ÉCOLE NATIONALE SUPÉRIEURE DES MINES DE SAINT-ÉTIENNE

MASTER'S 1 REPORT

Implementation of a robot behavior learning simulator

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in the

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Declaration of Authorship

I, Kushagra Singh BISEN, declare that this thesis titled, "Implementation of a robot behavior learning simulator" and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at this University.
- Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.
- I have acknowledged all main sources of help.
- Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself.

Signed:

Date:

"Thanks to my solid academic training, today I can write hundreds of words on virtually any topic without possessing a shred of information, which is how I got a good job in journalism."

Dave Barry

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Abstract

Faculty Name
Institu Henri Fayol, IT and Intelligent Systems department

Master's 1 in Cyber-Physical and Social Systems

Implementation of a robot behavior learning simulator

by Kushagra Singh BISEN

The Thesis Abstract is written here (and usually kept to just this page). The page is kept centered vertically so can expand into the blank space above the title too…

Acknowledgements

The acknowledgments and the people to thank go here, don’t forget to include your project advisor…

Contents

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List of Abbreviations

LAH	**L**ist **A**bbreviations **H**ere
WSF	**W**hat (it) **S**tands **F**or

Physical Constants

Speed of Light $c_0 = 2.997\,924\,58 \times 10^8\ \mathrm{m\,s^{-1}}$ (exact)

List of Symbols

a	distance	m
P	power	W (J s^{-1})
ω	angular frequency	rad

For/Dedicated to/To my…

Chapter 1

Context of the Work

1.1 Introduction

The work is based on an Industry 4.0 scenario, which is a cyber-physical environment consisting of various different actors and objects involved. The different actors involved are either stationary or mobile. Moreover, complexity of the environment increases when we account for heterogeneous actors with various decision making capabilities. Robots with various manufacturers present various transform frames, different software and sensors. Due to the heterogeneous nature of the robots involved, we can not depend on information we receive from the robot, as this particular information will differ from a robot to other based upon it's configuration. The problem is solved by creating a digital twin which records the information of the environment as well as the robot. The simulator notes the state of the robot and obstacles it surrounds as it passes through the obstacle grid.

1.1.1 Motivation

The structure of a dynamic Industry 4.0 environment is highly volatile, the structure is defined through a stationary frame that has been declared before. The decision making capabilities of the robot to navigate the environment while avoiding obstacles and other robots can have a great impact on the performance and the utility of the environment.

1.2 Robot

1.2.1 What is a Robot?

The origin of the word robot can be found in Czech playwriter Karel Chapek's play titled "Rossum's Universal Robots (R.U.R)" in 1921. Thw word robot results from combining the Czech words *rabota* meaning compulsory work and *robotnik* meaning an agricultural bound labor. A **robot** is a system existing in a physical world, with decision making capabilities of varying extent, can sense the environment it's in to achieve some goals. A goal can be differ according to the need of autonomous behaviour. Essentially, robot is a cyber-physical system combining sensing, actuation, and computation. With the advancements in technology and materials essential to build a robot, we can see numerous different robots with different applications. Robots such as,

- a self-foldabel / self-actuated robot developed at MIT Sung, 2016
- a lightweight aerial robot developed at University of Penn

- consumer-grade drones by DJI
- Autonomous Vehicles developed at Google.
- Autonomous Surface Vehicles by ASV Global

Robots help humans to do *dirty*, *dull*, and *dangerous* tasks that no human wishes to do, although they are important to be done. As any machines, in an Industry 4.0 environment humans can integrate robots into the development/production process, thus these processes can be optimized. Optimizing robots with different applications can help us to exploit robot technologies to leviate pressure imposed by growing population by using in applications such as,

- mobility-on-demand
- automated highways
- drone swams for servillance
- truck platoons for long distance logistics

Along with these mobile wheel bearing vehicular robots, we hav other robots such as,

- autonomous behaviour on any terrain for search and rescue with Big Dog robots.
- Persobal Robots for help with menial tasks, for example, iCub Robot.
- Emotional Robots wit Human Computer Interface designed to ease the interaction for example, Pepper Robot.

1.3 Autonomous Behavior

For an entity to display auto behavior in an environment, it must be able to model and percieve the world it is in, be able to process information and perform required actions and plan it's behavior in adverse conditions. The level of such autonomy varies with different use cases. These challenges are solved by deploying perception module, action module and decision-making module. These three modules will be mounted and developed on an cyber-physical system, thus differentiating cyber-physical systems in this case with pure artificial intelligence. Architectures employed in Robotics combine the three modules to be used by the developer to develop such CPS systems.

1.3.1 Perception

For a robot to initiate any form important autonomous behavior of decision making, the robot should know where the robot is present in the given Industry 4.0 environment. A robot uses different sensors to infer it's pose in the environment. The different sensors provide measurements of the environment and extract meaningful information for autonomous behavior. Proprioceptive sensor in a robot is used to determine the coordiante location of the robot relative to the frame it is in. These coordinates when changed define the movement of the robot. Another exteroceptive sensor is used to acquire information regarding the environment the robot is currently present in by calculating light intensity and sound amplitude to measure the distance from theh nearest obstacle. The perception module will save the information about the map to be inherited in other modules.

1.3.2 Action

Action module decides the force and orientation for a robot to perform the task assigned. Action module deals with low level control of the robot's motor. In presence of a predefined goal, the action module will calculate the rotational and forward velocities to reach the goal. Action module comprises of various equations responsible to calculate the linear and angular velocities.

1.3.3 Decision Making

In order to achieve a higher order goal, the robot will use the action and perception modules to initiate *navigation* to reach a predefined goal. **Perception** module has provided the neccesary information to the robot about the environment and location of obstacles. **Action** module provides the neccesary equations to calculate the velocities to pursue the motion towards the goal. Delibrative planning is executed by the decision-making module to compute a path that does not collide with the obstacles and respects robot's motion constraints. In real Industry 4.0 environment, we've multiple robots and mobile entities. Collaboration, Communication and Coordination among the robots for path planning to calculate efficient algorithms for calculating linear and angular velocities are an interesting subject for research. For example, collective movement between robots as well as aerial unmanned vehicles such as drones can be initiated by either having a distributed architecture or a centralized leader-follower control. A decentralized system is prone to failure much more than a leader-follower control system.

Appendix A

Frequently Asked Questions

A.1 How do I change the colors of links?

The color of links can be changed to your liking using:
`\hypersetup{urlcolor=red}`, or
`\hypersetup{citecolor=green}`, or
`\hypersetup{allcolor=blue}`.
If you want to completely hide the links, you can use:
`\hypersetup{allcolors=.}`, or even better:
`\hypersetup{hidelinks}`.
If you want to have obvious links in the PDF but not the printed text, use:
`\hypersetup{colorlinks=false}`.

Bibliography

Sung, C. (2016). “Computational design of foldable robots via composition”. In: URL: https://dspace.mit.edu/handle/1721.1/113734.