An Auction-based Task Allocation Algorithm in Heterogeneous Multi-robot System

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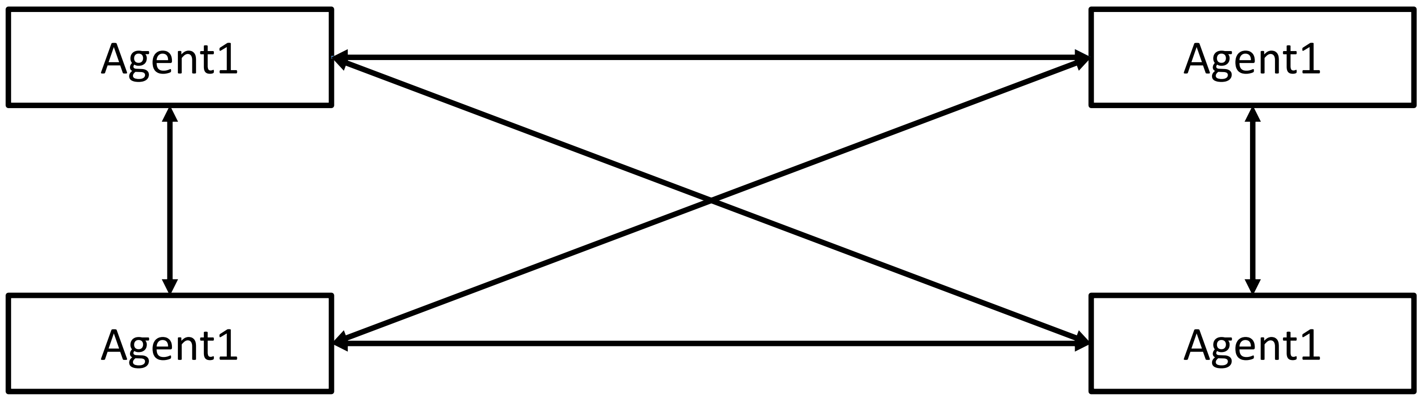
Presentation Structure

- Introduction
- Model and Algorithm Description
- Experiment Results and Analysis
- Conclusion and Future Work

1.1 Multi-agent System

- What is a Multi-agent System?
  - A coupled network of solvers that work together to solve problems that are beyond their individual capabilities.



1.2 MRTA Problem

- Multi-robot task allocation problem is an optimization problem.
- It aims to improve the efficiency of the whole agent system.
- Under certain circumstances, MRTA problem can be thought of as an assignment problem.

1.3 Auction Algorithm

- It is an iterative procedure and related to a sales auction, where multiple bids are compared to determine the best offer.
- An auction algorithm applies to several variations of a combinatorial optimization algorithm which solves assignment problems, and network optimization problems with linear and convex/nonlinear cost.

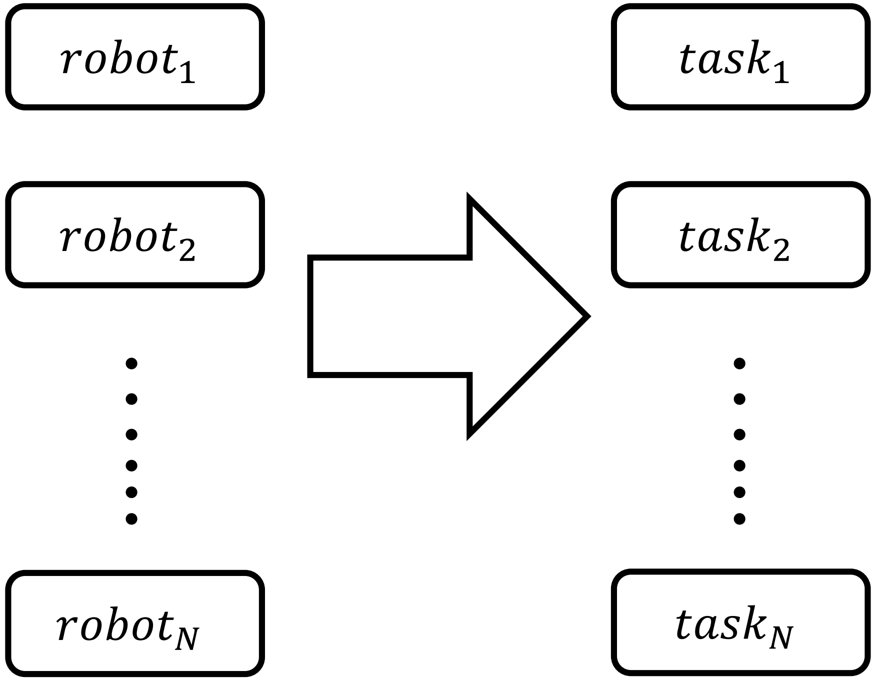
1.4 DAMCR

- In this kind of changing and dynamic multi-robot system, a successful task scheduling strategy show fulfill two points below:
  - *Optimization*
  - *Dynamic*

In response to the above two requirements, based on auction, we propose a merging method.

2 Model and Algorithm Description

- Model Description
- Algorithm Description
- A Simple Example
- Dynamic Adjustment



2.1 Model Description

- The number, as well as the states of tasks are not static.
- The states of robots and the task allocation results are changing with time as well.

So time t is a significant parameter in this model.

2.1 Model Description

- We use auction as a basic method to allocate tasks, a formalized auction can be represented as below:

$$A=\langle B,T\rangle$$

B is the set of bidders, in other words, robots waiting for tasks.

T is the set of tasks waiting to be assigned in this auction.

2.1 Model Description

The damage that $task_j$ will cause to the system can be formalized as below:

$$cost_i^j = \int_{t_0}^{t_0 + t_{ij}^1} cost_j(0)dt + \int_{t_0 + t_{ij}^1}^{t_0 + t_{ij}^1 + t_{ij}^2} cost_j\left(AR_j^t\right)dt$$

We need to point out that AR_j^t is the accomplishment rate of $task_j$ at time t.

Clearly, $AR_j^t \in [0,1]$

2.1 Model Description

- The object of this auction is to minimize the whole damage system will get. So this problem can be view as a linear programming problem.

$$min \sum_{i \in B} \sum_{j \in T} cost_i^j$$

2.2 Algorithm Description

- Step 1: *Set* ϵ *and* p_k
- Step 2: *This step is an iterative process:*
  - *Decision phase: obtain maximum relative gains and its second relative gains*
  - *Bidding phase: All robots bid for the most gainful task, the bidding price of the robot is determined as*

$$a_{ij_i} = p_{ij_i} - u_i + v_i - \epsilon = cost_i^{j_i} + v_i - \epsilon$$

  - *Allocation phase: update the price of the task j to the highest bid price*
- Step 3: *each robot can meet the complementary slackness condition*

2.3 A Simple Example

	r_1	r_2	r_3	r_4
$task_1$	6	3	7	5
$task_2$	2	6	3	9
$task_3$	6	4	2	5
$task_4$	1	8	6	8

If we use the traditional auction model,

the cost of the task we get will be:

3+2+2+8=15

And the cost of the best solution is:

3+3+5+1=12

2.4 Dynamic Adjustment

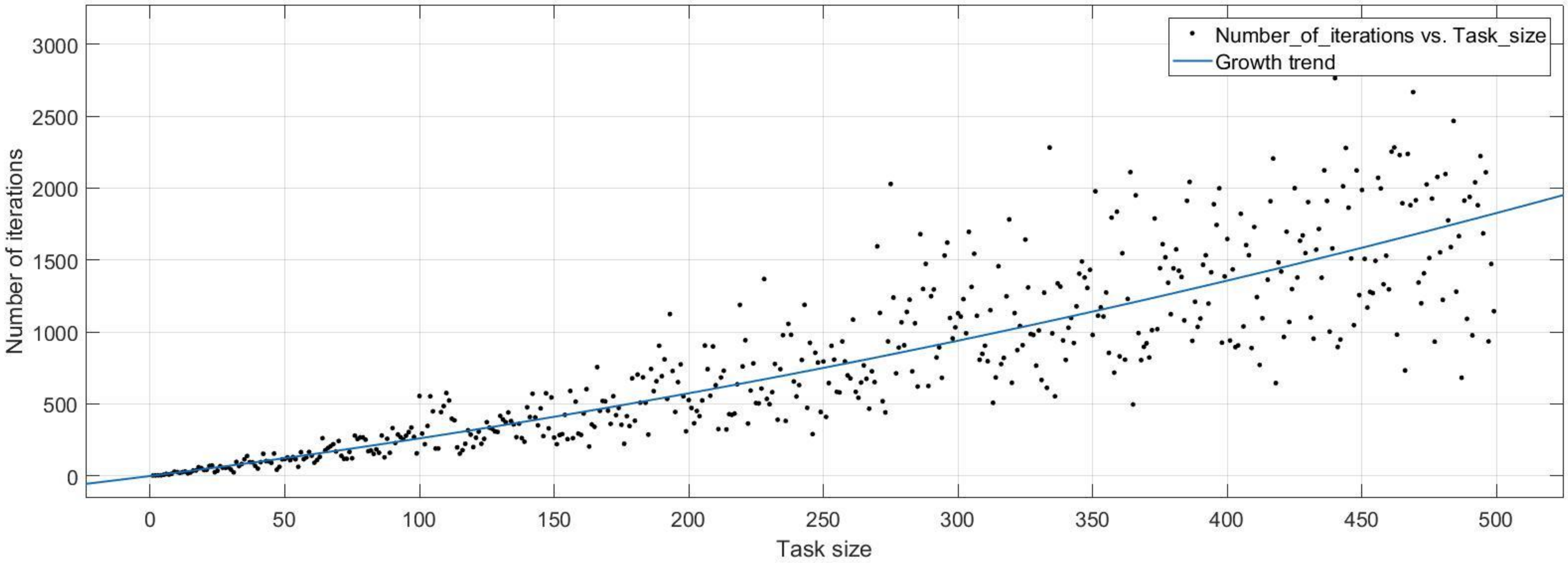
- In some special cases, we need to adjust the task executors. We quantify the emergency rate using E_j. The definition of urgency is:

$$E_j = \frac{w}{\beta v}$$

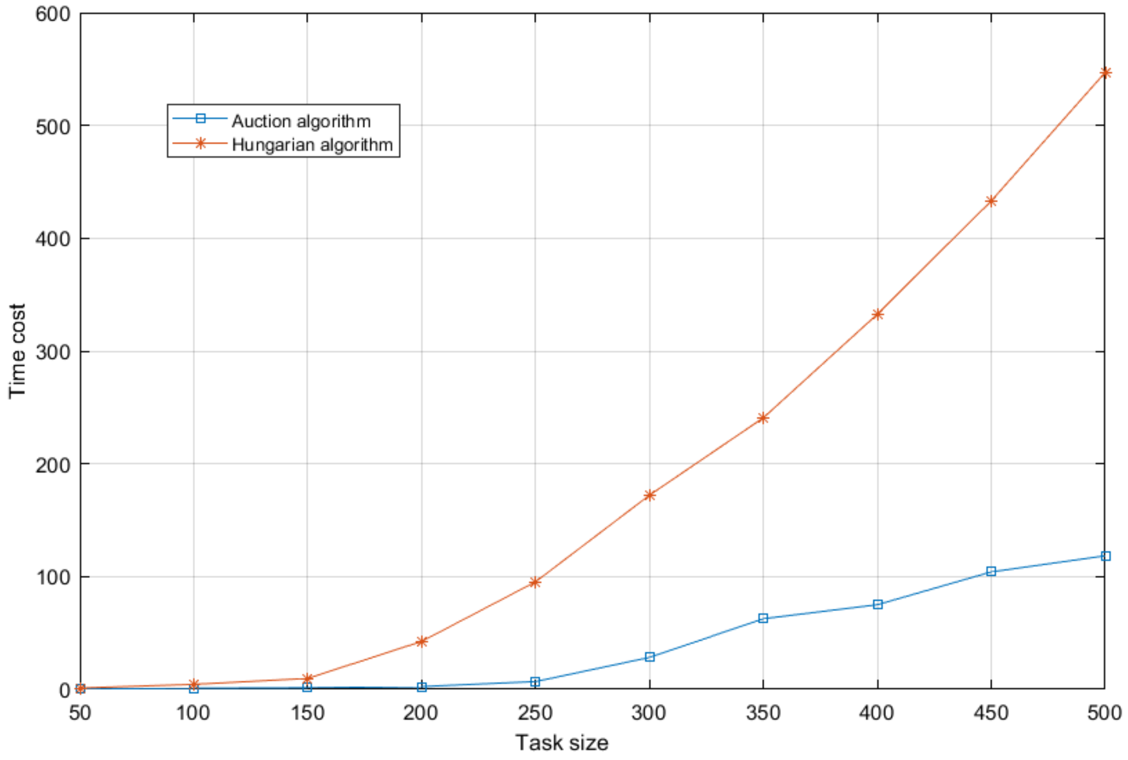
3 Experiment Results and Analysis

- Use randomly generated task cost matrix
- Choose the *Hungarian classical algorithm* for comparison.
  - ➢The Hungarian algorithm is a combination optimization algorithm, which is used to solve assignment problem.

3 Experiment Results and Analysis



3 Experiment Results and Analysis



The number of tasks has a greater impact on the running time of the *Hungarian algorithm* than the algorithm we proposed.

4 Conclusion and Future Work

- We propose a new auction model and use the auction algorithm to study multi-robot task allocation problem.
- Compared with the Hungarian algorithm, when the number of tasks is small, the auction algorithm has a lower time complexity and the same exact result.
- The proposed auction algorithm has excellent computational complexity.

4 Conclusion and Future Work

- A mechanism must be added to the auction algorithm to find out the infeasibility of the problem.
- Robots may need to stop their current work and carry out new tasks.
- The ability and preference of robots to perform certain tasks is not considered.
- For more urgent tasks, it should have priority and can be accomplished by more agents.