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Self-Reactive Planning of Multi-Robots with Dynamic Task Assignments

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Abstract

In this research, we formalize the problem of multi-robot planning for fulfilling dynamic tasks represented through a Behavior Tree (BT).

We design a framework with corresponding distributed algorithms for communications between robots and negotiation and agreement protocols incorporating a novel priority mechanism.

Finally, we evaluate our framework through simulation experiments.

Research Questions

- How to divide and integrate groups and select group members basing on the quantity and priority of the dynamic tasks?
- How to assign the robots within the formation shape of the group while guaranteeing the system utility?
- How to avoid collisions in case robots have conflicting route/path plans while moving to the assigned position within the formation shape?

Background and Motivation

- **In nature, the interaction between and within various elements exhibit complex behaviors that emerge as a result of often nonlinear spatiotemporal interactions at different levels of organization [1].**
- **Multi-robot systems (MRS) could potentially share the properties and advantages of swarm intelligence when they are deployed in various tasks such as search, rescue, mining, map construction, and exploration, etc. [2].**
- **Swarm Robotic System is a kind of Complex Adaptive System (CAS) [3], where task-dependent reconfiguration into a team are among the grand challenges in Robotics [4] necessitating the research at the intersection of communication, control, and perception.**

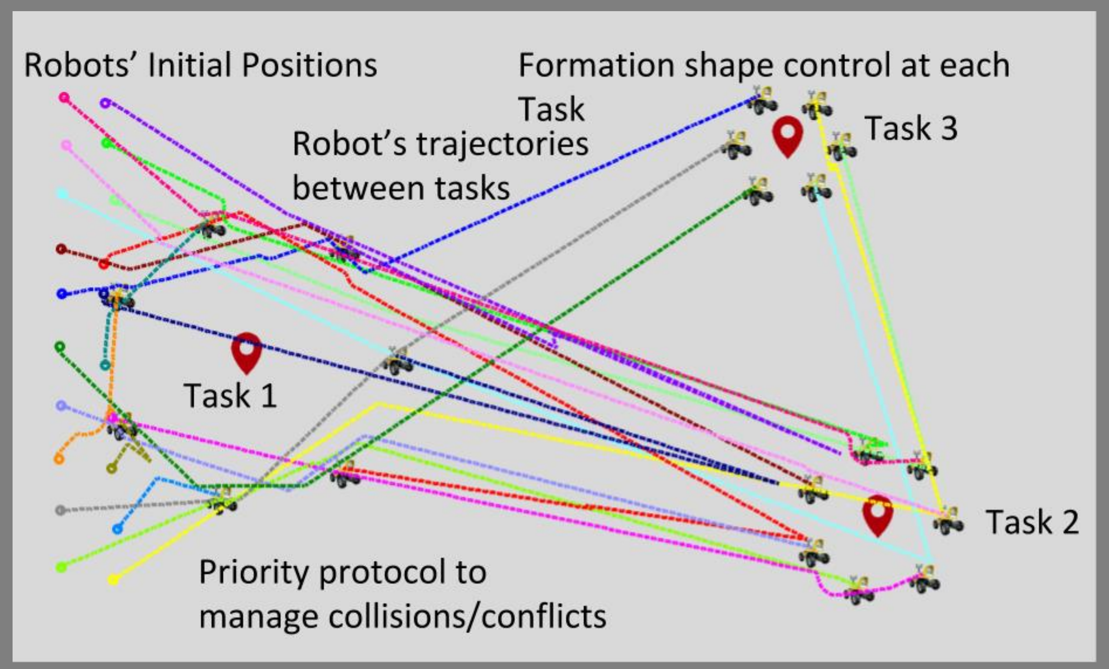

Figure 1

Figure 2

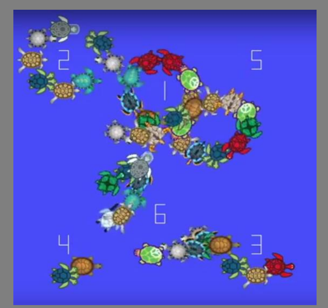

Figure 3

Fig 1. Illustration of self-reactive multi-robot planning where robots move to Task 1 and Task 2 from their initial positions. Then, Task 3 is assigned, and the robots react to this new task requirements.

Fig 2-3. Simulation of 12 and 50 Swarm Robots using discrete events simulation technique in ROS.

Proposed Approach

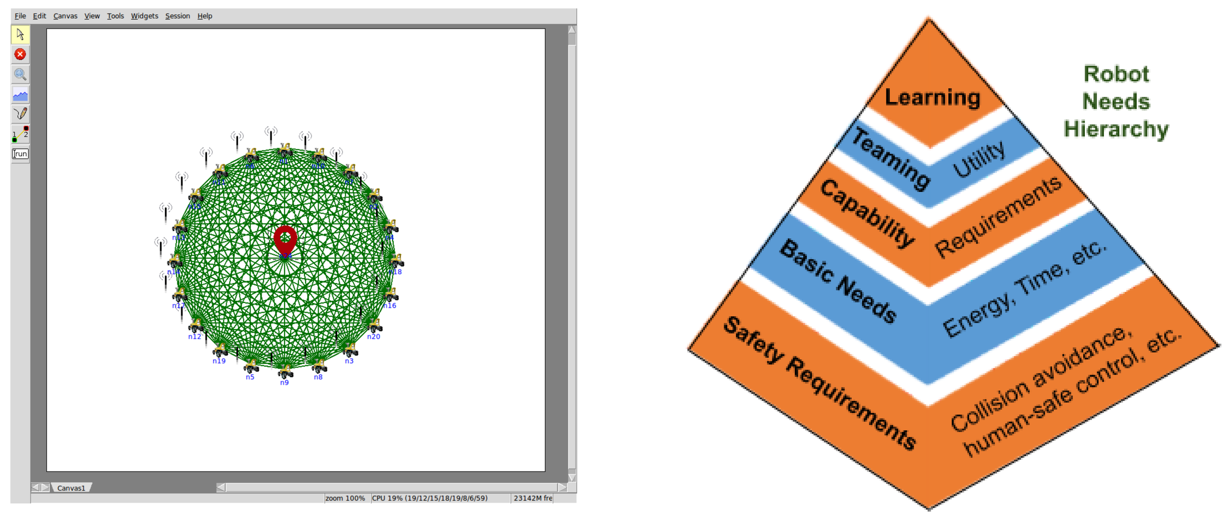

Fig 4. Illustration of CORE simulator (left) and the proposed robot needs hierarchy inspired by Maslow's law of human needs (right).

1. We consider a scenario, where a group of robots will cooperate to complete some tasks. Since the task assignments change dynamically, the robots need to change their plans and adapt to the new scenario to guarantee the group utility.
2. We decompose the complex tasks into a series of simple sub-tasks through which we can recursively achieve those sub-tasks until we complete the high-level task.
3. Based on this approach, we can divide the whole task plan into three *Atomic Operation* for the swarm behavior: **selection, formation, and routing.**

Proposed Method and its Implementation

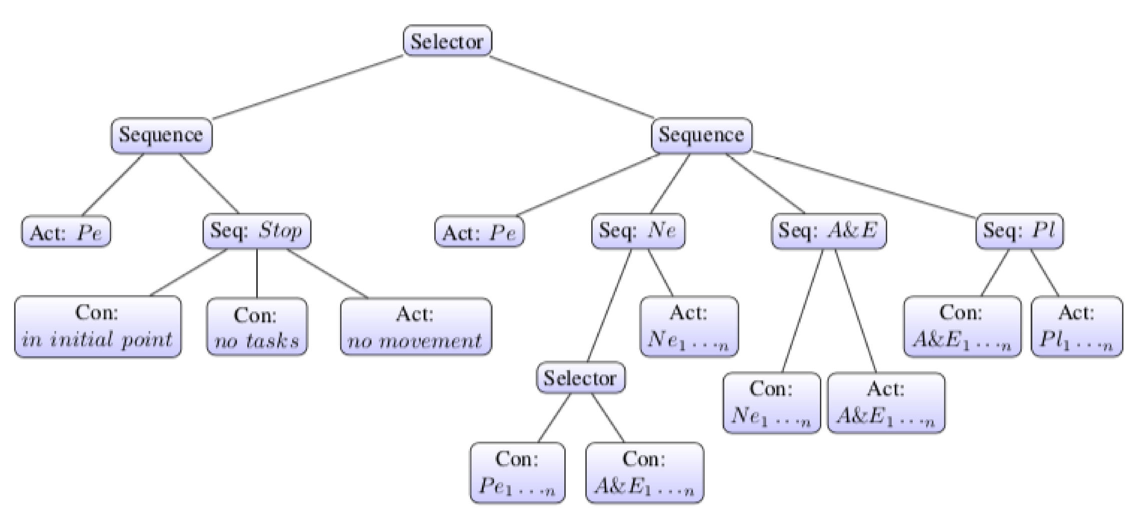

Fig 5. Behavior Tree based reactive plan acting on every robot. Con - Conditions, Act - Actions, Pe - Perception, Pl - Plan, Ne - Negotiation, A&E – Agreement and Execution.

- **Perception**: Each robot uses various on-board (local) sensors for localization, mapping, and recognizing objects/obstacles in the environment.
- **Communication**: The process of communication between robots includes broadcasting and reception of robot's messages (state) to/from other robots.
- **Planning**: We divide this process into three steps: Selection, Formation, and Routing; and introduce a priority queue technique (Fig. 4) helping individual robot negotiation and get an agreement efficiently.
- **Negotiation**: Robots will compare their plans with that of the group members until they get an agreement.
- **Agreement and Execution**: If all the robots' plans do not have conflict after the negotiation phase, they will have a final agreement and execute their plans according to the flow of the Behavior Tree.

Preliminary Experiments and Results

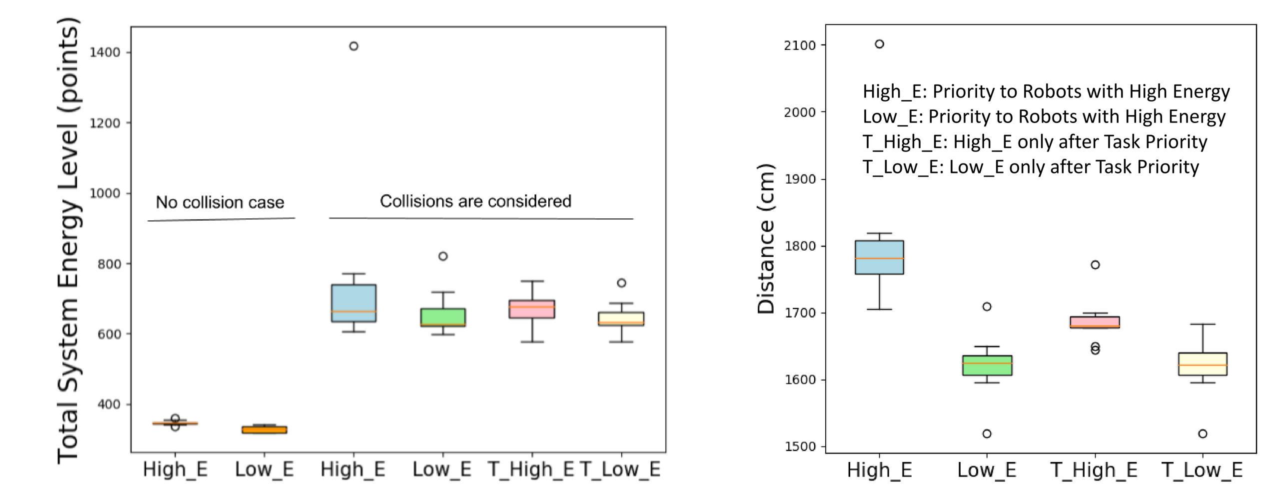

Fig 6. Experiments on static task assignments with 20 robots and 3 tasks

TABLE I
ENERGY LEVEL COMPARISON IN DYNAMIC TASK ASSIGNMENTS

Tasks Style	Priority	Collision	Max	Min	Mean
1+1+1	high energy	√	69.42	55.52	64.18
1+1+1	low energy	√	63.09	45.70	56.00
1+1+1	task + high energy	√	70.04	56.75	63.24
1+1+1	task + low energy	√	63.25	49.18	56.62
1+2	task + low energy	√	45.97	31.78	39.60
2+1	task + low energy	√	44.69	31.66	39.07
1+1+1	task + low energy	-	49.88	29.48	41.20
1+2	task + low energy	-	32.70	23.14	28.50
2+1	task + low energy	-	38.53	24.72	30.36

Using the preliminary results of static (Fig. 6) and dynamic tasks (Table 1), we can conclude that our framework provides a way of abstracting the individual robot needs and the global system utility through the negotiation and agreement protocols represented through a BT.

Conclusion and Future Work

✓ **In summary, each robot will follow the BT logic and first verify the task assignments. If assigned, it will compute an appropriate plan according to its current state and needs.**

✓ **Then, it will communicate with other robots and perform the negotiation and agreement process until there are no conflicts.**

✓ **Finally, the robots will execute their plans. This process is repeated as a loop in the BT, which process the flow from left to right.**

✓ **In future, we would like to verify our framework for scalability and implement our framework in ROS and open-source the method.**

References and Project Team

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More details available at the Project Webpage
http://hero.uga.edu/research/selfreactivemrs