Degree Project in Computer Science

Second cycle, 30 credits

3D Boids in Safety-critical Collapsed Building Search and Rescue Scenarios Represented by Artificial Potential Fields

A subtitle in the language of the thesis

LINUS WALLIN

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Abstract

Search and rescue (SAR) teams are a key part of finding missing people in the event of a natural catastrophy. To increase the likelihood of finding the missing people in SAR scenarios and reduce the time to do so, autonomous or teleoperated robots and multi-robot systems have become a key tool in aiding the SAR teams. The robots can help SAR teams map the area, monitor, or search for the vicitms in multiple different types of SAR scenarios.

A common factor for the SAR scenarios is that time is of the essence, since the missing person might be in a critical health state. The issue with having a SAR team controlling the drones is that only one drone can be controlled by one person. By using swarm robotics it is possible for SAR teams to use a large amount of drones to cover larger areas and find the missing people faster.

There are different swarm robotics algorithms and it is in the publics interest to test them all on SAR scenarios, to see which is the best. One algorithm that could be used in SAR scenarios is the boids algorithm in combination with a control barrier function (CBF) that reduces collisions. This paper aims to explore the possible benefit of guiding the boids algorithm with a artificial potential field (APF).

The boids algorithm and potential field will be evaluated on X SAR scenarios that highlight different aspects of real SAR operations.

The findings suggest that ...

Keywords

Boid, Search and Rescue, Safety-critical, Artificial Potential Field

Sammanfattning

Nyckelord

Boid, Räddningsaktion, Säkerhets Kritisk, Artificiellt Potential Fält

Acknowledgments

I would like to thank xxxx for having yyyy. Or in the case of two authors: We would like to thank xxxx for having yyyy.

Stockholm, August 2025
Linus Wallin

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Chapter 1

Introduction

1.1 Background

Search and rescue (SAR) can be aided by autonomous or teleoperated robots and multi-robot systems, which can help the SAR teams map the area, monitor, or search for victims. There are multiple SAR scenarios in which robots can aid the rescuers, where one such scenario category is urban SAR in which small robots can be used to find their way through collapsed buildings or other urban environments[1].

As earthquakes are very serious disasters which can be fatal due to buildings collapsing and trapping people, it is important that the victims can be found and get help fast. This is an area in which research has been done on multi-agent systems and how they can be used for collapsed building SAR scenarios.[2]

My project will build on the paper by Hengstebeck, et al.[3] which explores the usage of 2D boids in SAR scenarios. Their paper adds ghost boids to the boids algorithm in order to reduce collisions and direct the boids towards a target with a set strength. To reduce the amount of collisions further, Hengstebeck, et al.[3] implemented a control barrier function (CBF).

I will begin my project with implementing the proposed boids algorithm, but in 3D, and also adding the CBF to reduce collisions. The goal is then to expand on it by adding a high level planner (HLP)[4] in the form of an artificial potential field (APF)[5] and explore how it affects the 3D boids SAR algorithm.

The project is of interest to SAR organizations and the general public, as it could lead to advancements in SAR methods which help individuals in difficult scenarios. Collapsed building SAR scenarios are not that common in Sweden, as we do not have high magnitude earthquakes. Although I want to focus on these scenarios in this project, the results might be transferable to other areas that are more relevant in Sweden. Areas that this could be applicable in would be scenarios with fires in buildings or other urban SAR scenarios which might be more of interest to Swedish society.

The high level objective of the degree project is to contribute to the field of SAR by presenting an improvement of the methods that currently used find targets in collapsed building scenarios. The goal is to increase the efficiency of the rescuers by giving them the tools which would allow them to scout a larger area faster than they could without the tools.

1.2 Problem Description

1.3 Research Question

This thesis explores the possible benefits of guiding boids with a APF representing the scenario environment. It also explores the importance of CBF and how it affects the boids algorithm in combination with the APF.

RQ1: *How does target-seeking affect the 3D boids algorithm in terms of coverage, safety, and number of boids that are able to find the target location?*[3]

RQ2: *How does adding a CBF to the boids algorithm affect the 3D boids algorithm in terms of coverage, safety, and number of boids that are able to find the target loctaion?*[3]

RQ3: *How does adding a high level planner in the form of a artificial potential field affect the 3D boids algorithm in terms of coverage, safety, and number of boids that are able to find the target.*[3][5]

1.3.1 Research Methodology

The research will have a quantative approach, where the different algorithms will be compared to each other in simulations on various SAR scenario environments.

1.4 Purpose

The purpose of the thesis is to provide insight into the potential of APF in combination with the *boids algorithm* to find missing people in SAR scenarios with collapsed buildings.

1.5 Delimitations

Altough the goal is to provide valuable information about how well APF in combination with the boids algorithm could do in real collapsed building SAR scenarios, the focus of the project will not be to create realistic scenarios nor take into account for everything that could affect the agents in real life.

One of the delimitations for the project will be that it will not take into account how the drone would have to adjust in real life to achieve the movement in the simulation. This could lead to the agents movement not being completely realistic.

Another delimiation of the project will be that delays in signal processing will not be considered for both the communication between the different agents in the scene and the potential delays in the hardware of the real life drones. This should not make much of a difference, since the delays in todays drone hardware is quite low.

1.6 Structure of the thesis

Chapter 2

Background

2.1 Summary

Chapter 3

Methods

3.1 Overview

3.2 Implementing Boids

3.3 Implementing Control Barrier Function

3.4 Implementing Artificial Potential Field

3.5 Combining Boids with Control Barrier Function

3.6 Combining Boids with Artificial Potential Field

3.7 Hardware/Software

The thesis was implemented in Unity 6 and the simulations were run on a windows based computer with AMD Ryzen 5 CPU and a Nvidia 1080ti GPU.

3.8 Assessing reliability and validity of the data collected

3.8.1 Validity of method

3.8.2 Reliability of method

3.8.3 Data validity

3.8.4 Reliability of data

3.9 Planned Data Analysis

3.9.1 Data Analysis Technique

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4.3 Validity Analysis

Chapter 5

Discussion

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5.2 RQ2:

5.3 General Research Question

5.4 Limitations

5.5 Future work

Chapter 6

Conclusions and Future work

6.1 Conclusions

6.2 Reflections

References

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