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種別(和文)	論文要旨
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（博士課程）
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論 文 要 旨

THESIS SUMMARY

専攻： Department of	SYSTEMS AND CONTROL ENGINEERING 専攻	申請学位（専攻分野）： Academic Degree Requested	博士 (ENGINEERING) Doctor of
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要旨（英文 800 語程度）
Thesis Summary (approx.800 English Words)

The title of the thesis is "Multi-Modal Image Registration and its Application." This thesis will contain the complete information of all the works that were done during doctoral program at Tokyo Institute of Technology. It includes 1 international presentation, 2 conferences papers, and 1 journal paper.

Chapter 1 contains introduction. Infrared light is introduced and categorized based on its wavelength. In this thesis, we consider long-wavelength infrared light in addition to visible light for joint image processing application. Temperature information captured by infrared camera can be useful in many applications such as autonomous driving and robotics. Multi-modal camera system refers to the system of cameras that capture multiple modality of data. Such system already exists or is even commercialized. However, existing image processing technique does not take advantage of the system. Therefore, our work will utilize the system to its full potential. We will refer to visible light as RGB and infrared light as IR for the rest of the summary. The diagram of the organization of thesis, outlining the relationship between chapters, is shown at the end of the chapter.

Chapter 2 contains literature reviews. We consider multiple multi-modal images as input so image registration is essential. Image registration has been extensively studied in RGB domain but the technique does not translate well to IR domain. The existing IR image registration assumes that the input IR image is high quality. For RGB-IR cross image registration, the existing method only consider small misalignment between both images. As we work with multiple cameras, camera calibration is preferred. The existing calibration method will works as long as common pattern can be detected in input image. For IR images, special calibration board was previously proposed so RGB-IR calibration is possible. Enhancing images using another images as a guide was also introduced in the form of guided upsampling. The original work successfully super-resolutes depth image using RGB image as a guide. Our work will adopt the same idea but will apply on IR image as oppose to depth image.

Chapter 3 starts with our first attempt to solve IR image registration problem. The challenge lies on the low-resolution IR images (80x60) where common feature detection does not perform well. We propose a framework for IR image enhancement which consists of two main steps. The first step is to perform RGB image registration on RGB images. The second step is to combine registration information, in this case Homography, from RGB image registration and RGB-IR calibration parameter and obtain IR image registration. As a result, both RGB images and IR images are registered. We perform image stitching to merge all RGB images and apply guided upsampling on combined IR images. As a result, we obtain high-resolution IR image. This result is qualitatively better than that of existing methods which only use IR images as input.

Chapter 4 reuses the same framework as chapter 3. However, the differences are more input images and wider camera movement. By choosing an appropriated RGB image registration algorithm, IR image registration can be inferred seamlessly. As a result, we are able to create RGB and IR panorama images. Because IR image registration is difficult task, other existing methods fail to properly construct IR panorama images. In addition, our approach allows a combination of independently created panorama. This is shown by changing upward orientation of the cameras between each round of data collection.

Chapter 5 introduces new multi-modal camera system. The system is inspired by IR panorama result from chapter 4. If we can create real-time IR panorama, we can use the system in surveillance application. The existing system consists of only IR camera which rotates around to generate near-real-time IR panorama. The proposed consists of 5 IR cameras and 5 RGB cameras, each with 90 degree field of view. Captured images will cover the entire 360 degree field of view. The challenge is the calibration process for the entire system. We combine two existing approaches. The first approach only calibrates RGB-IR camera pair so we have to apply the method for every pair. The second approach calibrate camera system of the same modality

so we adopt its loop-closing technique to globally optimize camera parameters from the first approach. Once the system is calibrated, we can generate RGB and IR panorama at 15 frames per second.

Chapter 6 explores the potential of obtaining depth information from RGB-IR image pair. The existing methods for estimating depth works well on IR-IR image pair but does poorly on RGB-IR image pair. We propose a guided filtered cost volume for similarity measurement. This measurement takes into account the weak correlation concept between RGB and IR images. Although quantitatively our approach slightly outperforms existing methods, the qualitative results look much better.

Chapter 7 will summarize the contents from previous 6 chapters.