. So, a reliable autonomous path planning is one of the mandatory features in an USV guidance system.

The development of truly robust robotic autonomous system in sea environments with adversary conditions, as static and dynamics obstacles, fog, coastal proximity, and standard communication isolation is a current challenge. [Liu et al.2016].

In general, for USV, planning strategies are applied to path search and the treatment of any other decision like collision avoidance, is made by changes in world representation or in the path planning itself. For path planning common applied techniques are genetic programming [Svec and Gupta2011, Gupta2013], A* [Larson, Bruch, and Ebken2006], Ant Colony [Wang and Cen2016], Artificial Potencial Fields (APF) [Xie et al.2014], and Velocity Obstacle (VO) [Bertaska et al.2015].

The only found study that uses hierarchical planning related to the USV domain, apply this planning technique for control of a fleet in a mine countermeasure mission [Lesire et al.2016].

Focusing on the dynamics obstacles challenge, this work propose the development of a reactive guidance system for USV. The proposed system is capable of avoid collision with another boat respecting the Convention on the International Regulations for Preventing Collisions at Sea, 1972 (COLREGs) and use Hierarchical Task Network (HTN) planning.

2 Technical Approach

In this section we present the proposed work, describing it and indicating problem constraints.

Proposed Work

The proposed work consists on the development of a local guidance system for determination of USV actions to avoid collision with detected target ships. HTN planning will be used for formalization of the problem.

Local guidance system The local guidance system will be responsible for:

1. Defining a danger zone around the own USV. Any vessel in the danger zone will be treated as a possible collision and must be avoided.
2. Definition of the appropriated COLREGs rule based on the own USV and the other vessel velocity, heading, position, closest point and predicted intersection time. Three possible situations will be evaluated: overtaking, head-on, and crossing.
3. Generation of trajectory commands compliant to the COLREGs rule chosen.

Tasks Hierarchy Definition Figure 1 [Liu et al.2016] presents a possible flowchart to collision avoidance decision make. Based on Figure 1 and the local guidance task above its possible to determine the following tasks hierarchy:

1. Sail following way-points
   (a) Verify-collision
      i. Monitoring range around
      ii. COLREGs Rule Selection
      iii. Selected rule execution.

Problem constraints Below we present some assumptions for the proposed work:

1. For mission definition it will be assumed that the global motion is guided by way-points - one of the most common strategies applied on USV studies [Liu et al.2016].

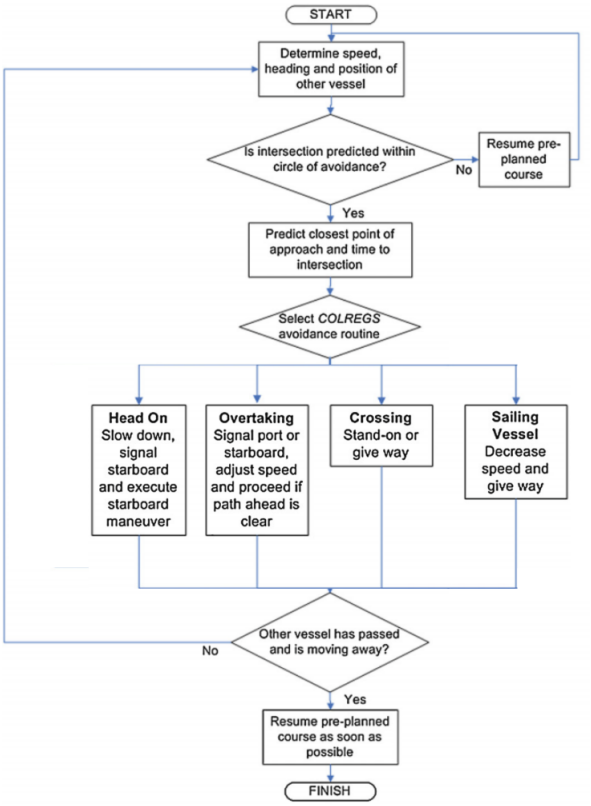

Figure 1: COLREGs Behavioural Flowchart

2. Any **speed**, **heading** and **position** of other vessel will be known in advance
3. Prediction of **closest point of approach** and **intersection time** will be known in advance
4. The system will only treat vessels obstacles

3 Project Management

The major tasks to accomplish are:

1. **Development of the local guidance system based on HTN**
   (a) Tools installation
   (b) Definition and implementation of methods and operators
   (c) Test and validation
   (d) Correction
2. **Experiments**
   (a) Collision danger situations description
   (b) Evaluation of guidance systems decisions
      i. Comparison of the decision and related COLREGs rule
      ii. Definition of other metrics
3. **Article writing**

Related to the major tasks above, Figure 2 present the proposed schedule for development of the COLREGs-compliant local guidance system for USV based on HTN:

	Weeks				
Tasks	15/10 - 19/10	22/10 - 26/10	29/10 - 02/11	05/11 - 09/11	12/11 - 15/11
1					
2					
3					

Figure 2: Tentative schedule

4 Conclusion

To the end of the semester we will accomplish the **development** and **evaluation** of a high level reactive guidance system COLREGs-compliant, modelled with HTN planning and capable of treat at least head-on, overtaking and crossing situations. Then this system can be used for comparison to other solutions in the literature. And future work can be done using this system as a core system.

References

Bertaska, I. R.; Shah, B.; Von Ellenrieder, K.; Švec, P.; Klinger, W.; Sinisterra, A. J.; Dhanak, M.; and Gupta, S. K. 2015. Experimental evaluation of automatically-generated behaviors for USV operations. *Ocean Engineering* 106:496–514.

Gupta, S. K. 2013. Developing Autonomy for Unmanned Surface Vehicles. Technical report.

Larson, J.; Bruch, M.; and Ebken, J. 2006. Autonomous navigation and obstacle avoidance for unmanned surface vehicles. 623007(May 2006):623007.

Lesire, C.; Infantes, G.; Gateau, T.; and Barbier, M. 2016. A distributed architecture for supervision of autonomous multi-robot missions: Application to air-sea scenarios. *Autonomous Robots*.

Liu, Z.; Zhang, Y.; Yu, X.; and Yuan, C. 2016. Unmanned surface vehicles: An overview of developments and challenges.

Svec, P., and Gupta, S. K. 2011. Automated planning logic synthesis for autonomous unmanned vehicles in competitive environments with deceptive adversaries. In *Studies in Computational Intelligence*.

Wang, Y. H., and Cen, C. 2016. Research on optimal planning method of USV for complex obstacles. *2016 IEEE International Conference on Mechatronics and Automation, IEEE ICMA 2016* 2507–2511.

Xie, S.; Wu, P.; Peng, Y.; Luo, J.; Qu, D.; Li, Q.; and Gu, J. 2014. The obstacle avoidance planning of USV based on improved artificial potential field. *2014 IEEE International Conference on Information and Automation (ICIA)* (12140500400):746–751.