LANDMARK DETECTION FOR VISION BASED OF AUTONOMOUS GUIDED VEHICLE

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ABSTRAK

Ciptaan kenderaan pacuan automatik memberikan banyak kelebihan dalam kehidupan harian manusia. Tesis ini tertumpu kepada system kawalan navigasi untuk kenderaan pacuan automatik dengan mengesan dan meniktiraf mercu tanda buaatan dengan USB webcam. USB webcam bertindak sebagai sensor yang menyediakan maklumat yang sesuai untuk navigasi kenderaan pacuan automatik dan pengesanan mercu tanda. Projek ini melibatkan system penglihatan tunggal. Tujuan utama thesis ini adalah untuk mebangunkan satu algoritma untuk kenderaan pacuan automatic berdasarkan penglihatan. Beberapa kaedah pemprosesan imej yang terlibat di dalam project ini. Algoritma dibangunkan bukan sahaja untuk mengesan tetapi juga dan mengiktiraf tetapi juga membezakan mercu tanda dari bukan mercu tanda. Bukan mercu tanda barangkali mempunyai cirri-ciri yang sama dengan mercu tanda. Mercu tanda yang mesti dikesan dan diiktiraf oleh deria penglihatan yang tepat dalam masa yang sebenar. Mercu tanda adalah dalam bentuk yang mengadungi arahan untuk pergerakan dan kedudukan kerderaan pacuan automatik. Kajian utama dalam projek ini adalah reka bentuk algoritma.

ABSTRACT

The creation of Autonomous Guided Vehicle (AGV) gives many advantages in our lives. This thesis is focused on navigation control system for an Autonomous Guided Vehicle (AGV) by detecting and recognizing artificial landmark with using USB webcam. USB webcam act as sensor that provides the appropriate information for the AGV navigation and landmark detection. This project involved single vision system. The aim of this project is to develop an algorithm for vision based AGV. Several image processing pipelines involved in this project. The algorithm is developed not only to detect and recognize but also to distinguish landmark from non-landmark. Non-landmark might possibly have the same features or characteristic with landmarks. The landmarks must be detected and recognized by vision sensor accurately in a real-time. The landmarks are in the form of shape that consists of command for the movement, direction and position of AGV. The key study in this project is the algorithm design.

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CHAPTER 1

INTRODUCTION

1.1 AGVs

The process of unloading, loading and transporting materials or goods from one place to another place is one of the key issues for every production site or plant. This process of loading, unloading and transporting have a great impact on company cost. Therefore, an autonomous guided vehicle (AGV), robotic transporters have been design to help the industries to achieve high productivity at minimum cost. AGVs come essentially with in form: AGV guided by wires in the floor or traditional AGV and AGV guided by visual markers in the environment (Ling et al., 2010). AGV guided by visual marker in the environment is an automatically guided vehicle without having any wires but with some intelligence (Barbera, H.M. and Perez, D.H., 2010; Daintith, J., 2004 and Ling, M. et al., 2010). The intelligence is use to select the correct path of travel. The AGV have the capability to move around their environment and does not fixed to one location only. AGVs that rely on wires in floor require the development of a specific infrastructure. These types of AGVs face some limitation. They are restricted to follow those wires that in plant in floor (Ling, M. et al., 2010). In order to change the path of AGV, some modifications to the wires in floor in require.

There are several types of AGVs that are extending the functionalities of traditional AGV. The types of AGV are vision based AGV, optically base position location system for an autonomous guided vehicle laser scanner based free navigation of AGV, and model-based recognition and range image foe a guided vehicle. Vision based navigation is powerful enough than other sensors because it can provides a lot of information about environment around AGV for a better navigation (Guzel). Vision navigation also enhances the accuracy and flexibility of AGV by providing information of the real world accurately (Barbera, H.M. and Perez, D.H., 2010, and Borenstein, J. et al.1996).

The ultimate goals of this project it how to develop an algorithm for the vision based navigation of AGV using suitable landmarks. The vision system shall be able to distinguish landmarks from obstacles. The landmark use can be either natural landmark or artificial landmark (Borenstein, J. et al.1996, and Lee, J.D., 1997). The framework for the AGV is using on board camera and suitable landmarks. Landmark must have noticeable features that AGV can recognize through on board camera where the camera acts as a sensor (Guzel, and Borenstein, J. et al.1996).

1.2 PROJECT BACKGROUND

AGV have been around since 1950's. The main benefit of AGVs to industries is that they reduce labor costs, time reduction and reduce the dangerous risk during handling the materials or goods. With having AGV in the factory or warehouse, material handling from one point to another point can be done by the AGV. Thus, reduce the company labor cost to hire operator or person in charge to handle the materials and reduce the risk of injury during handling materials such as driving fork lift to fast or does not have license to operate fork lift. Besides that, by having AGV in the factory, it helps the company to reduce lead time because AGV have the capability to send material at production line on time when require without fail. In industries, it is important for the AGVs to have fast and accurate vision based navigation (Barbera, H.M. and Perez, D.H., 2010). The vision sensor involve is passive sensor where camera act as sensor. Vision sensor is powerful sensor that can provide different kind of information about the environment and can be use for landmark detection and recognition (Guzel, and Borenstein, J. et al.1996). In order to allow navigation, the features of landmarks must be easily detected by camera. Landmark not only provides location information for self localization but also the next instruction to be executed (Borenstein, J. et al., 1996). Landmarks can be classes into two; natural landmark and artificial landmark. Natural landmark does not involve any environment modifications. Natural landmark can be walls, corners or doorway. While an artificial landmarks need some modifications environment. Artificial landmark is a powerful for self-localization because the exact size and shape of artificial landmark can be known in advance. It also can be in a geometric shape and may have additional information such as bar-codes. It also can be as simple as small dots in pattern or as complex as bar-codes (Guzel).

1.3 PROBLEM STATEMENT

The reasons to build an AGV is to overcome the logistic problems in factory such as transferring raw materials or goods on time, reducing production lead time and labor cost. AGV can perform tiring job and reduce cost of diesel to run forklift during handling materials or goods. AGV help to deliver raw materials to the production line when require without human assist. Thus it prevents production to stop just because of out of stock. To ensure the AGV deliver the material to production line or other require place, the AGV must accurately locate it position in factory. In vision based navigation of AGV case, in order to fast and accurately locate the AGV, the landmarks must be detected and recognized by vision sensor accurately in a real-time (Barbera, H.M. and Perez, D.H., 2010). Therefore it is important to determine the suitability of landmarks and strategic place for the landmarks to be placed. Then AGV should be able to distinguish landmark from any obstacles and the obstacles might possibly have the same features with landmarks. In (Roborealm) it introduced landmark tracking of vision based robot based on color and rectangular shape. Unfortunately the landmark features is not robust enough. It only focuses on rectangular tracking without considering the exact size of landmark and orientation of landmark. Thus, this project attention is to develop a various shapes of landmarks to navigate vision based AGV.

1.4 OBJECTIVES OF PROJECT

The objectives of this project are:

a) To develop an algorithm for vision based autonomous guided vehicle and navigate the autonomous guided vehicle using suitable artificial landmark in manufacturing industries.

b) To ensure autonomous guided vehicle able to detect and recognize artificial landmark.

c) To ensure autonomous guided vehicle able to distinguish landmark from non-landmark.

1.5 PROJECT SCOPES

The main concern of this project is to develop an image processing algorithm for landmark detection and recognition. Landmark is one of tools used to navigate an indoor vision based AGV. It is known that artificial landmark is a powerful for AGV self-localization because the exact size and shape of artificial landmark can be known in advance. Thus, landmark must have noticeable features that AGV can recognize through on board camera.

1.6 SIGNIFICANT OF PROJECT

This research will contribute for artificial landmark detection and recognition by vision based AGV. These landmarks contain information for the execution for the AGV and allow the AGV to travel from starting location to target location.

CHAPTER 2

LITERATURE REVIEW

2.1 VISION SYSTEM

2.1.1 Single Vision

Monocular camera is applicable to a small robot due to its low cost and small size, but it has no ability to measure the distance to an object (Hwang, S.Y. and Song, J.B., 2011).

2.1.2 Stereo Vision

In (Lee, J.D., 1997), a stereo vision is developed using two single cameras. Two cameras are use to capture navigation information. The disadvantage of stereo vision is that a feature visible in one camera's image may not even be visible in the other.

2.1.3 Omnidirectional Vision

Matsumoto, Y. et al. (1996) presented a work on landmark direction angle estimation based on omnidirectional image. Omnidirectional image is a 360˚ image projection of world on a single image plane and can be obtained with different catadioptric vision systems. Catadioptric combine a camera and convex mirror. It is a combination of an orthographic camera and parabolic mirror or a conventional camera and hyperbolic camera.

2.2 VISION-BASED ROBOT NAVIGATION

The indoor vision-based navigation has fall into three different approaches:

- Map-Building Navigation
- Map-Based Navigation
- Mapless Navigation

2.2.1 Map-Building Navigation

Map building navigation is a navigation that requires the robot to possess (position and orientation) a map or a model of the environments. But model descriptions are not always easy to generate, especially if one also has to provide metrical information. Therefore many researchers have proposed automated or semiautomated robots that could explore their environment and build an internal representation (DeSauza, G.N. et al., 2010). In other world, mobile robot built its own map and updated the map itself.

2.2.2 Map-Based Navigation

The main features of map based approaches in providing the robot with a model or replica of environment. The replica can be as complex using a complete CAD of the environment or as simple using graph of interconnection or interrelationships between the elements in the environment. Some of the very first vision-based systems symbolized the knowledge of environment using the 2D grid representation. The size of every object in environment was represented by a 2D projection of its volume onto horizontal plane. The main purpose of map-based navigation is to provide the robot direct or indirect a sequence of landmark expected to be found during navigation, the task of the vision system is then to search and identify the landmarks observed in image. Once there are identified, the robot can used the provided map to estimate the robot’s position by observation landmark against the expectation landmark descript in database (DeSauza, G.N. et al., 2010). In (DeSauza, G.N. et al., 2010), computations involved in vision-based localization can be divided into four steps:

i) Acquiring sensory information. This mean acquiring and digitizing camera image for vision based navigation.

ii) Landmark detection. The extraction of edges, smoothing, filtering, and region segmentation based on differences in grey levels, color depth or motion.

iii) Observation and expectation matching. Observed landmark are identify by searching in database for possible matches based on some measurement criteria.

iv) Calculate position. Once match is obtained, the system needs to calculate its position as a function of the observed landmarks and their position in the database.

a) Navigation and Localization with Global Matching Technique

Abe, Y. et al. (1999) presented a work on global matching technique to localize the robot when the robot failed to recognized the landmark in the environment. They approach to use global matching as the behavior to relocate the self-position of the robot. Global matching is defined as the behavior of error recovery in Hierarchical Adaptive and Learning Architecture System (HALAS). When the robot failed to recognized the landmark, the behavior recovery error in HALAS will choose a suitable behavior to cope with it. The robot move to next landmark with dead reckoning referring the map, and modifies for self localization under the landmark, where the landmark recognize by a camera (Abe, Y. et al., 1999).

From the research in (Abe, Y. et al., 1999), this method helps the robot to localize itself when failed to detect the landmark in the environment in a real time image processing. However, this approach is limited for landmark fixed on the ceiling only. Moreover it is impossible for the robot to detect the landmark on the ceiling if the area or environment having such high ceiling.

b) Navigation and Localization using Simultaneously Localization and Mapping (SLAM) Technique

Spampinato, G. et al. (2009) propose a stereo vision based localization and mapping of automated vehicles using natural landmark. In industrial environment or industry the lightening placed on the ceiling act as natural landmarks. The lamp already exists in the working area. There are two phases for localizing and mapping of the robot. First phase the algorithm optimizing for estimating the external parameter of two camera system. The incoming information came from Stephen and Harris feature detection algorithm are combined with the odometry information. Second phase is calibrating the camera parameters. In second phase algorithm, the Extended Kalman Filter (EKF) based probabilistic method has been implemented for simultaneously estimating the camera parameters and the position of robot landmarks in environment. The identification of first landmark related to initial camera view and used by SLAM algorithm as reference frame for robot global localization and landmark positioning is the environment map (Spampinato, G. et al., 2009).

This approach is done to navigate the robot using lightening on the ceiling as landmark. Same as in (Abe, Y. et al., 1999), this approach is limited for landmark fixed on the ceiling only. Moreover it is impossible for the robot to detect the landmark on the ceiling if the area having such high ceiling. This method is suitable enough to be use in office area or hospital environment but not in industrial environments that have height ceiling.

Hwang, S.Y. et al. (2011) presented a work on monocular vision based simultaneous localization and mapping (SLAM) of a mobile robot using an upward looking camera. They use corner features and the circular shaped brightest part of the ceiling image for detection of lamp features. Moreover vertical and horizontal line are combined to robustly detect line-based door features to reduce the problem that line features can be easily misidentified due to near edges. They propose monocular vision based SLAM using corner, lamp, and door feature because most in home environments does not contain a wide variety of features. Lamp is useful for SLAM because there are widely spaced in the environment thus can be reliably detected from the image. In this paper they used circular lamp to detect circular part, the brightest part in the image is found using binary image. Then each brightest part is grouped, and the edge points are extracted using a Cany Edge Detector. Door can represent by a three lines. Door composed of vertical and horizontal line. Since there are many line features in real images, a process that classifies the line into vertical and horizontal lines is required to find door column and bar. A monocular camera can only provide only information of landmark, so the distance can be estimated by collecting several bearing measurement for different position. They use EKF to deal with the relationship between the robot pose and the landmark positions (Hwang, S.Y. et al., 2011).

As mention in (Hwang, S. Y. et al., 2011), they use a circular lamp as a landmark to avoid having similar feature from the environment. This paper only focused on standard shape such as round or square. A future research need to be conduct using various shapes of landmarks.

c) Navigation using Topological Corrected Map

Launay, F. et al. (2002) propose corridors light based navigation using topological corrected map to navigate mobile robot including teaching of environment. The mobile robot self-localize by detecting the fluorescent tubes with camera pointing on the ceiling. Mobile robot detect landmark on the ceiling rather than on the floor to avoid obstacle or being obstructed. The robot map is built in advance. The map is obtaining by guiding the vehicle under each light in corridors and adds landmark information to the map whenever a new light seen. The distance between light and ceiling is unknown; therefore two images from different place used for to convert light position to image for mobile robot reference (Launay, F. et al., 2002).

This approach failed to navigate the mobile robot using fluorescent tube on the ceiling due the sunny day or closed window. This approach cannot be applied to navigate robot if fluorescent light switch off. In (Launay, F. et al., 2002), the approaches have same purpose with (Abe, Y. et al. 1999; Spampinato, G. et al. 2009, and Hwang, S.Y., 2011). The approach is done to detect landmark on the ceiling.

d) Navigation by Landmark Tracking

Garibotto, G. et al. (1998) developed a computer vision of a control of an intelligent forklift truck. This forklift navigate through it path by detecting artificial "H shape" landmark. The "H shape" sign are place on the floor along the robot routes every 10m or more. Moreover the landmark used is suitable in very cluttered, quickly change environments. Landmark is made up of pair parallel line called track and one orthogonal join the parallel line, called bar. To detect track, image processing involved is track edge detection, edge clustering based on gradient direction, hypotheses generation, track hypotheses verification and track localization. While image processing to detect bar is bar edge detection, clustering based on distance from the vehicle and computation of bar position. This forklift used dead reckoning with an intermittent external measurement of the forklift position and orientation to correct cumulative error. Besides recognize landmark in any kind of floor, this forklift must also notwithstanding the changing illumination; recover of 3D position and orientation precisely. In this paper, the forklift also required to lift up the pallet. This is done by detecting two pallet holes center through adaptive growing and then 3D pallet position and orientation computation (Garibotto, G. et al., 1998).

From this research, they develop an autonomous forklift. This forklift used to transport goods without human assistance. Moreover, in (Garibotto, G. et al., 1998) state that this vision system is suitable for mobile robot with inaccurate odometry estimators.

e) Navigation using Fuzzy Template Matching

Fukuda, T. et al. (1995) presented a work on mobile robot that recognized air conditioning system outlets (anemo) located on the ceiling as landmark. To detect the anemo, they proposed a fuzzy template matching (FTM). FTM does not involve any image processing. Moreover they use neural network to makes the landmark found by the robot quickly. The fuzzy template (TM) is modeled based on edge information of anemo in the image frame. In image processing, firstly the original grey image was exchange to edge image. Then it follows by edge extraction, smoothing, binarization, and isolated pixel removing and executed. FT is a substitute of the template in usual template matching. Membership grade of the FT are inputted into neural network that learned in advance so that the output of neural network may make FT approach the landmark in an image, membership grade the FT maximum values and the landmark detection finished (Fukuda, T. et al., 1995).

This method approach is suitable to navigate a robot that track landmark on the ceiling. Since FTM method does not use image processing, there is no possibility the robot mismatch the landmark. Moreover the possibility for landmark being obstruct is low.

f) Navigation using Cartesian Map-Based

Gilg, A. et al. (1993) presented a work on landmark oriented visual navigation of a mobile robot with purely or Cartesian map-based. In this paper, robot navigation is distinguished based on Cartesian map-based and relative sensor based method. Purely map-based navigation requires a detailed 2D or 3D model of environment. This navigation also required a dead reckoning for real time localization. For landmark oriented navigation a vehicle “motion task” can be specified by a symbolic course description. For this purpose each motion task is decompose into operations such as move, turn, park, etc. this task can be sequentially executed by a motion control system with requiring any knowledge about the total mission. This task must be detected by a sensor. To the landmarks and event 3D sensory information is required. The sensory systems consist of CCD-camera for image processing purposes (Gilg, A. et al., 1993).

In (Gilg, A. et al., 1993), the landmark oriented is required for path specification and execution. Each landmark consist a command or motion work. Therefore landmark helps robot to execute to desire location.

g) Navigation by using ID Tag and WEB Camera

Lin, W. et al. (2004) works on localization of mobile robot based on ID tag and WEB Camera. In this approach the path is expressed with node. Every node consist of two landmarks, which is pairs of two landmarks are affixed to ceiling or distinct, and middle point of every pair of landmark in a node indicates the absolute position of the node because the unique ID of tag, the absolute position of robot can be expressed with the absolute node and position and orientation relative to this node. Every node indicates a distinct location. In this approach it required a PSD sensors pyroelectric sensor for obstacle avoidance. If we link all node together, a path map is got. Localization is implementing with two steps: detecting the ID in one node with RF communication and measuring position and orientation of mobile robot relative to this node with camera. If one ID tag is detected, rough position of the robot is determined. Tag reader is mounted on top of robot. Webcam is mounted on mobile robot perpendicular to ceiling so measurement of relative position and orientation is simplified. Since node is placed at ceiling, the webcam is always aiming at ceiling (Lin, W. et al., 2004).

The node in this experiment also acts as a landmark. The landmark placed at where camera can easily detect. Therefore, we can have exact localization of the robot.

2.2.3 Mapless Navigation

In (DeSauza, G.M. et al., 2010) this approach contains all systems in which navigation is achieved without any prior description of the environment. Mapless navigation methods not require any map and no map ever created. Observation and extraction of related information about the element such as chair, table, dustbin or doorway in the environment will determine the robot motions.

a) Navigation using Color Landmark Recognition

Yoon, K.J. and Kweon I.S. (2001) presented a research on artificial landmark tracking based on color histogram. They propose a simple symmetric and repetitive color patch of landmark for self-localization and fast detection by a mobile robot. Based on the color landmark proposed they develop a tracking algorithm. They design a landmark that shows invariance characteristics under geometric distortion and photometric distortion. Invariance under geometric distortion is related to the shape or color pattern of the landmark, while invariance under photometric distortion is related to color space which processing is involved. They post three symmetric and repetitive arrangement of color patch as landmarks at different distances and the landmarks size in an image are different according to the distance (Yoon, K.J. and Kweon, I.S., 2001).

In this research the landmark color approach is limited to two colors but it is robust for navigation. Even though the landmark has only two colors, the ways of color arrangement can interprets difference command to mobile robot.

Park, J. et al. (2008) propose an efficient method to parking AGV into park lot by using visual artificial landmark. AGV function is to transport goods or material autonomously and efficiently. The artificial landmark is designed for effective detection based on corner feature and color information. The landmark has three features that distinguish the object from clutter surrounding. The first feature, the landmark is in circular shape. It allows that dependent to the approach direction of the vehicle and insensitive to rotation or scale variance of landmark. Second feature, the landmark has corner feature at the center of the object. The arrangement of the color is also considered. Last feature, landmark has color information. After detecting landmark phase, the position of the landmark in the capture image, tracking phase follows the trace landmark in the successive image sequences. Tracking phase consist two stages. The stages are estimation and refinement steps (Park, J. et al., 2008).

From this research (Park, J. et al., 2008), it is known that landmark helps to navigate AGV from one location to another location following desire path. Landmark can bring information. In (Lee, J.D., 1997) stated that landmark must at least have information about direction, distance and destination. Artificial landmark is powerful enough to navigate the robot (Barbera, H.M. and Perez, D.H., 2009 and Guzel).

Guo, Y. and Xu, X. (2006) presented a work on color landmark design for mobile robot localization. Artificial landmark can be use in a complex environment. An efficient landmark must be designed so that sensing system can detect, recognize and localization. In landmark detection, the robot must be able to quickly determine whether or not there is any landmark in its frame view. Next, the robot must be able to differentiate between different landmarks in the robot environment. Once the landmark being identified, the robot can localize to desire location or for self localization. In (Guo, Y. and Xu, X., 2006), they propose two red rectangles under two seven part numbers are use to produce a cross-ratio horizontal. Left and right two rectangles of seven-part numbers are used to generate another cross-ratio of the perpendicular direction. Red information of the landmark can be used to search landmark under illuminant condition (Guo, Y. and Xu, X., 2006).

Landmark from primary color can be detected easily (Roborealm). Colors do play a role in navigation. Therefore, it is important to select a suitable landmark to navigate the robot.

b) Navigation by Landmark or Object Tracking

Lee, J.D. (1997) presented a work on indoor robot navigation by landmark tracking. In order to guide the mobile robot to the destination it follows each artificial landmark in unknown environment based on novel approach. The landmark proposed contains information about destination, direction and distance to destination. The robot finds the landmark using three strategies; landmark finding, landmark location and landmark understanding (Lee, J.D., 1997).

The method approached can detect landmark with various shapes and colors. Moreover, in industries AGV may require many commands to perform tasks. Different symbols refer different command for AGV locomotion. Therefore novel approach is one of the effective methods to navigate the AGV in manufacturing floor.

Gaussier, P. et al. (1997) had works on visual navigation in an open environment without map. The system used is neural network architecture inspired from neurobiological studied using recognition of visual pattern called landmarks. In this paper they show the experimental results of a navigation model proposed. The model is a neural architecture named PerAc (perception action) based on animals navigation model which do not require a precise map of the environment to navigate. This approach reduces the algorithmic complexity and increases their robustness. PerAc consist in an action level and perception level trying to recognize particular situations and to associate them with correct action through an associative or reinforcement learning rule. The perception level allow robot to react to a situation even if it is too complex to allow action pathway to propose an answer by generalization of previously learned situation. First to recognize a place, the robot must be able to isolate a local view. Then information about the landmarks recognition and associated angle are merged to produce a unified representation that can be easily learned and matched with previously learn representation. The merging is represented by the matrix product of the information corresponding to "what" (landmark) and "where"(Azimuth) the object are. With this representation, there is no need to recognize specifically what landmarks are. For example if the landmark (fridge) is removed because of the "image" in the scene is noisy, the other landmarks can allow a good recognition (Gaussier, P. et al., 1997).

This approach makes the robot not depending on the landmark 100 percents. In case one of the landmarks cannot be detected by the robot, the robot still can navigate using other landmarks. This approach is really helpful to navigate robot with worrying the robot localization.

c) Navigation using View-Sequenced Route Representation (VSRR)

Matsumoto, Y. et al. (1999) presented a work on navigating the robot using View-Sequenced Route Representation (VSRR). VSRR act as model of the route, which contains sequence of view images memorized by the robot. Firstly the robot view the image obtained from the camera facing forward and memorized it. Then when the robot view another image, the image matches on of the memorized view image, the robot recognized its position. The memorized image correlate with next view image which compose the VSRR. The image consist in VSRR has necessary information for localization, steering angle determination and obstacle detection (Matsumoto, Y. et al., 1999).

This method approach allowed the robot to navigate base on the image memorized in VSRR. In this method, the robot must first learn the model of road in