Task Allocation and Planning for Offshore Mission Automation

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Abstract

Task planning for multi-robot problems with capability constraints requires efficient tools capable of optimising goal allocation. This work aims to improve the performance of centralised task planning by combining a novel task allocation method with temporal planning to obtain high-quality plans. We integrate our method with the ORCA Hub Simulator, a framework which unifies multiple autonomous systems, and demonstrate our approach to plan generation for a fleet of heterogeneous robots in an offshore energy environment.

Introduction

Robotic platforms provide an alternative solution to human operators that must work in dangerous environments, such as search and rescue in disaster zones and monitoring of offshore energy platforms. However, robotic solutions for these applications require a variety of advanced robotic capabilities that must be highly coordinated to accomplish complex tasks, e.g., inspection and manipulation capabilities in ground, aeriel, and subsea domains. As a result, robots are not only expected to coordinate and collaborate with each other, but must also be robust enough to support long-term autonomous operation without human intervention.

This system demonstration showcases work that is being performed as part of the EPSRC ORCA Hub[1] project aimed at developing artificial intelligence solutions for autonomous decision making and intervention capabilities in offshore domains. In particular, the *ORCA Task Allocation and Planning (ORCA-TAP)* framework generates multi-robot plans by combining a novel *task allocation* strategy, which optimises goal distribution by considering robot capabilities, task implementation time, goal coordinates and redundancy of the sensory system; together with a *temporal planning* approach which implements task decomposition to achieve mission goals. We focus on implementing high-level mission plans that increase the performance of autonomous fleets of *heterogeneous* robots, and demonstrate the execution of these plans in a *simulated oil rig environment* (Pairet et al. 2019) (see Figure 1). Testing has indicated that the approach is scalable and, since the tools are domain independent, can be applied in other complex scenarios.

[1]https://orcahub.org/.

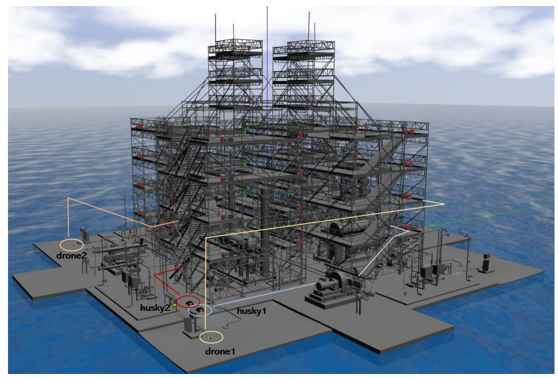

Figure 1: Overview of the ORCA Hub Simulator with multiple aerial and ground robots executing a mission plan.

System Framework

Figure 2 shows the high-level system architecture in the ORCA-TAP framework with the Multi-Role Goal Assignment (MRGA) component, the central temporal planner and plan dispatcher, and the ORCA Hub Simulator.

MRGA Strategy: The MRGA (Carreno et al. 2020) component is responsible for allocating mission goals to a fleet of multiple heterogeneous robots before planning. This method considers two cost functions to allocate goals: (i) the number of solvable tasks based on the robot capabilities, and (ii) the linear combination of the task makespan, i.e., the distance between the points of interest (POIs) and redundancy of the robot's sensory system. The MRGA strategy optimises the distribution of robots in the environment to reduce mission time and avoid worst case scenarios where all goals are allocated to a single agent. However, robots can implement tasks in different parts of the environment by considering goal capability requirements and robot capabilities (e.g., the ability to inspect a region, manipulate a valve, etc.). The approach is planner agnostic and can be used with different planners, with the output of MRGA described in standard PDDL.

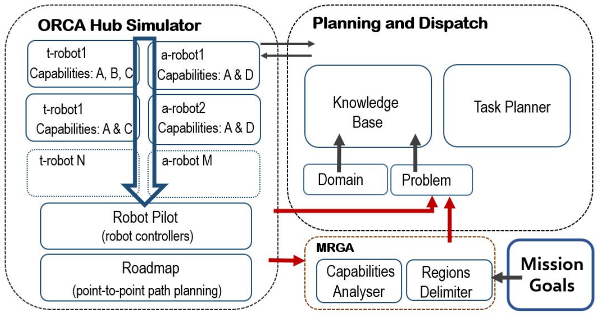

Figure 2: High-Level mission planning framework.

Planning and Dispatch: The planning and dispatch module is responsible for generating plans that links a robot's actions with the implementation of goals previously assigned to it by the MRGA component. Missions are created by considering robot capabilities and the characteristics of the environment. The module interacts with other modules in the framework (MRGA and the simulator) to obtain a world model that provides information about the robot states, capabilities, and information of the operating environment (e.g., distance between the POIs and map of possible refuelling points). Such information is used to generate domain and problem descriptions in PDDL,[2] which directly interacts with the mission knowledge base. The task planner uses mission knowledge to generate a plan which satisfies the goal allocation restrictions imposed by the MRGA component. Plans are built using the Optimizing Preferences and TIme-dependent Costs (OPTIC) planner (Benton, Coles, and Coles 2012) which shows good planning performance in a large number of domains, with domain-independent heuristics and fast generation. We connect high-level task planning with low-level robot control using ROSPlan (Cashmore et al. 2015).

ORCA Hub Simulator: The ORCA Hub Simulator (Pairet et al. 2019) is a ROS-enabled oil rig environment (see Figure 1) composed of four towers. The simulator provides a semantic description of the oil rig structure, i.e., a map from 3D coordinates to high-level labels. Moreover, to ease some of the inherent robotic challenges, the simulator provides a road map for autonomous point-to-point navigation and collision-free planning. The simulator allows multiple instances of different robotic platforms to coexist and implement complex missions with large goal sets. The robots are connected with the task planning framework via ROSPlan.

High-Level Task Allocation and Planning

Plans are built in ORCA-TAP by first applying MRGA for task allocation, to generate a set of constraints that limit robot actions to a particular set of POIs, followed by plan generation which generates a plan using a temporal planner with a definition of the domain's mission properties and problem description. The domain setting for this demonstration (see Figure 3) is an oil rig with four towers and multiple terrestrial (t-robot) and aerial (a-robot) robots which must implement actions associated with their own capabilities to achieve the goals of the mission (e.g., inspect a valve, turn a valve, monitor an area, etc.).

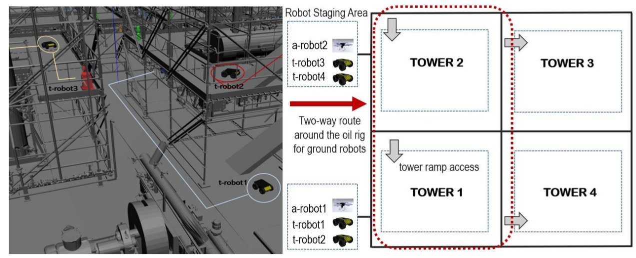

Figure 3: Top view of the offshore oil rig mission scenario.

We use a centralised planning approach to generate plans, where all robots in the mission share the same knowledge. MRGA assigns mission goals to robots by generating a set of instances of the PDDL predicate `(robot_can_act ?r ?poi)`, where `?r` is a robot and `?poi` is a goal POI. Domain actions include this property as a precondition which restricts the implementation of the actions to those robots that can act in the particular POI (Carreno et al. 2020). For instance, consider a mission with two robots (`r1` and `r2`) and a goal `(inspect_valve poi34)`, and say that MRGA's output contains one instance associated with `poi34`, defined as `(robot_can_act r1 wp34)`. In this case, the planner will allocate the goal to `r1` to satisfy the constraint imposed by MRGA. This allocation also relaxes the problem complexity for the plan generation phase.

The ORCA-TAP system has been tested in simulation using multiple robot sets. For the system demonstration, we will illustrate its operation with a series of mission plans involving multiple terrestrial and aerial robots autonomously performing tasks in the ORCA Hub oil rig environment.

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[2]Domain and problem instances are available in the MRGA repository at https://github.com/YanielCarreno/MRGA