

Sharing Information Efficiently in Cooperative Multi-Robot Systems

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INTRODUCTION

Multi-robot systems (MRS) are sets of intelligent and autonomous mobile robots that are assumed to cooperate in order to carry out collective missions (Arai, Pagello, & Parker, 2002; Cao, Fukunaga, & Kahng, 1997; Rocha, Dias, & Carvalho, 2005). Due to the expendability of individual robots, MRS may substitute humans in risky scenarios (Maimone et al., 1998; Mataric & Sukhatme, 2001; Parker, 1998; Thrun et al. 2003). In other scenarios, they may relieve people from collective tasks that are intrinsically monotonous and repetitive. MRS are the solution to automate missions that are either inherently distributed in time, space, or functionality.

MRS involve the distribution of sensors, computation power and mission-relevant information. This inherent distribution is both an opportunity and a challenge. On one hand, it endows MRS with interesting features, such as space and time distribution, managing complexity through distribution, distribution of risk and increased robustness (Arkin & Balch, 1998). On the other hand, these potential advantages and their utility are to a greater extent dependent on the effective cooperation among robots when performing some collective mission (Rocha, 2005).

Since information is intrinsically distributed, cooperation requires, in turn, efficiently sharing information through communication (Rocha et al., 2005). A method for efficiently sharing information within a MRS is herein presented, which is based on an information utility criterion (Rocha et al., 2005). This concept is illustrated on MRS whose mission is to build cooperatively volumetric maps.

Robotic Mapping

Robotic mapping addresses the problem of acquiring spatial models of physical environments with mobile

robots equipped with distance sensors, such as cameras, range finders and sonars. Usually the map is not the goal itself and those mobile robots are used to safely navigate within the environment and perform other useful tasks that require an up-to-date map of the environment (e.g., search and rescue). But mobile robots may also be used for building detailed maps of indoor environments (Martin & Moravec, 1996; Stachniss & Burgard, 2003), being particularly useful on mapping missions of hazardous environments for human beings, such as underground mines (Thrun et al., 2003) or nuclear facilities (Maimone et al., 1998).

As sensors have always limited range, are subject to occlusions and yield noisy measurements, mobile robots have to navigate through the environment and build the map iteratively. Some key challenges in this context are the sensor modeling problem, the representation problem, the registration problem and the exploration problem (Thrun, 2002). This article focuses on efficiently sharing sensory information within a team of mobile robots, so as to build a volumetric map in less time than a single robot.

Sharing Information within Multi-Robot Systems

Most of the work about multi-robot systems (MRS) has been devoted to the definition of different architectures (Gerkey & Mataric, 2002; Mataric et al., 2001; Parker, 1998) that rule the interaction between the behaviors of individual robots. Communication is a central issue of MRS because it determines the possible modes of interaction among robots, as well as the ability of robots to build successfully a world model, which serves as a basis to reason and act coherently towards a global system goal. Communication may appear in three different forms of interaction (Cao et al., 1997): (1) *via environment*, using the environment itself as the

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