AUTONOMOUS ROBOT WITH LANE DETECTION SYSTEM

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ABSTRAK

Autonomous Robot with Lane Detection System

Robot pintar telah memberi kesan yang mendalam ke atas industri sejak 20-30 tahun lalu. Baru-baru ini, teknologi ini telah diaplikasikan ke atas kenderaan dalam percubaan menghasilkan kereta pintar. Walaupun peralatan dan perisian telah membangun dengan stabil namun masih hanya sedikit pembangunan projek-projek penghasilan kereta pintar dan tiada yang mampu mencapai komersil. Sejak potensi perisian komputer dalam menolong pemanduan kenderaan diperakui, banyak usaha diperuntukkan dalam pembangunan teknik-teknik yang berkaitan seperti; pengenalpastian lorong, pengelasan objek, menjejaki, dan pengantian kerja untuk objek berkaitan. Untuk sistem sebegini, bagi melaksanakan tugasnya ia harus mengesan persekitarannya dengan menggunakkan satu atau lebih alat pegesan. Kebiasaannya satu proses kompleks, pengabungan, dan penterjemahan data pengesan diperlukan dan mengenakan arkitektur modular untuk sistem keseluruhan. Projek ini adalah mengenai pembinaan untuk penglihatan komputer secara perisian dan peralatan robot pintar pengenalpastian lorong. Struktur peralatan menggunakan kamera untuk melihat kawasan sekeliling. Perisian penglihatan komputer diperlukan untuk mengenalpasti lorong dan bedasarkan cara "Hough Transform".

ABSTRACT

Autonomous Robot with Lane Detection System

Autonomous robots have made their impact felt in industry for the past 20-30 years. More recently, the technology has been applied to vehicles in an attempt to create the autonomous car. Although hardware and software has been steadily advancing there have still been very few car projects to achieve complete autonomy and none to achieve commercial viability. Since the potential of soft-computing for driver assistance systems has been recognized, much effort has been spent in the development of appropriate techniques for robust lane detection, object classification, tracking, and representation of task relevant objects. For such systems in order to be able to perform their tasks the environment must be sensed by one or more sensors. Usually a complex processing, fusion, and interpretation of the sensor data is required and imposes a modular architecture for the overall system. This project is about constructing the computer vision hardware and software components of an autonomous lane detection robot. The hardware setup makes use of a camera to view of its surroundings. The computer vision software is required to locate the lane and is based on Hough Transform method.

ACKNOWLEDGMENTS

Alhamdulillah, thanks to God for all his bless and giving us the opportunities to complete this final year project successfully and on the time with title 'AUTONOMOUS ROBOT WITH LANE DETECTION SYSTEM'. I would like to thank all the following people: Mr. Azali Saudi our supervisor for his extensive advice and assistance with the software and hardware, as well as the hardware part support from him; Mr Liawas Barukang for suggestions and motivation that he gives, particularly for the idea to make faster software. I also want to thanks my entire group member for all the hard works their gives for this project. In these opportunities, I also want to thanks all the lecturers that involve in this project direct or indirectly, my friends and family for their support and guidance this year. Last word, I hope that this project can give a good impact to all the parties.

Thank you,

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION TO THE PROJECT

The world of technology and information is evolving faster everyday. New invention, technology, creation and other is introduce almost everyday. To reach the goals to be one of the developed countries in the world and also achieve the ambition of 2020, development technology in Malaysia must be improve in all area of this sector. Now in Malaysia, almost all agency government or non-government start to participate and using the new technology that has been introduce by other country.

Malaysia also has started to developing new technology in many aspects such as electronic and electrical, software and hardware, robotics, telecommunication and others. One of the most important technology and have evolving very fast is robotic. Many countries have been competed in this technology for the past few years. This is because robotic is one of the most advance technologies for this century and it is said to be the technology of the future. Robotic is a new technology that has spreads very quickly to many sectors in all over the world. Most of new inventions in robotics technology give a huge impact to the way of people living and work. The main idea or purpose robotics technology is to make the lifestyle of people in working, living, communicating, socialize and others become much easier, systematic, organize, effective, consistent and giving faster and better result.

There are many type of robots, an each of its have different way to use and how to use it. Autonomous robotics is an area of research dedicated to robots that can do all their tasks (e.g. maneuver, exploit opportunities, react to changes in the environment etc.) autonomously. The perception, navigation, planning, and reasoning capabilities of such robots has improved considerably over the last few years and as a consequence the field of autonomous robotics has become a challenging test bed for developing and testing many engineering and computer science concepts. Our project is to build such robot that is based on lane detection using vision sensor. Lane detection is widely researched purposely for assisting in driving autonomous vehicles. For example an automatic transport that do not need a driver and operate or assisted automatically by a program.

1.2 PROJECT OBJECTIVES

Generally, with the involvement of every student in building a project gives the student place to practice and applied all their knowledge that their have learn. This will help the student understanding much more with their studies and gives preparation for the working world.

With a good and well prepare schedule and plan, its also help us to discipline ourselves to keep on time, responsible, doing all the duty that been give and done the project as good as possible. At the same time, it will build a spirit of team ship among members to be more consideration, helping each others, more understanding among members and much more positive impact. With this also every each of members will have opportunity to show theirs own capability by building the project.

The main objectives of this project are to build a robot with the provided basic robot frame for the robot and our tasks are to design and to construct a mobile robot. Second objective is to build the software for the robot based on lane detection system. For this project the testing environment is at the hallway of SKTM building that has brown tiles and light yellow tiles.

1.3 PROJECT SCOPE

As we all know the scope of our project is lane detection. Lane detection is widely researched purposely for assisting in driving autonomous vehicles. Our project is to build a lane detection mobile robot using camera.

The robot will use a web camera to capture images which will then be processed to differentiate the lane environment and for this situation it will differentiate between colors for example; black color with white color or dark environment with bright environment, so that the robot can choose and follow the correct lane or path by itself. The robot that we want to create will be using three tires, one in front and the other two on the right side and the left side. Each right and left tires will use a motor for movements. The motors will be controlled by a laptop computer through a parallel port. The laptop computer will be connected to a web camera to capture images that will be sent to the laptop computer for further processing with a lane detection system. After processing the data the laptop give order to the motors to follow the correct path.

With the discussion and research that we have done about the project, we have concluded that our project has divided to a several main task:

1.3.1 Assembling Robot Parts

Firstly for this project we have to assemble and install all the robot parts according to what the project asks and needs. All the components are the platform, three tires, two motors, two power supply (batteries), one laptop, one web cam and together with wires and some accessories.

1.3.2 Processing Images

The web camera captured images that will be processed to determine an available lane. The images will be differentiate and calculate according its color and brightness to search the correct direction and areas lane available. The images are captured in between a period of time constantly so it can produce much precise result.

1.3.3 Movement of the robot

After processing the images, the result will be analyzed by the lane detection system and movement signals will be sent from the laptop to the motors that will make the robot move. This process also will be run between a periods of time constantly to gives more precise and correct movement.

1.4 PROBLEM BACKGROUND

The background problem for this project is to build an autonomous robot that can detect an available lane using a web camera by processing the captured images and follows it on its own. The image processing must have the abilities to differentiate between colors, brightness and any others areas and situations for searching an available lane.

1.5 CONCLUSION

Our project consisted on designing and constructing a robot that would utilize vision based lane detection to move. This project consists of programming for processing image and sending command to the motors. It also requires a basic knowledge in electrical to make the robot's electrical circuits. The testing area will be at hallway of SKTM building that has brown tiles and light yellow tiles. The border between the brown and light yellow tiles makes a convenient path for a robot to follow. The basic operation of the robot is acquiring an image frame through a web camera, detect and identify the lane boundaries from the image, estimate the parameters of the lane model, and then move within the lane. If this project is a success, then it can be applied to many other situations like in assisting in driving autonomous vehicles.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Literature review is one of the basic factors to help in developing a project. Its help both in concepts and also as a guide in developing the project. Its give better view of the picture of the project that we develop. it is helpful and suit the purpose for the research that been continue by other researcher. Literature review is very important for all research.

2.2 REVIEWS RESEARCHES

Among the complex and challenging tasks of future road vehicles is road following. It is based on: lane detection (which includes the localization of the road, the determination of the relative position between vehicle and road, and the analysis of the vehicle's heading direction), and obstacle detection (which is mainly based on localizing possible obstacles on the vehicle's path).

In most prototypes of autonomous vehicles developed worldwide, lane following is divided into the following two steps: initially the relative position of the vehicle with respect to the lane is computed and then actuators are driven to keep the vehicle in the correct position.

Conversely, some early systems were not based on the preliminary detection of the road's position, but obtained the commands to be issued to the actuators (steering wheel angles) directly from visual patterns detected in the incoming images. For example, the Autonomous Land Vehicle in a Neural Net (ALVINN) system is based on a neural net approach: it is able to follow the road after a training phase with a large set of images.

Nevertheless, since the knowledge of the lane position can be conveniently exploited by other driving assistance functions, the localization of the lane is generally performed. A few systems have been designed to handle completely unstructured roads: for example, the Supervised Classification Applied to Road Following (SCARF) and POSTECH Road Vehicle (PVR III) systems are based on the use of color cameras and exploit the assumption of a homogeneously colored road to extract the road region from the images.

Nevertheless it must be faced problems like; the presence of shadows (projected by trees, buildings, bridges, or other vehicles) produces artifacts onto the road surface and thus alternates the road texture. Most research groups face this problem by using highly sophisticated image filtering algorithms. When lane markings are not well visible(because of low contrast, shadows, bad weather conditions), the use of pattern-based techniques can be helpful. The system developed at the Toyota Central R&D Labs, for example, is based on a voting method, in which lane marking patterns are generated and provided. After ordinary edge extraction, edge points are matched to each pattern. At the end of the process, the patterns with the greater number of votes are chosen as the best approximations of the left and right lane markings. Other algorithms exploit the processing of color images; this is the case of the Michigan Off-road Sensor Fusing Experimental Test bed (MOSFET) autonomous vehicle which uses a color segmentation algorithm that maximizes the contrast between lane markings and the road.

2.2.1 First concepts

Lane detection is a complicated problem under different light/weather conditions. In this class project we analysis the easy case first: the images are captured from the crossover above the road, assume the lanes to be detected are straight, at daytime and with good weather condition. The lane markings can be solid or dash lines. Other than detecting the lane markers, the mid-line of each lane is also calculated to identify the position of the vehicle with respect to lane makings, which is useful for autonomous driving.

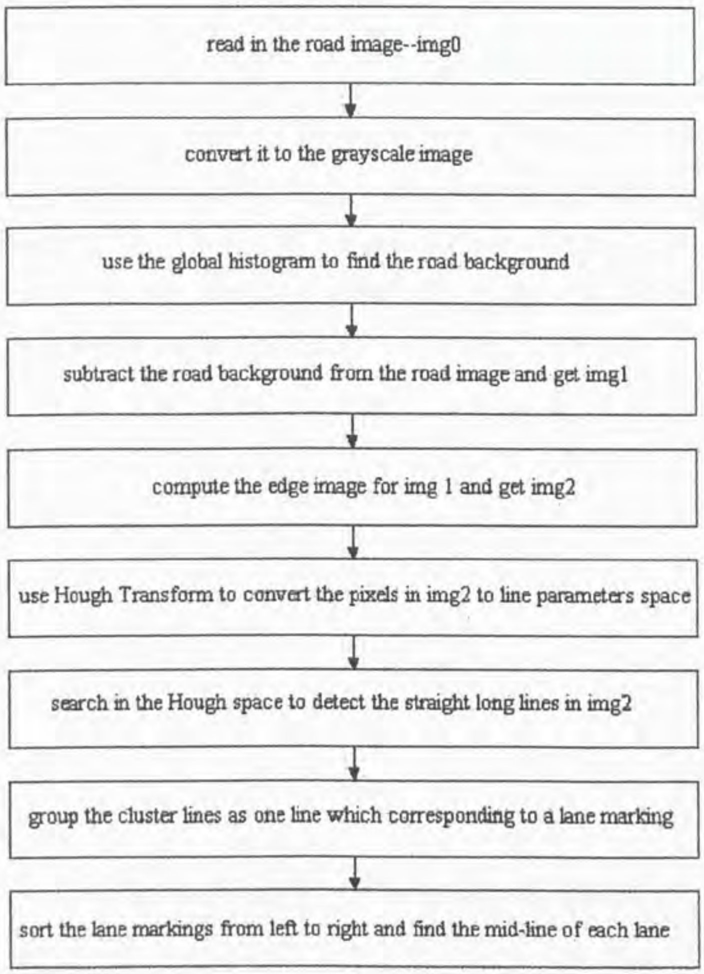


Figure 1: The line detection algorithm

The figure above is based on edge detection and Hough Transform. First the RGB road image is read in and converted into the grayscale image. Then we use the global histogram to find the road background gray and subtract it from the grayscale image to get img1. Edge operation is executed on img1 and lane marking features are preserved in img2. The key technology here is using Hough Transform to convert the pixels in img2 from the image coordinate (x, y) to the parameter space (ρ, θ), and then search in the Hough space to find the long straight lines, which are lane marking candidates. The candidate lines are post-processed: delete the fake ones, select one line from a cluster of closing lines as a lane marking. Finally the lane makings are sorted by their position in the road from left to right. Also the mid-line of each lane is computed to localize the lane.

The Hough transform is used in a variety of related methods for shape detection. These methods are fairly important in applied computer vision; in fact, Hough published his transform in a patent application, and various later patents are also associated with the technique. Here we use it to detect the straight lines. Figure 2 is the fundament idea to convert each pixel in the image to parameter space. We define the origin of the image coordinate as the upper-left point.

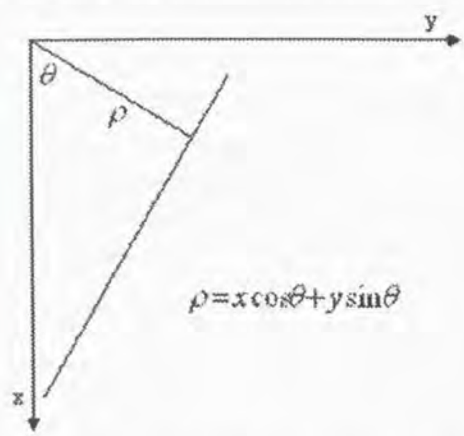


Figure 2: Hough transform for detecting straight lines

A count array [ρ] [θ] is constructed for each candidate line and some other array are constructed to record each line's start/end position. Since the lane markings are not close to the origin and they are not horizontal in the image (for autonomous driving application, the camera is mounted on the vehicle with front view), we only detect the straight lines with restriction $\rho > 10, 30 < \theta < 150$, and also the calculation time cost is reduced.

2.2.2 Second concepts

Dense optical flow data are calculated in real-time and used to control steering, and avoid collisions. When the obstacle avoidance is insufficient to avoid collision, the divergence data warn the robot of the impending collision then the robot stops, turns and resumes wandering straight ahead in the new direction until it detects a next warning.

Optical flow is a concept with many definitions: the apparent motion that an observer notices in an image, a two dimensional vector that indicates the motion of objects, or features, in a sequence of images. The definition is less important than the fact that it is the preferred option for calculating three-dimensional properties of the environment, and to obtain other useful motion information, starting from the luminance changes of the image plane points.

The sensing modes can be exploited by the framework:

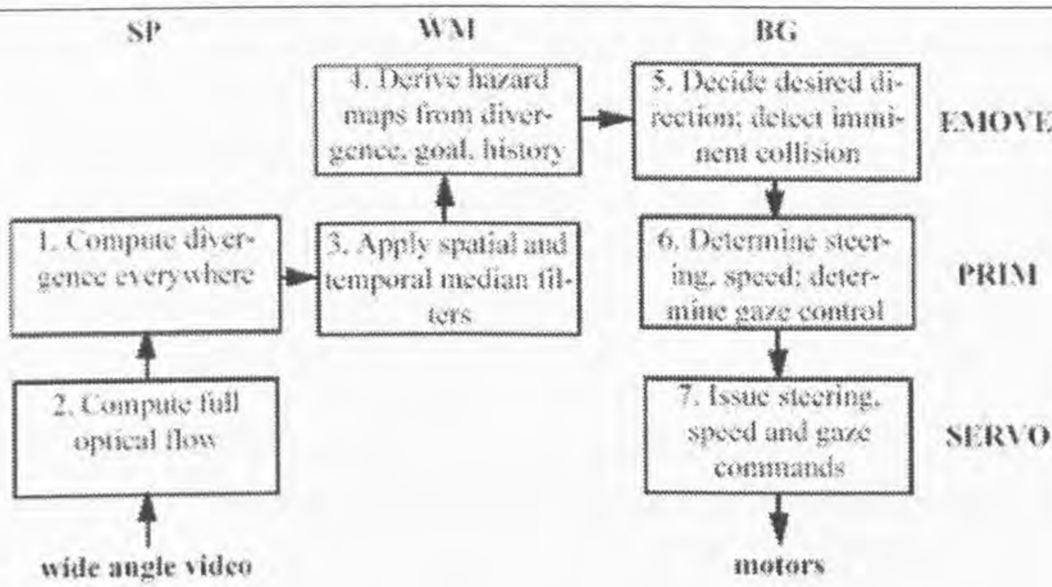


Figure 3: Optical Flow Framework

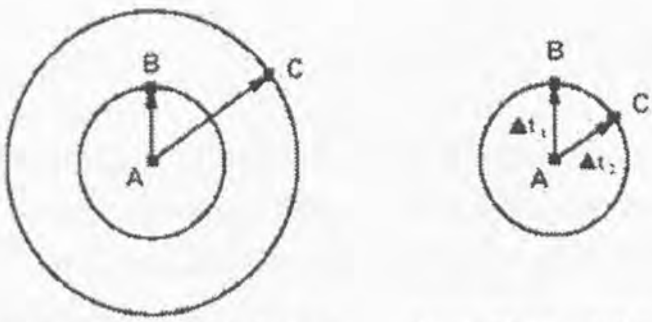
This method fulfils all the requirements of a robotic vision system: being robust, fast and accurate enough for real-time applications. In correlation-based flow, the motion for pixel at [x, y] in one frame to a successive frame is defined to be the displacement of the patch P_v + 1) x (2j of v x v pixels centred at [x, y], out of (2j is an arbitrary parameter dependent on+ 1) possible displacement (where j maximum expected motion in the image).

The correct motion of the patch of pixels is determined by simulating the motion of the patch for each possible displacement of [x, y] and considering match strength for each displacement. If represents a matching function which returns a value proportional to the j match of two given features (such as the absolute difference between the two pixels' intensity values, E_1 and E_2 respectively), then the match strength M (x, y; u, w) for a point [x, y] and displacement (u, w) is calculated by taking the sum of the match values between each pixel in the displaced patch P_v in the first image and the corresponding pixel in the actual patch in the second image:

$$\forall(u, w) M(x, y; u, w) = \sum_{(i, j) \in P_v} \phi(E_1(i, j) - E_2(i + u, j + w))$$

The actual motion of the pixel is taken to be that of the particular displacement, out of (2j + 1) x (2j + 1) possible displacements, with the maximum neighbourhood match strength (or equivalent, minimum patch difference). Because the patch of a given pixel largely overlaps with that of an adjacent pixel, match strengths for all displacements for adjacent pixels tend to be similar (except at motion boundaries). Therefore the resultant optical flow field tends to be relatively smooth, without requiring any additional smoothing steps.

A significant limitation with the traditional correlation-based algorithm is that its time grows quadratically with the maximum possible displacement allowed for the pixel.



Constant time delay, variable distances.

Constant distance, variable time delays.

(a) As the maximum pixel shift increases linearly, the search area increases quadratically.

(b) However, with a constant shift distance and variable discrete time delays, search over time is linear.

Figure 4: Time Delays and Distances

However, the relationship between velocity, distance and time:

$$vel = \frac{\delta dist}{\delta time}.$$

In order to search for variable velocities, the inter-frame delay delta t is usually kept constant and search over variable distances:

$$\Delta v = \frac{\Delta d}{\delta t}, d \leq \eta.$$

But from Figure above, this results in an algorithm that is quadratic in the range of velocities present. Alternatively, we can keep delta d constant and search over variable time delays:

$$\Delta v = \frac{\delta d}{\Delta t}.$$

In this case, we generally prefer to keep delta d as small as possible (e.g. a single pixel) in order to avoid the quadratic increase in search area (Note, there is nothing preventing an algorithm based on both variable delta d and delta t).

2.2.3 Third concepts

An overview of the original algorithm for lane detection (described in [Lakshmanan (1995)]) including indication for its improvement are given. The given likelihood function is non-concave and has many local maxima. To locate its global maximum a Monte-Carlo method is proposed [Lakshmanan (1995)].

This approach is easier compared to complicated gradient based methods for the global search. The original algorithm proceeds as follows:

1. Set counter j = 0, initialize $(\Omega l(0),\Omega r(0))$, and evaluate $L(\Omega l(0),\Omega r(0))$

2. Pick randomly $(\Omega l(j+1),\Omega r(j+1))$ from all the possible parameter values in the neighborhood of $(\Omega l(j),\Omega r(j))$

3. Evaluate $L(\Omega l(j+1),\Omega r(j+1))$ and update $(\Omega l(j),\Omega r(j))$ with $(\Omega l(j+1),\Omega r(j+1))$ as best fitting set of parameters if it is more likely.

4. Set $L(\Omega l(j),\Omega r(j)) = L(\Omega l(j+1),\Omega r(j+1))$ and j = j + 1

5. If j < jmax go to step 2, else stop. To improve fitting, the template is modified to fit better its direct environment. That increases the likelihood.

2.2.4 Fourth concepts

While edges (i.e. boundaries between regions with relatively distinct gray levels) are by far the most common type of discontinuity in an image, instances of thin lines in an image occur frequently enough that it is useful to have a separate mechanism for detecting them. Here we present a convolution based technique which produces an image description of the thin lines in an input image. Note that the Hough transform can be used to detect lines; however, in that case, the output is a parametric description of the lines in an image. The line detection operator consists of a convolution kernel tuned to detect the presence of lines of a particular width n; at a particular orientation Θ. Figure 5 shows a collection of four such kernels, which each respond to lines of single pixel width at the particular orientation shown.

a)

-1	-1	-1
2	2	2
-1	-1	-1

b)

-1	2	-1
-1	2	-1
-1	2	-1

c)

-1	-1	2
-1	2	-1
2	-1	-1

d)

2	-1	-1
-1	2	-1
-1	-1	2

Figure 5: Four line detection kernels which respond maximally to horizontal, vertical and oblique (+45 and - 45 degree) single pixel wide lines.

These masks above are tuned for light lines against a dark background, and would give a big negative response to dark lines against a light background. If we are only interested in detecting dark lines against a light background, then we should negate the mask values. Alternatively, we might be interested in either kind of line, in which case, we could take the absolute value of the convolution output. If R_i denotes the response of kernel i, we can apply each of these kernels across an image, and for any particular point, if $R_i > R_j$ for all $j \neq i$ that point is more likely to contain a line whose orientation (and width) corresponds to that of kernel i. People usually thresholds R_i to eliminate weak lines corresponding to edges and other features with intensity gradients which have a different scale than the desired line width. In order to find complete lines, one must join together line fragments, with an edge tracking operator.

2.3 CONCLUSION

There are many research that been done in processing images for lane detection. It gives many type methods and steps in lane detection and considers many aspect of the lane detection using camera like the proportion between colors, shadows and lights. How to check those different colors, calculate it and take the best choice of method. It gives concepts of how to calculate and make the most suitable algorithm for many situations and also consider the change of image for many situations. One of the approaches is Hough transform. It is used in method shape detection that important to applied computer vision. This method in this case will detect a straight line. All of this shows us how they solve the problems in this area and what kind of system that have been build that related in this part and further more it also give examples and the concept to solve many more problems that related in lane detection.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

The robot has two type communication that is between camera and laptop that take pictures and calculate the pictures using the Hough transform and between the robot and laptop that is sending of movement signals that been processed by the laptop to the robot. Robot navigation is the task of an autonomous robot to move safely from one location to another (goal). The robot have three problems in navigation that is finding out the whereabouts of the robot (robotic localization), it has to identify a goal (goal recognition) and lastly finding a way to get to the goal (path planning). If the robot is in an unknown situation or environment, the navigation system will navigate it by moving it to the front until it in the correct environment or in this condition in the correct lane. In this environment, the camera will capture images that will be processed by lane detection systems. Then, the navigation system will decide the movement of the robot so that it will be always be in the lane according to the data that been processed by the lane detection system. The relationship for navigation is shown in the Figure 6 below.

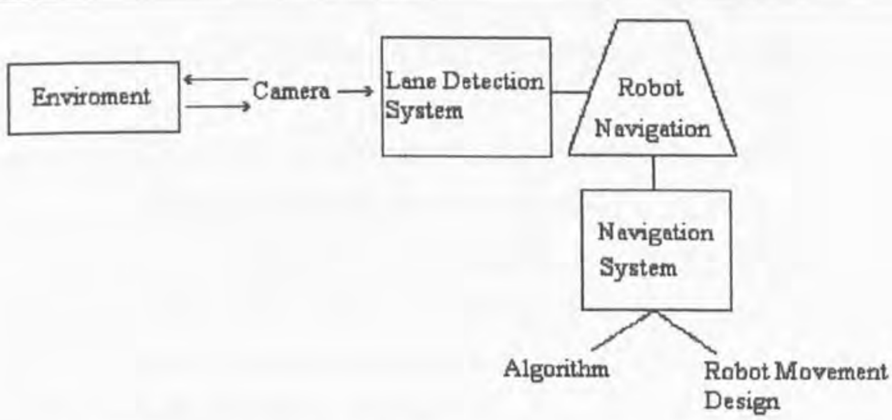


Figure 6: Relationships between Modules in Robot Navigation

The movement of the robot that is the navigational of the robot will be programmed so that it can minimize movement mistakes and giving more accurate movement by thinking by itself. To make sure the robot give more accuracy movement and minimize error, a suitable and reliable algorithm and also more strategic approaches and planning must be developed.

The robot design is one of the main factors to achieve this objective, which is to minimize movement error. The better robot design the less error in movement it will produce. For example, if the robot is not stabilizing like sloping to the right, the movement of the robot is not accurate and will produce more error especially in movement of turning right and left. That why the robotic design is important for navigate the robot more accurately.

The integration between camera and lane detection, and also the integration between robot design and system navigation are also needed so it can performed a correct decision that efficiently, reliably and consistent for any environment.

3.2 APPROACHES

As the hardware is limited, the robot will rely heavily on the lane detection system and navigation system to move inside a lane. To make sure the robot give more accuracy movement and minimum error, a suitable and reliable algorithm and also more strategic approaches and planning must be developed. So an incremental design is adopted to produce a robust and complete system. The concept of this incremental design helps the entire project of building an intelligent system to advance toward to the goal steadily one step at a time.

Overall system will be implemented in traditional single process as all input or data required is acquired automatically by the system. To ensure smooth movements of the robot, the lane detection system must perform at an acceptable time to minimize delay in the movements of the robot. As Hough transform used as the line detector, pre-processing of the image is needed to make sure useless calculation in finding the line can be avoided thus reduced the time taken.

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