CLAWAR 2018: 21st International Conference on Climbing and
Walking Robots and the Support Technologies for Mobile Machines,
Panama City, Panama, 10-12 September 2018

Scalable Task Cleanup Assignment for Multi-agents

Arata A. Saraiva[1]

UTAD University,Coimbra, Portugal
ORCID 0000-0002-3960-697X [1]E-mail: aratasaraiva@gmail.com

Costa. NJC[2]

State University of Piaui,
Piripiri, Piaui, Bazil
ORCID 0000-0001-5636-424X [2]E-mail: trisna@prp.uespi.br

Jose Vigno M Sousa[3]

State University of Piaui, Piripiri,Brazil
University Brazil, Sao Paulo, Brazil
ORCID: 0000-0002-5164-360X [3]E-mail: vigno@prp.uespi.br

Thelmo Pontes De Araújo[4]

Ceara state University, Fortaleza, Ceara, Brazil
[4]E-mail: thelmo.dearaujo@gmail.com

N. M. Fonseca Ferreira[5]

INESC-TEC Technology and Science, Campus da FEUP, Rua Dr. Roberto Frias, 378,
4200 - 465 Porto, Portugal,
Knowledge Engineering and Decision-Support Research Center (GECAD) of the
Institute of Engineering, Polytechnic Institute of Porto
Department of Electrical Engineering, Institute of Engineering of Coimbra,
Coimbra, Polytechnic Institute
Rua Pedro Nunes, 3031-601 Coimbra, Portugal
ORCID: 0000-0002-2204-6339 [5]E-mail: nunomig@isec.pt

Antonio Valente[6]

INESC-TEC Technology and Science
Campus da FEUP, Rua Dr. Roberto Frias, 378, 4200 - 465 Porto, Portugal
School of Science and Technology, University of Trás-os-Montes and Alto Douro,
Vila Real, Portugal
ORCID: 0000-0002-5798-1298 [6]E-mail: avalente@utad.pt

This paper describes a group of robots for cleaning a simulated environment and proposes an efficient algorithm for navigation based on Pathfinding A *. No need for vision sensors. As a result it was observed that the robots can work cooperatively to clear the ground and that the navigation algorithm is effective in cleaning. In order to test its efficiency it was compared the combination of the Pathfinding A* algorithm and the decision algorithm proposed in this paper with Pathfinding A* and Euclidean distance, resulted in an improvement in time and distance traveled.

Keywords: Multi robots; Cleaning; Cooperative work; Navigation.

1. Introduction

The issue of protecting the environment from pollution is necessary and especially by the fact that natural resources are under threat. The human impact on the environment is undeniable and can be altered by the use of autonomous robotics.

Utility companies can benefit by reducing routine work, reaching hard-to-reach regions, and can perform service at scheduled times.[1] During harvesting, the robot moves independently on the given surface, removing garbage from it. Having found an obstacle in the way, the robot decides a method to overcome it based on special algorithms.[2]

The type of autonomous system to be developed takes into account the possibility of combining several simple yet functional techniques that are already known in the literature to solve the problem of having mobile agents identify and follow to soar, dirty target.

In the project it is proposed to use Breadth First Search (BFS) to do the mapping using the target pattern. This target will be arranged in a plane position and orientation environment, so the Euclidean distance is used to plot the route. Based on these readings the positioning control would be applied so that it can follow the target within the environment. A comparison was made by merging the navigation algorithm Pathfinding A *, Euclidean distance and the algorithm proposed in this work with Pathfinding A *, Euclidean distance.

The document is divided into 5 sections, in which section 2 is characterized by the contextualization of the work. It follows the methodology applied in section 3. The results after the application of the proposal are presented in section 4 and the conclusion in section 5.

2. Contextualization of work

Surface cleaning robots are environmental protection equipment used primarily to collect garbage. According to the task requirements, they can be used to monitor the environment of parks, orchards, squares and accumulating information through sensors and performing dangerous operations such as search and rescue. They are also important tools in assessing environmental pollution, providing warnings and disaster prevention, which provides enormous economic and social benefits in addition to possible potential applications[34].[5]

One of the potential applications is in the work of[6] that a vacuum cleaning system is proposed integrated with a fuzzy inference system to improve the accuracy of the system. In[7] a system of automatic control of a room cleaning robot with cellular control capability using DTMF with the ability to avoid self-controlled obstacles, together with a system of cleaning of residues and dust is developed.

In[8] proposes an improvement in cleaning efficiency not because of obstacles and route planning. To solve this problem it develops a localization algorithm with the use of stereoscopic vision and wireless network. The use of multirobots for optimization of activities has been expanding[9] and in[10] a multi-area cooperative cover is applied to develop complex tasks where multiple robots are required to cover together in several areas. Practical operations such as garbage removal, demining and area scanning for information acquisition.[11]

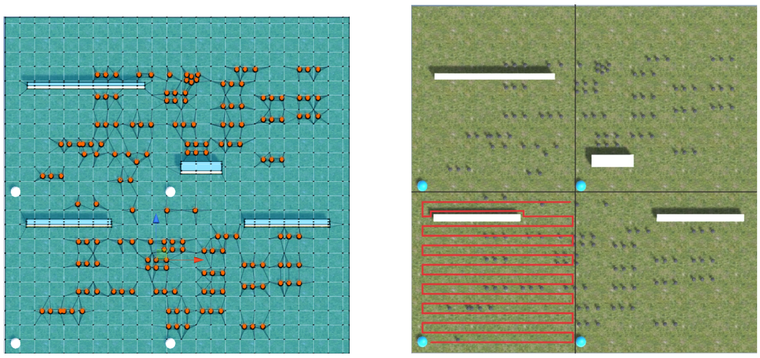
Based on this information a work was developed with the objective of constructing a group of robots in which the agents are able to share cleaning workloads automatically and in an intelligent way. In addition, it is programmed to detect obstacles around it and control the robot to avoid collisions. The metology adopted is detailed in the following section.

3. Methodology

In this article, the game engine, Unity 3D, was used as the simulation environment for natively presenting robust features for the development of the[12] simulation environment, as shown in figure 1.

The figure 1 (b) represents the area of action and division of the mapping, in quadrants of 50 x 50 meters and each agent is circled in blue. At this stage they are responsible for traversing the quadrant, analyzing and storing the location where it contains dirt particles. The mapping route of an agent in the lower left quadrant, in red color, is also demonstrated.

Communication between the robots was done through sockets.[13] As a search algorithm for mapping, BFS[14] was chosen to go through the quadrant, we can check the route in the 1 (b) figure. Next, a navigation mesh will be generated, figure 1 (a), and routes to the dirt points. At each frame the



(a) (b)

Figure 1.

agents calculate (algorithm 3.1) the closest point, this point must belong to only one agent.

A navigation mesh (NavMesh) has been created that consists of several two-dimensional convex polygons and defines which areas of an environment are likely to be traversed by agents. In other words, an agent can move within these unobstructed areas of the environment and Agents in a NavMesh can avoid collision detection checks with obstacles in the environment.[15]

NavMesh allows a large number of algorithms to search for graphics, and the algorithm discussed in this work was Pathfinding A* in each of the agents.[16] In the figure 1 (a) in blue, represents the finished mesh.

The algorithm Pathfinding A* is an algorithm capable of finding the shortest path,[17] it uses a function to determine which squares to traverse, according to equation 1.

$$f(n) = g(n) + h(n) \tag{1}$$

Where g is the cost of moving from a starting point to a given square,[17] oh (n) is the cost estimate of the ideal path from node n to destination.[17]

3.1. *Control Algorithm*

A priori is divided into two parts, mapping and cleaning. The BFS is the algorithm responsible for guiding the next point that the agent must follow in the mapping phase. The points were divided in the quadrant area and allowed to travel in a larger area. In order to perform the cleaning, two algorithms were used, one for navigation Pathfinding A* and the other, algorithm 3.1, for point selection. A test without the algorithm 3.1 was also performed to evaluate the performance of the algorithm.

In conjunction with the algorithms, a decision method was proposed, which evaluates the most advantageous point that the agent should move, to carry out the cleaning. It calculates the distance of all mapped points and takes the closest one. Subsequently, the distance of the other agents is calculated to the chosen point, if only the agent in question is the shortest distance, is moved to the point, otherwise it picks up another nearby point and remakes the calculation. The method described is represented in the 3.1 algorithm.

The actions are shown in the flowchart, Figure 2, demonstrates the operation of the two steps described, mapping and cleaning, it is possible to verify that the agent always checks if there are still points that need cleaning, the algorithm 3.1.

Algorithm 3.1 Method of decision

```
procedure NextPoint(agent, point)
    a ← ShorterDistanceThisAgent
    b ← ShorterDistanceOthesAgents
    if a < b then return nextPoint          ▷ Check if it's the closest
    else return nextInitial                 ▷ Return to starting point
```

4. Results

In this section we present the performance of the algorithms, mapping and control. In the tables 1 and 2, the time each agent finished cleaning, the amount of dirt points collected and the distance traveled are represented.

Based on the results obtained, represented in the tables 1 e 2, the algorithm 3.1 presents a gain in time and distance, representing a differential of 91.46 seconds faster and a saving of 482.77 meters.

The use of the BFS mapping algorithm in conjunction with Pathfinding A* has been shown to be efficient, since the function of BFS is to ensure that the search is linear, but since the scenario has the presence of obstacles it was necessary to integrate the two for better efficiency. In the tests performed the agents were able to map the area and find all points.

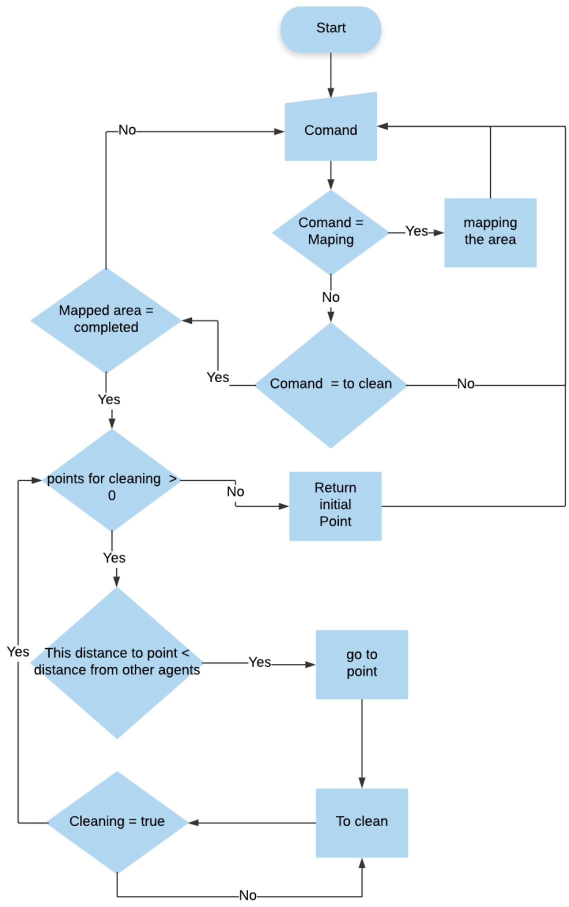


Figure 2. Control software flowchart

Table 1.

Agent	Time	Collected dirt	Travelled distance
5000	29.24 s	42	241.45 m
5001	35.45 s	49	295.57 m
5002	34.48 s	37	319.65 m
5003	27.16 s	40	242.17 m
Total	126.33 s	167	1098.84 m

Note: Pathfinding A*, algorithm 1

Table 2.

Agent	Time	Collected dirt	Travelled distance
5000	54.61 s	36	367.47 m
5001	54.52 s	39	438.39 m
5002	53.97 s	36	393.44 m
5003	54.69 s	56	382.31 m
Total	217.79 s	167	1581.61 m

Note: Pathfinding A*, Euclidian Distance

5. Conclusion

In this article we have demonstrated the use of algorithms already known in the literature in the aid of autonomous robotics, the agents were able to clean, map, route routes and avoid obstacles. Because it is more than one agent, a combination was proposed in the algorithm of navigation Pathfinding A * with algorithm of decision based on Euclidean distance, as a result obtained an improvement in the time performance and distance traveled.

Acknowledgments

This work is financed by the ERDF - European Regional Development Fund through the Operational Programme for Competitiveness and Internationalization - COMPETE 2020 Program within project POCI-01-0145-FEDER-006961,and by National Funds through the FCT - Fundação para a Ciência e a Tecnologia (Portuguese Foundation for Science and Technology) as part of project UID/EEA/50014/2013.

Bibliography

1. M. S. Couceiro, N. M. Fonseca Ferreira and R. Rocha, Multi-robot exploration based on swarm optimization algorithms, in *7th European Nonlinear Dynamics Conference ENOC*, 2011.
2. M. S. Couceiro, R. P. Rocha and N. M. Fonseca Ferreira, A novel multi-robot exploration approach based on particle swarm optimization algorithms, in *2011 IEEE International Symposium on Safety, Security, and Rescue Robotics*, Nov 2011.
3. K. R. Muske, H. Ashrafiuon, G. Haas, R. McCloskey and T. Flynn, Identification of a control oriented nonlinear dynamic usv model, in *American Control Conference, 2008*, 2008.
4. F. Y. Lee, B. H. Jun, P. M. Lee and K. Kim, Implementation and test of isimi100 auv for a member of auvs fleet, in *OCEANS 2008*, 2008.
5. J. Wang, W. Gu, J. Zhu and J. Zhang, An unmanned surface vehicle for multi-mission applications, in *Electronic Computer Technology, 2009 International Conference on*, 2009.

6. W. H. C. Wickramaarachchi, M. A. P. Chamikara and R. A. C. H. Ratnayake, Towards implementing efficient autonomous vacuum cleaning systems, in *2017 IEEE International Conference on Industrial and Information Systems (ICIIS)*, Dec 2017.
7. H. Rashid, A. Mahmood, S. Shekha, M. Rasheduzzaman and S. Reza, Design and development of a dtmf controlled room cleaner robot with two path-following method(12 2016).
8. K. R. Muske, H. Ashrafiuon, G. Haas, R. McCloskey and T. Flynn, Identification of a control oriented nonlinear dynamic usv model, in *American Control Conference, 2008*, 2008.
9. A. Saraiva, R. Melo, V. Filipe, J. Sousa, N. M Fonseca Ferreira and A. Valente, Mobile multirobot manipulation by image recognition, in *International Journal of Systems Aplications, Engineering and Development*, 2018.
10. B. Xin, G.-Q. Gao, Y.-L. Ding, Y.-G. Zhu and H. Fang, Distributed multi-robot motion planning for cooperative multi-area coverage, in *Control & Automation (ICCA), 2017 13th IEEE International Conference on*, 2017.
11. M. Couceiro, C. Figueiredo, R. P. Rocha and N. M. Fonseca Ferreira, Initial deployment of a robotic team - a hierarchical approach under communication constraints verified on low-cost platforms, in *2012 IEEE/RSJ International Conference on Intelligent Robots and Systems*, Oct 2012.
12. C. Bartneck, M. Soucy, K. Fleuret and E. B. Sandoval, The robot engine—making the unity 3d game engine work for hri, in *2015 24th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)*, Aug 2015.
13. M. Xue and C. Zhu, The socket programming and software design for communication based on client/server, in *2009 Pacific-Asia Conference on Circuits, Communications and Systems*, May 2009.
14. S. Beamer, K. Asanovic and D. Patterson, Direction-optimizing breadth-first search, in *High Performance Computing, Networking, Storage and Analysis (SC), 2012 International Conference for*, Nov 2012.
15. M. S. Couceiro, F. M. Martins, R. P. Rocha and N. M. Fonseca Ferreira, *Journal of Intelligent & Robotic Systems* **76**, 353 (2014).
16. W. van Toll, A. F. Cook and R. Geraerts, Navigation meshes for realistic multi-layered environments, in *2011 IEEE/RSJ International Conference on Intelligent Robots and Systems*, Sept 2011.
17. J. Hu, W. gen Wan and X. Yu, A pathfinding algorithm in real-time strategy game based on unity3d, in *2012 International Conference on Audio, Language and Image Processing*, July 2012.