THESIS TITLE HERE

A Thesis Submitted
In Partial Fulfillment of the Requirement
for the Degree Of
Master of Technology

by

YOUR NAME

(154320)
to the

DEPARTMENT OF MECHANICAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY KANPUR

July, 2020

Certificate

It is certified that the work contained in this thesis entitled "THESIS TITLE HERE" by "YOUR NAME" has been carried out under our supervision and that it has not been submitted elsewhere for a degree.

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July, 2020

Declaration

This is to certify that the thesis titled "THESIS TITLE HERE" has been authored by me. It presents the research conducted by me under the supervision of Dr. X and Dr. X-2.

To the best of my knowledge, it is an original work, both in terms of research content and narrative, and has not been submitted elsewhere, in part or in full, for a degree. Further, due credit has been attributed to the relevant state-of-the-art and collaborations (if any) with appropriate citations and acknowledgements, in line with established norms and practices.

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ABSTRACT

Name of the student: **YOUR NAME** Roll No: **154320**
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Month and year of thesis submission: **July, 2020**

The thesis work includes ....

Acknowledgements

First and foremost, I would like to extend my sincerest gratitude to my thesis supervisors ....

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Abbreviations

DOF	**D**egrees **o**f **F**reedom
CoM	**C**enter **o**f **M**ass

Symbols

R_{AB}	Rotation matrix from frame A to frame B

Dedicated to someone special

Chapter 1

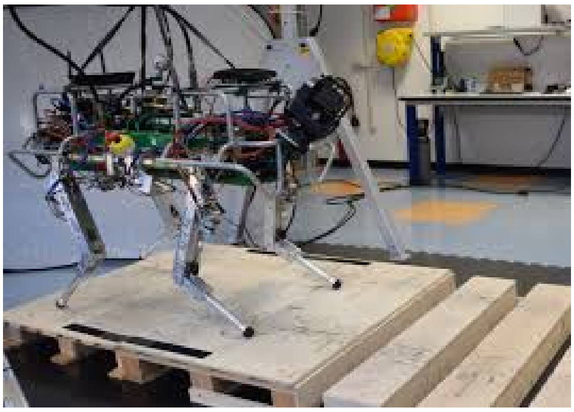
Introduction

Robots have moved from being predominantly in factories to our daily lives. The flying drones doing surveillance, cleaning and serving robots, autonomous cars, and underwater vehicles are all common nowadays.

1.1 Motivation and Objectives

The legged robots have shown great potential in locomotion

(a) BigDog



(b) HyQ: Hydraulic Quadruped

Figure 1.1: (a) Boston Dynamics' BigDog which could carry upto 340 pounds at 4 miles per hour over a rough terrain, which was designed to support military operations, but had issues with noise which was audible from 4 miles away [1], (b) HyQ developed by IIT, Genoa, Italy[2]

1.2 Literature Review

your content here .....[3]

Some assumption or definition explained in footnote[1].

1.3 Outline

The thesis focuses on the ....

Chapter 2 introduces .... Chapter 3 describes ...

Chapter 4 focuses on the trajectory optimization .... Later in Chapter 5, the results obtained from .... Chapter 6 provides the conclusion of the work along with the future scope.

[1] My footnote content here

Chapter 2

Mathematical Modelling

Some more introduction... discussing a trivial problem

2.1 Mathematical Preliminaries

The modelling of a system requires understanding the .... [4].

2.1.1 Rotation Matrices

The configuration of a point is completely described by its position vector in $\mathbb{R}^3$, whereas for a rigid body, the orientation of the body in space also needs to be defined. The orientation of a body-fixed frame B with respect to a reference frame A as shown in Fig. 2.1 is given by R_{AB}. The rotation matrix that transforms the coordinate frame A to coordinate frame B has the property:

$$R_{AB}^{\intercal} \cdot R_{AB} = \mathbb{I}_{3\times 3}. \tag{2.1}$$

Further, the rotation matrix belongs to a special orthonormal group $SO(3)$, and has properties $R_{AB}^{-1} = R_{BA} = R_{AB}^{\intercal}$.

The orientation of a body could be parametrized in many ways. There are a total of nine parameters in a 3×3 rotation matrix, but they are constrained by the orthogonality condition of Eq. 2.1. There are only three independent parameters, and Euler angles are used for a minimal representation of rotations in space.

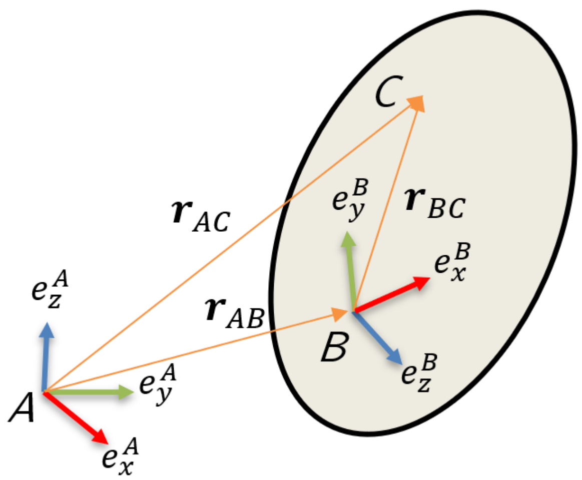


FIGURE 2.1: Coordinate transformations for a single rigid body

Chapter 3

Model Design

3.1 Robot Model

.....

3.2 Forward Dynamics

The forward dynamics of the quadruped can be derived using Lagrangian or Newton-Euler method [3].

3.2.1 Equation of Motion

The equation of motion for a rigid multi-body system is usually written in a canonical form [5]:

$$M(\mathbf{q})\dot{\mathbf{u}} + C(\mathbf{q}, \mathbf{u}) = \boldsymbol{\tau}, \tag{3.1}$$

Refer to Eq. 3.1

See Appendix A

Chapter 4

Optimization

your content here .....

Example See Section 3.2.1

Chapter 5

Results and Discussion

The chapter presents the results of ......

5.1 Planning and Optimization

The Y method is used ..... [6]

Table 5.1 shows the parameters used in the simulation.

TABLE 5.1: Parameters used in simulation

Robot parameters	Symbol	Value
Mass	M	10 Kg
Length	l	600 mm
Width	w	420 mm

Chapter 6

Conclusions and Future work

6.1 Conclusions

The conclusions of the work presented in the thesis are mentioned as follows:

1. conclusion 1
2. more ...

6.2 Future Work

There is a vast scope of research in the field ....

1. Do this and that
2. Improve this way

Bibliography

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[3] Donald T Greenwood. *Classical dynamics*. Courier Corporation, 1997.

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Appendix A

Some Definitions ad Hypotheses

A.1 Null Space

Null Space: The null space of a matrix A is defined as the set of all the vectors $\mathbf{v}$ such that $A\mathbf{v} = 0$, i.e.,

$$N(A) = \{\mathbf{v} | A\mathbf{v} = \mathbf{0}\} \tag{A.1}$$

Appendix B

Addons

This section shows the derivations of some part ....

B.1 Derivation for Link Model

The link model ......

Appendix C

Simulation Codes

C.1 SIM Codes

```
% function ........................
function q = sample_code(q_a)

    % code content here
  q = q_a.';

end
```