Lower-Limb Motion Estimation

Kinematic Modelling and Estimation of the Gait using Cameras and an IMU

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Terms of Reference

Title

Lower-Limb Motion Estimation - Kinematic Modelling and Estimation of the Gait 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 minimal volume 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 movement in the unconstrained real world.

Deliverables

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

- Functional harness to hold data capture equipment
- Estimation and fusion algorithm to process captures data
- Kinematic model of the human lower-limbs

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

October 6, 2017

Acknowledgements

I would like to thank some people...

Abstract

This research aims to extend the work completed by the Mechatronics Lab at the University of Cape town. This research studied the use of subject borne cameras to analyse, model and estimate the kinematic motion of a cheetah tail. Computer vision has progressed significantly within the last few years and studying the motion of animals with subject borne cameras allow unconstrained environments.

Contents

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Glossary

Abbreviations listed here are used throughout the document.

- DOF - Degrees of freedom
- GPHS - GoPro Hero Session
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Chapter 1

Introduction

1.1 Background to the study

Human motion capture systems are often very costly and confine the capture area to a certain confined space. These limitations prevent us from understanding bipedal motion in complex environments, knowledge that proves to be critical in the development of humanoid robotics.

Recent work [3] completed by the Mechatronics Lab at the University of Cape Town showed data capture with subject-borne cameras and sensors can be used to better understand unconstrained movement in a natural environment. The presented work showed the successful kinematic modelling of a cheetah (Acinonyx jubatus) tail whilst running freely. This work was inspired by [4] where the importance of a tail for manoeuvrability was demonstrated.

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.

This is followed by a chapter titled methodology that presents the the planning and ideation of the thesis. It serves as a link between the theoretical work presented in the literature review and the engineering and application detailed in the that follow it.

The final three chapters that make up the body of this report are titled "Designing the Data Capture System", "Processing the Captured Data" and "Data Fusion and State Estimation" in order of appearance.

A chapter is then dedicated to presenting and discussing the results followed by the closing chapter that draws conclusions from the presented work and makes recommendations on future work.

Chapter 2

lit review

2.1 introduction

This research project brings together various disciplines of research. by combining techniques from computer vision with IMU data etc we can build a data capture system that can

2.2 Human Motion and Gait

2.3 Computer Vision

2.3.1 Computer Vision in robotics

2.3.2 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. [3] 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.; [5] where falcon (Falco Peregrinus) borne cameras were used to better understand airborne pursuit of prey.

2.3.3 Human Motion Analysis Using Computer Vision

2.4 Inertial Measurement Units

2.4.1 Inertial Measurement Units in robotics

2.4.2

2.4.3 Human Motion Analysis Using Inertial Measurement Units

2.5 Mathematical Modelling

2.5.1 math model of the human gait

2.5.2 linear kinematics

2.5.3 rotational matrices

2.5.4 KF and EKF

The Kalman filter

2.6 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. [6] 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

2.7 conclusion

Chapter 3

Methodology

To ensure the success of this project a basic plan of action was created. The following diagram shows the critical phases of the project and their dependence on each other.

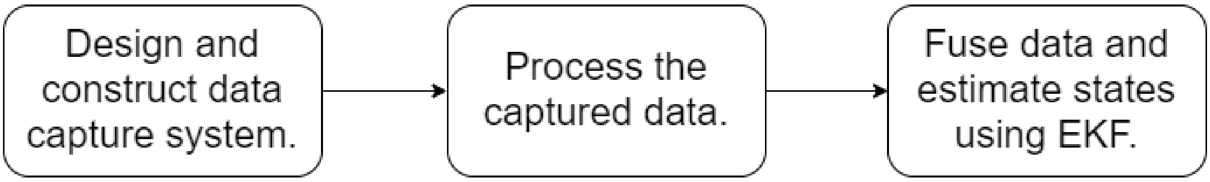

Figure 3.1: Diagram showing the progression and dependence of the major stages of this project

Chapter 4

Designing the Data Capture System

To obtain data for the Extended Kalman Filter, a data-capture system needed to be designed. Since the data sources have been identified as multiple video sources and a 9-DOF IMU.

4.1 Designing the Body Harness

sdfgsdfgsdfg

adsfasdfsdfg

sdfgsdfgdsf

sdfgdsfgdsfg

4.2 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 4.1: GoPro Chesty camera mount from [1]

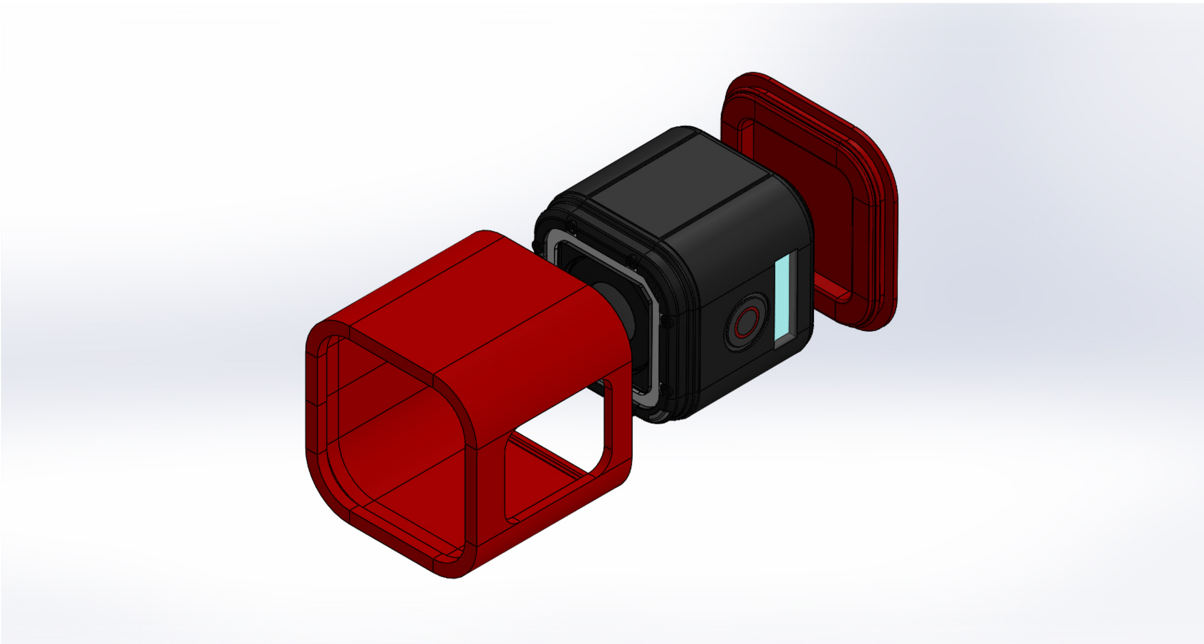

Figure 4.2: Solidworks model of the GoPros Hero 4 Session

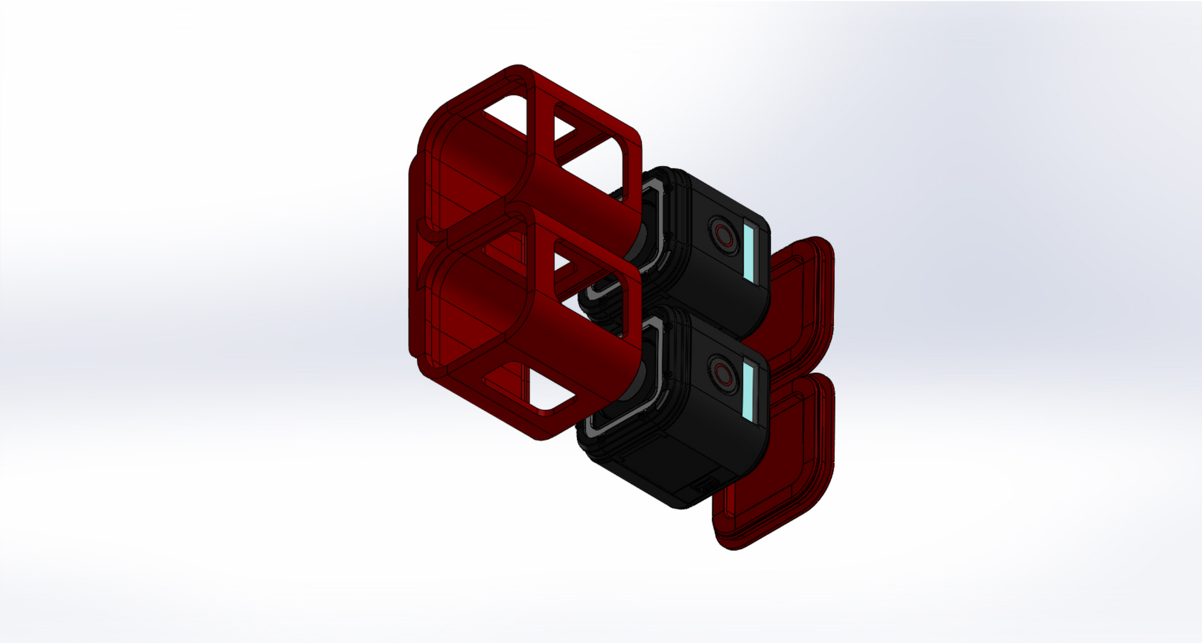

Figure 4.3: angle 1

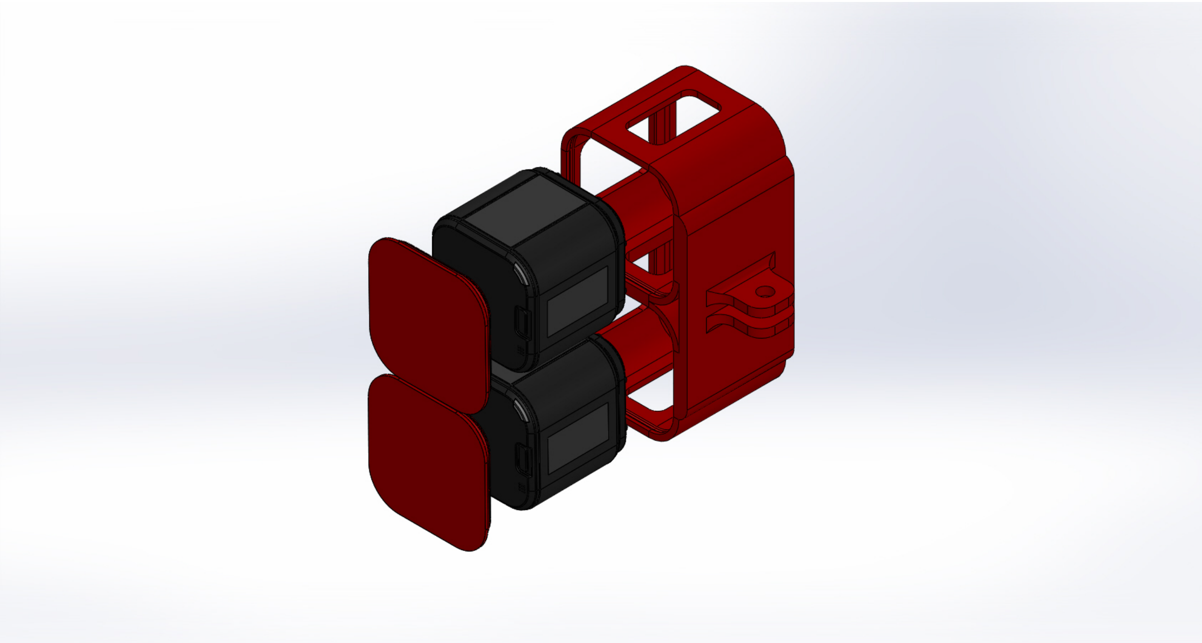

Figure 4.4: angle 2

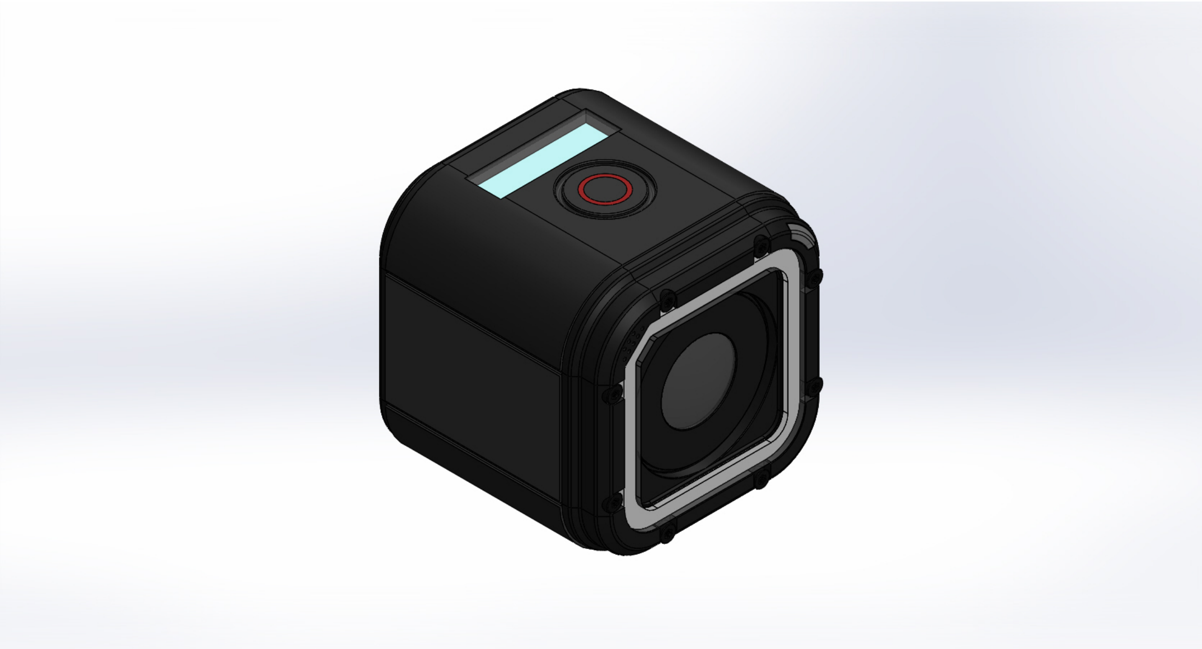

Figure 4.5: Solidworks model of the GPHS Action Camera from [2]

Chapter 5

Processing the Captured Data

Chapter 6

Data Fusion and State Estimation

Chapter 7

Results and Discussion

Chapter 8

Conclusions and Future Work

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