COMPARISION OF FOCUS MEASURES FOR COLLISION AVOIDANCE APPLICATION OF MOBILE ROBOTS

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ABSTRACT: *Low cost fixed focus cameras are focused to infinity. This will introduce an amount of blur in the image of objects in the close range. This blur effect is called defocusing effect. Researchers in the past introduced focus measures to quantify the defocusing effect in an image. Our purpose is to find the suitability of Focus Measures for collision Avoidance Application of mobile robots. In order to do that, an experimental setup was developed with a low cost fixed focused camera, single board computer and an ultrasound module. Controlled experimental data was collected using the developed setup. Using the collected data, four different focus measures from the literature were analyzed for three different field of views. Results show that GLVN focus measure in the full field of view is more suitable for the collision avoidance application.*

Keywords: Collision Avoidance, Focus Measure, Blur Metrics, Mobile Robotics, Robotic Vision

1. INTRODUCTION

Sonars and Laser range finders are commonly used for collision avoidance and distance measurements in mobile robotic applications (Ansari & Umrani, 2009; Calado et al., 2011; Montano & Asensio, 1997). Cameras have become a cheap commodity hardware with the introduction of camera in the mobile phones. Unlike sonars and laser range finders cameras multiple purpose such as teleoperation and target detection. Sonar, laser range finders and infra-red sensors are active sensors. Active sensors disturb the environment by sending the sound or light waves where measurement is taken. Even though, humans are insensitive to active content of these sensor. They may create disturbance to other living beings and create interference problems when used at large. Cameras are passive sensors and do not possess any of the problems of active sensors. However, high computation demand of cameras is one of the serious limitation. Increasing processing power of CPUs and the introduction of GPUs will overcome this limitation in the near future.

Cameras capture a 3D scene into 2D image. As a result, in an ideal setting, the output image loses all the information regarding depth from the scene. Stereo or binocular vision systems use two cameras to capture a scene in a slightly different view angles and solve the problem to some extend. Thus stereo vision systems are a well-studied subject in mobile robotics domain (Hamzah, Rosly, & Hamid, 2011; Kumar, 2009; Meng, Zhihao, & Yingxun, 2012). However, stereo vision systems are complex to simple applications. In contrast to the ideal cameras, when a real camera focused to a far object, objects in the close range appear blurry and it is called defocusing effect. Fixed focus cameras are focus to the infinity. Therefore, these cameras introduce some amount of blur to the scene when it is in the close

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range of the camera. The amount of defocus from the image can be exploited to recover some depth information of the scene. Earlier researchers developed several metrics to quantify the defocusing effect.

Nayar(Nayar, 1992) developed the sum-modified-Laplacian (LAPM) operator to provide local measures of the quality of image focus. He also demonstrated the ability of obtaining the depth estimates from optical microscope samples using his LAPM operator. Pech-Pacheco (Pech-Pacheco, Cristobal, Chamorro-Martinez, & Fernandez-Valdivia, 2000) studied number of different focus measures for the purpose diatom autofocusing in bright field microscopy. They proposed variance of laplacian (LAPV) approach for better performance. Krotkov and Martin (Krotkov & Martin, 1986) demonstrated the ability of recovering the distance of an object from the image by using their implementation of tenegrad (TENG) measure.

The main use of focus measure is autofocusing the camera lenses (Jeon, Lee, & Paik, 2011; Li, Tang, & Huang, 2017). Researchers also used focus measure to recover shape from focus (SFF). Pertuz et al. (Pertuz, Puig, & Garcia, 2013) did a detail analysis of focus measures and techniques for Shape from focus applications. Focusing effect for obstacle avoidance of mobile robots also studied (Nourbakhsh, Andre, Tomasi, & Genesereth, 1997; Pacheco, Cufí, & Cobos, 2007). Nourbakhsh et al. used three closely grouped cameras and a simple algorithm for driving a mobile robot. However, the studies use existing focus measures with single camera for robotic application is limited.

In this paper, we did an experimental data collection and comparison of four focus measures; LAPM (Nayar, 1992), LAPV (Pech-Pacheco et al., 2000), TENG (Krotkov & Martin, 1986), GLVN (Santos et al., 1997) from existing literature to find the suitability of the focus measure for collision avoidance in mobile robotics using single low cost fixed focus camera.

2. METHODOLOGY

2.1 Experimental Setup

An Experimental Setup using Raspberry Pi camera V1.3, Raspberry Pi 2B and HC-SR04 sonar module was created for this study. A USB Wi-Fi adapter also connected to the Raspberry Pi computer for the purpose of login and execute software system in the Raspberry Pi. Figure 1 shows the Experimental Setup. The Raspberry Pi cameras is used for capturing images and the sonar is used to measure the distance between the camera and the imaged object. Raspberry Pi single board computer is used to operate and control sensors and record data.

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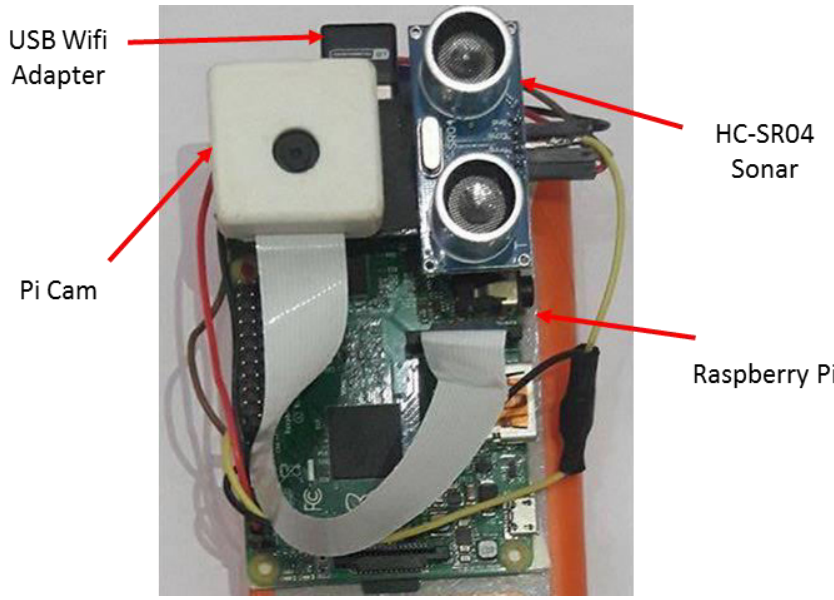

Figure 1. Experimental Setup

The hardware system interconnection of the system is shown in figure 2. Sonar module is connected to the Raspberry Pi via GPIO ports. Raspberry Pi I/O pins use 3.3v for operation but the HC-SR04 Echo pin output is 5V. Therefore, a voltage divider arrangement was made by using a 10kΩ and a 4.7kΩ resistors to connect the Echo pin of the sonar to the Raspberry Pi's pin 24.

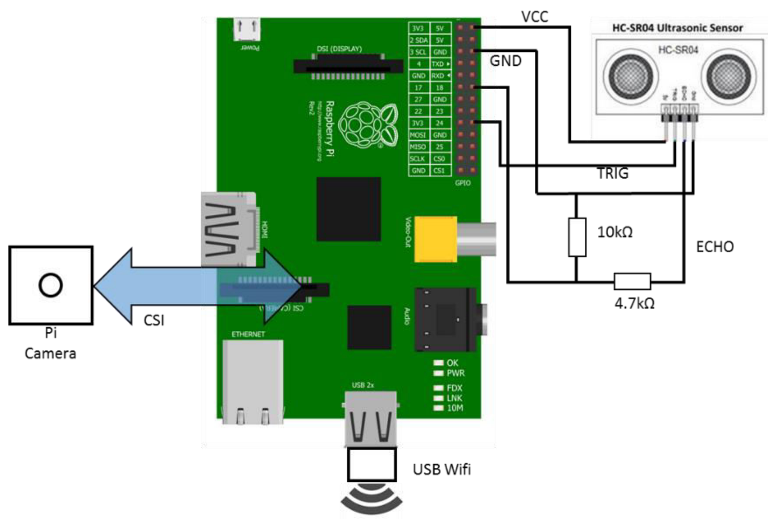

Figure 2. Hardware interconnection diagram of the Experimental Setup

The software system for data collection and analysis was developed using Robotic Operating System (ROS). Three ROS modules (ROS terminology: nodes) were developed (Figure. 3). The Image Capture Node captures images in 15Hz from Raspberry Pi camera and Sonar Node read distance values from the sonar in 30Hz.

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The images and the sonar data are processed and recorded by the Main node. Open CV is used to implement image processing algorithm in the Main Node.

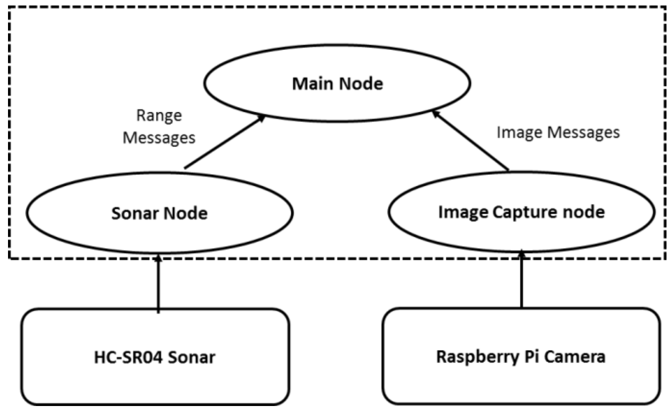

Figure 3. The Software System

2.2 Experimental Procedure

The manufacturer indicated hyperfocal distance for the Raspberry Pi Camera 1 Module is 100cm (Raspberrypi.org, 2016). Therefore, the Experimental Setup was placed against a flat wall away from 120cm and the distance between the setup and the wall was reduced slowly down to 2 cm. While moving the setup, sensor data were recorded. Mobile robots usually encounter complex 3D environment for obstacles. Images from a complex environment may have different amount of depth in each pixel depending on the covered area. Controllability of experiment is one reason for selection of flat surface as an obstacle for this experiment. Other reason is only a small area of the scene is covered when the camera is in the close proximity. Therefore, the assumption of flat surface is reasonably true.

Focus measures were calculated using the main node. The Raspberry Pi camera used has horizontal and vertical field of view of 53 and 41 degrees respectively while the HC-SR04 has 30 deg of field of view . In normal video mode, the full field of view of the cameras is corresponding to 640X480 frame size. The calculations were repeated for $1/2^{th}$ and $1/4^{th}$ of the original field of view. Since the field of view of the camera is fixed, the image frame was cropped to the sizes of 320X240 and 160X120 respectively for this purpose. Figure 4 shows the relative coverage of each field of view in scale.

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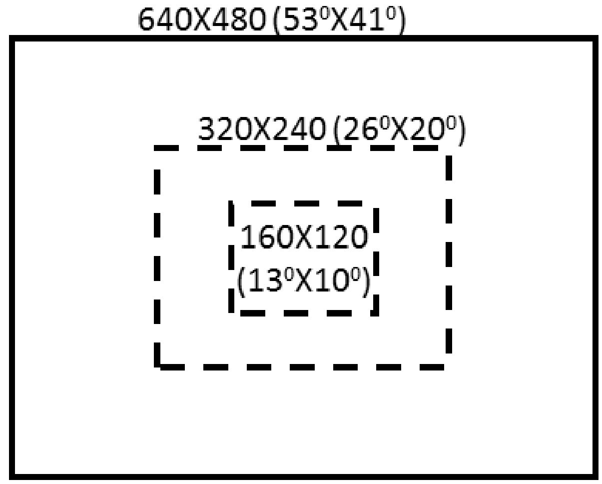

Figure 4. Relative coverage of each fileld of view in scale

Our motivation to reduce the field of view is to increase the sharpness of the measurement and the computational speed of the robot control loops.

3. RESULTS AND DISCUSSION

Output of different focus measures are in different scale. For an example, LAPM measure has 0.8889 and 2.0230 for minimum and maximum respectively and TENG measure has 269 and 759 for minimum and maximum respectively. Therefore, focus measure values are normalized for the purpose of comparison. Figure 5 shows Normalized focus measures plotted against the distance from the obstacle for original field of view. All 4 measures show similar increasing trend with the distance. Other than the GLVN measure all other measures are considerably noisy. Especially LAPV measure looks noisier than all other methods. In TENG and GLVN measures, a sudden increase can be observed around 17cm. GLVN measure indicates less sensitiveness to the distance from 20cm to 100cm.

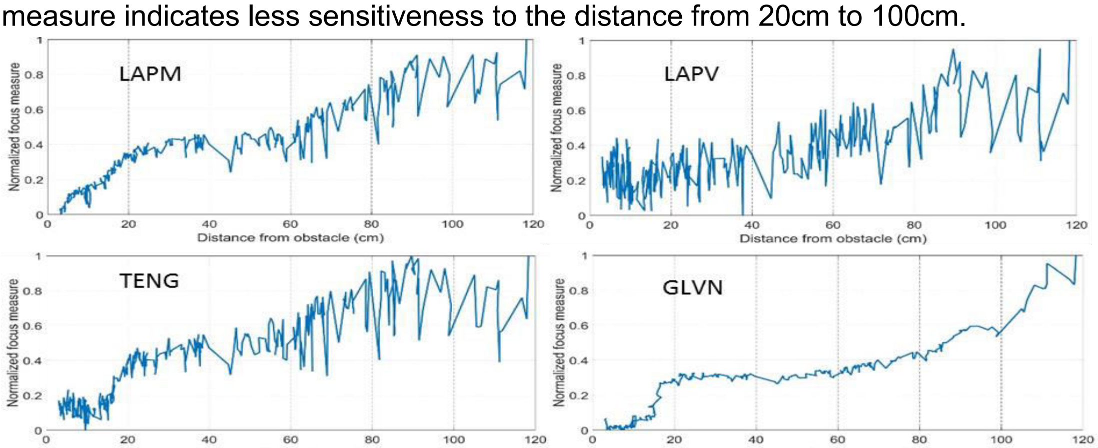

Figure 5. Comparison of focus measures for original field of view (640X480)

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Figure 6 and 7 shows results for 320X240 and 160X120 frame sizes. In Figure 6, LAPM, LAPV and TENG measure show almost similar trend with the Figure 5 values. GLVN measure is more susceptible to the field of view and show a completely different trend from figure 5 values. This measure has become noisy also. In Figure 7, with only a 13^0 of field of view, all focus measures show unexpected behavior in comparison to Figures 5 and 6. However, all the measures show a rise-peak-fall trend with the distance. A sudden increase also can be observed around 30cm distance of all the plots. Analyzing the Figures 5, 6 and 7 shows, the reduction of the field of view slightly moves the point of sudden increase away from the origin in TENG and GLVN measures.

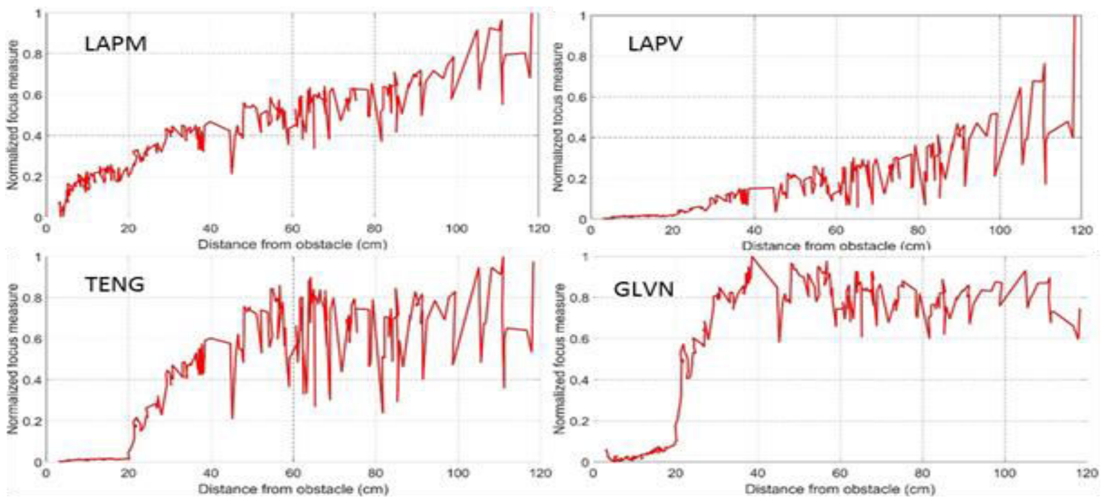

Figure 6. Comparison of focus measures for 320X240 field of view

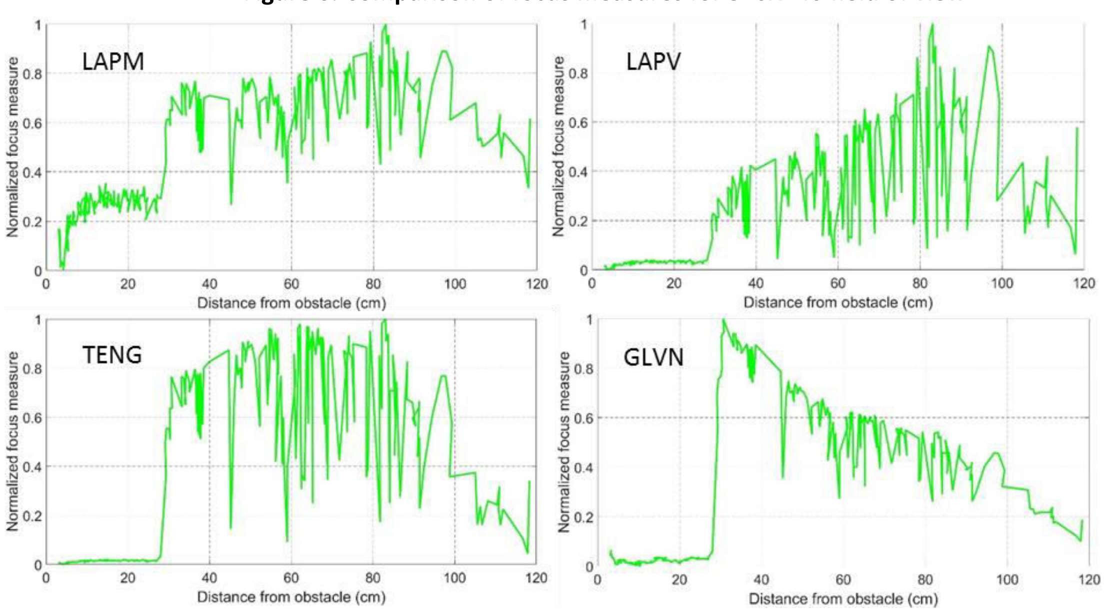

Figure 7. Comparison of focus measures for 160X120 field of view

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4. CONCLUSION

Four different focus measures were experimentally evaluated for collision avoidance application of mobile robots. Focus measures were calculated for three different field of views. The overall results show that the focus measure of a fixed focused camera can be used as a replacement for other active sensors such as sonars and laser range finders in collision avoidance application of mobile robots. The GLVN focus measure is more suitable for larger field of view applications. LAPM and LAPV measures show an increasing trend with the 25^0 of field of view images. But the values are too noisy for any direct application. Temporal filtering may be used for removing the noise from these measures. There are two corresponding distance values for same focus measure in 12^0 field of view images. Therefore, there may be practical limitation in using them for collision avoidance. However, the sudden change in the focus measure around 30cm can be used to stop slowly moving robots.

Overall, GLVN focus measure in full field of view is more suitable for direct application without any intermediate filtering steps. Other measures may produce inconstant results with robotic controllers due to the noise. Furthermore, GLVN measure has sudden change around 15cm distance. It is an added advantage when there is a need to stop the robots in a very close range.

Future work involves developing a control algorithm using GLVN focus measure for collision avoidance of a mobile robotic platform and testing the performance.

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