Modified Effective Path Formation Using Task Allocation In Swarm Robotics

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ABSTRACT

Path formation is a prerequisite for task completion in cooperative swarm robotics. Path formation is the task performed by a group of swarm robots to find a path between a goal and a starting point by using intermediate sub-goals. This research proposes a task allocation model to increase the performance of swarm path formation. Proposed model is implemented using local communication protocols and light signal based communication. Simulation experiments were carried out to evaluate the performance using the Argos multi-physics robot simulator.

OBJECTIVE

- The main objective of the research is to increase the efficiency of swarm path formation by addressing problems in past research.
- In the past research, a path formation was performed using intermediate robot based sub goals.
- When a large number of robots working on a task, the performance of swarm path formation decreases due to traffic.
- This research work tries to find optimized shortest path without traffic delays and with adequate resources.

ENVIRONMENTAL SETUP

- Parameters used in the ARGoS Simulator are given in Tables 1, 2, 3.
- A cylinderical nest and goal items are added in the environment. Both are characterized by unique color LEDs.

Diffusion Parameter	Value
Go straight angle range	-5.5
delta	0.1

Table1: Diffusion parameters in Simulator

State Parameter	steps
Minimum Resting time	1
Initial Exploring time	10
Minimum search for place in nest	50

Table2: State parameters in Simulator

Wheel Turning parameter	Value
Hard turn angle threshold	90
Soft turn angle threshold	70
No turn angle threshold	10
Maximum speed	10

Table3: Wheel turning parameters in Simulator

METHODOLOGY

- A robot can be in one of many states (Fig 1 and Table 4). Each state is differentiated by a unique color LED.
- Robots have different behaviors in each state (Table 5) and use light signal based communication for local interactions.
- Robots explore to find the goal and send exploration details to other robots using communication protocol (Figure 2).

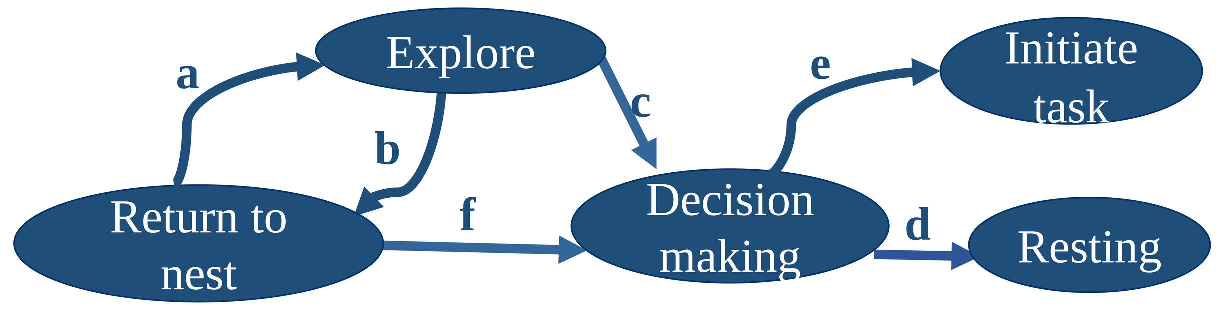

Figure1: Finite state machine of proposed task allocation method.

Transitions	Description
a	Explore to find goal until a minimum exploring time is reached.
b	If goal not found in minimum exploring time return to nest and increase minimum exploring time to explore more.
c	Found the target and return to nest for making decision about how many robots needed to go for path formation in that exploring time.
d	Decided to rest.
e	Decided to go for path formation.
f	Get information in the nest about an already found target.

Table4: State Transition of proposed task allocation model

States	Description
Return to nest	Bring robot to the starting place - through this the loss of a robot can be prevented.
Exploring	Searching the goal from the starting point(nest). Searching will happen in the opposite potential field from the starting point. Robots have a max step size - if a robot fails to find the goal point then that robot changes the state as returning to nest.
Decision making	When a robot finds a goal or a robot finds another robot which has found the goal, it goes to this state. Here robots decide whether to go for path formation or resting.
Initiate task	Go to subgoal based path formation task.
Resting	If allocating Robots to path formation task reached it's optimal level, other robots go to resting state.

Table5: State description of proposed task allocation method.

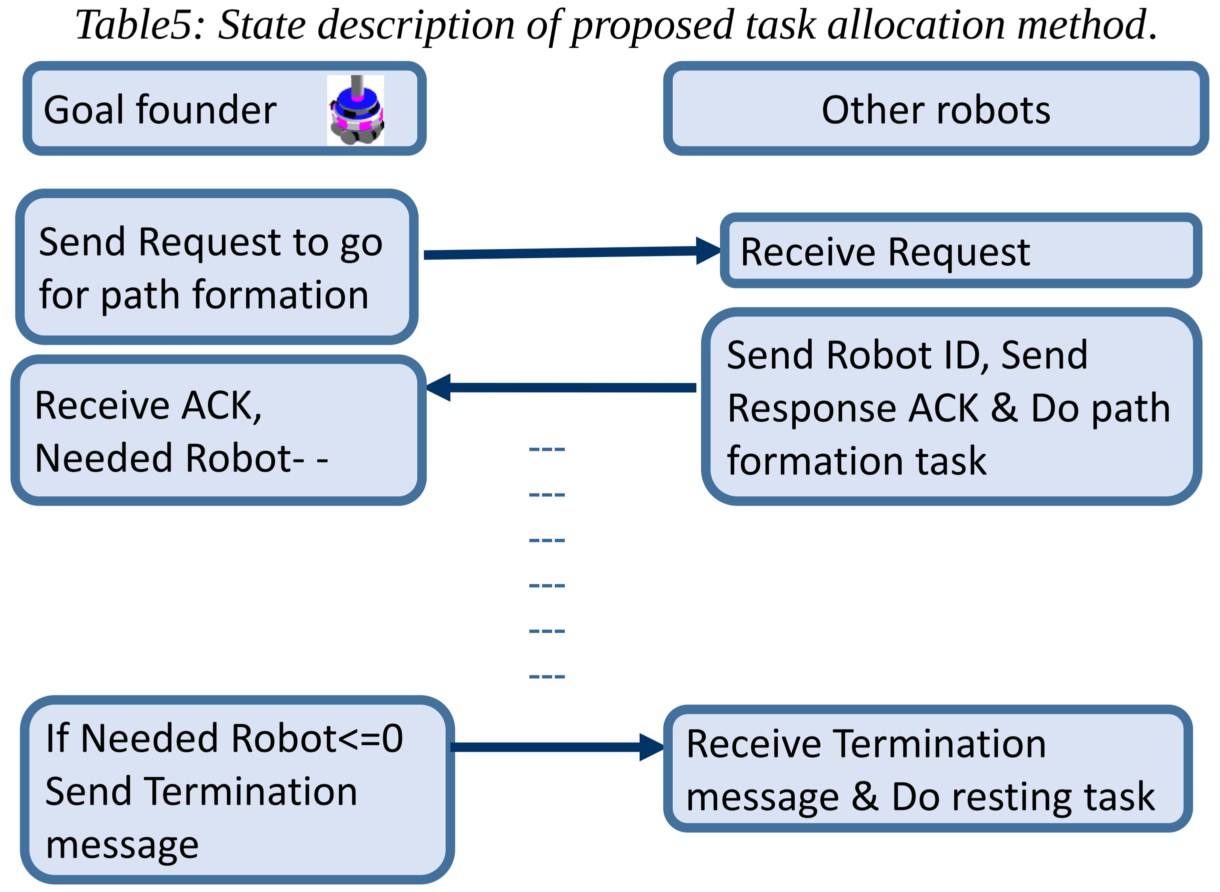

Figure2: Communication protocol used to allocate robots to do path formation and resting task

Communication protocol

- **Goal Founder Robot**: Robots explore to find goal. If one finds the goal, it becomes as goal founder and sends the exploration details to other robots and request to do path formation task.
- Calculate the path length using the exploring time and robot speed. **Path length = exploring time*speed**
- Calculate needed no. of robots to complete path using the path length. **Needed Robot Size = Path Length / Robot Visual Range**
- **Other Robots:** If receive request then send acknowledgement and their robot Id, and do path formation task.
- **Termination:** Once enough robots are allocated to path formation task.

Data[0]: ExploringTime/255	**Data[5]:**Robot ID/255
Data[1]: ExploringTime%255	**Data[6]:**RobotID%255
Data[9]: Send Request to Do Path formation task	**Data[8]:**Send Response ACK
	Data[7]: Send Termination Message

RESULTS

Model was tested in eight different environments (3 x open, 3 x obstacle and 2 x complex) and each with 60, 70, 80, 90, 100 robots. Fig. 3 describe 100 robots in eight different environments. Each path (green) compared with a path formed by A*algorithm (red) and path without task allocation model (blue). In each graph, plotted dots denote a robot location which is an intermediate sub-goal.

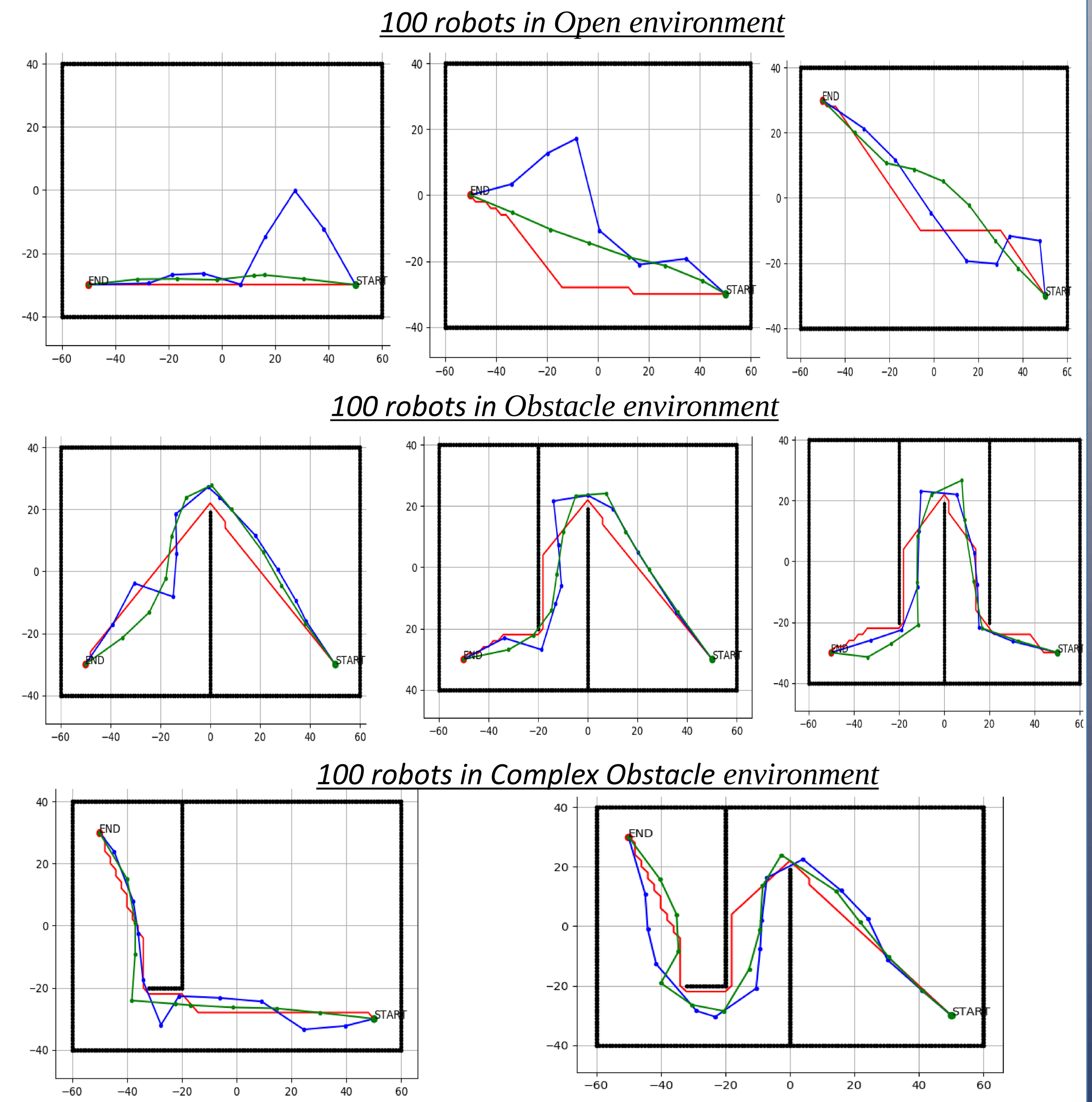

Figure3: Comparison of paths formed with A-star algorithm and without task allocation model.

Environment	Time taken to form path(ArGos Default step size)		Path Length(In ArGos default unit)			Resource Reduction (%)
	Without Task allocation	With Task allocation	A-star	Without Task allocation	With Task allocation	
1	4677	5047	100	131.4	100.3	77.1
2	7348	2389	112.8	147.5	104.4	75.4
3	5977	5026	132.9	149.5	118.6	75.4
4	9754	8393	144.3	197.6	158.2	52.5
5	10124	8164	158.9	150.3	146.2	49.2
6	14471	15280	172.5	201.0	183.1	47.1
7	10464	7679	143.1	142.3	145.9	76.2
8	20123	19770	191.2	211.4	209.2	42.9

Table6: Test results (average) for eight different environments

- Tested the performance in eight different environments each with five different deployed robot count. Table 6 shows the average of five cases in each environment.
- Resource efficiency was calculated using the deployed and allocated robot count. In average of 40 different test cases found to be using resources reduced by 61.93%.
- Path efficiency was tested by path length. In 40 test cases 40% of cases formed shortest path than A* algorithm. All 40 test cases formed shortest path compared to the model without task allocation.
- 87.5% cases of the model with task allocation formed paths quickly than the model without task allocation.

DISCUSSION & CONCLUSION

- ✓ Proposed task allocation model effectively used the robot resources by allocating only the adequate number of robots needed to do path formation task. Required resources can be reduced by the proposed model, hence deployment cost can be reduced.
- ✓ Can parellely use the excess robot resources to other tasks by allowing only adequate robots.
- ✓ In each environment, the model allowed only the needed no. of robots to do path formation task even with increased robot size.
- ✓ Compared with A* algorithm and the model with task allocation, the proposed model was able to form shortest paths.
- As future work, the model can be implemented with effective communication protocols and test the model with real robots in a real environment.

REFERENCE

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