Decentralised Multi-Agent Path Planning based on Self-Organised Time Division Multiple Access

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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.

Contents

List of Tables

1 Introduction

1.1 Brief Introduction

The main idea of this project is to attempt to utilise the principles of a decentralised channel sharing communication protocol (*Self-organised Time Division Multiple Access*, STDMA[1]) to achieve collision-free movement among multiple decentralised agents on a 2D plane.

1.1.1 Principles of STDMA

In STDMA, a 1D channel is represented with repeating frames that are consisted of discrete time slots.

STDMA enables agents to achieve **S**elf-organised **T**ime-**D**ivided **M**ulti-**A**ccess within the channel. That is, each agent independently finds a slot which is uniquely its own and uses this slot to broadcast its message.

The key idea of STDMA is to determine empty slots and apply for them.

This idea also works for collision-free moving on 2D plane —— to determine free space and apply for usage.

For detailed explanation about STDMA, please see **PLACEHOLDER**.

1.1.2 The 2D Plane

The 2D plane used in this project is represented with discrete pixels / grids, just like the STDMA protocol represents continuous time with discrete slots.

For such a representation of a 2D plane, there is a term called **grid world**[2].

For detailed assumptions, please see **PLACEHOLDER**.

1.1.3 Agents

To meet the requirement of decentralisation, the agents are assumed to be identical.

The agents can:

- Broadcast and receive messages in the given channel, but cannot do both at the same time (i.e., cannot be listening while speaking or speaking while listening).

- Move only one step / one grid in the map in one time step.

For detailed assumptions, please see **PLACEHOLDER**.

1.2 Aims

- Based on the idea of STDMA, design an algorithm for decentralised agents to achieve colission-free movement and space sharing on 2D plane.

- Evaluate the advantages and drawbacks of the designed algorithm, and therefore get a better understanding on the problem that the alrogithm aims to solve.

1.3 Objectives

1. Implement original STDMA communication protocol with ROS2, use nodes in ROS2 as agents in the channel, achieve self-organised channel sharing and communicating among agents.

2. Design the specific algorithmic content for agents to achieve collision-free movement.

3. Implement the designed algorithm with ROS2, use ROS2 nodes as agents moving on the 2D plane.

4. Build proper test scene and performance evaluator that could extract metrics (makespan, average finish time, etc.) from simulations.

5. Examine the advantages, disadvantages and limitations of the designed algorithm, summarize the results from observations.

1.4 Motivation

The motivation of this project is to answer a question which is inspired by [3], which is:

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

And this quesiton could be seperated to the following two parts:

1.4.1 Why STDMA?

1.4.2 Why 2D reource sharing?

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).

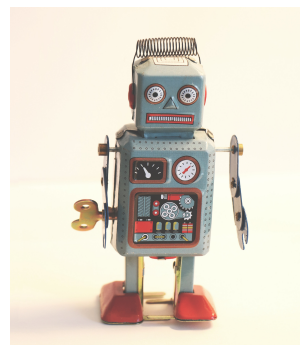introduction literature review implementation research methodology results

2.1 This is a section

2.1.1 This is a subsection

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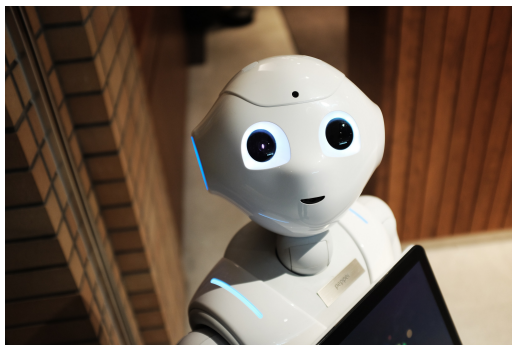
(a) This is a robot.

(b) This another robot.

Figure 2.1: These are two robots

For example, [4] 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 on 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

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

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.

References

[1] T. Gaugel, J. Mittag, H. Hartenstein, S. Papanastasiou, and E. G. Ström, *In-depth analysis and evaluation of self-organizing tdma*, 2013. DOI: `10.1109/VNC.2013.6737593`.

[2] B. Guillaume, World representation in artificial intelligence, in *Encyclopedia of Computer Graphics and Games*, N. Lee, Ed. Cham: Springer International Publishing, 2020, pp. 1–10, ISBN: 978-3-319-08234-9. DOI: `10.1007/978-3-319-08234-9_308-1`. available from: `https://doi.org/10.1007/978-3-319-08234-9_308-1`.

[3] E. F. Asadi and A. Richards, Scalable distributed model predictive control for constrained systems, *Automatica*, vol. 93 2018, pp. 407–414, 2018.

[4] D. Olivaw and I. Asimov, Discussion of two robots, *Nature*, vol. 548, no. 7665 2021, pp. 43–51, 2021.