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Landmark Navigation in Low Illumination Using Omnidirectional Camera

Zahari Taha[1] and Jessnor Arif Mat-Jizat[2]
[1,2] Faculty of Manufacturing Engineering, Universiti Malaysia Pahang, 26600 Pekan, Malaysia
(Tel : +60-9-424-5800; E-mail: zaharitaha@ump.edu.my [1] arifjizat@gmail.com [2])

Abstract - Landmark based vision navigation for mobile robot is critically dependent on successful recognition of landmarks. Landmarks, artificial or natural, are subjected to sufficient illumination in order for a successful recognition. Sufficient illumination is even more critical when the mobile robot is used for indoor. In this paper, experiments were conducted to recognize artificial landmarks using omnidirectional vision under low illumination. The objective of this paper is to demonstrate that landmark navigation in low illumination can be conducted without illumination invariance step and without images distortion correction. This landmark recognition performance thus demonstrates the robustness of landmarks especially under low light condition. The landmarks used were standard (ISO15417) Code-128 barcodes. The barcodes are placed besides turning machine and the illuminance is measured by a luxmeter on each barcode.
Keywords - Landmark navigation, omnidirectional vision, illumination, mobile robot.

1. Introduction

When dealing with vision based navigation, the subject of images and illumination are often the topics of discussion. This discussion is even more important with landmark navigation of mobile robot as the mobile robot depends solely on landmarks in order to navigate safely in its environment. Therefore, in order for a successful navigation, researchers usually adopt an illumination invariance step in their preprocessing stage in the vision algorithm. With a lower computing power, this illumination invariance step may consume more power and thus delaying the mobile robot decision making. It is therefore the objective of this paper to demonstrate that landmark navigation in low illumination can be conducted without illumination invariance step and without images distortion correction.

2. Related work

2.1 Omnidirectional camera

Unlike traditional camera, omnidirectional camera offers 360° field of view. This very wide field of view can be advantageous in landmark navigation as landmarks are less frequent falling outside the field of view of the camera. It has however a problem of image distortion against the height of the object [1]. The distortion presents a problem in the accuracy such that the landmarks may not be identified. Thus selection of landmarks for omnidirectional vision should be conducted very carefully in order to maintain landmarks robustness.

2.2 Landmark Navigation

Navigation using landmarks has garnered a lot of interest recently. Landmarks, as highlighted by Knapek et al [2] must be salient and distinctive. Salient in the sense that the landmarks are easily recognizable from its background and distinctive in the sense that it can be uniquely distinguished from one another. Due to the saliency and distinctiveness, artificial landmarks have a few advantages over natural landmarks.

Artificial landmarks provided flexibility to the system designer in term of size, colour, placement and orientation. Furthermore, artificial landmarks can be designed to contain information to further assist the mobile robot in completing its task. Placement of the artificial landmarks plays an important role in determining their saliency and distinctiveness.

For indoor mobile robot the landmarks are usually placed vertically perpendicular to the floor at camera height [3,4,5] while some [6,7] landmarks are placed on the ceiling. The landmarks, wherever they are placed are open to illumination variant when the landmark image is captured by the mobile robot vision system. This illumination variant may be primarily caused by the placement of the landmarks near light source, such as windows or light bulb, or in the shadow of other objects. The illumination variant may cause changes within the captured images of the landmark such as reduce color intensity and color hue shift [8]. When the landmark is placed near or facing the light source, it may become very bright whereas a landmark in shadow may become very dark.

Many researchers employ certain steps in their algorithm in order to recognize landmarks under varying illumination. Bayesian approach is among the popular choice for recognition [9,10]. F.Ramos et al.[11] used Bayesian approach to create probabilistic representation from small images set and applied it to real-time recognition. Their method was found to be very robust against varying illumination. However it still requires quite extensive image preprocessing.

3. Methodology

Our goal in this paper is to test landmarks detectability under low illumination condition.

3.1 The landmarks.

The landmarks used were standard (ISO15417) Code-128 barcode. The barcodes were enlarged to 840mm x 500mm. This size will ensure robust detection in daylight situation. The illuminance is measured by a luxmeter on each landmark. Each landmark contained navigation cue for the mobile robot. The navigation cues coded in the barcode for the robot were “MOVE SLOWER”, “TURN LEFT”, “TURN RIGHT”, or “MOVE FASTER”. The navigation is considered a success when the mobile robot reacts to the navigation cues. Figure 1 shows one of the landmarks used in this experiment.

Fig. 1. Barcode landmark with value of 84111 which represents "TURN LEFT".

3.2 The vision based mobile robot.

The mobile robot used in this experiment is a four-wheel car-like platform with front and rear wheel drive. A servomotor steers the front wheel for changing the heading. An omnidirectional camera is mounted on top of mobile platform at the height of 550mm. The camera has a resolution of 720x480 pixel. A personal computer is used to process the image from the omnidirectional camera using Roborealm software. RoboRealm is a commercial software for processing video images. It is a module-based image processing software to help integrate vision on robotics sensor systems. The software then communicates with an Arduino microcontroller to control the robot speed and steering.

3.3 Barcodes matching.

Using Roborealm software, the incoming feed from the omnidirectional camera goest through a minimum histogram leveling. Then the barcode match module is used to identify the barcodes from the incoming feed.

Once a barcode is identified, Roborealm will send control signals namely speed and steering to the Arduino microcontroller according to the data coded in the barcode. The mobile robot is set to move in a straight line in between code reading.

3.4 Experiments.

The experiments were conducted with multiple runs in which the mobile robot through its omnidirectional camera must read four different landmarks and react accordingly to the coded landmarks. Each landmarks is placed such that its illuminance is almost equal among the four landmarks. Subsequently the illuminance is varied until the mobile robot no longer reacts to the landmark navigation cue.

In order to control the illuminance to the landmarks, the experiments were conducted indoors during nighttime. The light source for the experiments comes from flood lights installed on circa 6m height ceiling. As the landmarks are placed further from the light source, the illuminance is lowered accordingly.

4. Result and discussion.

Figure 2 to Figure 5 show omnidirectional view at the instance when the mobile robot is acquiring the navigation cue. The illuminance is measured increasingly from 5 lux in Fig.2, 10 lux in Fig.3, 20 lux in Fig. 4, 30 lux in Fig. 5 and 50 lux in Fig. 6.

In Fig.2, it can be seen that the light source comes from the back of the barcode. Therefore, the barcode lies in it shadow. As a result, the mobile robot failed to react to the navigation cue encoded in the barcode as the barcode itself is too dark for any possible detection.

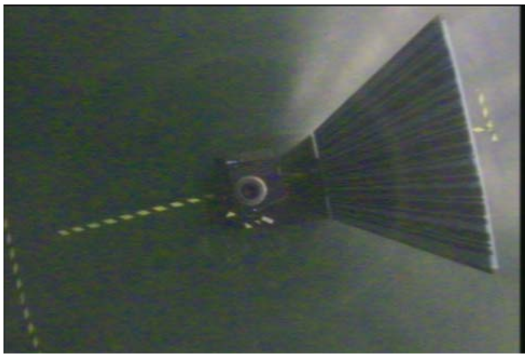

Fig. 2. Landmark reading at 5 lux.

Even though the barcode illumination has increase slightly to a value range of 10 lux, as seen in Fig. 3, the mobile robot still cannot read the navigation cue from the barcode. The illuminance of 10 lux can still be considered as insufficient for reading the navigational cue.

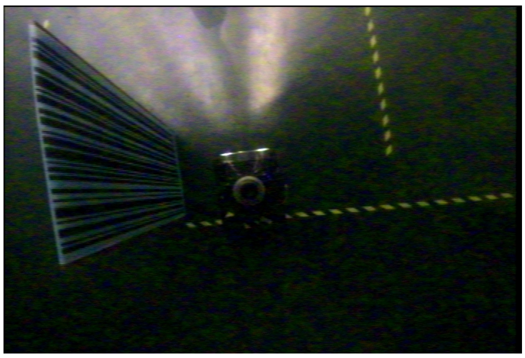

Fig. 3. Landmark reading at 10 lux.

When the illuminance is further increased to 20 lux as shown in Fig.4, the barcode becomes more visible. During the experiments, only a few of the navigational cue can be read from the barcode. However, it is not a reliable as the mobile robot may miss certain important navigational cue and thus could stray from the designated path.

Fig. 4. Landmark reading at 20 lux.

As the illuminance is increased further to 30 lux as shown in Fig. 5, most of the barcodes can be read. Thus the landmarks with 30 lux illuminance could be deemed as just sufficient for a low illumination landmark based navigation. It is hypothesized that with a better resolution and low noise camera, the landmarks can be detected sufficiently.

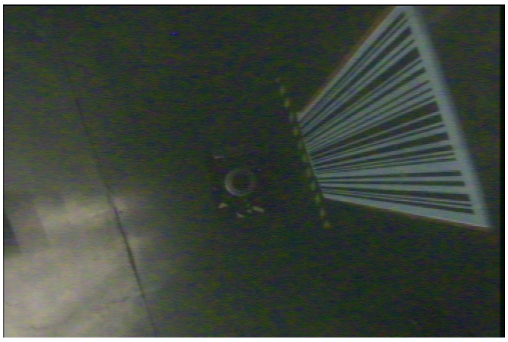

Fig. 5. Landmark reading at 30 lux.

With the illuminance measured at 50 lux, as shown in Fig. 6, the mobile robot can read all the landmarks and navigate safely according to the designated path. It is thus deemed sufficient for low illumination landmark based navigation. 50 lux is equivalent to the illumination of a family living room in Australia according to a study by Alan Pears [12] in 1998.

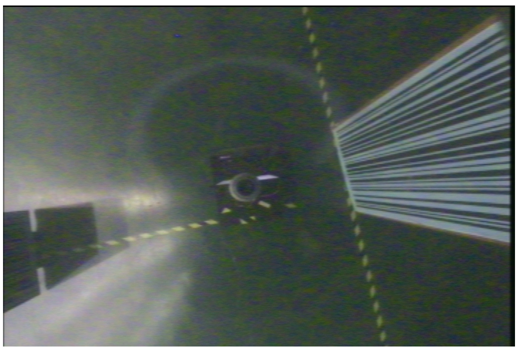

Fig. 6. Landmark reading at 50 lux.

5. Conclusion.

It is best to operate an autonomous vision based mobile robot in a high illumination environment. However, when it becomes necessary to run an autonomous vision based mobile robot in a low illumination environment, we conclude that lowest illuminance should be adopted is 50 lux. Nevertheless, as the vision sensor technology increases, it would be possible to operate in even lower illuminance.

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