NTNU
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Department of Engineering Cybernetics

TTK4550 - Specialization Project

# Design and Control of a Spring-actuated Jumping Quadruped in Earth Gravity

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# Abstract

This project report presents our specialization project, which is the design and control of a quadruped, spring-actuated, etc.

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# Abbreviations

| Abbreviation | Description |
|---|---|
| AI | Artificial Intelligence |
| API | Application Programming Interface |
| CPU | Central Processing Unit |
| DRL | Deep Reinforcement Learning |
| EKF | Extended Kalman Filter |
| ESKF | Error State Kalman Filter |
| GNC | Guidance, Navigation, and Control |
| INS | Inertial Navigation System |
| ML | Machine Learning |
| MOOS | Mission Oriented Operating Suite |
| PPO | Proximal Policy Optimization |
| RL | Reinforcement Learning |
| USV | Unmanned Surface Vehicle |

# 1 Introduction

## 1.1 Motivation

## 1.2 Scope

### 1.2.1 Problem Description

### 1.2.2 Related Work

[**schulman˙proximal˙2017**] is an important paper.

## 1.3 Report Outline

# 2 Crazy Matrix

$$\begin{bmatrix} 1 & 2 & 3 & 4 & 5 \\ 6 & 7 & 8 & 9 & 10 \\ 11 & 12 & 13 & 14 & 15 \\ 16 & 17 & 18 & 19 & 20 \end{bmatrix} \tag{1}$$

# 3 Theory

## 3.1 Reinforcement Learning

### 3.1.1 The Reinforcement Learning Problem Setting

### 3.1.2 Value-Based and Policy-Based Methods

### 3.1.3 Policy Gradient Methods

## 3.2 Artificial Neural Networks

## 3.3 Electric Motor Dynamics

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## 3.5 Kinematics, Jacobians, and Virtual Work

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## 3.6 Dynamical Systems and Contact Dynamics

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### 3.6.2 Contact Modeling and Impact Dynamics

### 3.6.3 Friction Models

# 4 Modeling and Simulation

## 4.1 Simscape

Her forklares Simscape og hvordan vi lagde en simscape simulering. Her forklares *ikke* hvordan vi valgte ut link-lengths, spring, motor, etc. Altså dimensjonering forklares ikke her. Kun hvordan

vi lagde simuleringen som etter hverdt skal brukes til dimensjonering. Det at den brukes til dimensjonering, forklares trolig i hardware/design seksjonen...

### 4.2 IsaacLab

## 5 Robot Design

This is where we explain "overall" design. It's motivation, etc. Also where we cover dimensioning, link-lengths, etc. We explain here our parameter sweep to find optimal design. We also explain here our kinematics-script that we used to derive the required stall-torque for our motor given springs and link-lengths.

### 5.1

### 5.2

## 6 Robot Hardware

This is where we discuss actual hardware, ie. component selection, materials, CAD, etc.

So here we specify motors and how they match specs, while referring to the design section to explain why we want these motors. We should here have a list of existing motors. The design section can link to this list to motivate its own choice. It will be circular, but that's okay.

## 7 Robot Control

### 7.1 RL Problem Description?

This is not where we explain the goal of the thesis, ie. "we want to jump". This is just where we explain the RL problem. That we want to * jump * land * etc. is something we describe earlier, for instance in Introduction/Scope/Problem Description.

## 8 Results

## 9 Discussion

## 10 Conclusion

# Appendix

## A Hello World Example

```
# This is a comment
print('Hello world from Python!')
print('I am using the "rrt" style to print this code in beautiful colors')
```

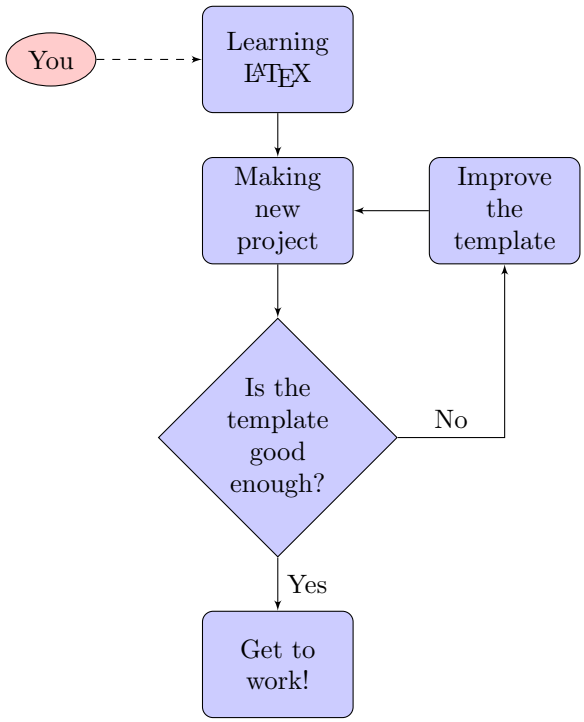
⋮

```
# This is a comment
print('Hello world from Python!')
print('I am using the "rrt" style to print this code in beautiful colors')
```

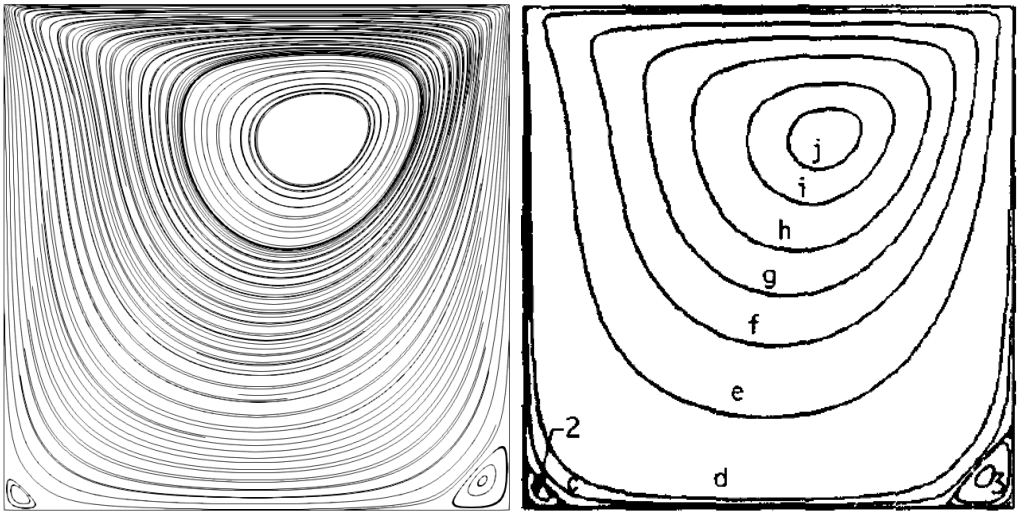
⋮

```
% This is a comment
disp("Hello World from MATLAB!");
disp("I am using the "tango" style to print this code in beautiful colors");
```

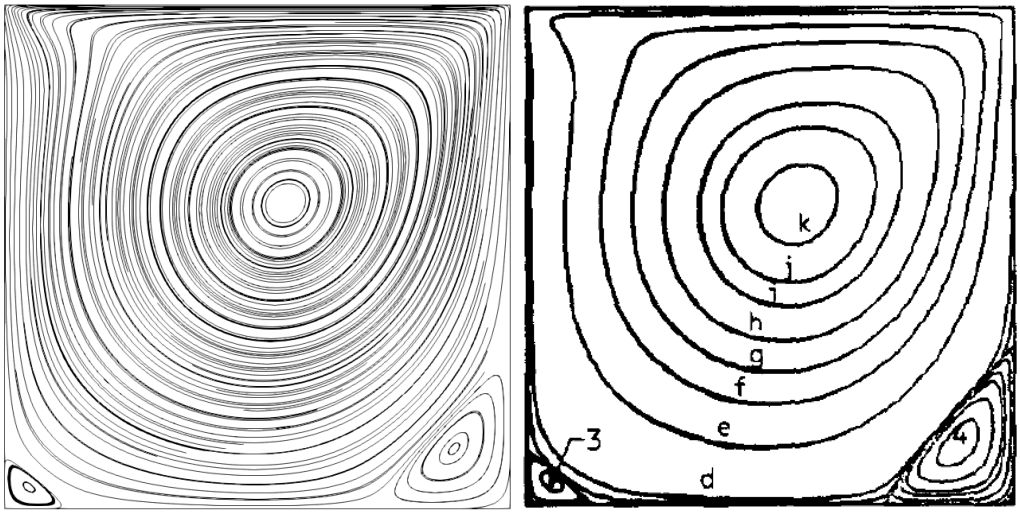
## B Flow Chart Example



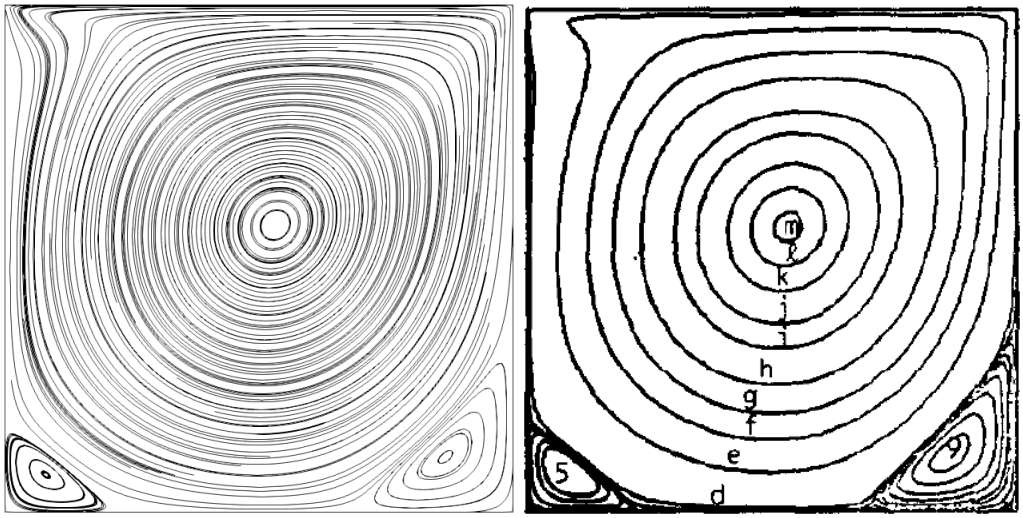
## C Sub-figures Example




$Re = 100$ - Exercise $Re = 100$ [**ghia˙1982**]




$Re = 400$ - Exercise $Re = 400$ [**ghia˙1982**]




$Re = 1000$ - Exercise $Re = 1000$ [**ghia˙1982**]

Figure 1: Streamlines for the problem of a lid-driven cavity.