A Meta-Level Architecture for Strategic Reasoning in Naval Planning (extended abstract)

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Abstract. The management of naval organizations aims at the maximization of mission success by means of monitoring, planning, and strategic reasoning. This paper presents a meta-level architecture for strategic reasoning in naval planning. The architecture is instantiated with decision knowledge acquired from naval domain experts, and is formed into an executable model which is used to perform a number of simulations. To evaluate the simulation results a number of relevant properties for the planning decision are identified and formalized. These properties are validated for the simulation traces.

1 Introduction

The management of naval organizations aims at the maximization of mission success by means of monitoring, planning, and strategic reasoning. In this domain, strategic reasoning more in particular helps in determining in resource-bounded situations if a go or no go should be given to, or to shift attention to, a certain evaluation of possible plans after an incident. An incident is an unexpected event, which results in an unmeant chain of events if left alone. Strategic reasoning in a planning context can occur both in *plan generation* strategies (cf. [4]) and *plan selection* strategies.

The above context gives rise to two important questions. Firstly, what possible plans are first to be considered? And secondly, what criteria are important for selecting a certain plan for execution? In resource-bounded situations first generated plans should have a high probability to result in a mission success, and the criteria to determine this should be as sound as possible.

In this paper a generic meta-level architecture (cf. [1, 2, 3]) is presented for planning, extended with a strategic reasoning level. Besides the introduction of a meta-level architecture, expert knowledge is used in this paper to formally specify executable properties for each of the components of the architecture. These properties are used for simulation and facilitate formal verification of the simulation results.

2 A Meta-level Architecture for Naval Planning

In Figure 1 the proposed generic architecture is shown for strategic planning applicable in naval command & control organizations. The components denote processes, solid lines denote information, and the dotted lines denote a separation between meta-levels. First of all, plans are executed within the deliberation cycle which is the part between the dotted lines. By comparing the perceived situation with the planned situation the Monitoring component generates evaluation information. In

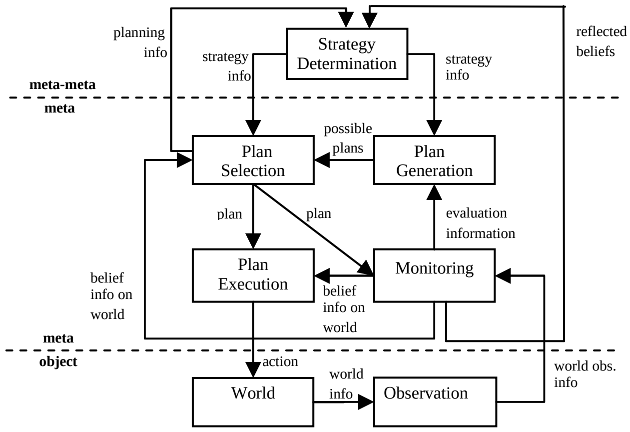

Fig. 1. Strategic planning processes applicable in naval organizations.

case the evaluation involves an exception PlanGeneration determines what the possible plans are, considering the situation. The conditional rules for the possible plans given a certain event are passed by the StrategyDetermination component. The possible plans are forwarded to the PlanSelection component which evaluates the plans taking the current beliefs on the world into consideration. In case an empty list of possible plans is received PlanSelection informs StrategyDetermination that no plan could be selected. The same is done when none of the plans passed the evaluation. The StrategyDetermination component can, in case of such a notification, provide PlanGeneration with additional conditional rules. It can also generate a new way to evaluate plans by means of different criteria rules. If a suitable plan has been found, it is passed to PlanExecution and becomes the current plan. The execution of the plan is done by means of the receipt of beliefs on the world and applying the plan to derive the next action. The actions that have been determined are passed to the World.

3 Case-study in Naval Domain

The model presented in Section 2 has been applied in a case-study in the naval domain. Executable properties for each of the components have been specified for this particular domain and include PlanGeneration and PlanSelection strategies based on the candidate plans and criteria passed from a StrategyDetermination, respectively. Selection criteria strategies incorporate mission success, safety and fleet moral, over which a weighed sum is calculated. Furthermore, candidate generation strategy determination is based on information from PlanSelection and PlanGeneration. Three different modes of operation are defined, which are *limited action demand*, *full preferred plan library*, and *exceptional action demand*. Finally, the StrategyDetermination component also includes executable properties that establish a change in the weights of the different selection criteria in case of failure to select an appropriate plan.

The above mentioned properties were used in a number of simulation runs. The results were formally verified by means the use of a developed software tool called *TTL checker*. These properties include upward and downward reflection (e.g., [3]), verifying whether no unnecessary extreme measures are taken, plans are not changed without a proper cause, and were all satisfied for the given trace.

4 Conclusion

This paper presents an architecture for strategic planning (cf. [4]) for naval domains. The architecture was designed as a meta-level architecture (cf. [1, 2, 3]) with three levels. The interaction between the levels is modeled by reflection principles (e.g., [2, 3]). The dynamics of the architecture is based on a multi-level trace approach as an extension to what is described in [2]. The architecture has been instantiated with expert naval domain decision knowledge. The resulting executable model has been used to perform a number of simulation runs. To evaluate the simulation results relevant properties for the planning decision process have been identified, formalized and validated. More simulation runs and the validation of properties for the simulation traces are expected to give more insight for future complex resource-bounded naval planning support systems.

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