（様式６号）「課程博士用」

学 位 論 文 の 要 旨

専　攻　名	Systems Engineering 専攻 （システム工学）	ふりがな 氏　　名	Kaluarachchige Don Chamika Janith Perera　㊞

学位論文題目

Low-Resolution Aerial Hyperspectral Image Processing for Agriculture-related Decision Making

（和訳：ドローンを用いた低解像度ハイパースペクトル画像処理と農作物の育成評価への適用）

Remote sensing in the field of agriculture has become a timely concern to maximize agriculture production from available resources. Information produced from the remote sensing methods has shown immense potential in providing insights that can be directly used in the decision-making processes in agriculture. The use of hyperspectral imaging for agriculture-related decision-making has gained significant attention in recent years due to its ability to provide detailed information on crop health and composition. Even though hyperspectral imaging was started in the domain of satellite-based acquisition systems, the advancement of technology has managed to produce cameras that are capable of mounting in Unmanned Aerial Vehicles such as multi-rotors. These platforms provide localized data acquisition capabilities having high spatial and temporal resolutions. However, the high cost and complexity of hyperspectral cameras have limited their widespread adoption in the agricultural sector. Recent introductions to UAV mountable hyperspectral cameras have managed to reduce this high entry cost and opened up new avenues for many research communities. This thesis was motivated by the potential of the use of low-resolution hyperspectral imaging as a more cost-effective and practical solution for agriculture-related decision-making.

The thesis begins by discussing the use of low-resolution hyperspectral cameras for the initial analysis of spectral signatures. Spectral signatures obtained using the hyperspectral camera were compared with the spectral signatures obtained via a field spectrometer to evaluate the usability of the camera in the domain of agriculture decision-making. However, while interpreting the aerial images captured from the drone, hyperspectral mosaic generation was identified as a significant barrier. Mosaic generation is a key step in interpreting the captured images and deriving information from the captured data. This is because it allows the capability to interpret information relative to the entire captured field rather than relative to each captured image.

Image mosaic generation can be subdivided into several key steps as follows. Feature identification, feature matching, transformation calculation, and finally image blending. However, it was identified that this process failed at the step of feature identification and matching in the low-resolution hyperspectral images. This is because current popular feature detection and matching algorithms fail to either identify features at all or fail to identify features that could be matched across the captured images. Indistinctive features in these low-resolution aerial images

続紙　有■　無□

氏名 (ふりがな)	Kaluarachchige Don Chamika Janith Perera ㊞

such as repeating patterns, low-contrast areas, and uniform textures prevent the traditional feature detection and matching algorithms from identifying any usable matches. To overcome this challenge, a successful stitching pipeline is proposed next, utilizing two learning-based feature-matching methods. The proposed method employs a stitching pipeline to create a low-resolution hyperspectral image mosaic. It employs two leaning-based feature detection and matching algorithms which have shown promising results in initial experiments with low-resolution hyperspectral images. Matched features were then used to transform the images into one plane and then blended producing the mosaic. Results indicate successful mosaic generations with consistent geometrical features compared to the captured field. The generated mosaic is then evaluated for spectral consistency within the same targets and spectral differentiability within different targets.

However, even with the state-of-the-art feature match detection methods, it was identified that certain landscapes especially at low altitudes struggle to produce any usable outputs. Hence an improved feature match detection method was needed to address the drawbacks. At the same time, it was highlighted that none of the feature detection methods in use utilizes all the spectral information available in a hyperspectral image. To utilize the missing information and increase the robustness of the detected and matched features, a novel feature match identification method based on 3D convolutional neural networks and edge detection was proposed in the second part of the thesis. A set of feature matches were generated using the hyperspectral image's edge maps. Physics-inspired edge detection algorithm was incorporated for this task and a set of SIFT feature matches were obtained for the matched images. The sensitivity of the SIFT detector was reduced so that an initial set of correct and incorrect feature matches were generated. Then the obtained set of feature matches was filtered by using a 3D Convolutional Siamese Network trained on matched features and non-matched features. The second half of the thesis discusses the feature set generation, architecture of the Siamese Neural Network, training, and evaluation of the proposed method. The proposed model was evaluated against 4 state of the art feature detectors and the results indicated the superior performance of the proposed method.

Overall, the initial mosaic generation method was capable of successfully creating image mosaics from a given set of hyperspectral images. Spectral and geometrical consistency was observed between the non-stitched image and the stitched image. Secondly, the proposed feature detection and matching method was capable of producing highly accurate feature matches across the evaluated image pairs compared to the state-of-the-art methods. However, a few limitations such as the processing speed were identified during the inference stage of the proposed method.