Low Cost Sensor Monitoring using Mesh Connected Ultra-Low Power Long-Range Transceivers

by

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Declaration

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Abstract

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Thesis: MEng (EE)

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Vibrating a tillage tool is an effective way of reducing the draft force required to pull it through the soil. The degree of draft force reduction is dependent on the combination of operating parameters and soil conditions. It is thus necessary to optimize the vibratory implement for different conditions.

Numerical modelling is more flexible than experimental testing and analytical models, and less costly than experimental testing. The Discrete Element Method (DEM) was specifically developed for granular materials such as soils and can be used to model a vibrating tillage tool for its design and optimization. The goal was thus to evaluate the ability of DEM to model a vibratory subsoiler and to investigate the cause of the draft force reduction.

The DEM model was evaluated against data ...

Uittreksel

Lae Koste Sensor Monitor Systeem wat Mesh-Verbind, Ultra-lae Krag, Lang Aftstands Versenders Gebruik

("Low Cost Sensor Monitoring using Mesh Connected Ultra-Low Power Long-Range Transceivers")

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Tesis: MIng (EE)

Maart 2021

Om ‘n tand implement te vibreer is ‘n effektiewe manier om die trekkrag, wat benodig word om dit deur die grond te trek, te verminder. Die graad van krag vermindering is afhanklik van die kombinasie van werks parameters en die grond toestand. Dus is dit nodig om die vibrerende implement te optimeer vir verskillende omstandighede.

Numeriese modulering is meer buigsaam en goedkoper as eksperimentele opstellings en analitiese modelle. Die Diskrete Element Metode (DEM) was spesifiek vir korrelrige materiaal, soos grond, ontwikkel en kan gebruik word vir die modellering van ‘n vibrerende implement vir die ontwerp en optimering daarvan. Die doel was dus om die vermoë van DEM om ’n vibrerende skeurploeg the modelleer, te evalueer, en om die oorsaak van die krag vermindering te ondersoek.

Die DEM model was geïvalueer teen data ...

Acknowledgements

I would like to express my sincere gratitude to the following people and organisations ...

Dedications

Hierdie tesis word opgedra aan ...

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Nomenclature

Constants

g =	$9.81\,\mathrm{m/s^2}$	

Variables

Re_{D}	Reynolds number (diameter)	[ ]
x	Coordinate	[m]
$\ddot{x}$	Acceleration	[$\mathrm{m/s^2}$]
θ	Rotation angle	[rad]
τ	Moment	[N·m]

Vectors and Tensors

$\overrightarrow{\boldsymbol{v}}$	Physical vector, see equation ...

Subscripts

a	Adiabatic
a	Coordinate

Chapter 1

Introduction

1.1 Background

Unmanned Aerial Vehicles (UAVs) are a technology that have gained popularity in various applications recently[1]. Originally, UAVs required a ground pilot to manoeuvre them, but are becoming an increasingly automated technology. Applications where UAV automation has been used include, but are not limited to, structure inspections[2], smart farming[3], disaster management[4], power line inspections[5], surveillance[6] and wildfire tracking[7].

Most of the research mentioned was done on the premise of using multi-rotor UAVs, quad-rotor vehicles in particular. It is important to note that the term UAVs also encompasses other aircraft types, like single rotor and fixed wing UAVs. Hybrids also exist that contain both rotary-wing and fixed-wing components[1].

Using UAVs poses a considerable advantage in applications like the ones mentioned when compared to unmanned ground vehicles (UGVs). Their capacity to fly over landscapes and around three dimensional structures makes their potential applications increase substantially. Relatively high altitude flying is a key reason why they are well suited to the application suggested in this paper, which is coverage path planning for search and rescue missions.

Coverage path planning (CPP) is a variant of the general motion planning problem. Originally, motion planning algorithms were predominantly used to find solutions for start-goal problems[8]. This implies finding a sequence of actions to get an object from some starting state to some goal state. An example would be finding a sequence of movements to get a robotic arm from one orientation to another. In the context of path planning it means getting an agent, a UAV for example, from some starting position to some goal position in an environment[9].

Coverage path planning is different from start-goal path planning in that it tries to determine a path for an agent to pass over all points in an environment[8]. It can be used with ground vehicles, for example, to automate field machines for smart farming[10]. Further examples include vacuum cleaning robots, spray painting robots[11], window cleaning robots[12] and automated lawn mowers[13]. For underwater vehicles it can be used for the inspection of difficult to reach underwater structures[14].

Furthermore, there have been developments in the use of UAVs to perform automated search and rescue operations using coverage path planning. Perhaps the most notable example is a project by DroneSAR where they use DJI drones to perform search and rescue tasks. Their implementation includes a mobile application that allows the user to designate a search area manually[15]. Search and rescue operations often span large areas and UAVs fly above most ground obstacles. Therefore, it is realistic to assume the environment can be mapped prior to the search operation[16].

DroneSAR uses one drone per search and rescue operation. Once the environment has been designated, the drone performs a back and forth manoeuvre across the area to achieve coverage. The search operation can be halted if the imaging system detects a possible target in the area. The drone can be switched to manual flight mode for closer inspection and the co-ordinates of the target, for example a person in turmoil, can be sent to the search and rescue team. Their system also allows for the manual assignment of way-points to a flight path to bypass the back and forth manoeuvre.[17]

In figure 1.1, a screenshot of their mobile application is shown. It illustrates the back and forth manoeuvre used to achieve coverage of the designated area.

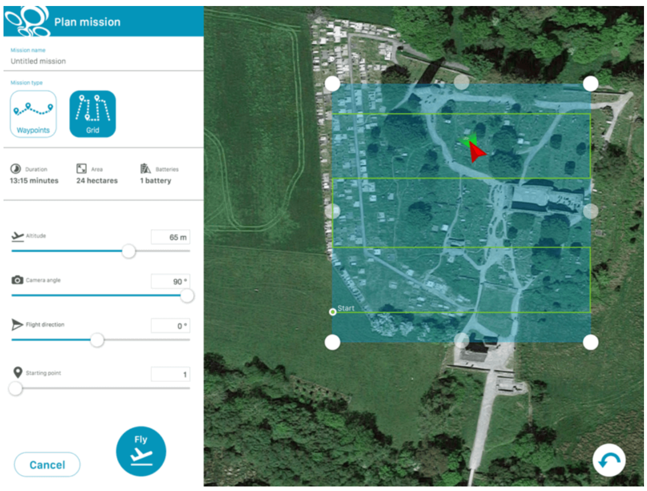

Figure 1.1: DroneSAR Mobile Application Showing Coverage Plan[15]

This paper also looks at coverage path planning for search and rescue, but suggests a multiple UAV approach to the problem. According to [15], when looking for a victim in a one square kilometre area on land, it takes a five-person rescue team two hours on average to find the victim. DroneSAR found that their drone could do the same job in under 20 minutes. Adding multiple

UAVs to cover an area could reduce this time even more, since it would mean more area is covered per unit time. This is important because in a search and rescue operation, time is always of the essence.

This paper also focuses on a grid-based approach to the coverage problem. According to the taxonomy represented in [8], this is referred to as an approximate method. Although one can achieve complete coverage of the grid, the grid itself is not an exact representation of the environment. It does, however, greatly simplify the process of allocating areas to different UAVs, which is a key process for multiple UAV coverage. Physical implementation of this method will not be addressed as part of the scope for this paper.

1.2 Research Aim

The main goal of this research is to develop a coverage path planning algorithm for multiple unmanned aerial vehicles (UAVs) to search an area. The research is intended to be applicable in search and rescue operations using unmanned aerial vehicles to assist.

1.3 Research Objectives

Based on the main aim of this project set out in section 1.2, a set of research objectives were formulated. These are intended to give a clearer picture of the main research goals and scope of the project. Scope and limitations are further discussed in section 1.4 and the methodology used to achieve these objectives are detailed in section 1.5.

1.4 Scope and Limitations

1.5 Methodology

1.6 Thesis Structure

Chapter 2

Literature Review

2.1 Coverage Path Planning

2.2 Divide Areas Algorithm

The previous section discusses alternatives to using the divide areas approach.

2.3 Individual Area Search

The previous section discusses the divide areas approach that is used in this report. Due to the use of this method, it is important to discuss the different techniques that can be used to search the areas allocated to each robot.

Chapter 3

Divide Areas Algorithm

3.1 Background

Chapter 4

Verifying SatSim Results

4.1 Scope

In granular or particle flow simulations with Discrete Element Method (DEM), the mechanical behavior of a system of particles are simulated. The basic building blocks of DEM are finite sized particles and walls. It is generally classified into two basically different approaches.

The first is the "hard sphere", event-driven method , where particles are assumed to be perfectly rigid and they follow an undisturbed motion until a collision occurs. Due to the rigidity of the interaction, the collisions occur instantaneously with accompanying momentum transfer. It is mainly used for collisional, dissipative granular gases.

The second is the so-called "soft particle" molecular dynamics pioneered by each other. Constrains on the physical space that a particle can occupy at a specific time is included with contact or penalty forces related to the amount of overlap and contact velocity between particles or between particles and walls. The motion of the system is modelled by the integration of Newton-Euler equations for motion of every individual particle.

Chapter 5

Hardware Selection

5.1 Scope

In granular or particle flow simulations with Discrete Element Method (DEM), the mechanical behavior of a system of particles are simulated. The basic building blocks of DEM are finite sized particles and walls. It is generally classified into two basically different approaches.

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Chapter 6

Hardware Design with Software Implementation

6.1 Scope

In granular or particle flow simulations with Discrete Element Method (DEM), the mechanical behavior of a system of particles are simulated. The basic building blocks of DEM are finite sized particles and walls. It is generally classified into two basically different approaches.

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Chapter 7

Hardware Verification and Comparison to SatSim

7.1 Scope

In granular or particle flow simulations with Discrete Element Method (DEM), the mechanical behavior of a system of particles are simulated. The basic building blocks of DEM are finite sized particles and walls. It is generally classified into two basically different approaches.

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Chapter 8

Conclusions

8.1 Scope

In granular or particle flow simulations with Discrete Element Method (DEM), the mechanical behavior of a system of particles are simulated. The basic building blocks of DEM are finite sized particles and walls. It is generally classified into two basically different approaches.

The first is the “hard sphere”, event-driven method where particles are assumed to be perfectly rigid and they follow an undisturbed motion until a collision occurs. Due to the rigidity of the interaction, the collisions occur instantaneously with accompanying momentum transfer. It is mainly used for collisional, dissipative granular gases.

The second is the so-called “soft particle” molecular dynamics pioneered by where the particles are allowed to overlap or penetrate each other. Constrains on the physical space that a particle can occupy at a specific time is included with contact or penalty forces related to the amount of overlap and contact velocity between particles or between particles and walls. The motion of the system is modelled by the integration of Newton-Euler equations for motion of every individual particle.

Appendices

Appendix A

Discrete Element Method Theory

A.1 Ball elements

A.1.1 Ball mass and inertia parameters

Consider a volume element $\mathrm{d}V$ with respect to a static base S of an arbitrary solid body with density ρ. The mass of the body is obtained by integrating over the volume of the body,

$$m = \int_{\text{body}} \rho \, \mathrm{d}V \tag{A.1}$$

In figure A.1, a ball with radius R_i and uniform density ρ_i is depicted. The mass of the ball is after integration of equation (A.1)

$$m_i = \tfrac{4}{3}\pi\rho_i \, R_i^3. \tag{A.2}$$

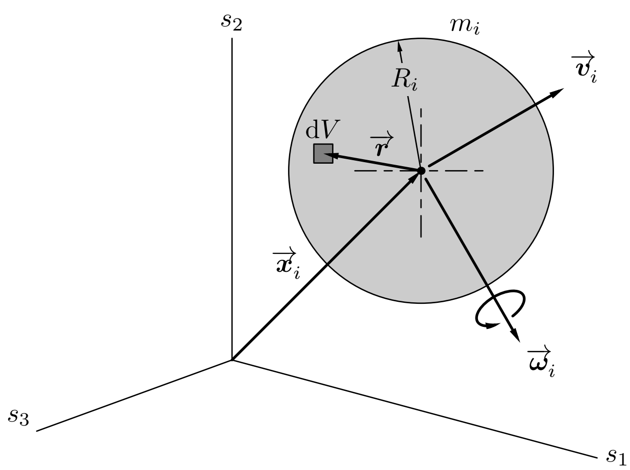

Figure A.1: Ball Element Parameters

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