Navigation System using Single Camera with Fuzzy Logic Control and Obstacle Avoidance*

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Abstract— **Mobile Robot is a system that is able to perform or navigate intelligently using sensor actuator control techniques. Currently the Mobile Robot system is developing rapidly in various fields and research on it is increasingly being carried out. The research that has been done aims to find an efficient navigation system to be applied to the Mobile Robot system. In its application the navigation system on the Mobile Robot uses one or more sensors embedded in the Mobile Robot. This can lead to inefficiencies in terms of computing and in terms of making decisions in navigating the Mobile Robot.**

In the navigation system on the Mobile Robot, simplification of the use of sensors and computing can be made. By using Sensor Vision, namely the camera and performing centralized computing, it can create a time- and memory-efficient navigation system. The use of Sensor Vision is to replace the sensor which is usually implanted directly on the Mobile Robot to recognize or read the Mobile Robot's working environment properly. The data that will be obtained from environmental readings are in the form of robot coordinates, goals, and obstacles using Object Detection. By computing centrally, the data will be processed with a Personal Computer (PC) using the Fuzzy Logic Control method, so that the Mobile Robot will only receive data in the form of right and left wheel speeds.

Keywords— **Mobile Robot, Object Detection, Sensor Vision, Obstacle, Fuzzy Logic Control.**

I. INTRODUCTION

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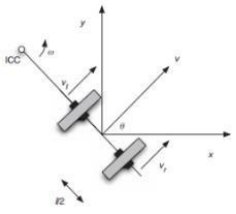
II. RELATED WORK

Previous research serves to analyze and enrich the research discussion, as well as to distinguish it from the current research. This study includes several previous research journals related to the concept of navigating a mobile robot system using the fuzzy logic method by utilizing the computer vision method for environmental reading. The implementation of the fuzzy logic method on the mobile robot navigation system has been carried out in the [1] research. The reading of the mobile robot environment is carried out extensively in the future. In the [2] research, a prototype was made on a wheelchair using a camera. Camera is used to read the surrounding environment. By using the Binary Image technique or the black and white extraction process from the actual image.

III. RESEARCH METHOD

A. Diffrential Wheeld Robot

Differential Wheeled Robot is the simplest drive mechanism for Mobile Robot. Differential Wheeled Robot has two wheels mounted on the same axis and driven by two different motors. The motion that will result from the speed of the two wheels can be in the form of straight or rotating motion. As the picture below describes the description and some of the parameters in the Differential Wheeled Robot[3].



the robot makes a rotational movement must have the parameters contained in each wheel moving around the ICC (Instantaneous Centre of Curvature) at the same angle ω, where the equation for the left wheel and right wheel is

$$\omega(R + l/2) = vr$$

$$\omega(R - l/2) = vl$$

B. Digital Imag

An image can be defined as a two-dimensional function, f(x,y), where x and y are the spatial coordinates, and the

amplitude f at each coordinate (x, y) is called the intensity or ash level. gray scale of the image at that point and it can be said to be a digital image. A digital image can be processed into several forms of image processing techniques. Image processing is a form of signal processing or processing with input in the form of images and transformed into other images as output with certain techniques[21].

C. Fuzzy Logic Control

Fuzzy logic is an improvement from Boolean logic which deals with the concept of partial truth. Fuzzy has a characteristic function: the values assigned to the elements of the universal set fall within a certain range and indicate the membership values of their elements on the set. A larger value indicates a higher set membership level. The set defined by the membership function is called a fuzzy set. The most used membership value range is the 0.1 unit interval. Some fuzzy sets represent linguistic concepts such as low, medium, and high. This concept is used to define the state of a variable.

1. Fuzzification

In the fuzzification process there is a fuzzy set obtained from each input variable and each input has a relationship with the specified output fuzzy set. Fuzzy sets of inputs and outputs are defined by a membership function. Let A be a fuzzy set in X defined as :

$$A = (x, \mu(x)||x \epsilon X)$$

2. Membership Function

A Triangular Membership Function is specified by three parameters (a, b, c) as follows :

$$triangular(x; a, b, c) = \begin{cases} 0 & ; x \leq a, \\ \frac{x-a}{b-a} & ; a \leq x \leq b, \\ \frac{c-x}{c-b} & ; b \leq x \leq c, \\ 0 & ; c \leq x, \end{cases}$$

A Trapezoidal Membership Function is specified by three parameters (a, b, c, d) as follows :

$$trapezoid(x; a, b, c, d) = \begin{cases} 0 & ; x \leq a, \\ \frac{x-a}{b-a} & ; a \leq x \leq b, \\ 1 & ; b \leq x \leq c, \\ \frac{c-x}{c-b} & ; c \leq x \leq d, \\ 0 & ; d \leq x, \end{cases}$$

A Gaussian MF is specified by two parameters c, σ :

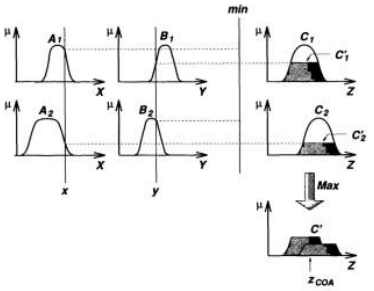
$$gaussian(x; c, \sigma) = e^{\frac{-1}{2}(\frac{x-c}{\sigma})^2}$$

D. Fuzzy Inference System

The Fuzzy inference system is a popular computing framework based on the concepts of fuzzy set theory, fuzzy if-then rules and fuzzy reasoning it has found successful applications in a wide variety of fields, such as automatic control, data classification, decision analysis, expert system, time series prediction, robotics and pattern recognition. Because of its. multidisciplinary nature, the fuzzy inference system is known by numerous other names, such as fuzzy-rule-based system, fuzzy expert system, fuzzy model, fuzzy associate memory, fuzzy logic controller, and simply (and ambiguously) fuzzy system [8].

1. Mamdani Fuzzy Models

The Mamdani Fuzzy inference system was proposed as the first attempt to control a steam engine an boiler combination by a set of linguistic control rules obtained from experienced human operators. An illustration of how a two-rule mamdani fuzzy inference system derives the overall output z when subjected to two crisp inputs x and y.

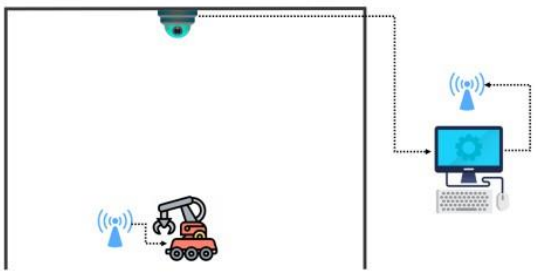


IV. SYSTEM DESIGN AND IMPLEMENTATION

The main objective of this research is to find a solution for a navigation system that will be applied to Mobile Robot by using Sensor Vision for an introduction to the Mobile Robot working environment. The discussion in this chapter covers system models and scenarios in which it refers to reading objects such as mobile robot and obstacle using the object detection process and fuzzy logic methods. In this thesis, a solution is designed for navigation on Mobile Robot by using Camera Vision to build a safe navigation system for Mobile Robot. There are several stages that will be carried out in this thesis to be able to full fill the objectives of this thesis. The indicator of success in this thesis is finding a solution in navigation for Mobile Robot that uses Camera Vision to identify the environment that supports the generation of safe navigation system to navigate. The test that will be carried out is to put Mobile Robot in any position, and to recognize its environment to detect any obstacles, using Camera Vision. Computing is done centred on Personal Computer, the method that will be used to build the navigation system will also be done on the Personal Computer. Mobile Robot will only receive information about right wheel speed and left wheel speed using fuzzy logic method.

A. System Design

Overall the system will consist of several components, namely nodes that contain the sensor system, personal computer, module communication, mobile robot, microcontroller. The whole system design

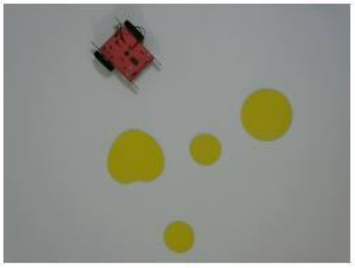


B. Object Detection

Object detection is a computer vision technique for locating instances of objects in images or videos. Object detection algorithms typically leverage machine learning or deep learning to produce meaningful results. When humans look at images or video, we can recognize and locate objects of interest within a matter of moments. The goal of object detection is to replicate this intelligence using a computer.

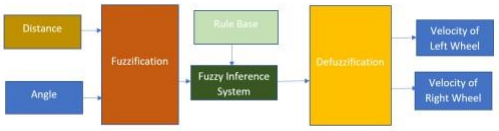
$$d = \sqrt{(X_T - X)^2 + Y_T - Y)^2}$$

No	Input	Minimum Value	Maximal Value
1	Very Close	0 mm	125 mm
2	Near	0 mm	250 mm
3	Medium	125 mm	375 mm
4	Far	125 mm	400 mm
5	Very Far	375 mm	500 mm



The destination point is symbolized by two small circles. More than one destination point is given to make it easier for the mobile robot to reach the final destination point.

C. Fuzzy Logic Control Design



1. Fuzzification of Distance Fuzzification on the distance variable is based on the formula below :
2. Fuzzification of Angle

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