CPS: TTP Option: Synergy: Collaborative Research: Dependable Multi-Robot Cooperative Tasking in Uncertain and Dynamic Environments

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Project Overview

Driven by both civilian and military applications, such as coordinated surveillance, search and rescue, underwater or space exploration, manipulation in hazardous environments, and rapid emergency response, cooperative actions by teams of robots has emerged as an important research area. This project focuses on fundamental theory studies so to enable a scalable, correct-by-construction formal design of multi-robot systems that can guarantee the accomplishment of high-level team missions through automatic synthesis of local coordination mechanisms and control laws. Furthermore, results from the research can be extended to the design of more general cyber-physical systems (CPSs) consisting of distributed and coordinated subsystems, such as the national power grid, ground/air traffic networks, and manufacturing systems. These CPSs are critical components of the national civil infrastructure that must operate reliably to ensure public safety. The multidisciplinary approach taken will help broaden participation of underrepresented groups in research and positively impact engineering education.

Project Objectives and Approach

Goal: Focusing on multi-robot teams, the goal of the research is to build foundations for a provably correct formal design theory for CPSs. This design theory will guarantee a given global performance of multi-robot teams through designing local coordination rules and control laws.

Hence our research tasks include:

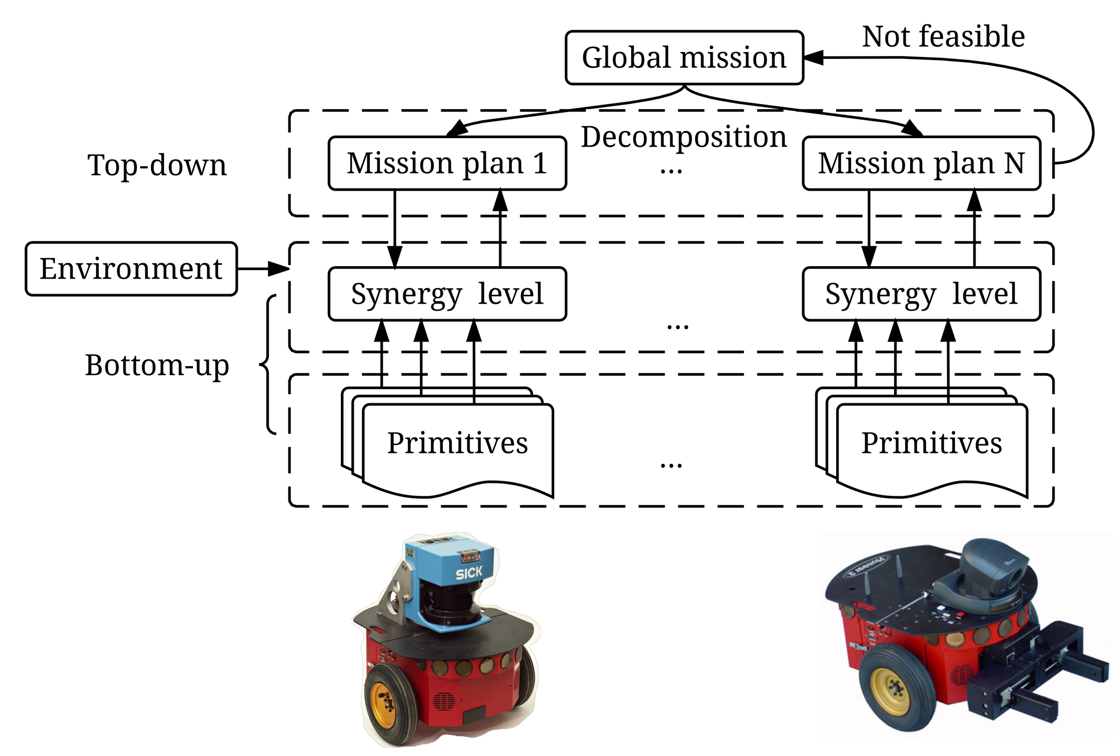
Objective 1. Automatically synthesize supervisors for uncertain discrete-event plants.

Objective 2. Automatically derive subtasks for individual robots from a given team mission.

Objective 3. Implement and demonstrate the top-down design approaches on real robotic systems.

Multidisciplinary approaches combining hybrid systems, supervisory control, regular inference and model checking will be utilized to achieve this goal.

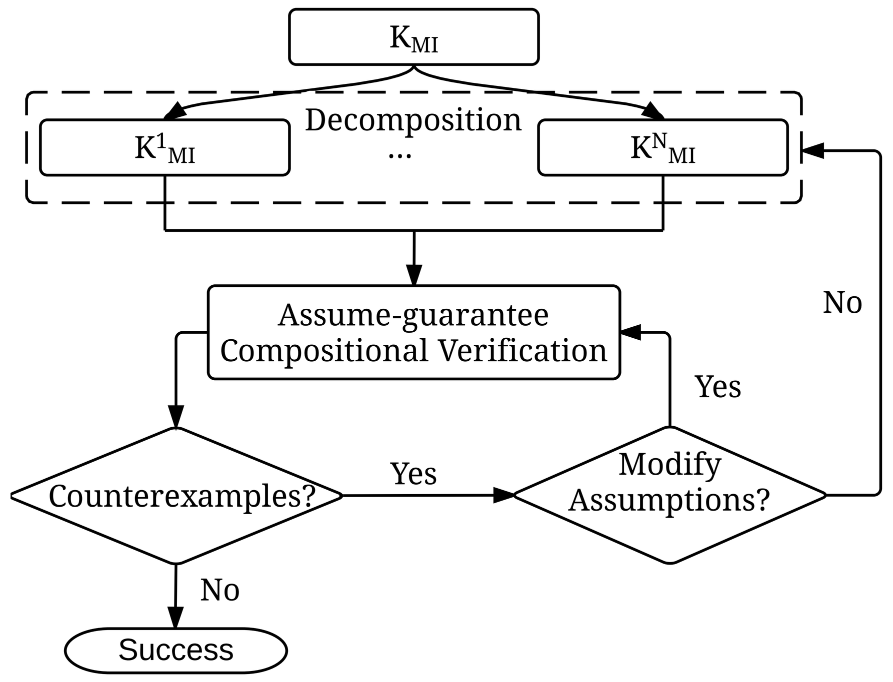
Overall Design Framework



We propose to **combine** top-down and bottom-up approaches so to com up with a **scalable** formal **correct-by-design** method for distributed coordination and control of multi-robot systems in **uncertain environments**.

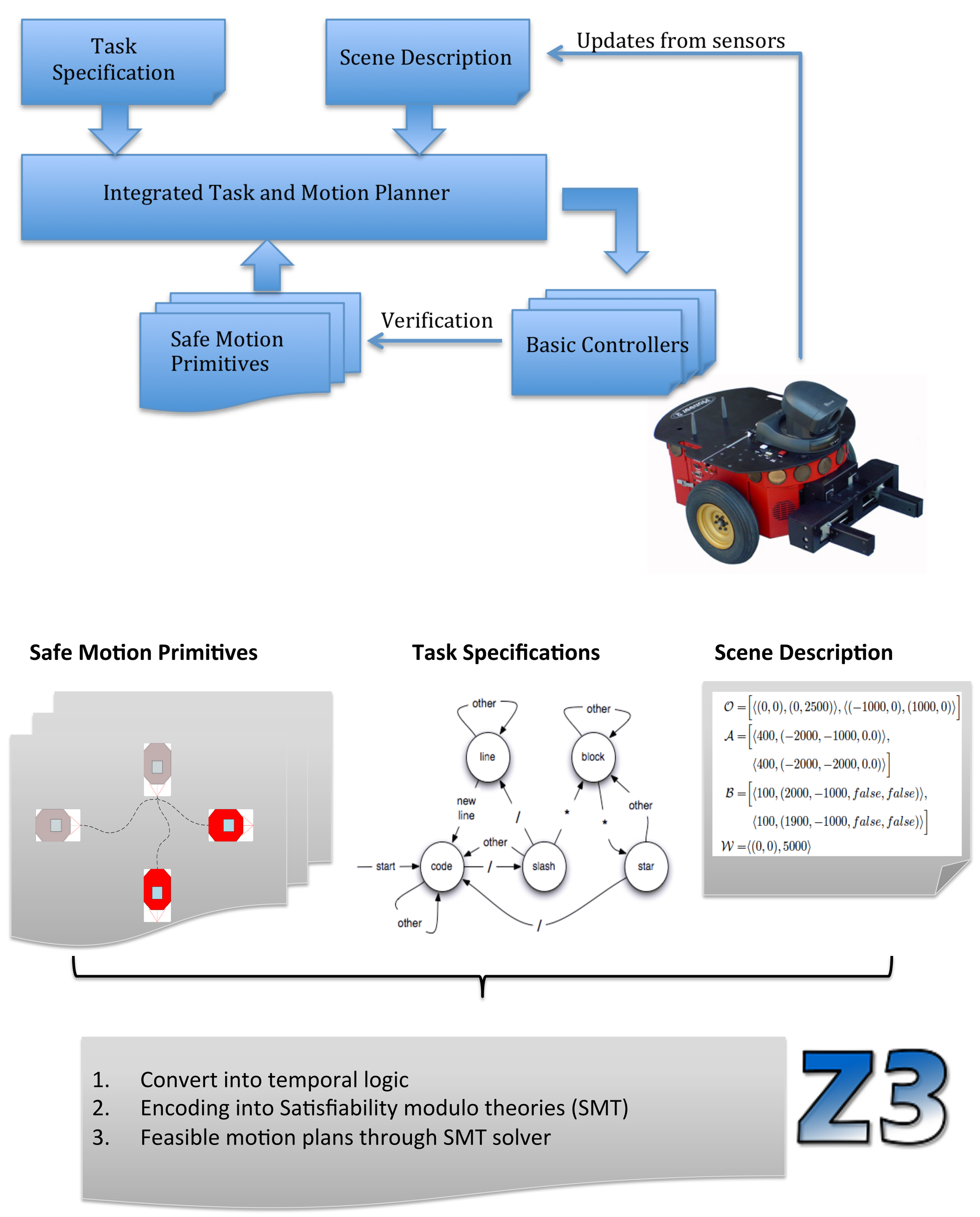
Top-down Task Decomposition

Basic idea is "divide-and-conquer." First, we decompose the team mission into subtasks for individual robots, and then synthesize a local supervisor individually for each robot to fulfill these subtasks.



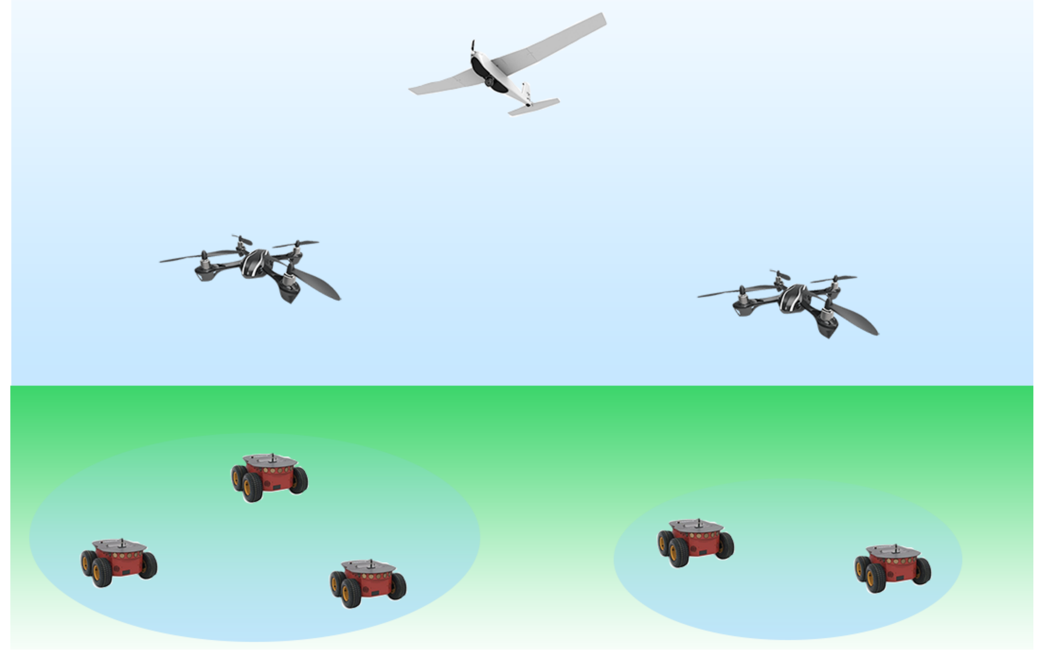
- Assume the global mission is given as regular languages.
- Need to decompose the global mission into individual robot tasks.

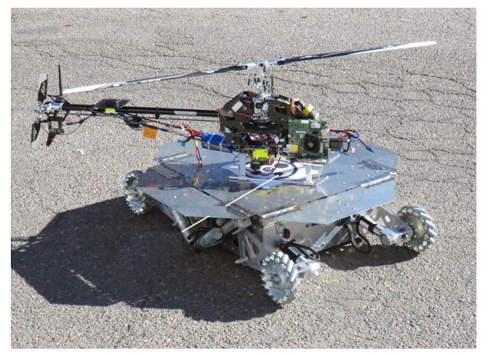
Bottom-up Motion Planning



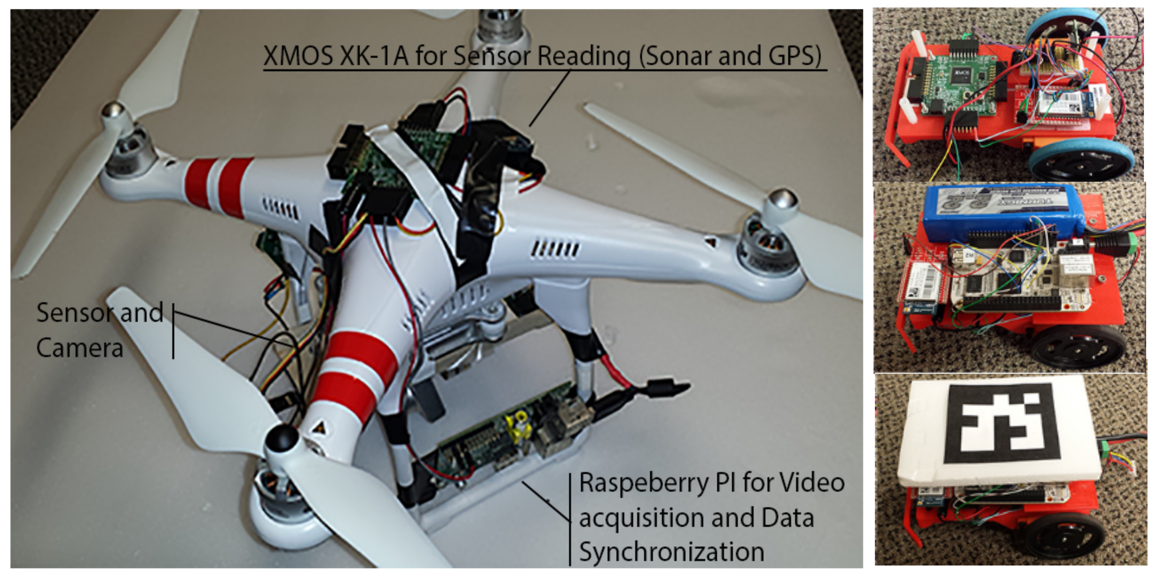
Robot Testbed Development

The testbed includes UGVs and heterogeneous UAVs (quadrotors, helicopters and fixed-wing) flying at different altitudes. A universal UGV-landing platform on which quadrotors and helicopters can land and takeoff has been developed and tested.





Robot Testbed Development



System for real time data acquisition and synchronization from different Sensors.

- Provide a reference altitude measurement to be compared with the altitude estimated through vision
- Altitude estimation using Sonar and precise timing achievable with real-time microcontrollers (XMOS)
- Test of simultaneous communication with different kind of sensors (using different protocols)
- Test serial communication and message exchange between Mid Level (Raspberry PI) and Low Level system (XMOS)

Layer 0: Real-time microcontroller for interaction with sensors and actuators.
Layer 1: Linux based embedded system for high level tasks: Control system - Mission management - Interaction with the supervisor.
Layer 2: Marker for localization system
Localization System

✓The software tracks all the marks with a frame rate of ~20Hz
✓Each marker is identified uniquely. The coordinates of the four corners of the marker are used to estimate the position of the center of the marker and its orientation.
✓The data are expressed in pixel coordinates.

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