SailAway: Spatial Cognition in Sea Navigation

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Pedestrians, bicyclists, car drivers, boat and airplane pilots, as well as other cognitive agents participating in public traffic must respect rules in order to avoid dangerous situations and to ensure a smooth flow of traffic. The SailAway project [1] investigates traffic and related navigational rules from a formal and computational point of view. The aim is to enable artificial cognitive agents to act in compliance with such rules. Traffic rules, which are expressed in natural language, usually subsume distinct, but similar situations and actions under more abstract spatial or temporal concepts and relations. In this paper we describe an approach to representing rules that exploits this qualitative nature of natural language descriptions used in traffic laws. Based on this approach we present methods for determining actions that are rule-compliant with respect to the current spatial situations of the agents involved. Finally we present the prototype of a control system of boats in sea navigation that implements exactly these methods.

1 Introduction

A considerable part of everyday human activities is guided by regulations. Typical examples include regulations of how to behave in traffic scenarios, recommendations of how to use escalators, rules on how to enter subways and buses, or politeness rules at bottlenecks. These rules are usually formulated in natural language and thus can be expressed in a language, which uses *qualitative terms* to describe the situations that are governed by the rule as well as "correct" (i.e., rule-compliant) behavior of agents. Artificial cognitive agents that interact with humans should be able to process such rule sets. This entails that an agent must be able to *localize* itself in both the physical space and the normative space of laws, rules, etc. In particular, the agent must perceive its current spatial situation, identify rules that might be relevant in this situation and with respect to its current *role*, and finally select appropriate (in terms of the agent's agenda), but notwithstanding rule-compliant actions.

In the following, we report on a case study that accounts for some aspects of rule-compliant behavior in the domain of sea navigation (though most of the discussed techniques carry over to other navigation scenarios). In particular, we show how representation formalisms and reasoning techniques known from *qualitative spatial reasoning (QSR)*, namely constraint solving procedures and *neighborhood-based reasoning* techniques, can be applied for deriving suitable actions for an agent that comply with a given set of right-of-way rules. Qualitative spatial representation formalisms abstract from metric data by summarizing similar quantitative states into a single qualitative description [2]. For this reason, such formalisms are suited as a basis for representing rules in a formal way. Neighborhood-based reasoning methods allow for reasoning about spatial situations that change in time [4]. We use these methods to construct transition systems which encode rule-compliant behavior in situations with two agents—in fact, many navigation rules only describe correct behavior for situations that are limited to two agents. Finally, constraint solving techniques [5] help us

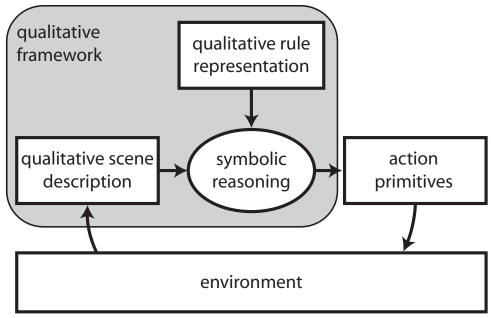

Figure 1: Qualitative methods underlying SailAway

to assign rule-compliant actions to all the agents involved in a particular situation.

The fundamental role of qualitative methods is reflected in the overall architecture of our demonstrator application *SailAway* (cf. Fig. 1). Based on a qualitatitive scene description that contains information about the relative position of each pair of vessels in an open sea scenario and a qualitative rule representation encoding parts of the *International Regulations for Preventing Collisions at Sea* (ColRegs—published by the International Maritime Organization), we use purely symbolic reasoning methods to select actions that avoid collisions between the involved agents.

2 Formalizing Spatial Knowledge

A qualitative representation formalism (or *qualitative calculus*) builds the basis for representing spatial knowledge in our project. The choice of such a formalism depends on the domain to be described and on the particular aspect of interest. A qualitative calculus then partitions the set of all possible constellations between objects into a finite set of relations summarizing similar constellations. Since we are interested in representing traffic rules such as "When two power-driven vessels are meeting head-on or nearly head-on courses so as to involve risk of collision each shall alter her course to star-

 Auszug aus: Künstliche Intelligenz, Heft 1/2008, ISSN 0933-1875, BöttcherIT Verlag, Bremen, **www.kuenstliche-intelligenz.de/order**