UNIVERSITY OF ŽILINA

FACULTY OF ELECTRICAL ENGINEERING

AND INFORMATION TECHNOLOGY

MASTER THESIS

BC., DANIEL ADAMKOVIČ

Realizing walking for a walking robot

using deep reinforcement learning

***The name is a placeholder until I get official english name**

Supervisor: Ing. PhD., Michal Gregor

Identifier: 69 69 420

Žilina, 2020

UNIVERSITY OF ŽILINA

FACULTY OF ELECTRICAL ENGINEERING

AND INFORMATION TECHNOLOGY

MASTER THESIS

BC., DANIEL ADAMKOVIČ

Realizing walking for a walking robot

using deep reinforcement learning

***The name is a placeholder until I get official english name**

Study program: Cybernetics

Field of study: 5.2.14 Automation

Supervising institution: University of Žilina, Faculty of Electrical Engineering and Information Technology,
Department of Control and Information Systems

Supervisor: Ing. PhD., Michal Gregor

Žilina, 2020

Namiesto tejto strany treba vložiť zadanie záverečnej práce!

Do elektronickej verzie práce vložte **oskenované podpísané** zadanie záverečnej práce, napr. vo formáte pdf alebo ako obrázok zväčšený na celú veľkosť papiera.

Acknowledgments

Poďakovanie nie je povinné. Ak nemá byť zahrnuté, stačí túto časť zakomentovať.

Abstract

Abstrakt obsahuje informáciu o cieľoch práce, jej stručnom obsahu a v závere abstraktu sa charakterizuje splnenie cieľa, výsledky a význam celej práce. Abstrakt sa píše súvisle ako jeden odsek a jeho rozsah je spravidla 100 až 500 slov.

Keywords: robotics, deep reinforcement learning, artificial intelligence, simulation

Abstrakt

Nejaký abstrakt po slovensky.

Kľúčové slová: robotika, hlboké učenie s odmenou, umelá inteligencia, simulácia

Obsah

Abbreviations

DRL deep reinforcement learning (svk. hlboké učenie s odmenou), s. 2, 3

RL reinforcement learning (svk. učenie s odmenou), s. 1, 2

Dictionary of terms

Slovník pojmov: Slovník pojmov je nepovinný. Na jeho odstránenie stačí zmazať všetky zadefinované pojmy v súbore modules/abbterms.tex.

Triedenie: Pojmy v slovníku sa automaticky triedia podľa abecedy. Ale pozor: triedenie sa deje prvého argumentu makra `DeclareAcronym` – nie podľa poľa `short`.

Viskozita: Fyzikálna veličina, miera odporu tekutiny deformovať sa pod vplyvom šmykových (tangenciálnych) napätí. Prejavuje sa vnútorným trením.

Zhlukovanie: Trieda metód strojového učenia, ktoré v daných dátach hľadajú zhluky.

Hierarchické zhlukovanie

Metódy zhlukovania, kde rozdelenie do zhlukov má hierarchickú štruktúru.

Fuzzy c-means zhlukovanie

Verzia algoritmu k-means pre fuzzy zhlukovanie.

1 | Introduction

In the last couple of decades we have witnessed many groundbreaking developments that would have previously been reserved for science fiction. Modern mobile robots can walk, interact with objects and humans, even independently accomplish simple tasks previously only reserved for humans. However while the robots are becoming more complex by the year, so does the complexity of their design and development. This is most obvious with robots that utilize legs for the purposes of locomotion, which forces engineers to develop complex controllers that allow such machines to move about. Design of these controllers is more often than not non-trivial and as such it is often reserved for experienced control engineers. Still, even with a lot of effort success is not guaranteed and even well-designed robots rarely achieve the same grace of movement that animals are capable of.

With this paragraph we have formulated the problem that this thesis addresses. For one way of solving it we can, as engineers often do, draw inspiration from nature. An animal learns to walk, not by performing a deep analysis of its tendons and muscles and then committing months to study of books on control theory. No, an animal learns in a much more straightforward way by simply making attempts and attempting to achieve ’good results’. We write good results in quotation marks as measuring goodness of something can be in practice a difficult and often very subjective task. Regardless, this simple concept of making attempts and obtaining a measure of success is, not only present in nature, it is also at the core of one of the most promising sub-fields of artificial intelligence known as reinforcement learning (RL).

In this text we will focus on:

1. **Introducing deep reinforcement learning (DRL) algorithms**: with RL maturing as a field a slew of different approaches at utilizing it become available. We will explore some of the most promising ones that are relevant for our use case.
2. **Simulation and modeling of a robot, task and reward**: just having an algorithm that works is not enough, so this chapter will be dedicated to creating a simulated environment within which we will train a virtual robot to walk.
3. **Implementing the DRL**:
   When I know more about the implementation details I need to modify this
4. **Training and results analysis**: this chapter will be dedicated to putting everything together and analyzing the obtained results.
5. **Transitioning into the real world**:
   See the comment above

2 | Deep reinforcement learning

In this chapter we will put DRL into the context of broader field of artificial intelligence and explain how it differs from other approaches that attempt to infuse agents with some form of intelligence. Afterwards we will proceed to introduce the main algorithms that are relevant for the use in environments with continuous action spaces.

2.1 DRL in the context of AI

ČESTNÉ VYHLÁSENIE

Vyhlasujem, že som zadanú prácu vypracoval samostatne, pod odborným vedením vedúceho práce, ktorým bol Ing. PhD., Michal Gregor a používal som len literatúru uvedenú v práci.

Súhlasím so zverejnením práce a jej výsledkov.

Dátum odovzdania práce, Žilina

podpis

UNIVERSITY OF ŽILINA

FACULTY OF ELECTRICAL ENGINEERING

AND INFORMATION TECHNOLOGY

PRÍLOHOVÁ ČASŤ

BC., DANIEL ADAMKOVIČ

Realizing walking for a walking robot

using deep reinforcement learning

***The name is a placeholder until I get official english name**

Supervisor: Ing. PhD., Michal Gregor

Identifier: 69 69 420

Žilina, 2020

Príloha A | Zeleninový šalát

Tvorba príloh je veľmi jednoduchá – stačí ich pridať ako nové kapitoly v časti dokumentu označenej ako `\appendix`. Prílohy sú automaticky číslované nie numericky, ale písmenami abecedy, čím sú dostatočne odlíšené od klasických kapitol. Ak práca obsahuje prílohy, šablóna automaticky vygeneruje titulný list oddeľujúci prílohovú časť práce od hlavnej časti práce.

A.1 Textová vata

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.