Trust-based Symbolic Motion Planning for Multi-robot Bounding Overwatch


Motivation
- Develop high-level motion plans under temporal logic constraints for robot team bounding Overwatch.
  - Traditional motion planning, such as A*, RRT*, does not consider temporal logic constraints in task and motion planning.
  - Decentralized/distributed symbolic motion planning (SMP) can mitigate the “state-space explosion” issue for multi-robot systems (MRS).
- Create computational trust models to evaluate the reliability of robot teams in performing the bounding Overwatch task.
- Encode the mission intent and trust into the motion planner for the robots to conduct the Overwatch tasks.

Fundamental Research Questions
- How to provide probably correct while computationally efficient SMP algorithms for MRS to overcome the “state-space explosion” issue?
- In the framework of SMP, how to optimally assign tasks to heterogenous MRS in the presence of uncertainty?
- How to encode both bounding Overwatch mission intent and trust into the robot SMP and role allocation?

Objectives & Overall Framework
- Develop a trust-based symbolic motion and task planning framework for MRS to perform the bounding Overwatch maneuver under temporal logic constraints.

Approach (continued)
2. Parallel decomposition of automaton $G$ of task specification:
   A set of parallel subtask automata $G_1, …, G_m$ can be obtained. MRS can perform each subtask automaton in parallel.

3. Synthesis of task and motion planning Markovian decision process (MDP) for each robot team:
   - Model checking for the capability transition system of each robot team $T_{EM}$ and its assigned subtask automaton $G_m$, i.e., $T_{EM} \times G_m$.
   - Discretize the mission environment based on robot sensing capability and height map, and obtain the discrete motion MDP of each robot team $T'M_m$.
   - Compose each model checking result with the robot team’s motion MDP to obtain the task and motion planning MDP $(T_{EM} \times G_m)[T'M_m]$.

4. Computational trust model for robot teams:
   - Use traversability and line of sight (LoS) as metrics to evaluate the trust of bounding Overwatch between neighboring discretized cells.
   - Use the computed trust value to estimate the reward of each transition in the task ad motion planning MDP.

5. Exploration with deep reinforcement learning (DRL) for the most trustworthy bounding Overwatch policy.


Preliminary Results
Given two teams of Summit-XL robots and the following scenario, the task specification for the robot teams is either (1) “first advance to fort $f_3$ and then $f_4$ or $f_5$, and finally conquer $f_6$ cooperatively”, or (2) “first advance to $f_4$ and then survey $f_3$, and finally conquer $f_6$ cooperatively”. Each robot team can move between any two forts. The RE formulae of the task is “((f3(f4|f5))|f4(f3)*)f6”.

Future Work
- Investigate more diverse metrics for robot team bounding Overwatch.
- Create computationally efficient trust models using machine learning approaches.
- Develop robot role assignment inside the robot team for bounding Overwatch.
- Combine task and motion planning with role assignment to achieve a global optimal solution.

Preliminary Results (continued)
- Use the computed trust value to estimate the reward of each transition in the task ad motion planning MDP.
- Exploration with deep reinforcement learning (DRL) for the most trustworthy bounding Overwatch policy.
- Synthesis of trajectory for each robot.

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