Lower-Limb Motion Estimation

Modelling the Kinematics of the Human Lower-Limbs using Cameras and an IMU

Prepared by:

Johann Hendrik Joosten

Department of Electrical and Electronics Engineering
University of Cape Town

Prepared for:

Dr. Amir Patel

Department of Electrical and Electronics Engineering
University of Cape Town

Submitted to the Department of Electrical Engineering at the University of Cape Town in partial fulfilment of the academic requirements for a Bachelor of Science degree in Mechatronics.

September 7, 2017

Terms of Reference

Title

Lower-Limb Motion Estimation - Modelling the Kinematics of the Human Lower-Limbs using Cameras and an IMU.

Description

Recent breakthroughs in the field of artificial intelligence has invigorated the pursuit of humanoid robots. Unfortunately, modern bipedal robots lack the elegance of motion and fluidity observed in nature. Perhaps then a modern take on the lower limb kinematics of humans could provide insight to the field of bio-inspired robotics. By using modern cameras with miniature footprints and accurate sensors data capture systems can be transferred onto the subjects in question. This methodology allows for a much larger spectrum of motion capture and can greatly improve our understanding of motion in the unconstrained real world.

Deliverables

The following items have been identified as critical deliverables for the project:

- functional harness to hold electronics
- data capture equipment
- estimation algorithm
- kinematic model of the human lower-limbs
- computer vision algorithm (!?)

Skills and Requirements

Mechanical Design, Electrical Design, Programming and Modelling.

Area

Computer Vision, Sensors, Biomechanics and Bio-inspired Robotics.

Declaration

1. I know that plagiarism is wrong. Plagiarism is to use another's work and pretend that it is one's own.
2. I have used the IEEE convention for citation and referencing. Each contribution to, and quotation in, this report from the work(s) of other people has been attributed, and has been cited and referenced.
3. This report is my own work.
4. I have not allowed, and will not allow, anyone to copy my work with the intention of passing it off as their own work or part thereof.

Signature:..........................
Hendrik Joosten

September 7, 2017

Acknowledgements

I would like to thank some people...

Abstract

Contents

List of Figures

List of Tables

Chapter 1

Introduction

1.1 Background to the study

review of the area being researched -

data capture with subject-borne sensor equipment,

bio inspired robotics,

human gait

This research project

The field of bio-inspired robotics aims to understand various natural phenomena and incorporate these techniques into the design of modern robotics.

current information surrounding the issue

previous studies on the issue

and relevant history on the issue

1.2 Objectives of this study

This research project aims to show that subject-borne sensors, primarily cameras and IMUs, can provide researchers in the field of biomechanics and bio-inspired robotics with extensive datasets to understand and model the seemingly magical natural world.

1.3 Scope and Limitations

The research presented herein does not seek to push the boundaries of modern sensor technology, nor does it wish to re-imagine understood and accepted models of natural phenomena. Instead, a methodology is proposed that brings together systems from exciting disciplines of research such that richer datasets can be generated and studied.

It should therefore be understood that the following work serves as a proof of concept and not as a final design of a motion capture system.

1.4 Plan of development

The following chapter contains an extensive literature review where various methods of modelling and verifying the human gait has been discussed. There are also sections dedicated to subject borne data capture, computer vision, inertial measurement units (motion sensors), humanoid robotics and mathematical modelling.

1.5 Report Outline

this was taken from sean's report This report covers the processes as described in the plan of development, following the order in which they were introduced. The report structure is outlined in Table 1.1.

Chapter(s) and/or Section(s)	**Project Stage**	**Description**
Chapter **??**	Review of literature	The entire chapter covers the review of literature on the history of the research into and exploration of space and Mars's place in this history. Research on the Mars Curiosity Rover is covered and the chapter ends off with a brief look into web technologies in the context of education and outreach as well as existing rover models.
Section **??**	Problem Definition	The problem definition sections include introduction of the problem as well as the client requirements. The functional breakdown and analysis is covered after which the technical specifications are listed.
Section **??**	Conceptual Development	Each of the conceptual development processes of each of the components of design are covered after which the final design choice and all technologies within are outlined and discussed.

Sections ?? to ??	Detailed Design	Detailed designs of each of the three project systems, mechanical, electrical and software, are covered chronologically in that order. After the design of each group of individual components is discussed, sub-assemblies or completed modules are outlined where applicable.
Sections ?? to ??	Development and Manufacture	The processes followed in developing and manufacturing the final product using the detailed designs is covered in this set of sections. The mechanical and electrical manufacture processes are dealt with first which included manufacturing plans and a bill of materials. The software development follows where significant areas of the large software system are covered with snippets included.
Chapter ??	Post-development Testing and Verification	In this chapter, post-development procedures are covered including the testing of the model in typical scenarios and a full verification of the final product against the technical specifications is included. The verification of specifications was used as a platform from which significant areas of the project were discussed.
Chapters ?? to ??	Conclusions and Reccomendations	In the final chapters, conclusions of the project that were drawn are covered and the recommendations formulated as part of the discussions are highlighted. Potential avenues for future work are also included.

Table 1.1: Description of the structure of the report as per the stages of design and development of the project.

Chapter 2

lit review

2.1 Introduction

This research project brings together various disciplines of research.

2.2 New Perspectives from Animal Borne Cameras

In large this researched project was inspired by work done in the Mechatronics Lab at the University of Cape Town. In 2017, Patel et al. [1] showed that using animal borne cameras and motion sensors the tail kinematics of the cheetah (Acinonyx Jubatus) could be tracked. Patel's work was partly inspired by Kane et al.; [2] where falcon (Falco Peregrinus) borne cameras were used to better understand airborne pursuit of prey.

2.3 Observing Natural Solutions for Robotic Shortcomings

Naturally the question arises: why would we want to better understand the dynamics of animals? A persistent problem in the field of modern robotics is that of mobility; robots struggle to navigate real world surfaces and obstacles. Work by Patel et al. [3] shows how we can look towards nature for inspiration to solve this mobility problem.

This follows the central philosophy of bio-inspired robotics as defined by

As demonstrated by various prototype robots built by Boston Dynamics bipedal robots are severely limited in manoeuvrability when compared to

2.4 Human Motion Analysis Using Computer Vision

2.5 Human Gait

2.6 Motion Sensors

2.7 Mathematical Modelling

2.8 all citations

Chapter 3

Methodology

3.1 Mechanical Design

3.1.1 GoPro Session Bracket

further designed bracket

3.2 Vision Calibration

matlab stereo camera calibration software 1. calibrate the cameras 2. get data from the recordings

took some vids

made matlab script to isolate frames in vids

put frames into stereo video camera calibrator

winning at life

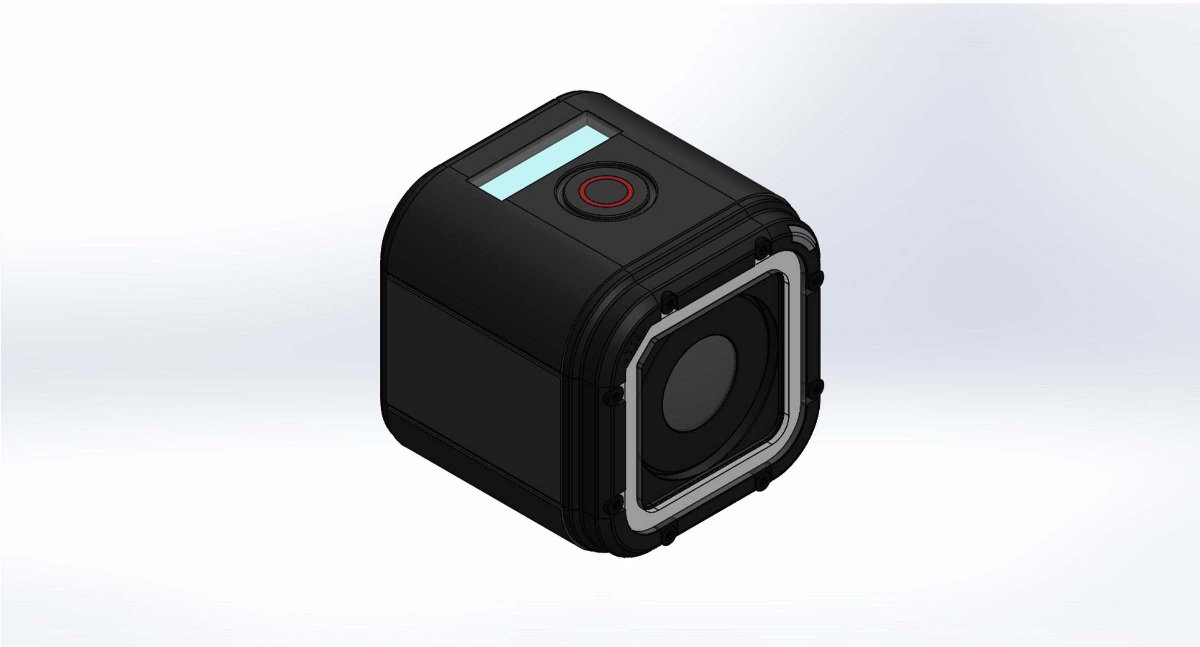

Figure 3.1: Solidworks model of the GoPros Hero 4 Session

Bibliography

[1] A. Patel, B. Stocks, C. Fisher, F. Nicolls, and E. Boje, "Tracking the cheetah tail using animal-borne cameras, gps, and an imu," *IEEE Sensors Letters*, vol. 1, no. 4, pp. 1–4, 2017.

[2] S. A. Kane and M. Zamani, "Falcons pursue prey using visual motion cues: new perspectives from animal-borne cameras," *Journal of Experimental Biology*, vol. 217, no. 2, pp. 225–234, 2014.

[3] A. Patel and M. Braae, "Rapid turning at high-speed: Inspirations from the cheetah's tail," in *Intelligent Robots and Systems (IROS), 2013 IEEE/RSJ International Conference on*. IEEE, 2013, pp. 5506–5511.