Autonomous Navigation of Mobile Trash Collector based on (method: Deep Reinforcement Learning) (LaTeX VERSION.BETA)

A THESIS SUBMITTED TO
THE SCHOOL OF Electrical Engineering

BY

FAUZI ABDUL ROHIM

2101182035

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE
OF
MASTER OF Electrical Engineering
IN
THE SCHOOL OF Electrical Engineering

TELKOM UNIVERSITY
2021

APPROVAL PAGE

Approval of the School of Computing of Telkom University
I certify that this thesis satisfies all the requirements as a thesis for the degree of Master Informatics.
Date Jan 08 , 2021 (*the date can be set manully)

(Dana Sulistyo Kusumo, Ph.D.)
Head of Master Informatics
This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Informatics.

Date Jan 08 , 2021

(Supervisor's name) (Co-Supervisor's name)
Supervisor Co-Supervisor

Examining Committee Members.
Date Jan 08 , 2021

(Jury's name) (Chairperson of the jury) :

(Jury's name) (jury's member) :

(Jury's name) (jury's member) :

SELF DECLARATION AGAINST PLAGIARISM

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Month/Date/Year Jan 08 , 2021
Name, last name: Your Name

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Name, last name of the Supervisor: Supervisor Name

Signature: _____

Month/Date/Year Jan 08 , 2021
Name, last name of the Co-Supervisor: Co-Supervisor Name

Signature: _____

ABSTRACT

YOUR ABSTRACT.

Keywords: Autonomous Mobile Robot, Reinforcement Learning, SLAM, Dynamic Environment, Behaviours Control

ABSTRAK

Abstract in bahasa Indonesia.

Kata kunci:

DEDICATION

This thesis is compiled with the support of my family. I praise GOD and thanks to all who have helped, directed, and supported this work. I dedicate the work to my beloved parents ALICE and BOB.

Finally this thesis is dedicated to all informatics students in the world. I hope that this research may provide valuable contribution in Computer Science.

ACKNOWLEDGMENTS

This thesis is compiled with the effort, help, and support from both students and lecturers. I would like to express my deepest gratitude and thanks to:

1. .....

2. .....

PREFACE

In thesis writing, the most difficult part to write is Chapter 1 (Introduction/The Problem). As they say, the most difficult part of any endeavor is the starting point. This is because the first chapter is where you conceptualize your entire research. The whole research/thesis can be reflected in Chapter 1 including expected results or outcomes. For your guidelines, please read the following sample format of Chapter 1.

Bandung,

YOUR NAME

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF TERMS

Terms	**Definition**
Classes	Number of individual in biometrics data
Sample	Number of images can be used to represent population in a class.
...	...

LIST OF NOTATIONS

Symbols	Definition
$\mapsto$	Mapping operator
(x_i, y_i)	Data point
$\|A\|$	Cardinality of A
$\|p - q\|$	Absolute of $p - q$
$\mathbb{R}$	Sets of real number

CHAPTER 1

INDTRODUCTION

1.1 Latar belakang masalah

Setiap tahunnya, lebih dari 2 (dua) juta ton plastik dibuang ke sungai dan akhirnya hanyut ke laut [1], sehingga sistem pembuangan sampah menjadi sektor yang cukup krusial [1][2]. Metode pengumpulan sampah secara manual menjadi metode yang sering digunakan untuk mengatasi krisis tersebut[3]. Namun, terdapat beberapa masalah pada pengelolaan sampah secara manual, keselamatan para tenaga kerja, tidak dapat menjaungkau daerah terpencil, biaya pengorprasian, dan lainya[3]. Autonomous Robot menjadi solusi untuk mengatasi permasalahan tersebut, karena dapat mengurangi resiko kecelakaan, dapat menjangkau daerah terpencil, dan dapat melakukan pekerjaan secara berulang [3][4]. Autonomous Robot telah banyak dikembangkan pada beberape penelitian, seperti: Robot pembersih dinding [5], pembersih air[6], dan pembersih lantai[4][7][8]. Berdasarkan pada sistem kerja Autonomous Robot, sistem pengelola sampah dapat dibuat secara otomatis[4][9][10].

Beberapa penelitian terkait Autonomous Robot untuk pengolahan sampah telah banyak dilakukan pada beberapa penelitian. Salah satunya pada penelitian yang dilakukan oleh Aditya P. P. Prasety, etc [10], di mana pada penelitian tersebut Autonomous Robot dibuat menggunakan lengan manipulator untuk mengambil sampah. Posisi robot dikendalikan berdasarkan sensor ultrasonic dan sistem navigasi. Robot tersebut mampu membersihkan dua jenis sampah sebanyak 40 kali. Penelitian lain serupa juga dilakukan oleh Muhammad Abbas Khan, et al [3], dimana pada penelitian tersebut Robot Semi-autonomous dibuat untuk mengambil sampah berdasarkan perintah dari perangkat Smartphone melalui bluetooth. Robot juga dilengkapi sensor ultrasonic sehingga mampu mendeteksi posisi sampah. Pada Referensi [4], sebuah Autonomous Robot dibuat untuk mengambil sampah yang beroperasi di rumput. Robot mampu mendeteksi sampah secara otomatis dan akurat dengan menggunakan algoritma Deep Neural Network [11]. Robot tersebut dilengkapi sensor ultrasonic[12] dan sistem navigasi [13]. Hasil pengujian menunjukan bahwa robot mampu mendeteksi sampah dengan akurasi 95%. Pada makalah[14], Autonomous Robot dirancang menggunakan algoritma Convolutional Neural Network (CNN) untuk mendeteksi berbagai jenis sampah, seperti kaleng, botol plastik, dan kotak makan siang secara otomatis. Sistem robot mampu mendeteksi sampah secara outdoor. Berdasarkan data hasil pengujian[14], robot tersebut mampu mendeteksi sampah dengan tingkat kepresisian sebesar 95,6% dan tingkat akurasi sebesar 96,8% .

Terispirasi dari makalah [4] dan makalah [14], thesis ini bertujuan untuk merancang *Autonomous Trash Collector System* (ATCS) menggunakan *Deep Reinfocement Learning*. Robot dilengkapi dengan sensor lidar dan sistem navigasi untuk mendeteksi posisi

robot. Selain itu, ATCS juga dilengkapi sistem kendali *Adaptive Neuro-Fuzzy Inference System* (ANFIS) sebagai sistem kendali pada motor[15]. Penelitian ini diharapkan dapat membantu mengatasi masalah pengelolaan sampah yang kebanyakan masih dikelola secara manual.

1.2 Rumusan masalah

1.3 Tujuan penelitian

1.4 Hipotesis

1.5 Metodologi

1.6 Research Method

CHAPTER 2

REVIEW OF LITERATURE AND STUDIES

This chapter starts with a brief introductory paragraph concerning the researcher's exploration of related literature and studies on the research problem. It should be organized thematically to confirm to the specific problems. It should synthesize evidence from all studies reviewed to get an overall understanding of the state of the knowledge in the problem area. As much as possible, the reviewed should be limited within the last ten years. A statement showing how the related materials had assisted the researchers in the present study should be the last part.

This chapter discusses the literature studies and theories of this study. It is divided into two sections: (1) the related literatures; and (2) the related studies.

2.1 Related Literatures

2.2 Related Studies

This section discusses about the related studies which support in the designing of the proposed method.

2.3 Behavior-Based Control Architectures

2.4 Reinforcement Learning

CHAPTER 3

RESEARCH METHODOLOGY

This chapter of a thesis commences a brief statement and enumerating the main topics that are to be covered in it; namely; (1) Research Design; (2) Sources of Data (Locale of the Study and Population/Sampling); (3) Instrumentation and Data Collection; and (4) Tools for Data Analysis. Writing chapter 3 of a thesis requires the assistance of a statistician (in most cases). This is because it is in this chapter that the thesis writer is usually required to indicate what statistical tools he intends to use in data analysis. Here is the basic format of Chapter 3.

3.1 Research Design

The appropriate research design should be specified and described (including requirement, modeling and detailed description of system/product/method development.

3.1.1 System/product/method Implementation

Describe the place where the study was conducted and the rationale behind its choice, the environment of the system (device specification, tools specification and language, which were used in the implementation)

3.1.2 Experiment Scenario

Describe the experiment scenario (including the objective, the procedure of the experiment and the variable which will be used in the experiment).

3.2 Population/Sampling

Describe the population of interest and the sampling of subjects used in the study.

3.3 Instrumentation and Data Collection

Describe the instrument, what it will measure, how to interpret. Discuss how the validity and the reliability will be established. Specify the level of reliability (probability). Give details of instruction given to assistants if persons other than the researcher gather data. State qualifications of informants if used in the study.

3.4 Tools for Data Analysis

Determine and justify the statistical treatment for each sub-problem, the scales of values used and the descriptive equivalent ratings, if any.

3.5 Robot Overview

3.5.1 Design

3.5.2 Actuators

3.5.3 Sensing

3.6 Target Tracking

3.6.1 Image Segmentation

3.6.2 Target Normalization Position

3.6.3 Velocity Estimation

3.7 Localization System

3.8 Software Architecture

CHAPTER 4

PRESENTATION, ANALYSIS AND INTERPRETATION OF DATA

In thesis writing, the most difficult part to defend is chapter 4 because it is in this section where you will present the results of the whole study. Here is a sample thesis format.

4.1 Presentation of Data

Present the findings of the study in the order of the specific problem as stated in the statement of the Problem. Present the data in these forms: (a) tabular; (b) textual; and (c) graphical (optional). The ZOOM LENS approach may be used for purposes of clarity in the presentation of data, i.e. general to particular, macro to micro or vice versa. **(Note: Mean of data in here is data of the experiment result, not the data for input of the system)**

4.2 Analysis of the Data

Data may be analyzed quantitatively or qualitatively depending on the level of measurement and the number of dimensions and variables of the study. Analyze in depth to give meaning to the data presented in the data presented in the table. Avoid table reading. State statistical descriptions in declarative sentences, e.g. in the studies involving:

1. Correlation
    (a) State level of correlation
    (b) State whether positive or negative
    (c) Indicate the level of significance
    (d) Make a decision
2. Differences of Measures
    (a) State the obtained statistical results
    (b) Indicate the level of significance of the difference
    (c) Make a decision
3. Interpretation of Data
    (a) Establish interconnection between and among data

(b) Check for indicators whether hypothesis/es is/are supported or not by findings.

(c) Link the present findings with the previous literature.

(d) Use parallel observations with contemporary events to give credence presented in the introduction.

(e) Draw out implications.

In thesis writing, the Chapter is simply a summary of what the researcher had done all throughout the whole research.

4.3 Summary of Findings

This describes the problem, research design, and the findings (answer to the questions raised). The recommended format is the paragraph form instead of the enumeration form. For each of the problems, present: (a) the salient findings; and (b) the results of the hypothesis tested.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

These are brief, generalized statements in answer to the general and each of the specific sub-problems. These contain generalized in relation to the population. These are general inferences applicable to a wider and similar population. Flexibility is considered in making of conclusions. It is not a must to state conclusions on a one-to-one correspondence with the problems and the findings as all variables can be subsume in one paragraph. Conclusions may be used as generalizations from a micro to a macro-level or vice versa (ZOOM LENS approach). **Conclusions should be written on paragraph**.

5.2 Recommendations

They should be based on the findings and conclusion of the study. Recommendations may be specific or general or both. They may include suggestions for further studies. They should be in non-technical language, feasible, workable, flexible, doable, and adaptable. An action plan is optional.

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Appendices

APPENDIX A

MISCELLANEOUS

This chapter discusses how to insert equation, figure and table on LaTeX document. All the object in this chapter just the examples to make you ease to write your awesome thesis.

A.1 Equation #examples

For simple equation, There is a equation $10 + 5x = 0$, then determine the value of x by solving that algebraic equation problem. The answer is shown by equation A.1

$$\begin{aligned} 10 + 5x &= 0 \\ 5x &= -10 \\ x &= -2 \end{aligned} \tag{A.1}$$

Besides that, for complicated equation will be explained as follow. The general equation for a 2D (N by M image) Discrete Cosine Transform is defined by equation A.2

$$F(u,v) = \sqrt{\frac{2}{N}}\sqrt{\frac{2}{M}} \sum_{i=0}^{N-1} A(i) * \cos\left(\frac{u(2i+1)\pi}{2N}\right) * \sum_{j=0}^{M-1} A(j) * \cos\left(\frac{v(2j+1)\pi}{2M}\right) * f(i,j) \tag{A.2}$$

where $A(i)$ is defined as $\begin{cases} \frac{1}{\sqrt{2}} \ , \ for \ u \ = \ 0 \\ 1 \ , \ otherwise \end{cases}$, while $A(j)$ as $\begin{cases} \frac{1}{\sqrt{2}} \ , \ for \ v \ = \ 0 \\ 1 \ , \ otherwise \end{cases}$

A.2 Figure #examples

This section contain how to insert figure (see figure A.1) and block diagram (see figure A.2). We recommend to use high resolution JPEG or JPG instead PNG format, it will make the compiling process to PDF faster, size of the PDF file is smaller and the quality is image still better when the PDF is print out or zooming out.

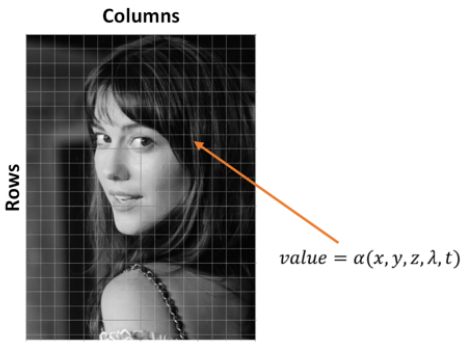

Figure A.1: Picture of mary elizabeth winstead

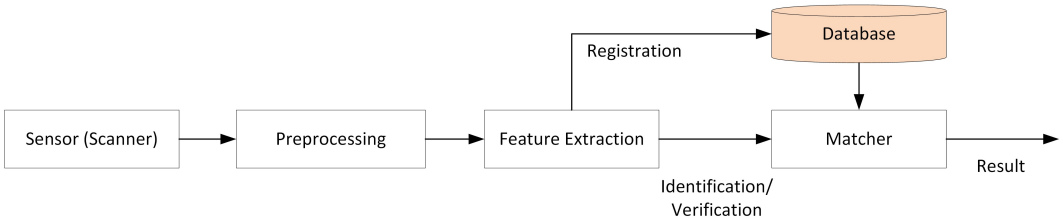

Figure A.2: Example of block diagram.

A.3 Table #examples

The regular table (see table A.1) only can be used in single page. So, for the long table which use multiple pages is recommended to use longtable (see table A.2)

1. Table
   Table A.1 will show you how to cite the reference, it can be the author or the year of the reference.

Table A.1: Example of Tables

Reference	**Paper or Journal**	
	Authors	***Full Authors***
[16]	**(author?)** [16][a]	**(author?)**
[11]	**(author?)** [11]	**(author?)**
[12]	**(author?)** [12]	**(author?)**
[13]	**(author?)** [13]	**(author?)**

[a] : **(year?)**.********.

2. Longtable

Table A.2: Iris flower data set #Example of longtable

Sepal length	**Sepal width**	**Petal length**	**Petal width**	**Species**
5.1	3.5	1.4	0.2	*I. setosa*
4.9	3	1.4	0.2	*I. setosa*
4.7	3.2	1.3	0.2	*I. setosa*
4.6	3.1	1.5	0.2	*I. setosa*
5	3.6	1.4	0.2	*I. setosa*
5.4	3.9	1.7	0.4	*I. setosa*
4.6	3.4	1.4	0.3	*I. setosa*
5	3.4	1.5	0.2	*I. setosa*
4.4	2.9	1.4	0.2	*I. setosa*
4.9	3.1	1.5	0.1	*I. setosa*
5.4	3.7	1.5	0.2	*I. setosa*
4.8	3.4	1.6	0.2	*I. setosa*
4.8	3	1.4	0.1	*I. setosa*
4.3	3	1.1	0.1	*I. setosa*
5.8	4	1.2	0.2	*I. setosa*
5.7	4.4	1.5	0.4	*I. setosa*
5.4	3.9	1.3	0.4	*I. setosa*
5.1	3.5	1.4	0.3	*I. setosa*
5.7	3.8	1.7	0.3	*I. setosa*
5.1	3.8	1.5	0.3	*I. setosa*
5.4	3.4	1.7	0.2	*I. setosa*
5.1	3.7	1.5	0.4	*I. setosa*
4.6	3.6	1	0.2	*I. setosa*
5.1	3.3	1.7	0.5	*I. setosa*
4.8	3.4	1.9	0.2	*I. setosa*
5	3	1.6	0.2	*I. setosa*
5	3.4	1.6	0.4	*I. setosa*
5.2	3.5	1.5	0.2	*I. setosa*
5.2	3.4	1.4	0.2	*I. setosa*
4.7	3.2	1.6	0.2	*I. setosa*
4.8	3.1	1.6	0.2	*I. setosa*
5.4	3.4	1.5	0.4	*I. setosa*
5.2	4.1	1.5	0.1	*I. setosa*
5.5	4.2	1.4	0.2	*I. setosa*
4.9	3.1	1.5	0.2	*I. setosa*
5	3.2	1.2	0.2	*I. setosa*

Sepal length	**Sepal width**	**Petal length**	**Petal width**	**Species**
5.5	3.5	1.3	0.2	*I. setosa*
4.9	3.6	1.4	0.1	*I. setosa*
4.4	3	1.3	0.2	*I. setosa*
5.1	3.4	1.5	0.2	*I. setosa*
5	3.5	1.3	0.3	*I. setosa*
4.5	2.3	1.3	0.3	*I. setosa*
4.4	3.2	1.3	0.2	*I. setosa*
5	3.5	1.6	0.6	*I. setosa*
5.1	3.8	1.9	0.4	*I. setosa*
4.8	3	1.4	0.3	*I. setosa*
5.1	3.8	1.6	0.2	*I. setosa*
4.6	3.2	1.4	0.2	*I. setosa*
5.3	3.7	1.5	0.2	*I. setosa*
5	3.3	1.4	0.2	*I. setosa*
7	3.2	4.7	1.4	*I. versicolor*
6.4	3.2	4.5	1.5	*I. versicolor*
6.9	3.1	4.9	1.5	*I. versicolor*
5.5	2.3	4	1.3	*I. versicolor*
6.5	2.8	4.6	1.5	*I. versicolor*
5.7	2.8	4.5	1.3	*I. versicolor*
6.3	3.3	4.7	1.6	*I. versicolor*
4.9	2.4	3.3	1	*I. versicolor*
6.6	2.9	4.6	1.3	*I. versicolor*
5.2	2.7	3.9	1.4	*I. versicolor*
5	2	3.5	1	*I. versicolor*
5.9	3	4.2	1.5	*I. versicolor*
6	2.2	4	1	*I. versicolor*
6.1	2.9	4.7	1.4	*I. versicolor*
5.6	2.9	3.6	1.3	*I. versicolor*
6.7	3.1	4.4	1.4	*I. versicolor*
5.6	3	4.5	1.5	*I. versicolor*
5.8	2.7	4.1	1	*I. versicolor*
6.2	2.2	4.5	1.5	*I. versicolor*
5.6	2.5	3.9	1.1	*I. versicolor*
5.9	3.2	4.8	1.8	*I. versicolor*
6.1	2.8	4	1.3	*I. versicolor*
6.3	2.5	4.9	1.5	*I. versicolor*

Sepal length	Sepal width	Petal length	Petal width	Species
6.1	2.8	4.7	1.2	*I. versicolor*
6.4	2.9	4.3	1.3	*I. versicolor*
6.6	3	4.4	1.4	*I. versicolor*
6.8	2.8	4.8	1.4	*I. versicolor*
6.7	3	5	1.7	*I. versicolor*
6	2.9	4.5	1.5	*I. versicolor*
5.7	2.6	3.5	1	*I. versicolor*
5.5	2.4	3.8	1.1	*I. versicolor*
5.5	2.4	3.7	1	*I. versicolor*
5.8	2.7	3.9	1.2	*I. versicolor*
6	2.7	5.1	1.6	*I. versicolor*
5.4	3	4.5	1.5	*I. versicolor*
6	3.4	4.5	1.6	*I. versicolor*
6.7	3.1	4.7	1.5	*I. versicolor*
6.3	2.3	4.4	1.3	*I. versicolor*
5.6	3	4.1	1.3	*I. versicolor*
5.5	2.5	4	1.3	*I. versicolor*
5.5	2.6	4.4	1.2	*I. versicolor*
6.1	3	4.6	1.4	*I. versicolor*
5.8	2.6	4	1.2	*I. versicolor*
5	2.3	3.3	1	*I. versicolor*
5.6	2.7	4.2	1.3	*I. versicolor*
5.7	3	4.2	1.2	*I. versicolor*
5.7	2.9	4.2	1.3	*I. versicolor*
6.2	2.9	4.3	1.3	*I. versicolor*
5.1	2.5	3	1.1	*I. versicolor*
5.7	2.8	4.1	1.3	*I. versicolor*
6.3	3.3	6	2.5	*I. virginica*
5.8	2.7	5.1	1.9	*I. virginica*
7.1	3	5.9	2.1	*I. virginica*
6.3	2.9	5.6	1.8	*I. virginica*
6.5	3	5.8	2.2	*I. virginica*
7.6	3	6.6	2.1	*I. virginica*
4.9	2.5	4.5	1.7	*I. virginica*
7.3	2.9	6.3	1.8	*I. virginica*
6.7	2.5	5.8	1.8	*I. virginica*
7.2	3.6	6.1	2.5	*I. virginica*

Sepal length	Sepal width	Petal length	Petal width	Species
6.5	3.2	5.1	2	*I. virginica*
6.4	2.7	5.3	1.9	*I. virginica*
6.8	3	5.5	2.1	*I. virginica*
5.7	2.5	5	2	*I. virginica*
5.8	2.8	5.1	2.4	*I. virginica*
6.4	3.2	5.3	2.3	*I. virginica*
6.5	3	5.5	1.8	*I. virginica*
7.7	3.8	6.7	2.2	*I. virginica*
7.7	2.6	6.9	2.3	*I. virginica*
6	2.2	5	1.5	*I. virginica*
6.9	3.2	5.7	2.3	*I. virginica*
5.6	2.8	4.9	2	*I. virginica*
7.7	2.8	6.7	2	*I. virginica*
6.3	2.7	4.9	1.8	*I. virginica*
6.7	3.3	5.7	2.1	*I. virginica*
7.2	3.2	6	1.8	*I. virginica*
6.2	2.8	4.8	1.8	*I. virginica*
6.1	3	4.9	1.8	*I. virginica*
6.4	2.8	5.6	2.1	*I. virginica*
7.2	3	5.8	1.6	*I. virginica*
7.4	2.8	6.1	1.9	*I. virginica*
7.9	3.8	6.4	2	*I. virginica*
6.4	2.8	5.6	2.2	*I. virginica*
6.3	2.8	5.1	1.5	*I. virginica*
6.1	2.6	5.6	1.4	*I. virginica*
7.7	3	6.1	2.3	*I. virginica*
6.3	3.4	5.6	2.4	*I. virginica*
6.4	3.1	5.5	1.8	*I. virginica*
6	3	4.8	1.8	*I. virginica*
6.9	3.1	5.4	2.1	*I. virginica*
6.7	3.1	5.6	2.4	*I. virginica*
6.9	3.1	5.1	2.3	*I. virginica*
5.8	2.7	5.1	1.9	*I. virginica*
6.8	3.2	5.9	2.3	*I. virginica*
6.7	3.3	5.7	2.5	*I. virginica*
6.7	3	5.2	2.3	*I. virginica*
6.3	2.5	5	1.9	*I. virginica*

Sepal length	**Sepal width**	**Petal length**	**Petal width**	**Species**
6.5	3	5.2	2	*I. virginica*
6.2	3.4	5.4	2.3	*I. virginica*
5.9	3	5.1	1.8	*I. virginica*

APPENDIX B

Curriculum Vitae # Example

PERSONAL INFORMATION

Name	:	Mr. Handsome
Date and Place of Birth	:	May 04, 2015 - Bandung, West Java
Address	:	...
City and Province	:	...
Postal Code	:	99999
Sex	:	Male
Nationality	:	Indonesia
Religion	:	...
Marital Status	:	Single
Language Skill 1	:	Indonesian (Mother Tongue)
Language Skill 2	:	English (Sufficient)
Language Skill 3	:	Minang (Sufficient)
Language Skill 4	:	Java (Intermediate)
Language Skill 5	:	Malay (Basic Knowledge)
Language Skill 6	:	Arabic (Basic Knowledge)
Phone 1	:	+62 851 xxxx xxxx
Phone 2	:	+62 852 xxxx xxxx
Fax	:	-
Email	:	youremail@students.telkomuniversity.ac.id

EDUCATION

Education Degree	**Institution**	**Period of Education**	**Year of Graduation**
Master	Telkom University	2013 - 2015	2015
Bachelor	...	2008 - 2012	2012
High School	...	2007 - 2008	2008
Middle School	...	2003 - 2005	2005

PUBLICATIONS

Title	Event	Year
...	...	2011
...	...	2012

TEACHING AND PROFESSIONAL EXPERIENCE

Position	Institution	Field	Period
...	...	...	2012 - 2013
...	...	...	2009 - 2013

TRAINING AND WORKSHOP

Training and Workshop	Organizer	Year
...	...	2012
...	...	2009

ACHIEVEMENT

Achievement	Event	Year
1^{th}	Winner of The Awesome Thesis 2015, Telkom University	2015

autonomous trash collector

========== mendesain sistem kontrol untuk sistem navigasi AMR pada robot real. pada banyak aplikasi robotika, sistem navigasi AMR (robot mandiri) pada lingkungan tidak struktur, sulit memperoleh model matematik yang tepat dari interaksi robot dengan lingkungannya. ketidak tahuan ====== The control architectures could be classified into three categories: Deliberative (Centralized) navigation, Reactive (Behaviour-based) navigation and hybrid (Deliberative - Reactive) navigation.

behavior-based architectures are described as they were originally designed. The architectures are Subsumption, Action Selection Dynamics, Motor Schema and Process Description Language.

Subsumption architecture advocates the competitive selection of behaviours, while the motor schemas rely on the use of cooperative coordination. Motor schema provides an ability to simultaneously use the outputs of more than one behavior with capturing their particular influence on overall output (Vuković and Miljković, 2009).

The overall advantages of behaviour-based navigation systems are: i) Their ability to build a navigation system in an incremental way of layer upon layer. ii) Their quick reaction to the unknown and dynamic environment. iii) They do not require modelling and storing the whole model of the environment. iv) There is less computation and shorter delay between perception and action. v) And they are more robust and reliable which means in case of a behaviour unit failure, the other units continue the tasks.

The drawbacks of behaviour-based control are as follows: i) Difficulty in coordination among the behaviours, the interaction between the system and environment is difficult and less predictable. ii) Behaviours are low level so they do not reflect high level tasks. iii) Lack of planning module could be not appropriate for some complicated tasks.

Behavior-based control layer. Design of a behavior-based control system which will be contained in the overall control architecture with the purpose of accomplishing simple tasks. A task is intended as one of the phases in which a mission can be divided. It is assumed that the sequential achievement of a set of tasks entails the achievement of the mission. The behavior-based control system must assure the safety of the robot while demonstrating a high control performance.

Reinforcement Learning-based behaviors. Integration of a reinforcement learning algorithm in the control architecture. This learning theory will be applied to the acquisition of the internal structure of a robot behavior. The purpose of using Reinforcement Learning is to reduce the required human work in the development of a new robot behavior. Instead of implementing the action-decision rules, the designer need only to define the goal of the behavior.

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is to reduce the required human work in the development of a new robot behavior. Instead of implementing the action-decision rules, the designer need only to define the goal of the behavior.

Reinforcement learning Reinforcement learning (RL) is a class of learning algorithm where a scalar evaluation (reward) of the performance of the algorithm is available from the interaction with the environment. The goal of a RL algorithm is to maximize the expected reward by adjusting some value functions. This adjustment determines the control policy that is being applied. The evaluation is generated by a reinforcement function which is located in the environment. Chapter 4 gives a detailed description of Reinforcement Learning and its application to robotics. Main references about RL are [Kaelbling et al., 1996, Sutton and Barto, 1998].