

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

by

Pieter Goos



*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*

Supervisor: Mr. A. Barnard

March 2021

Declaration

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

Date: 2020/11/01

Copyright © 2021 Stellenbosch University
All rights reserved.

Abstract

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

P. Goos

*Department of Electrical and Electronic Engineering,
University of Stellenbosch,
Private Bag X1, Matieland 7602, South Africa.*

Thesis: MEng (EE)

March 2021

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”)

P. Goos

*Departement Elektries en Elektroniese Ingenieurswese,
Universiteit van Stellenbosch,
Privaatsak X1, Matieland 7602, Suid Afrika.*

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 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 ...

Contents

Declaration	i
Abstract	ii
Uittreksel	iii
Acknowledgements	iv
Dedications	v
Contents	vi
List of Figures	viii
List of Tables	ix
Nomenclature	x
1 Introduction	1
1.1 Background	1
1.2 Objectives	1
1.3 Methodology	2
1.4 Scope of the Research	2
1.5 Thesis Structure	2
2 Background	3
2.1 SatSim	3
3 SatSim	4
3.1 Terrestrial	4
4 Verifying SatSim Results	5
4.1 Scope	5
5 Hardware Selection	6
5.1 Scope	6

6	Hardware Design with Software Implementation	7
6.1	Scope	7
7	Hardware Verification and Comparison to SatSim	8
7.1	Scope	8
8	Conclusions	9
8.1	Scope	9
	Appendices	10
A	Discrete Element Method Theory	11
A.1	Ball elements	11
	List of References	12

List of Figures

A.1	Ball Element Parameters	11
-----	-----------------------------------	----

List of Tables

Nomenclature

Constants

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

Variables

Re_D	Reynolds number (diameter)	[]
x	Coordinate	[m]
\ddot{x}	Acceleration	[m/s ²]
θ	Rotation angle	[rad]
τ	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]. Context in which UAVs have been applied include, but are not limited to, ...

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 [e.g. 2, 3], 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 Cundall and Strack [4] 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.

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.

The first is the “hard sphere”, event-driven method [e.g. 2, 3], 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 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 [e.g. 2, 3], 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.

The first is the “hard sphere”, event-driven method [e.g. 2, 3], 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 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 [e.g. 2, 3], 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 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 [e.g. 2, 3], 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 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 [e.g. 2, 3], 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.

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 ρ . 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 ρ_i is depicted. The mass of the ball is after integration of equation (A.1)

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

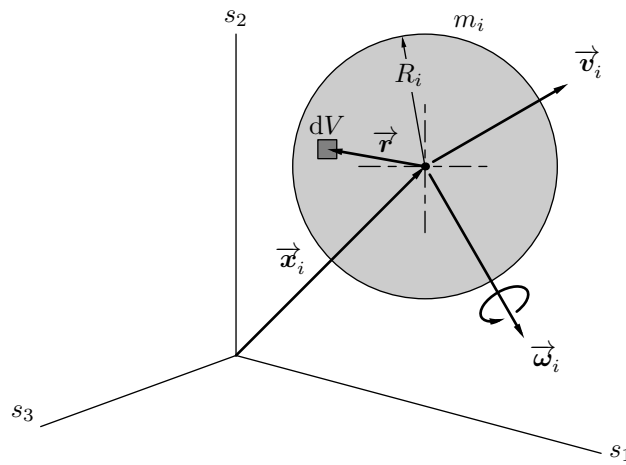


Figure A.1: Ball Element Parameters

List of References

- [1] T. M. Cabreira, L. B. Brisolara, and P. R. Ferreira, “Survey on coverage path planning with unmanned aerial vehicles,” 2019.
- [2] S. Luding, “Models and simulations of granular materials,” PhD, Universität Freiburg, 1994.
- [3] —, “Molecular dynamics simulations of granular materials,” in *The Physics of Granular Media*, H. Hinrichsen and D. Wolf, Eds. Weinheim: Wiley-VCH, 2004, pp. 299–324.
- [4] P. A. Cundall and O. D. L. Strack, “A discrete numerical model for granular assemblies,” *Géotechnique*, vol. 29, no. 1, pp. 47–65, 1979.