

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

by

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*Thesis presented in partial fulfilment of the requirements for  
the degree of Master of Engineering (Electrical and  
Electronic) in the Faculty of Engineering at Stellenbosch  
University*

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# Declaration

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# Abstract

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

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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 Sisteem 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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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 te modelleer, te evalueer, en om die oorsaak van die krag vermindering te ondersoek.

Die DEM model was geëvalueer 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

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

## Variables

$Re_D$	Reynolds number (diameter) . . . . .	[ ]
$x$	Coordinate . . . . .	[m]
$\ddot{x}$	Acceleration . . . . .	[m/s <sup>2</sup> ]
$\theta$	Rotation angle . . . . .	[rad]
$\tau$	Moment . . . . .	[N·m]

## Vectors and Tensors

$$\vec{v} \quad \text{Physical vector, see equation ...}$$

## 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 applications mentioned were done 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 functionality 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].

- \* Cpp

- \* multiple UAVs

The scope of this paper looks specifically at the application of UAVs in

search and rescue operations. Manually piloted UAVs have already been integrated into search and rescue missions...

Furthermore, there have been developments in the use of drones to perform automated search and rescue operations. One such example is a project by DroneSAR where they use DJI drones to perform search rescue tasks. Their implementation focuses on the automatic coverage of a manually designated area using a single drone. This implementation is the first of its kind and has already showed promise in shortening the time it takes to locate victims. Included in their design is imaging and tracking technology to help locate victims in search and rescue operations.

Automated

UAVs - manual operation vs automated flight What is CPP Talk about SAR

## 1.2 Objectives

The main objective of this thesis was to develop a coverage path planning algorithm that utilises multiple UAVs to search a known environment. This research is intended to be applicable to search and rescue operations.  
[1]

## 1.3 Methodology

## 1.4 Scope of the Research

## 1.5 Thesis Structure

# Chapter 2

## Background

### 2.1 SatSim

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. Constraints 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 3

## SatSim

### 3.1 Terrestrial

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 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.

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# 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.

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.

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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.

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.

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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.

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.

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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.

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# Appendices

# Appendix A

## Discrete Element Method Theory

### A.1 Ball elements

#### A.1.1 Ball mass and inertia parameters

Consider a volume element  $dV$  with respect to a static base  $S$  of an arbitrary solid body with density  $\rho$ . The mass of the body is obtained by integrating over the volume of the body,

$$m = \int_{\text{body}} \rho dV \quad (\text{A.1})$$

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

$$m_i = \frac{4}{3}\pi\rho_i R_i^3. \quad (\text{A.2})$$

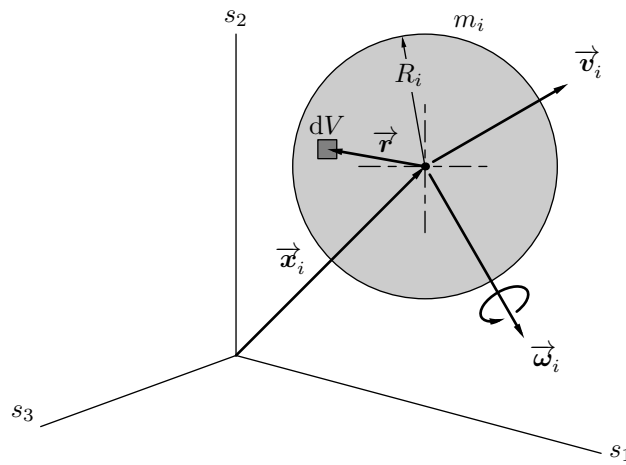


Figure A.1: Ball Element Parameters

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