Chapter 1

A Decision Support Architecture for Maritime Operations Exploiting Multiple METOC Centres and Uncertainty

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ABSTRACT

Maritime operations are affected significantly by meteorological and oceanographic (METOC) conditions. The availability of multiple METOC centres able to deliver more accurate forecasts in the near future (2/3 days) is a promising resource toward better operational planning. However, how a specific maritime operation can benefit from such forecasts is not straightforward. A decision support architecture is required to combine METOC forecasts and human knowledge and select the best action from a set of pre-defined actions for the maritime operation. This paper describes a decision support architecture developed at the NATO Undersea Research Centre that is an improvement over a previous version in two ways: (1) it exploits forecasts coming from more than one METOC centre, and (2) it exploits uncertainty associated with METOC forecasts. The former allows for the exploitation of different abilities of METOC centres at different conditions. The latter allows for the propagation of input uncertainty on output products (the risks related to each action), thus allowing operators to assess if risks related to different actions are statistically different. Both features increase the robustness of the previous decision support architecture. The effectiveness of the new architecture is demonstrated on an underwater glider surfacing experiment carried out on data collected during a cruise in the Adriatic Sea in 2006.

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INTRODUCTION

The planning of maritime operations (underwater glider deployment/recovery, amphibious landing, naval refuelling, etc.) can benefit from the current availability of multiple centres devoted to the forecasting of meteorological and oceanographic (METOC) conditions. In general, the knowledge of future environmental conditions can help decision-making at all levels (strategic, tactical and operational). In a military setting, environmental operation support is the key to success in the battlefield (Grasso et al., in press).

Environmental data sets (measurement and forecast models) available for that purpose are distributed in time and space and involve a number of atmospheric, oceanographic and hydrographical parameters. The goal of decision support is the reduction of this massive data flow and the extraction of the information needed by the mission planner in form of added value products such as risk maps, traffic light maps, etc.

The NATO Undersea Research Centre (NURC) has been conducting research and development in the field of decision support systems for maritime operations since 2002. These efforts were reported in a recent paper (Grasso et al., in press), where a generic decision support architecture was presented. This architecture uses the forecasts of a set of variables (e.g., sea current speed, significant wave height) provided by a single METOC forecasting centre and, based on a hybrid fuzzy-Bayesian framework (Ross, 2010), computes the posteriors associated with each of three classes of environmental conditions (favourable, marginal, and unfavourable). Once the posteriors are computed (thus having an objective quantification of how good the current environmental condition for the maritime operation at hand is) they are utilized to compute the risks associated with each action defined for the operation (e.g., run mission/reschedule mission), using predefined costs associated with each pair (class of environmental condition, action).

This architecture was generic in the sense that it was able to ideally support any maritime operation. Different operating rules and constraints (e.g., “very low wind speed”, “low to medium significant wave height”) associated with different maritime operations simply require the change of the fuzzy rule-base used by the fuzzy-Bayesian framework (Grasso et al., in press). Since then we have improved the architecture in two ways, as described here.

Improvements over the Previous Work

This work improves a previous decision support architecture developed at NURC (Grasso et al., in press) in the following major aspects: (1) it exploits forecasts coming from multiple METOC forecasting centres; (2) it exploits uncertainty in METOC forecasts. Regarding the first major improvement, the information provided by different METOC centres can be combined at METOC variable, feature and decision levels.

The benefits of fusing prediction coming from multiple METOC centres are twofold: (1) it automatically solves the problem of which METOC centre to use, and (2) it tends to be more robust than using a single METOC centre approach (different METOC forecasting centres can have different performance at different conditions).

The benefits of taking into account input uncertainty and to estimate its effect on the systems output are: (1) the decision maker is aware of the statistical significance of the difference between estimated risks associated with different actions, (2) the unwanted effect of continuous switching over time between actions having similar risks (i.e., statistically equal risks levels) is reduced.

Related Work

Recently, some interesting works concerning decision support for aiding maritime operations have appeared in the literature. Balmat et al. (2009) have