Application of Hungarian Algorithm for Assignment Problem

Ventseslav Kirilov Shopov and Vanya Dimitrova Markova

Institute of Robotics,
Bulgarian Academy of Sciences

Introduction

This article is in the field of creating formations of teams of autonomous robots. This study uses methods in the field of control theory, graph theory, robotics and AI. The question we are considering is the construction of an algorithm for determining the optimal bisection between the initial location of the robots and their positions in a predetermined formation.

Introduction

The aim of our study is to apply the decentralized Hungarian algorithm for moving each agent in the network to the position in a predetermined formation. Therefore, it is first necessary to assign each agent a unique position in the formation. Each agent will move to the assigned position, and over time the positions of the agents must match exactly those of the translated and rotated formation. In this article, we present the first results in the field of application and adaptation of the distributed Hungarian algorithm in the field of distributing groups of agents (robots) in a 2D working environment.

Hypothesis and criterion

The hypothesis is that we compare two algorithms: the original Kuhn-Munkres algorithm and the modified Distributed Kuhn-Munkers algorithm.

The comparison criteria are the sum of the distances that the robots have to travel to their positions.

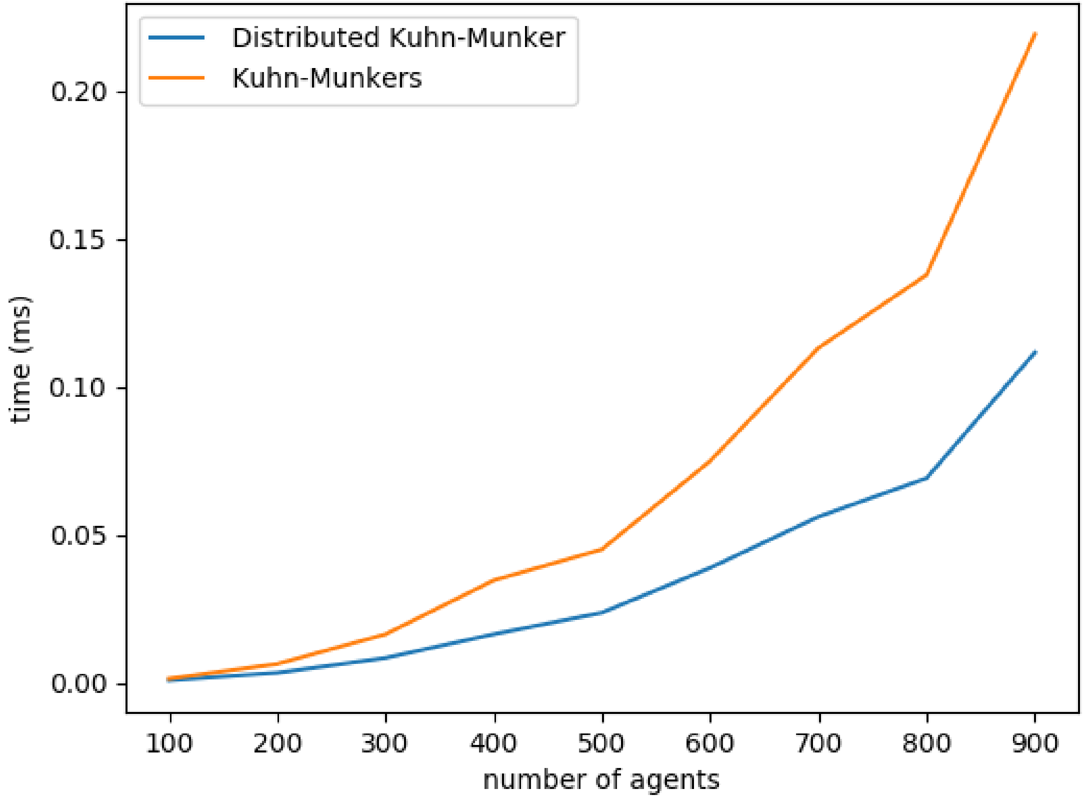
Experiment

The graph G is a fixed geometric graph, so the agents simply need to move to the corresponding positions. We consider cases with 4, 9, 16 and 81 agents randomly distributed in 2D space. The formation is described as a rigid geometric graph in the form of a grid 2x2, 3x3, 4x4, 9x9.

We investigate how the two algorithms behave in shitting the number of agents. On figure 1 one can see the results for the case when and number of agents is 100 to 1000 agents randomly distributed in a range of 0 to 1000 meters in a two-dimensional square field.

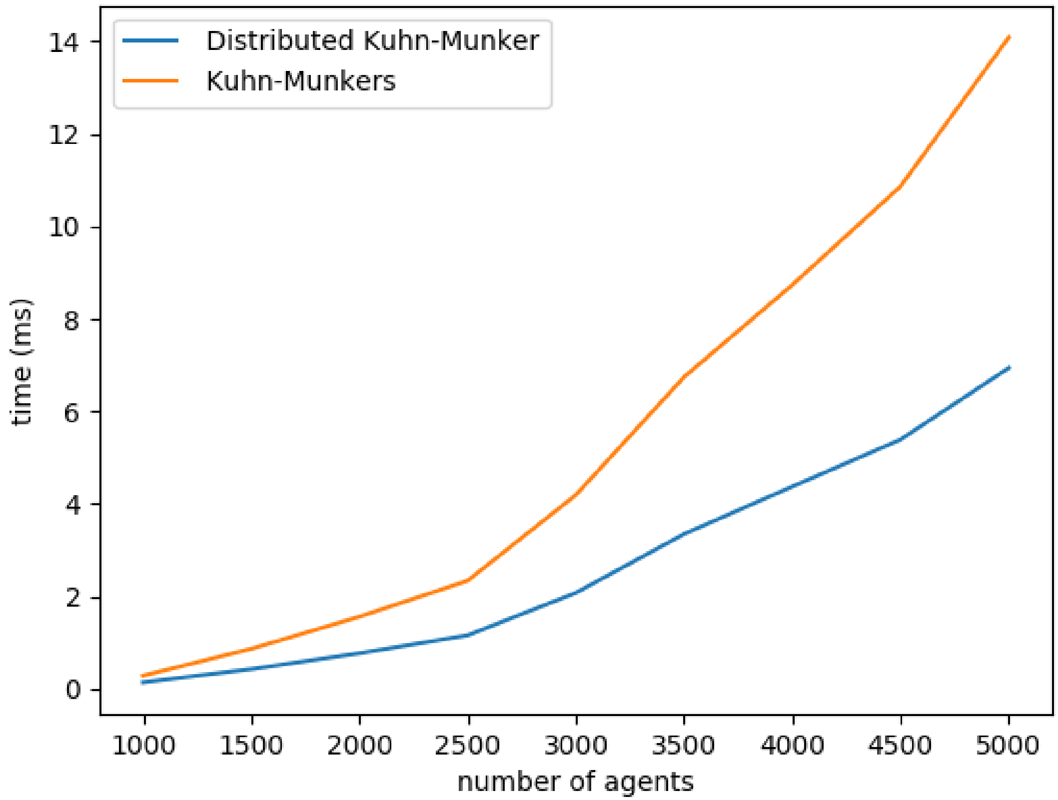
In the second experiment(fig. 2), we compute ten cases: from 1000 to 5000 agent evenly distributed in a square field with size and from 0 to 10000 meters. In the third experiment, we look at 1,000 to 10,000 agents in a square field from 0 1 to 15,000 meters.

Experiments



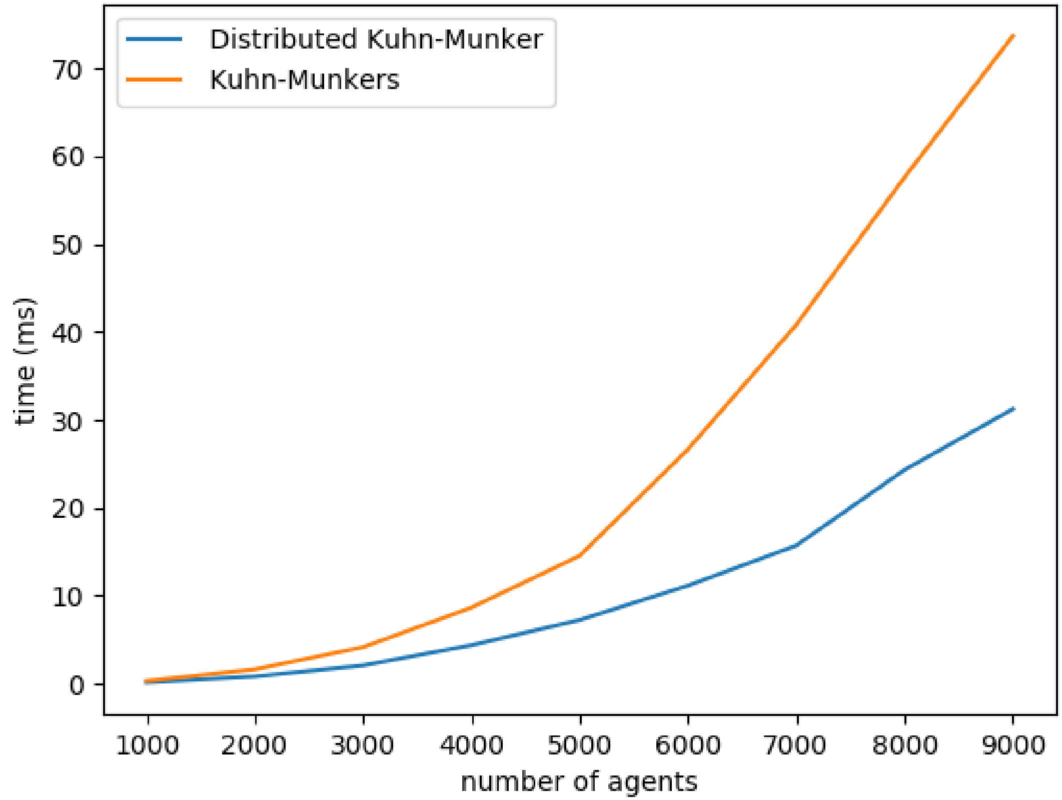
Comparison of Distributed Kuhn-Munkers and Kuhn-Munkers algorithms for range of number of agents from 100 to 1000

Experiments



Comparison of Distributed Kuhn-Munkers and Kuhn-Munkers algorithms for range of number of agents from 1000 to 5000

Experiments



Comparison of Distributed Kuhn-Munkers and Kuhn-Munkers algorithms for range of number of agents from 1000 to 9000

Experiment

The algorithms are easily scaled from N = 100 to N = 1000 and do not require any modifications for this. This shows that the position for setting and forming does not change, as each robot moves to its designated point. By checking, we can see that no robot should travel too far to reach its destination as we would expect. In addition, we can see that the centroid of the final configuration coincides with the centroid of the initial configuration. It should also be noted that in all three cases the trajectories of the robot do not intersect, even with 10000 robots.

Conclusion

In this study, we consider the application of a Hungarian algorithm for allocating positions in robotic formations. Two modifications of the Hungarian algorithm are compared: namely the Distributed Kuhn-Munkers and Kuhn-Munkers approach method. In theory, the first march for square matrices has O (n3) complexity and the modified variant has O (n2m). Experimental results show that for small values of the number of agents the difference is even smaller than theoretical.

As the number of agents increases, there is a significant slowdown in the Munkres approach. From the experiments made in this way, it can be concluded that it is desirable to use the Distributed Kuhn-Munkers approach even for a small number of agents.

REFERENCES

[1] T. Abeywickrama, Liang, V. and Tan, K.L.,. Optimizing bipartite matching in real-world applications by incremental cost computation. Proceedings of the VLDB Endowment, 2021, 14(7), pp.1150-1158.

[2] S. Chopra, Notarstefano, G., Rice, M. Egerstedt, A distributed version of the hungarian method for multirobot assignment. IEEE Transactions on Robotics, 2017. 33(4), pp.932-947.

[3] J. Yu, S.J. Chung, P.G. Voulgaris, ”Target assignment in robotic networks: Distance optimality guarantees and hierarchical strategies”, IEEE Transactions on Automatic Control, 60 (2), 2015, pp. 327-341

[4] R. Duan, Pettie, S.,. Linear-time approximation for maximum weight matching. Journal of the ACM (JACM), 2014, 61(1), pp.1-23.]

[5] Y. Dong, Gao, Y., Peng, R., Razenshteyn, I. and Sawlani, S.,. A study of performance of optimal transport. 2020, arXiv preprint arXiv:2005.01182.

[6] B.P. Gerkey, M.J. Matarić “A formal analysis and taxonomy of task allocation in multi-robot systems”, International Journal of Robotics Research, 23 (9), 2004, pp. 939-954

[7] G.A. Korsah, A. Stentz, M.B. Dias, “A comprehensive taxonomy for multi-robot task allocation”, International Journal of Robotics Research, 32 (12), 2013, pp. 1495-1512

[8] H.W. Kuhn, “The Hungarian method for the assignment problem”, Naval Research Logistics Quarterly, 1931-9193, 2 (1–2), 1955, pp. 83-97

[9] A. Mirzaeinia, M. Hassanalian, Minimum-cost drone–Nest matching through the Kuhn–Munkres algorithm in smart cities: energy management and efficiency enhancement. Aerospace, 2019, 6(11), p.125.]

[10] D. Morgan, G.P. Subramanian, S-J. Chung, F.Y. Hadaegh, “Swarm assignment and trajectory optimization using variable-swarm, distributed auction assignment and sequential convex programming” International Journal of Robotics Research, 2016, pp. 1-25

[11] AR Mosteo, E Montijano, D. Tardioli, “Optimal role and position assignment in multi-robot freely reachable formations”. Automatica. 2017 Jul 1;81:305-13.

[12] . Munkres, “Algorithms for the assignment and transportation problems”, Journal of the Society for Industrial and Applied Mathematics, 5 (1) , 1957, pp. 32-38

[13] E. Munapo, Development of an Accelerating Hungarian Method for Assignment Problems. Eastern-European Journal of Enterprise Technologies, 2020, 4(4), p.106.

Authors:

Ventseslav Shopov,
vkshopov@yahoo.com

Vanya Markova,
markovavanya@yahoo.com

Thank You!