京都大学	博士（　　工　　学）	氏名	Nguyen Tien Hoang
論文題目	Development of transformation method of multispectral imagery into hyperspectral imagery for detailed identification of metal and geothermal resources-related minerals （金属と地熱資源関連鉱物の詳細抽出を目的としたマルチスペクトル画像からハイパースペクトル画像への変換法の開発)		

Hyperspectral remote sensing is superior to multispectral remote sensing because of continuous reflectance spectra that enable detailed, precise mapping of the earth surface compositions. Because of this spectral feature, hyperspectral remote sensing has been applied to various fields, particularly land surveys including mineralogy, biology, and environmental monitoring. However, hyperspectral imagery has a shortcoming of swath width, which is much narrower than multispectral imagery. In addition, no hyperspectral imager has covered entirely the earth surface. These conditions point to a need for hyperspectral transformation of multispectral images to extrapolate the coverage area of hyperspectral imagery. Landsat series imagery is the most suitable data source of this transformation, because it represents the longest-operating earth observation that has accumulated high-quality images for all the land areas. Based on those background, this dissertation completes the results of a study that has developed a new method, Pseudo-Hyperspectral Image Transformation Algorithm (PHITA), to transform multispectral imagery into pseudo-hyperspectral imagery. This advanced method contributes to more detailed identification of minerals and mineral deposit exploration than traditional multispectral remote sensing. This dissertation is composed of the following six chapters.

Chapter 1 summarizes important backgrounds to understand the goals of the dissertation. Simulation of a hyperspectral image from a multispectral image is an innovative technique by compensating the disadvantages of each image type. Although several preceding studies have succeeded in simulating a hyperspectral image from a multispectral image, they verified their methods only for the overlapped areas of both the images. In this study, PHITA was validated even for areas outside the original coverage of hyperspectral image.

Chapter 2 explains in detail the development of PHITA to transform a multispectral image into a pseudo-Hyperion image using correlations between band reflectance data in their overlapped area. Landsat 7 ETM+ and Hyperion images are selected as an example for the transformation. Effectiveness of the hyperspectral transformation was multiply evaluated by general image appearance, spectral reconstruction, statistical indices, and mineral mapping. The validation methods and data preprocessing are also presented in this chapter.

Chapter 3 demonstrates and discusses the results of the Hyperion image transformation from ETM+ image by PHITA. The resultant pseudo-image has a number of high-quality Hyperion bands of the same scene size as the ETM+ image. The pseudo-Hyperion image was proven very similar to the original band reflectances, because of large Pearson's correlation coefficients (generally > 0.94), small RMS error (mostly < 0.016), high structural similarity, and similar appearance of the color composite image. Using a reference mineral map built from an AVIRIS image and field surveys as ground truth, an advantage of the pseudo-image is clarified for the Cuprite hydrothermal alteration area in the western United States. The identification and mapping accuracies of metal deposit-related minerals were high even in areas outside the original Hyperion scene.

Chapter 4 extends the PHITA to transform Landsat 5 TM, Landsat 8 OLI, and EO-1 ALI sensor images into pseudo-Hyperion images. By choosing a part of the Fish Lake Valley geothermal prospect area in the western United States for a case study, the pseudo-Hyperion images produced from the TM, ETM+, OLI, and ALI images by PHITA were confirmed to be applicable to a mineral mapping of geothermal resource exploration. Using a reference map as the ground truth, three main minerals (muscovite and chlorite mixture, opal, and calcite) were identified with high overall accuracies from the pseudo-images. The highest accuracy was obtained from the ALI image, followed by ETM+, TM, and OLI images in descending order. The TM, OLI, and ALI images can be alternatives to ETM+ imagery for the hyperspectral transformation that aids the production of pseudo-Hyperion images for areas without high-quality ETM+ images because of the scan line corrector failure, and for long-term global monitoring of land surfaces.

Chapter 5 examines the capability of PHITA for simulating an airborne hyperspectral image, AVIRIS, from OLI and ASTER images and a possibility of joint spectral and spatial downscaling. In this experiment, PHITA follows the principles of supervised machine learning workflow with a training area in the United States and a validation area in the northern Chile. These are typical hydrothermal deposit areas. The pseudo-AVIRIS image has 205 bands and a downscaled spatial resolution of 15 m, half of the multispectral spatial resolution. Pseudo-reflectance spectra were generally agreeable with the original spectra. The OLI-based pseudo-image was superior in the spatial downscaling but inferior in the spectral downscaling. Using 4-m SASI-based mineral map as ground truth of the distribution of selected minerals, the ASTER-based pseudo-image was confirmed to be sufficiently applicable to mineral identification and mapping for an area that contains the Sierra Gorda Copper-Molybdenum Mine, a large porphyry copper deposit in the northern part of the study area.

Finally, Chapter 6 summarized the essential results of each chapter as a grand conclusion of this study. Important future works are also discussed in this chapter to develop furthermore PHITA studies for global exploration of mineral and geothermal resources.