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論文題目　**Applications of hyperspectral remote sensing in agricultural land and wetland**

（農地および湿地におけるハイパースペクトルリモートセンシングの応用）

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Hyperspectral remote sensing data provides the potential for more accurate and detailed information extraction than any other type of remotely sensed data. It is very appealing for detailed land classification and similar surface targets discrimination. This research studied mainly on the applications of hyperspectral remote sensing in agricultural land and wetland.

Japanese agricultural lands are characterized by complicated class components and patterns, and usually divided into many various patches planted with different kinds of crops. The farm buildings, roads, vinyl-mulches and different types of soils intensify the complication of the landscape, which makes it more difficult to classify the agricultural lands. In addition, it is often hard to find enough large number of training samples to satisfy the requirements of the conventional statistical classification because the areas of the patches of cultivated fields are commonly small. To solve this problem, some feature extraction methods before the data were inputted into classifier are necessary to reduce the high dimensionality of hyperspectral data and improve classification accuracy. This thesis tried to find the comparative effective classification method for mapping complicated Japanese agricultural land cover.

Conservation of endangered plant species in wetlands has been proposed as one of the important components of environmental conservation worldwide because wetland can supply growth environment for various vegetations and animals. In Watarase wetland, the biggest lowland wetland located in central Japan, more than 40 endangered vegetation species listed in the national red list are growing in moist tall grasslands. In these endangered plant species, there are some species, such as *Arisaema heterophyllum*

Blume, are very peculiar and they only exist in Watarase wetland, but not any other place in the world. Therefore, it is very important to make clear the potential distribution of these endangered plant species, in order to protect them from extinction from the world, and to conserve the biodiversity of the whole environment of Watarase wetland. Hyperspectral remote sensing is considered as a time-effective and costless way to monitor them, but almost all these endangered species are growing under the moist tall grasslands of *Miscanthus sacchariflorus* and *Phragmites australis.* The tall grasses cover the endangered plants and prevent the endangered plant from exposing to hyperspectral sensors. But each endangered plants are associated with a certain habitat where either grass species is predominating, or both are mixed more evenly. Therefore, estimation of the relative dominance of *M. sacchariflorus* or *P. australis* may help in evaluation of the potential habitat area of the endangered species. The research focused on the estimation of the two tall grasses using hyperspectral remote sensing data to provide a base for estimating the potential habitat of endangered plants species.

In the agricultural land classification study, several combinations of different feature extractions and classifiers were compared to find the most effective method for mapping small-patches agricultural land of Miura Peninsula, in Japan by AISA (Airborne Imaging Spectroradiometer for Application) data. PCA (Principal Component Analysis) and DBFE (Decision Boundary Feature Extraction) were compared as the feature extraction methods to reduce the large number of bands of the hyperspectral data. MLC (Maximum Likelihood Classification) and ECHO (Extraction and Classification of Homogenous Objects) were compared as different classifiers. The above procedures produced four feature extraction/classification methods, i.e. PCA-MLC, PCA-ECHO, DBFE-MLC and DBFE-ECHO. The DBFE has shown much better classification accuracy than PCA when the feather extraction results were inputted into same classifier. The ECHO classifier performed a little better than MLC when the same feature extraction inputs were used. Therefore, the combination of DBFE-ECHO was found to be most effective for improving classification accuracy.

Moreover, a step of separating the whole image into rough classes of vegetated and non-vegetated areas by NDVI (Normalized Difference Vegetation Index) was inserted before the above described four classification methods were applied to the image. It hypothesized when we try to distinguish both species of crops and different types of soils, the little difference between the subclasses (species of crops or different types of soils) seems to be obscured by the difference between the main classes such as vegetated and non-vegetated areas. Thus, we separated the vegetated regions from non-vegetated regions using NDVI, which reflects living biomass in each pixel. The NDVI value was computed using the band 35 (683nm) and band 47 (783nm) representing red and near-infrared band. This procedure was expected to prevent confusion among categories in classification process. The pixels with the NDVI value larger than 0.3 was assigned as vegetated pixels, while the pixel smaller than 0.3 was defined as non-vegetated pixels. Then the four classification methods were applied to the separated vegetated and non-vegetated areas. The results have indicated that the pre-classification process using NDVI that separates the whole image into vegetated area and non-vegetated area improved classification accuracy for each of the method we proposed in this study. Therefore, we can conclude that the pre-classifying the image into vegetated and non-vegetated areas have prevented some confusion of classification.

In the application of hyperspectral remote sensing in wetland tall grasses estimation, we have tried to map area based abundance of *M. sacchariflorus* and *P. australis* using hyperspectral data, in which the accuracy was evaluated by comparison with the ground estimates of shoot density and total stem volume. Extensive ground data collection was conducted right after the imagery acquirement from May 22 to June 14, 2004. Nine 5×5 square meter plots were placed to determine the *M. sacchariflorus* abundance, while fifteen plots, *P. australis* abundance.

Matched filtering (MF), a special type of spectral mixture analysis, filters the input image for good matches to the chosen target spectrum by maximizing the response of the target spectrum within the data and suppressing the response of everything else (which is treated as a composite unknown background to the target). One major advantage of the method is that MF does not require finding the spectra of all endmembers for the other endmembers that occur in the scene. A minimum noise fraction (MNF) transformation of AISA image was first performed in this study. The data were subjected to a dimensionality reduction and noise whitening process by MNF. The first 15 MNF images (with large eigenvalues) were chosen for further analysis. The *M. sacchariflorus* endmember and *P. australis* endmember derived from the AISA image where the relative plant densities are high by ground investigation were used as the endmember in the MF analysis. The relationships between MF estimates of subpixel *M. sacchariflorus* and *P. australis* ground estimates of their shoot density and total stem volume were examined using simple linear correlation analysis for all sites.

The correlation coefficient of MF fraction values against shoot density of *M. sacchariflorus* was 0.89 at significance level of 0.01. For total stem volume the correlation coefficient was 0.94 at 0.01 level of significance. On the other hand, the correlation coefficient of MF fraction values against shoot density of *P. australis* was only 0.43 with no significance, and that against total stem volume was 0.51 with no significance. The MF analysis for *P. australis* didn't seem as effective as for *M. sacchariflorus*. The leaves of *M. sacchariflorus* tend to spread more horizontally because it has a relatively soft leaves. This makes the land surfaces and underneath plants to be covered almost entirely by the leaves of *M. sacchariflorus*. This enables the hyperspectral sensor to capture pure spectrum of *M. sacchariflorus* unaffected by the background materials such as soils, litters and short plants in the bottom layer. The leaves of *P. australis*, on the other hand, are relatively hard, erect and grow up straight that exposes the soil and underneath plants. Thus hyperspectral sensor captures a mixed spectrum of *P. australis*, underlying soil and short plants. The physical difference between the two plants provides the key in the effectiveness of the MF fraction to estimate the abundance and distribution of *M. sacchariflorus* and *P. australis* in the study area.

Selecting endmember affects unmxing performance very much. It is limited to discriminate some given targets when the pure pixel is hard to find. To avoid endmember selection, we used stepwise multiple linear regression analysis to find most effective indices for *M. sacchariflorus* and *P. australis* abundance. The parameters of abundance include shoot density and biomass (dry weight). The biomass was calculated by the shoot height investigated in ground truth surveying. The shoot density and biomass composed the dependent variables of regression analysis. On the other hand, the surface original reflectance, band ratio, PCA components of reflectance and DBFE components of reflectance were used as independent variables for regression. Among the four types of independent variables, band ratio refers to the band ratios which coefficients between the ratio and the ground survey data are largest. The number of band ratios we used is 200. PCA components refer to 6 components which have the large eigenvalues; and DBFE components include 18 components which have the largest eigenvalues.

In estimating the plant density, the DBFE method showed the best predictive ability that the smallest RMSE for *M. sacchariflorus* was 7.31/m^2 which was a 9.8% error relative to the maximum shoot density, and RMSE for *P. australis* was 20.08/m^2 which was a 19.4% error relative to the maximum shoot density of *P. australis*. But in estimating the biomass of the two plant species, no one method showed great priority than the other methods. For *M. sacchariflorus,* the band ratio method obtained the lowest RMSE of 138.26g/m^2, which was an 11.5% error relative to the maximum biomass. For *P. australis*, the PCA method showed the lowest RMSE of 201.95/m^2, which was a 16.6% error relative to the maximum biomass. The error occurred in biomass estimation may partly due to the error of biomass calculation.

The best regression equations derived from DBFE components for estimation grasses shoot density have been used to map the distribution of the two grasses. By composing the distribution maps of the two grasses, the relative predominance map was also made. This map was expected to be helpful in estimating the potential distribution of the endangered plant species in Watarase wetland.

From the results of the thesis, we conclude that DBFE has shown versatility as effective feature extraction for classification and as effective indices for discriminating spectrally similar targets using hyperspectral remote sensing data. DBFE can be considered as the first choice when we want to distinguish similar objects by hyperspectral remote sensing. Unmixing is a simple method, but only effective when the pure pixel for endmember in imagery is sure to be found, or the atmosphere corrected pure pixel spectrum is available in hyperspectral data analysis. The atmosphere correction needs a lot of effort within the limited time when the airplane passes by the study area, and it is often not so practicable. The statistical method avoided this weakness of unmixing. The stepwise multiple linear regression method is thought more suitable than unmixing when the endmember is not available.