

Self-Organised Multi-Agent Path Planning Based on STDMA

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Declaration of own work

I declare that the work in this MSc dissertation was carried out in accordance with the requirements of the University's Regulations and Code of Practice for Research Degree Programmes and that it has not been submitted for any other academic award. Except where indicated by specific reference in the text, the work is the candidate's own work. Work done in collaboration with, or with the assistance of, others, is indicated as such. Any views expressed in the dissertation are those of the author.

Name and Date

Acknowledgement

I would like to thank ...

Abstract

Abstract should give a short summary of the motivation, the approach and important insights and results.

Number of words in the dissertation: words.

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1 Introduction

1.1 Aims

Based on the self-organised channel resource allocation principle of the STDMA (Self-organised Time Division Multiple Access) [1] communication protocol, develop a method for agents to achieve collision-free moving on a 2D plane, make it self-organised, decentralised and scalable.

1.2 Objectives

- Develop a multi-agent communication scenario with STDMA in ROS2. In this scenario, multiple identical agents will share the same channel and all agents have both receiving and transmitting capabilities. The goal is to enable agents to autonomously organise/join the communication process after start up.
- On the basis above, a grid world is implemented: a 2D map composed of grids, each grid represent a part of space. Agents could move from one grid to another in the map.
- ...

1.3 Motivation

The motivation of this project is to answer a question inspired by [2], which is:

What will happen if use STDMA for 2D resource sharing?

The detailed explanation of the motivation is as follows.

1.3.1 Why STDMA?

What is STDMA? The *Self-organised Time Divided Multi Access* (STDMA) is a channel access technique for communication. It is based on a set of policies dictating how agents ought to apply for slots in repeating frames. In short, STDMA is a protocol that allows agents to autonomously share 1D resources (time) among themselves.

The reason for using STDMA is its **characteristics**:

1. **Deterministic**: Agents arrange their data transmission based on a determined timetable.
2. **Decentralised**: Agents listen to the channel first, then find free slots in the timetable for themselves to use.

These characteristics could be useful for multiple agents to achieve collision-free (use free slots only), self-organised (find slots on its own) resource sharing.

There are also two **reasons that making this challenging**:

1. **Purpose difference**: In the original STDMA, an agent only needs to find one unused slot in the repeating frame (which is generally of a fixed length chosen manually) and maintain ownership of that slot, which means agents don't need to move from one slot to another slot, i.e., don't have destination in the channel allocation timetable. But that's different for 2D space moving, where agents have their destinations and need to move grid by grid to reach their goals.
2. **Complexity difference**: Channel sharing only requires randomly selecting one slot from the known free slots, while space sharing in a 2D plane requires the agent to find a path that doesn't collide with other agents, and the possibility space for the path could be enormous (map size \times predicting horizon), but the processing time available to the agent is limited (must broadcast its presence at regular intervals so that other agents can be aware of its plans and thus avoid collisions).

These characteristics and challenges make this project interesting and worthy of research.



Figure 1.1: Kiva system operating in Amazon warehouse².

1.3.2 Why 2D plane path planning?

2D plane path planning is a name for better understanding and is not the accurate name for this problem. This problem is actually a **Multi-Agent Path Finding (MAPF)** problem [3], [4].

Here, the term "finding" could be somewhat confusing. In fact, the MAPF problem combines both **collision-free movement** of multiple agents and **path efficiency optimising**.

Overall, the problem of *Multi-Agent Path Finding* (MAPF) concerns **the movement of multiple agents in a grid world**.

To easily get a better understanding of this problem, please refer to this website¹. The website presents the MAPF problems and their solutions through a simple and engaging animation (estimated time required: 1~2 min).

MAPF algorithms have broad prospects for use.

- **Warehouse Automation:** Pick-pack-and-ship system in warehouse (like Fig 1.1). Delivering items in sorting station [5], [6].
- **Intersection Management:** Coordinate autonomous vehicle movement through intersections [7].
- **Robot Fleet:** Automating fleets of autonomous robots like forklift fleets [8], [9].

¹<https://primalgrid.netlify.app/primal>

²<https://spectrum.ieee.org/interview-brad-porter-vp-of-robotics-at-amazon>

- **Agents in video games and CGIs:** Flock simulating and animating[10], [11].
- **Swarm Robots:** Controlling self-organised robot swarms[12].

In general, the application of this algorithm is very broad. Furthermore, in the context of Industry 4.0 and flexible manufacturing, it has even better prospects for application[13]–[15], as centralized control is gradually becoming inadequate to meet new production needs.

2 Literature Review

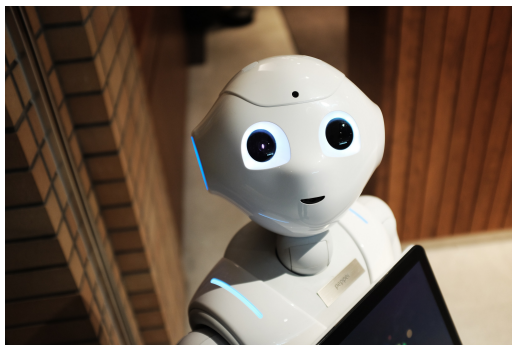
Use your literature review to help the reader to understand the value and the interest in your project. You should look for related works already published that either support the merit of your project, or provide the background understanding/information to make your new claims. Try to avoid writing a "catalogue" of related works (e.g this would have little of your own insight added). Instead, describe to the reader why the related work is interesting or relevant to your own work. What did they achieve? What did they overlook? It is highly recommend you finish your Literature Review with a final subsection "Summary", where you may wish to formulate highly specified research questions or hypotheses, or assert the need for your Research Methodology (next chapter).

introduction literature review implementation research methodology results

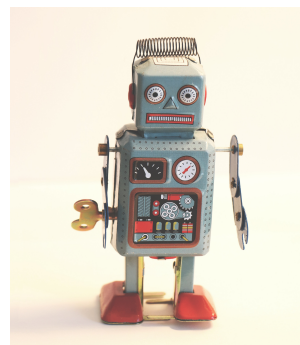
2.1 This is a section

2.1.1 This is a subsection

This is subsubsection



(a) This is a robot.



(b) This another robot.

Figure 2.1: These are two robots

For example, [16] discusses the two robots depicted in Figure 2.1. There is a robot in Figure 2.1a and another robot in Figure 2.1b.

3 Research Methodology

The Methodology section should provide a clear explanation of the research approach. You want your reader to agree that you carefully considered your method so that we can trust your results to be both insightful (mean something) and credible (not subject to error):

- A clear description of the methodology, how it creates a scientific investigation and operates to collect meaningful data.
- A clear justification of why you have chosen this particular approach.
- Information needed for a reader to understand how you did it (can a reader reproduce your work, and collect equally valid results? e.g. hardware/software used, configuration, number of trials, any procedures used, etc.)
- A description of any approaches taken to process collected data, e.g. metrics are used to combine data in a meaningful way - you should state any used explicitly, their utility, their suitability to your methodology and their limitations.

As one can see in Table 3.1 there are numbers involved.

Frame number	User 1 state	User 2 state	Resulting state
n	0	0	1
n+1	0	1	2
n+2	1	0	3
n+3	1	1	4

Table 3.1: An example of a table.

For example, if $x > 0$ then we can write

$$\sigma = \int_{x=0}^{\infty} \frac{1}{x^2} dx \quad , \quad (3.1)$$

where σ is the integral (see Equations 3.1).

4 Results

The Results section should provide

- An overview of all obtained results
- An in detail discussion/explanation of all results
- A scientific interpretation of the results

4.1 Common attributes to pay attention to are:

- When comparing plots, keep the scale of axes consistent. To do otherwise is misleading for the reader.
- If you are going to compare separate plots, consider if they can be better evaluated when combined into a single plot.
- When plotting data, particularly the *mean*, ensure that you also plot error bars (or other method) of indicating the distribution.
- If a figure or plot is included, ensure it is referenced explicitly in the body text discussion.
- When a large table of data is included, consider whether it would be better communicated as a box-plot or something similar.
- All axes should be labelled and include units of measurement where applicable.
- All captions and figures should have captions with enough information to be understood at a glance. Do not use captions to provide information that is better placed in the body text.
- Remember to identify result outliers and anomalous data and to attempt an explanation or justification.

5 Discussion and Conclusion

The conclusion needs to provide

- A short summary (What has been done and what are the main results)
- Limitations of your work, where applicable.
- Discussion of your work in the bigger picture (How does this contribute to the research field?)
- Future work (What could be next steps in this work?). Remember to keep future work realistic. A good approach is to discuss what the next progression of this project would be, and to justify why this would be interesting.

You will find it easier to write your conclusion if you copy-and-paste your *Aims*, *Objectives*, and any research questions or hypotheses you stated. You can then discuss each of these explicitly in turn, and how you were able to answer them or complete them successfully. When things have not gone as well as you would have hoped, demonstrate your critical thinking and reasoning to analyse the short-comings of your project - to demonstrate that you understand the underlying causes and that you could conduct good futurework from this learning experience.

A Appendix

This is optional. Not every report needs an appendix. If you have additional information like code pieces, long tables, etc. that would break the flow of the text in the report, you can put it here.

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