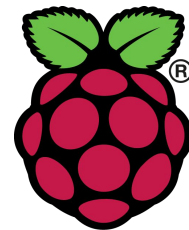


HAMSTER V6

Micro AUGV



ROS
Robot Operating System



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HAMSTER V6

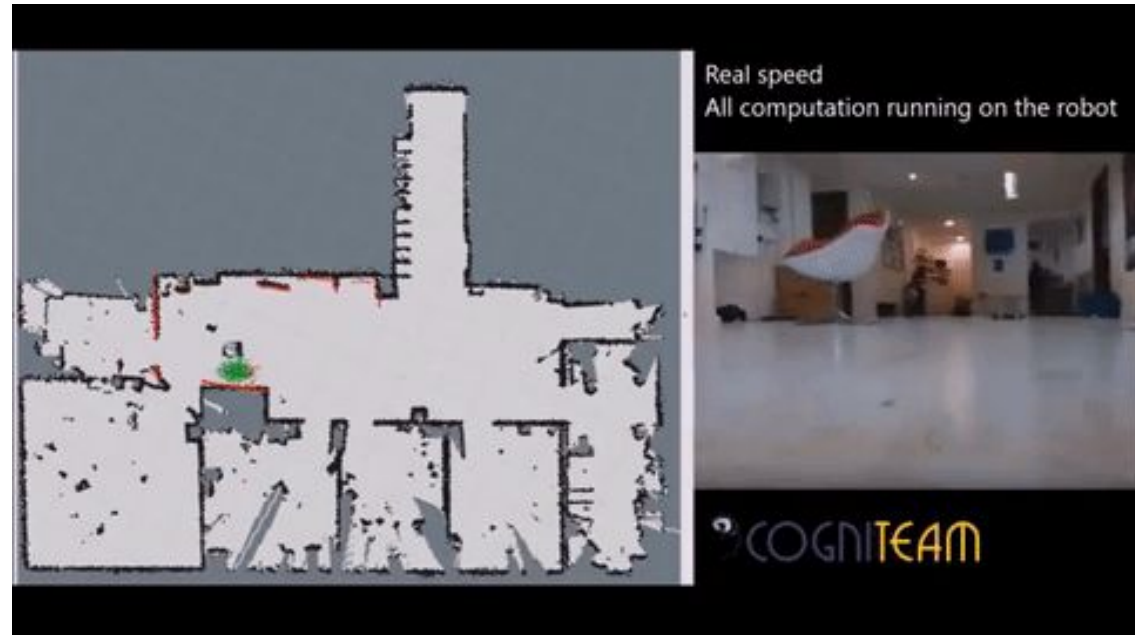
Micro AUGV

Hamster v6 is a development platform for autonomous robotics and multi-agent teams. There are multiple use cases for deployment:

- Teaching
- Education
- Research
- Prototype Development

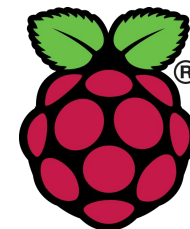
The **Hamster v6** platform is currently used by several Fortune 500 companies and a dozen world class universities. Hamster is a convenient and affordable solution for various research areas including:

- Human Robot Interaction (HRI)
- Automotive
- Multi- robot coordination



Built-in software capabilities:

*Path Planning *Autonomous Mapping *Autonomous Localisation *Autonomous Exploration *Multi-Robot Coordination *Battery Monitoring *Navigation *Obstacle Avoidance



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HAMSTER V6

Micro AUGV

HAMSTER v6 is a robust micro Autonomous Unmanned Ground Vehicle (AUGV) capable of powering, carrying and interfacing various payloads.

HAMSTER v6 is capable of powerful computations, including **Mapping (SLAM), Localization, Path Planning, Exploration, Waypoint Driving, Obstacle Avoidance, Live Video Streaming and Blob Detection** - **all running on board the robot.**

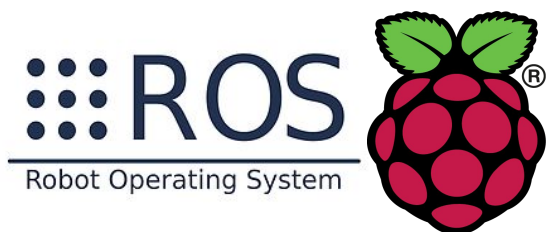
For outdoor environments, **HAMSTER v6** is equipped with **GPS**, a **motor encoder** and an **IMU** which enables high location accuracy and **PID control** for travelling at up to 4 km/h.



Power	<ul style="list-style-type: none">• 90min operation on a single charge• Affordable Lithium-ion polymer battery• PDU• 5v regulated
Computing	<ul style="list-style-type: none">• Raspberry PI 3 Model B• Linux and full ROS• Arduino Uno
Sensors	<ul style="list-style-type: none">• Motor Encoder• Camera (1080p30, 720p60 and VGA90)• 2D LIDAR 360, 10Hz, 10m range• GPS• IMU
Software	<ul style="list-style-type: none">• Path planning, waypoint driving, obstacle avoidance, blob detection• GPS and IMU• ROS drivers Simulation (Gazebo)• OCU for up to 10 robots
Connectivity	<ul style="list-style-type: none">• AC Wifi• Ethernet between CPUs
Dimensions	<ul style="list-style-type: none">• 190mm(W)• 240mm(L)• 150mm (H)

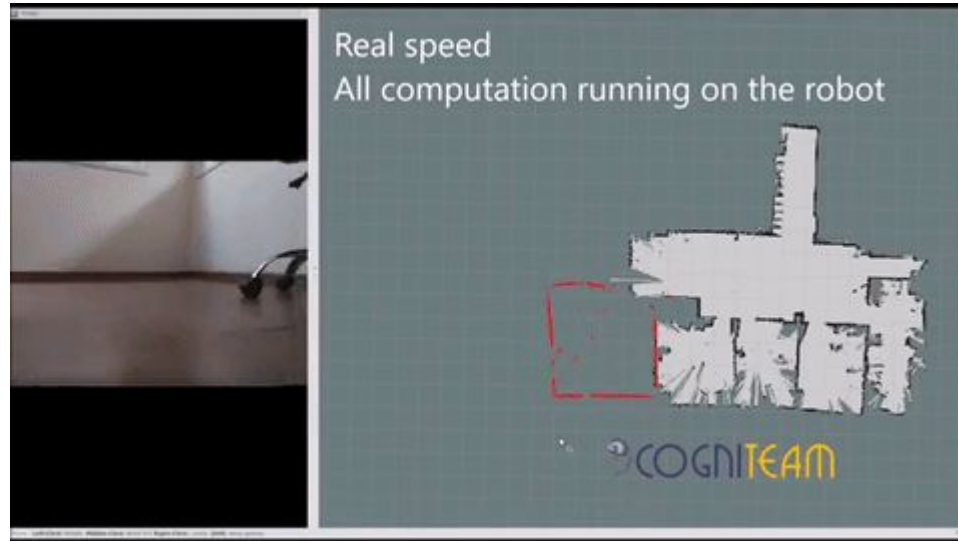


The robot is **open platform**, built using COTs and designed to support **ROS (Robotic Operating System)** and targeted for research labs and developers. It comes with a **full ROS distribution installed** and includes a **simulated environment** and an **OCU** for simultaneous control of up to 10 robots.

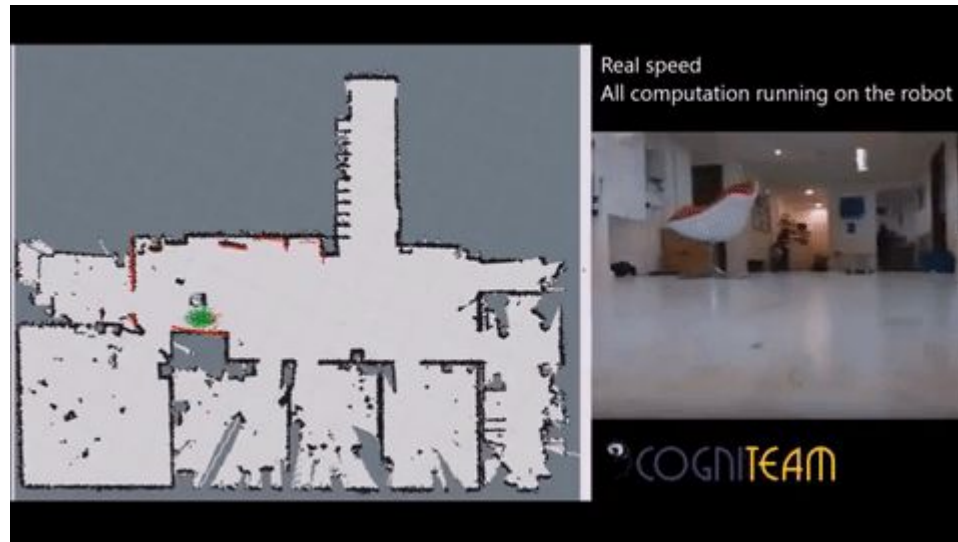


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MAPPING



LOCALIZATION



PUBLICATIONS

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 (MAO) 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 Pomplil, 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

*We thank Cogniteam Ltd. for all their support.

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 *few-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 aerial robots [Miller, 2004; Cummings et al., 2007; Pangniban, 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

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

Maintaining Communication in Multi-Robot Tree Coverage*

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Abstract

Tree coverage is an important task for mobile robots, mainly due to its applicability in many domains, such as search and rescue. In this paper we study the problem of multi-robot coverage, in which the robots must obey a strong communication restriction: they should maintain connectivity between teammates throughout the coverage. We formally describe the *Multi-Robot Connected Tree Coverage* problem, and an algorithm for covering perfect N -ary trees while adhering to the communication requirement. The algorithm is analyzed theoretically, providing guarantees for coverage time by the notion of *speedup factor*. We analyze the theoretically-proven solution with a *greedy* heuristic algorithm, and show in extensive simulations that it significantly decreases the coverage time. The algorithm is then adjusted to general (not necessarily perfect) N -ary trees and additional perimeters prove its efficiency. Furthermore, we show the use of our solution in a simulated office-finding scenario. Finally, we deploy our algorithm in real robots in a real office building setting, showing efficient coverage time in practice.

Introduction

One of the applications of mobile robots is coverage: visitation in a known or unknown environment in order to perform a task [Rogge and Aeyels, 2007a; 2007b; and Kaminka, 2008; Jensen and Gini, 2013; Jensen et al., 2011]. The problem has been studied extensively using a robot, seeking a coverage path that visits each point in the environment at least once in minimal time, e.g., [Gabriel et al., 2001]. Naturally, one can speed up the coverage by using multiple 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 et al., 2007].

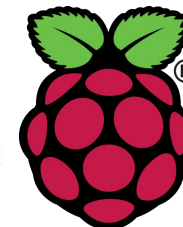
*This research was supported in part by a grant from the Ministry of Science & Technology, Israel & the Japan Science and Technology Agency (JST), Japan & ISF grant #1337/15.

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; Brats et al., 2011; Cabreria-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; Brats et al., 2011; Cabreria-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* (SF(A)) [Wilkinson and Allen, 1999], which represents the speedup attained by some algorithm 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 *drifting* heuristic algorithm, the Connected Coverage Tree Algorithm (CCTA), that was shown in extensive simulations to significantly decrease the coverage time of NCOCTA. In addition, the CCTA algorithm works on general trees. We have implemented our solutions on ROS/Gazebo¹, 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.

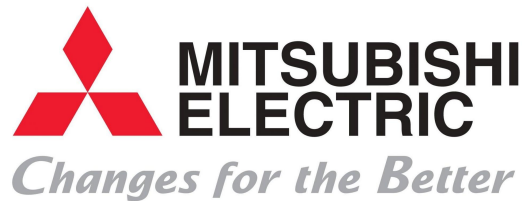
¹<http://www.ros.org/http://gazebo.sim.org>



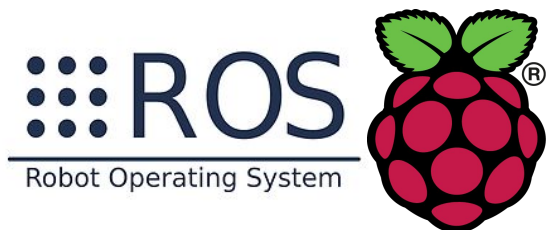
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