Thermal Stereo System for Visible Range Extension of Disaster Robot

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***Abstract*—This paper presents a thermal stereo system to extend a visual range for disaster robots in the heavy smoke situation. A thermal camera is a sensor that can detect the temperature of an object in heavy smoke situations and at the same time recognize the surrounding environment. In addition, the thermal stereo, which is composed of two thermal cameras, has a wide angle of view and can be used in the fire environment because it can acquire shape and distance information of the object even in the heavy smoke situation.**

I. INTRODUCTION

Disaster response robots need sensors that can be recognized in a disaster environment with short visibility due to heavy smoke and high temperature as shown in Fig. 1. It is difficult to recognize the environment only by the RGB camera of the visible ray band in the heavy smoke situation. In order to compensate for this, studies are being conducted to expand the visible range by fusing various band sensors. The thermal camera on the LWIR(Long-Wave Infrared) band can detect the temperature of an object in heavy smoke environment and recognize its surroundings.

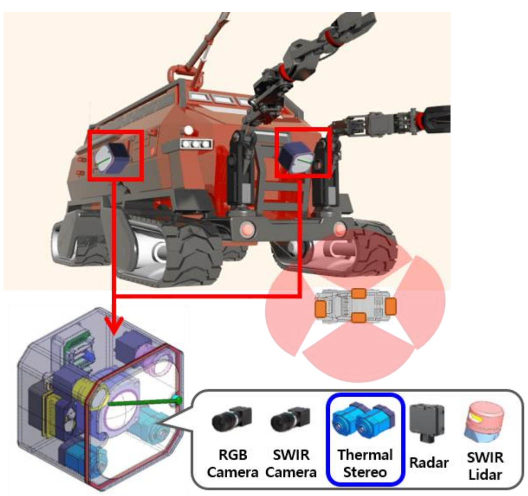

Figure 1. Visualization sensors of disaster robot

In this paper, we propose a thermal stereo system using two thermal cameras to extend the FOV of the thermal image and acquire the distance information to the object. We also propose a method to detect fire and human in a dynamic environment where a thermal image camera moves in a place where vision is not secured.

II. THERMAL STEREO

A. Thermal Camera Calibration

There is a difference between the actual 3D world and the image acquired by the camera due to the structural part inside the camera, so calibration is needed to correct it. A typical RGB camera calibration is performed by detecting corners using the contrast of the black and white portions of the chessboard [1]. However, since the input of thermal camera is the temperature, not the luminance of the light, it is impossible to detect the corner with a normal chessboard. To overcome to this, a chessboard was constructed so that corner detection was possible even in a thermal camera by raising the temperature of the corner by installing a heating element in the corner of the chessboard as shown in Fig. 2.

B. Thermal Image Stitching

In order to perform stereo matching, two thermal cameras must be physically aligned as shown in Fig. 3. However, in an actual stereo system, both cameras are not co-planar and are not row-aligned. Therefore, images taken from two thermal cameras should be re-projected on the front plane and positioned so that the two images are exactly parallel. To re-project onto the front plane, we extract the SURF [2] features for both images and calculate the matching points between the features. Then, a homography matrix is created using matching points extracted from two images. The homography matrix is applied to the left image to create a warped image, and the result is overlaid on the right image as shown in Fig. 4. The image obtained from one thermal camera has a FOV of 48 degrees, but the stitched image from two thermal cameras has a FOV of 60 degrees.

(a) Heating chessboard (b) Thermal image

Figure 2. Heating chessboard for thermal camera calibration

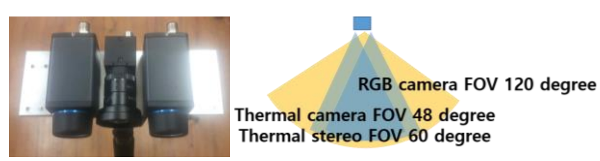

Figure 3. Thermal stereo configuration

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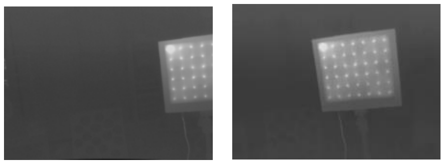
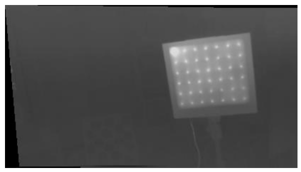


(a) Left thermal image (b) Right thermal image



(c) Stitched thermal image

Figure 4. Thermal images stitching

C. *Thermal Stereo*

In the heavy smoke situation, it is impossible to measure the distance from most sensors such as LIDAR, laser, ultrasonic sensor. In order to obtain the distance information, two thermal images were applied to the SGBM [3] method with CUDA parallel processing. The SGBM method calculates the cost of various directions for each pixel. In order to improve the speed, we apply the parallel processing every time the cost value of each direction is calculated. Then, the disparity is calculated by a smooth merge method for each direction cost calculated for each pixel to obtain the depth value. Depth image and the stitched image are both based on the left image (Fig.(a)) as shown in Fig. 5, the fusion image is completed by overlaying the depth image on the stitched image. STIXEL [4], which is a method of visualizing depth information using a number of bars connecting the height of a specific object from the boundary between the object and the flat surface, was used to visualize the distance information.

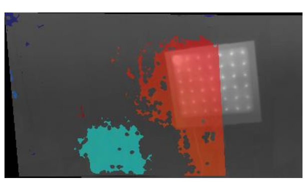


Figure 5. Overlayed depth image on the stitched image

III. Object Detection

A. Fire Detection

To detect the fire, the outline of the fire is obtained by using the temperature information obtained from the thermal camera, and the distance from the center point to the outline of 64 identical angles is obtained. The variation of average distance between each point is obtained, and if the variation exceeds a certain range, it is regarded as fire [5].

B. Human Detection

A candidate region corresponding to the temperature of human is obtained from a temperature value by thermal camera, a posture is classified by calculating a ratio to the region, and a pixel frequency for each direction is obtained through histogram projection for each posture. If it matches the distribution corresponding to the standing posture, the sitting posture, and the lying posture, the human is detected [6].

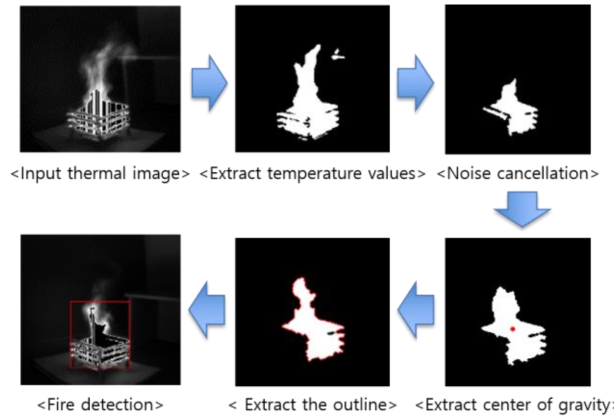


Figure 6. Process of fire detection

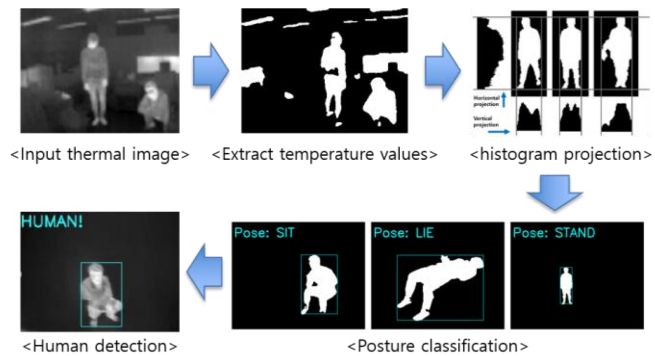


Figure 7. Process of human detection

IV. Conclusion

We proposed a thermal stereo system using two thermal cameras in the heavy smoke situation to extend the FOV and obtain the distance information to the object. We also proposed a method to detect fire and human by using it. We will develop to obtain more precise distance information by applying stabilization technique to adjust dynamic range of thermal camera.

Acknowledgment

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