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Range-Image Acquisition for Discriminated Objects in a Range-gated Robot Vision System

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1. Introduction

Vision systems used to acquire two-dimensional (2D) and range images are usually designed for use in clear atmosphere [1]. For practical outdoor applications, the systems must be considered to perform in harsh environments, such as in the presence of smoke, fog, and haze [1]. The imaging capability of a surveillance vision system from harsh low-visibility environments such as in fire and detonation areas is a key function to monitor the safety of the facilities. 2D and range image data acquired from low-visibility environment are important data to assess the safety and prepare appropriate countermeasures.

Passive vision systems, such as conventional camera and binocular stereo vision systems usually cannot acquire image information when the reflected light is highly scattered and absorbed by airborne particles such as fog. In addition, the image resolution captured through low-density airborne particles is decreased because the image is blurred and dimmed by the scattering, emission and absorption [2]. Active vision systems, such as structured light vision and projected stereo vision are usually more robust for harsh environment than passive vision systems. However, the performance is considerably decreased in proportion to the density of the particles. Although an active vision system based on laser point scanning is a robust technique, the image acquisition time is longer than a 2D imaging system because of the point scanning [3].

Range-gated imaging (RGI) is a robust active vision system for harsh environments like smoke and fog. In contrast with active laser scanning techniques, the RGI signal displays a two-dimensional image of the scene. The RGI is a direct visualization technique using its own illumination source and imaging sensor. The RGI system illuminates objects using a high intensity illuminant having limited light length and receives light reflected from a limited area using a gated imaging sensor. The RGI technique extracts vision information by summing time sliced vision images. The RGI system provides 2D and range image data from several RGI images and it moreover provides clear images from low-visibility fog and smoke environment by using the sum of time-sliced images [4].

Nowadays, the Range-gated (RG) imaging is an emerging technology in the field of surveillance for security applications, especially in the visualization of invisible night and fog environment. Although RGI viewing was discovered in the 1960's, this technology is, nowadays becoming more applicable by virtue of the rapid development of optical and sensor technologies. Especially, this system can be adopted in robot-vision system by virtue of its compact portable configuration. In contrast to passive vision systems, this technology enables operation even in harsh environments like fog and smoke. During the past decades, several applications of this technology have been applied in target recognition and in harsh environments, such as fog, underwater vision [4, 5]. Also, this technology has been demonstrated 3D imaging based on range-gated imaging.

Robot vision is a key technology to remotely monitor structural safety in radiation area of nuclear industry. Especially, visualization technique in low-visibility areas, such as smoking and fog areas, is essential to monitor structural safety in emergency smoking areas.

In this paper, a range acquisition technique to discriminate objects is developed. The developed technique to acquire object range images is adapted to a range-gated vision system. Visualization experiments are carried out to detect objects in low-visibility fog environment. The experimental result of this newly approach vision system is described in this paper.

2. Experiments to Acquire Object Range Image Using Developed Vision System in Low-visibility Fog Environments

A block diagram of a developed robot-vision system based on the RGI is shown in Fig. 1.

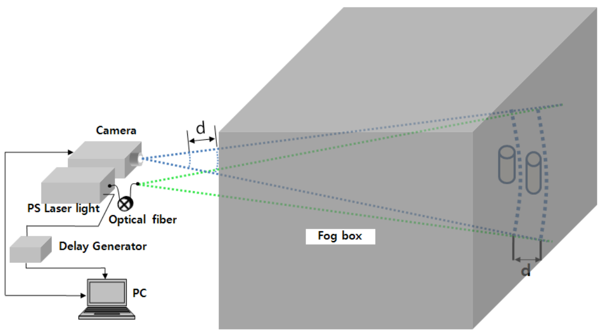

Fig. 1. Block diagram of a developed RGI vision system.

As depicted in Fig. 1, the laser light illuminates certain range area of d, and then the camera activates the image sensor to receive the light reflected from the d area. The receiving area of d is moved from near to far area sequentially.

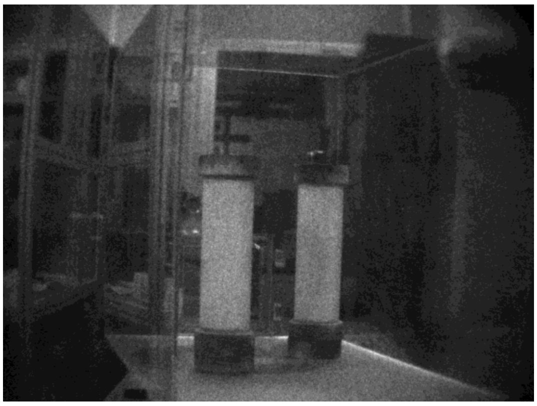

Fig. 2. Sample photo installed in clear environments.

Fig. 3. Sample photo installed in low-visibility fog environments.

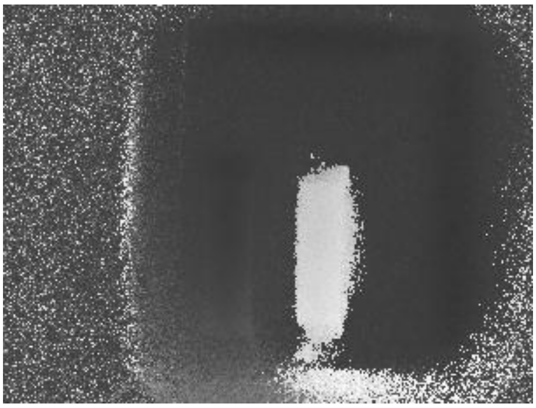

Fig. 4. Acquired range Image without an object discriminator from low-visibility fog environments.

The system consists of a picoseconds camera, a picoseconds laser light, a delay generator, and a computer.

During acquisition, the system catches maximum intensity area at each pixel position and saves its image position. After acquisition, the system deactivates low value position of the one-period frequency coefficient if the value of f_1 is relatively low when compared to the averaged frequency over $f_{>1}$. Then, the system extracts precise position data from the saved active maximum intensity group and adds the value to the previously saved image updated position.

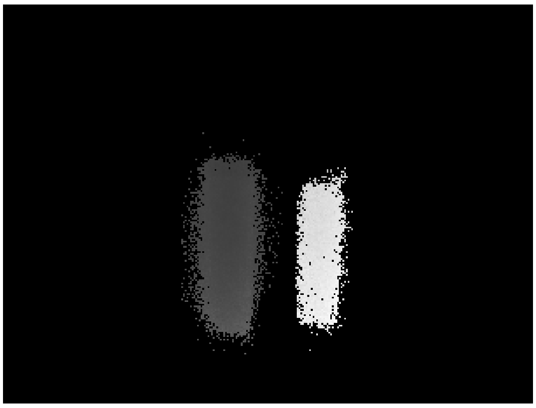

Fig. 5. Acquired range Image with an object discriminator from low-visibility fog environments.

The camera images in clear and foggy environments are shown in Fig. 2 and Fig. 3, respectively. Range images with and without an object discriminator are shown in Fig. 4 and Fig. 5, respectively.

As shown in the experiments, the developed range-gated imaging system provided improved object range data from the low-visibility foggy environments.

3. Conclusions

To acquire object range images in low-visibility foggy environments, an active range-gated imaging system adopting a developed object discriminator is configured and experimented in this paper. As the experimental results, the developed vision system provided precise object range images from low-visibility fog box. We confirmed that the developed active vision system will be valuable for various automatic robot vision applications.

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