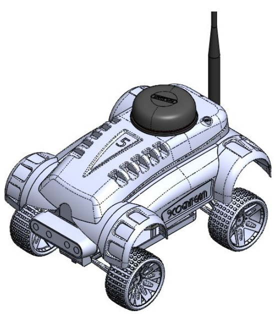
HAMSTER VISION & Machine Learning

Micro AUGV



Robot Operating System

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HAMSTER V7 - VISION

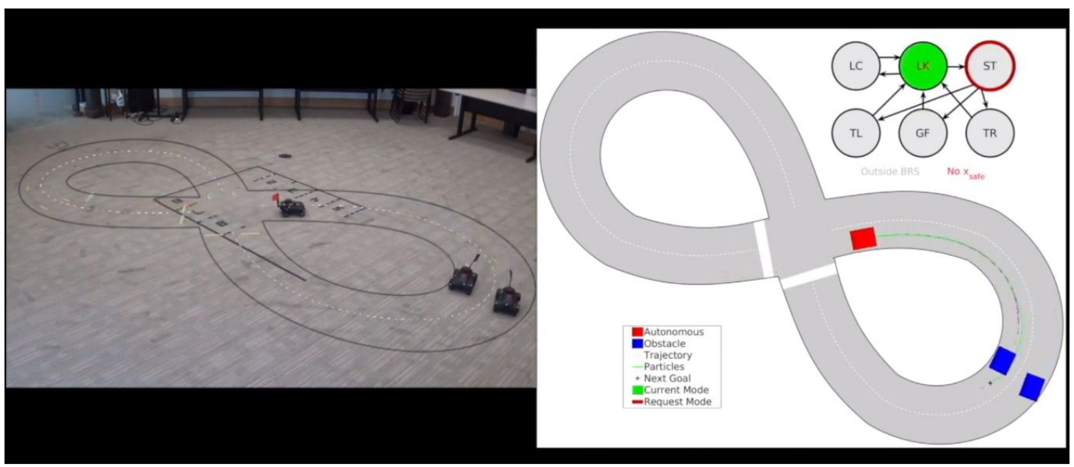
Micro AUGV

HAMSTER v7 is a robust micro Autonomous Unmanned Ground Vehicle (AUGV) capable of powering, carrying and interfacing various payloads.

HAMSTER v7 is capable of powerful computations, including Mapping (SLAM), Localization, Path Planning, Exploration, Waypoint Driving, Obstacle Avoidance and classification using HW supported VPU - **all running on board the robot**.

HAMSTER V7-I computing is AAEON UP Squared + Myriad VPU

HAMSTER V7-N computing is NVIDIA Jetson Xavier NX



Power	• 45min operation on a single charge • Affordable batteries • PDU • 5v regulated
Computing	• AAEON up squared + Myriad VPU OR Nvidia Jetson Xavier NX • Linux and full ROS • Arduino Uno
Sensors	• Motor Encoder • Intel d435i stereo vision camera (with IMU) • 2D LIDAR 360 deg, 10Hz, 10m range
Software	• Path planning, waypoint driving, obstacle avoidance, obstacle classification • ROS drivers Simulation in Robomaker • OCU for up to 10 robots
Connectivity	• AC Wifi
Dimensions	• 190mm(W) • 240mm(L) • 150mm (H)

ROS
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The robot is open platform, built using COTs and designed to support ROS (Robotic Operating System) and targeted for research labs and developers. It comes with a full ROS distribution installed and includes a simulated environment and an OCU for simultaneous control of up to 10 robots.

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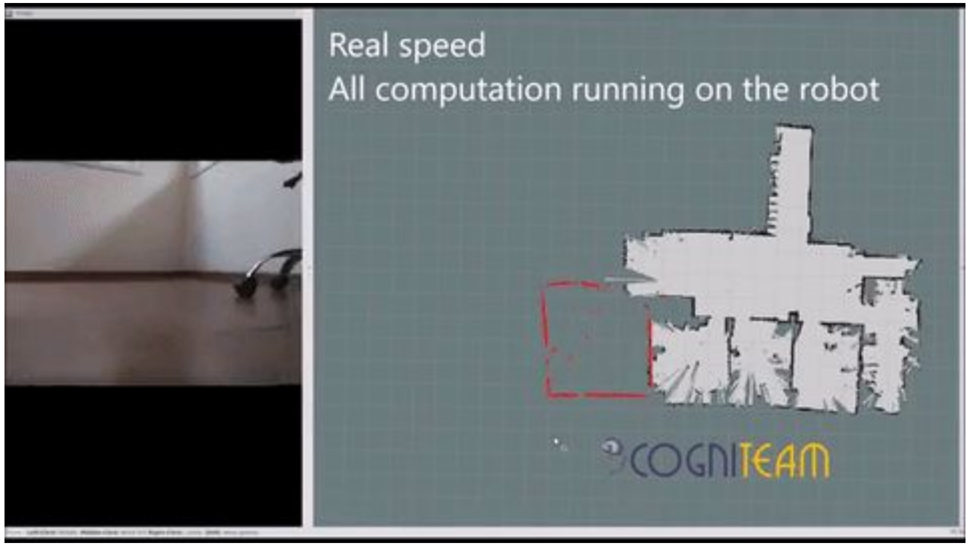
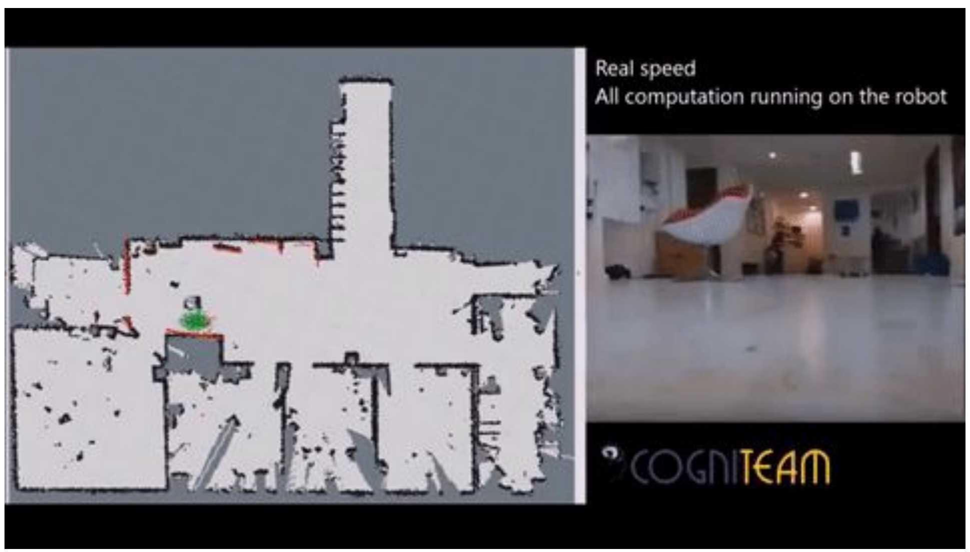
MAPPING



LOCALIZATION



PUBLICATIONS

Proceedings of the Twenty-Fourth International Joint Conference on Artificial Intelligence (IJCAI 2015)

Intelligent Agent Supporting Human-Multi-Robot Team Collaboration*

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Abstract

The number of multi-robot systems deployed in field applications has risen dramatically over the years. Nevertheless, supervising and operating multiple robots at once is a difficult task for a single operator to execute. In this paper we propose a novel approach for utilizing advising automated agents when assisting an operator to better manage a team of multiple robots in complex environments. We introduce the *Myopic Advice Optimization (MYAO) Problem* and exemplify its implementation using an agent for the Search And Rescue (SAR) task. Our intelligent advising agent was evaluated through extensive field trials, with 44 non-expert human operators and 10 low-cost mobile robots, in simulation and physical deployment, and showed a significant improvement in both team performance and the operator's satisfaction.

1 Introduction

Multi-robot systems are being applied to different tasks, such as Search And Rescue (SAR) [Liu and Nejat, 2013], automatic aircraft towing [Morris *et al.*, 2015], fire-fighting [Saez-Pons *et al.*, 2010], underwater missions [Kulkarni and Pompili, 2010] and construction [Parker and Zhang, 2002]. Common to most of the work in multi-robot systems is the assumption that either the robots are autonomous, or they are controlled centrally by one computer. A hidden assumption in this case is that the robots perform relatively smoothly, with the infrequent need to overcome failures.

The deployment of low-cost robots in real-world environments has shown that they usually face difficulties in completing their tasks. Specifically, failures are common. In such situations, a human operator must get involved in order to solve the problem. That is, robots are usually *semi-autonomous*, and should be supported by an operator whenever they cannot handle the situation autonomously. For example, during the deployment of robots at the World Trade Center disaster, each robot got stuck 2.1 times per minute (on average), and required human assistance [Casper and Murphy, 2003].

In the context of multi-robot systems, the supervision and control of multiple robots at once can be overwhelming for a single human operator—resulting in sub-optimal use of the robots and a high cognitive workload [Chen and Terrence, 2009; Squire and Parasuraman, 2010]. Wang et al. [2009] claimed that this *fan-out* (the number of robots that a human operator can effectively operate at once) plateau lies "somewhere between 4 and 9+ robots depending on the level of robot autonomy and environmental demands".

Improving the performance of supervised multi-robot systems can be done using one of the following dominant approaches: Either (1) Improving the robot's hardware and software—thus, relying less on human supervision (making the robots more autonomous), or (2) Improving the efficiency of the Human-Robot Interaction (HRI). Assuming we are given a team of robots, and we cannot control the reliability of its hardware or software, this paper deals with improving the HRI in order to allow a person to control a team of many (possibly unreliable) robots.

As shown in most multi-robot systems controlled by a human operator, a single operator may get overwhelmed by the number of requests and messages, resulting in sub-optimal performance. For example, Chien et al. [Chien *et al.*, 2013] have studied robots that could self-report encountered faults. In their reported experiment, participants performed the foraging task while assisted by an alarm system, under different task loads (3 robots vs. 6 robots). The results show that participants in the 6-robot scenario did not perform better than those controlling only 3, while some even performed significantly worse. The results also show that operators devoted their resources in a sub-optimal way, leaving fewer resources for more urgent and critical tasks. These findings are consistent with previous studies with ground robots [Velagapudi and Scerri, 2009; Wang *et al.*, 2009; Chen *et al.*, 2011; Squire and Parasuraman, 2010; Lewis, 2013] and areal robots [Miller, 2004; Cummings *et al.*, 2007; Panganiban, 2013]. Rosenthal and Veloso [2010] suggest a different approach, in which robots should request (and receive) help from humans for actions they could not have performed alone due to lack of capabilities. However, in the presence of many robots' requests, Rosenthal and Veloso's approach could (potentially) overwhelm an operator.

In this paper, we present a novel methodology that enhances operators' performance by using an intelligent advising agent. The agent provides advice for the operator regarding which actions she should take and acts as a

*We thank Cogniteam Ltd. for all their support.

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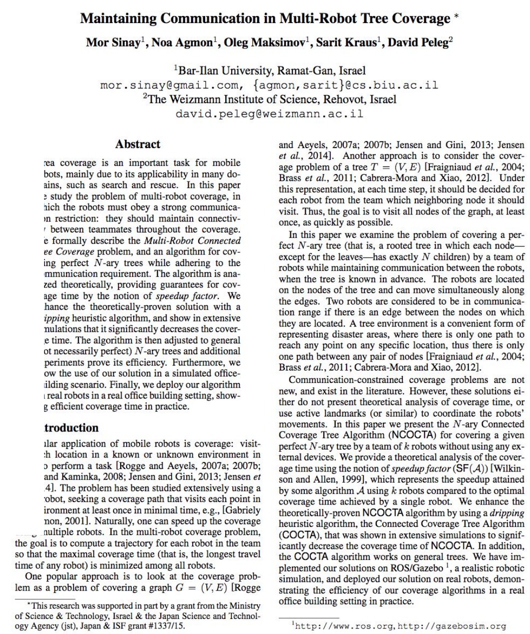
https://www.merl.com/publications/docs/TR2019-062.pdf

http://www.ijcai.org/Proceedings/15/Papers/270.pdf



Maintaining Communication in Multi-Robot Tree Coverage *

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Abstract

rea coverage is an important task for mobile bots, mainly due to its applicability in many doains, such as search and rescue. In this paper study the problem of multi-robot coverage, in hich the robots must obey a strong communican restriction: they should maintain connectiv between teammates throughout the coverage. e formally describe the *Multi-Robot Connected ee Coverage* problem, and an algorithm for coving perfect N-ary trees while adhering to the mmunication requirement. The algorithm is anazed theoretically, providing guarantees for covage time by the notion of *speedup factor*. We hance the theoretically-proven solution with a *ipping* heuristic algorithm, and show in extensive nulations that it significantly decreases the cover e time. The algorithm is then adjusted to general ot necessarily perfect) N-ary trees and additional periments prove its efficiency. Furthermore, we ow the use of our solution in a simulated officeilding scenario. Finally, we deploy our algorithm real robots in a real office building setting, showg efficient coverage time in practice.

troduction

ılar application of mobile robots is coverage: visith location in a known or unknown environment in perform a task [Rogge and Aeyels, 2007a; 2007b; and Kaminka, 2008; Jensen and Gini, 2013; Jensen *et* 4]. The problem has been studied extensively using a obot, seeking a coverage path that visits each point in ironment at least once in minimal time, e.g., [Gabriely non, 2001]. Naturally, one can speed up the coverage nultiple robots. In the multi-robot coverage problem, the goal is to compute a trajectory for each robot in the team so that the maximal coverage time (that is, the longest travel time of any robot) is minimized among all robots.

One popular approach is to look at the coverage problem as a problem of covering a graph $G = (V, E)$ [Rogge and Aeyels, 2007a; 2007b; Jensen and Gini, 2013; Jensen *et al.*, 2014]. Another approach is to consider the coverage problem of a tree $T = (V, E)$ [Fraigniaud *et al.*, 2004; Brass *et al.*, 2011; Cabrera-Mora and Xiao, 2012]. Under this representation, at each time step, it should be decided for each robot from the team which neighboring node it should visit. Thus, the goal is to visit all nodes of the graph, at least once, as quickly as possible.

In this paper we examine the problem of covering a perfect N-ary tree (that is, a rooted tree in which each node—except for the leaves—has exactly N children) by a team of robots while maintaining communication between the robots, when the tree is known in advance. The robots are located on the nodes of the tree and can move simultaneously along the edges. Two robots are considered to be in communication range if there is an edge between the nodes on which they are located. A tree environment is a convenient form of representing disaster areas, where there is only one path to reach any point on any specific location, thus there is only one path between any pair of nodes [Fraigniaud *et al.*, 2004; Brass *et al.*, 2011; Cabrera-Mora and Xiao, 2012].

Communication-constrained coverage problems are not new, and exist in the literature. However, these solutions either do not present theoretical analysis of coverage time, or use active landmarks (or similar) to coordinate the robots' movements. In this paper we present the N-ary Connected Coverage Tree Algorithm (NCOCTA) for covering a given perfect N-ary tree by a team of k robots without using any external devices. We provide a theoretical analysis of the coverage time using the notion of *speedup factor* ($\mathsf{SF}(\mathcal{A})$) [Wilkinson and Allen, 1999], which represents the speedup attained by some algorithm $\mathcal{A}$ using k robots compared to the optimal coverage time achieved by a single robot. We enhance the theoretically-proven NCOCTA algorithm by using a *dripping* heuristic algorithm, the Connected Coverage Tree Algorithm (COCTA), that was shown in extensive simulations to significantly decrease the coverage time of NCOCTA. In addition, the COCTA algorithm works on general trees. We have implemented our solutions on ROS/Gazebo [1], a realistic robotic simulation, and deployed our solution on real robots, demonstrating the efficiency of our coverage algorithms in a real office building setting in practice.

*This research was supported in part by a grant from the Ministry of Science & Technology, Israel & the Japan Science and Technology Agency (jst), Japan & ISF grant #1337/15.

[1]http://www.ros.org, http://gazebosim.org

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