HYPERSPECTRAL REMOTE SENSING TECHNOLOGY AND APPLICATIONS IN CHINA

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ABSTRACT

In recent years, hyperspectral remote sensing has stepped into a new stage in China. There are several advanced hyperspectral imaging systems developed in Chinese. Especially the Chinese Academy of Sciences(CAS) has been playing a very important role in such High-technology developing activities. Pushbroom Hyperspectral Imager (PHI) and Operative Modular Imaging Spectrometer (OMIS) are two types of representative hyperspectral imagers developed by CAS. A hyperspectral digital camera system (HDCS), with limit-number bands but high spectral resolution, was also developed and tested in 2000. Aiming to different observation objects and applications, the spectral wavelength and resolution of HDCS can be easily changed by selecting different interference filters. According to these airborne hyperspectral sensors, some data processing and info-extraction models are also developed in China. These models have been widely used in many remote sensing projects, such as precise agriculture, mineral exploration, urban investigation, and so on. In addition, a Hyperspectral Image Processing and Analysis System (HIPAS) software were also developed.

Keywords: Hyperspectral Remote Sensing, Imaging spectrometer, Image processing.

1. INTRODUCTION

The trend in the of development of remote sensing has been, with the increase of the spectral resolution, to move from the panchromatic multispectral to the hyperspectral, and then to the ultraspectral. During the last 15 years , studies on the hyperspectral remote sensing have been carried out intensively in China. In the Chinese airborne remote sensing system, the hyperspectral sensor is already in place as one of the basic systems. Under the great supports of Chinese High Technology Developing Project), two new kinds of hyperspectral sensors, PHI and OMIS, were designed specifically for hyperspectral applications. In addition, a small hyperspectral digital camera system (HDCS) with limited number but narrow band was also implemented for environmental and agricultural monitoring. With the development and perfection of the hyperspectral remote sensing technologies, hyperspectral remote sensing has been the major technique applied in many studies. For hyperspectral sensors have become available to provide both high spatial and high spectral resolution with high signal/noise ratio. Due to the sufficient spectral features such as spectral reflectance with wavelength it provides, hyperspectral data plays an important role in the different fields. So it is a rush now to develop some special algorithms and models for hyperspectral data processing, information extraction, classification and identification. The technical characteristics of some hyperspectral imagers in the world are presented in table 1.

Name	Spectral Coverage (μm)	Number of Bands	Spectral Interval (nm)	IFOV (mrad)	FOV (degree)	Developer	Available Date
MAIS	0.44-11.8	71	20/600	3	90	China	1991
AVIRIS	0.38-2.5	224	10	1	30	JPL, U.S.A	1987
GERIS	0.4-2.5	63	25/120/16	2.5	90	GER Corp. U.S.A	1986
CASI	0.4-1.0	288	2.9	1	35	ITRES Research, Canada	1989
MIVIS	0.43-12.7	102	20/50/8/400	2.0	70	Daedalus Enterprise Inc., U.S.A	——

Table 1. some technical characteristics of the hyperspectral imagers.

In the field of vegetation study especially for precise agriculture, some successful progresses are already achieved. They are the works of Tanvir[1], Chadbum[2],

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et al.[3, 4, 5, 6] by using derivative spectral analysis model for background noise elimination, “red edge” determination or biochemical parameter detection. Another attempt is to search all kinds of spectral parameters or parameter combinations to build reliable relationship with biochemical parameters such as LAI[7, 8]. Furthermore, special angle mapper (SAM) model is also proved to be effective[9, 10]. However, there still are many difficulties due to the unique spectral features of vegetation as: **1**). The spectral shapes of all vegetation are somewhat similar while the spectra of a same species vary remarkably and therefore it is very difficult to classify using the usual method for multi-band image; **2**). Vegetation is active with a high dynamic and therefor it has a strong spatial and temporal variation; **3**). Usually it is a mixed spectrum and is strongly effected by many kinds of background even the weather; **4**). The influencing factors and their effects are very complicated; **5**). The spectral effects of different pixel size is variable. Therefore, new model to consider the complex, mixed, dynamic and temporal properties of vegetation spectrum must be studied and developed to promote the better application of hyperspectral remote sensing in vegetation detection. Due to the particularity of hyperspectral data processing, some special hyperspectral data processing and analysis models and software were developed for remote sensing applications.

2. HYPERSPECTRAL IMAGER DEVELOPMENT

2.1 Airborne Hyperspectral Imager

Following the world foreland of remote sensing, several kinds of applied hyperspectral imagers were built in China. Shanghai Institute of Technical Physics is working on the development of airborne multispectral scanner, imaging spectrometer and scanning laser ranging-imager sensor for 20 years. In 1991, the modular airborne imaging spectrometer (MAIS) had been tested in Darwin, Australia. Since 1994, the project group led by Pro. XUE Yong-Qi began to develop a new concept imaging spectrometer. Based on the fundament of optics imager technology and diffract technology, a series of multispectral scanner, imaging spectrameter and two generation of pushbroom hyperspectral imager had been developed and applied in the field of environment monitoring, geology study, oil and gas prospecting, vegetation, ocean observation, city layout, fine agriculture, forest fireproofing and so on.

Operational Modular Imaging Spectrameter(OMIS) has two models-OMIS-I and OMIS-II. The scanning mirror cross track, the flight of plane along track. OMIS collects reflective and radiation light from ground by RC telescope. The dispersal of light is by Grating.

Table 2 The specification of OMIS

OMIS-I				OMIS-II			
Total Waveband Number			128	Total Waveband Number			68
Spectrometer	Spectral Range μm	Interval of Spectral Sampling nm	Bands	Spectrometer	Spectral Range μm	Interval of Spectral Sampling nm	Bands
	0.46—1.1	10	64		0.4—1.1	10	64
	1.06—1.70	40	16		1.55—1.75		1
	2.0—2.5	15	32		2.08—2.35		1
	3.0—5.0	250	8		3.0—5.0		1
	8.0—12.5	500	8		8.0—12.5		1
Instantaneous field of View (mrad)	3			1.5/3 optional			
Field of View (°)	>70 Across-Track						
Scan Rate(s/s)	5、10、15、20 optional						
Spatial Sampling	512pixels/line			1024/512pixels/line			
Quantization (bit)	12						
Maximum Data Rate(Mbps)	21.05						
Detector	Si、InGaAs、InSb、MCT			Si、InGaAs、InSb/MCT			

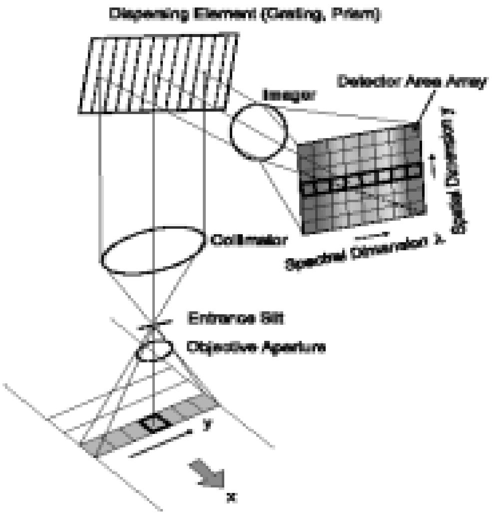
Pushbroom Hyperspectral Imaging is a new method to acquire the imaging spectrum data with the developing of focal plane technology. As showed in Figure1, the fore optics collects lights reflected from ground. The length and width of entrance slit effect the spectral resolution and swath. The incoming electromagnetic radiation will be separated into distinct angles. The spectrum of a single ground pixel will be dispersed and focused at different locations of one dimension of the detector array. The number of pixels is equal to the number of ground cells for a given swath. The motion of the aircraft provides the scan in along track direction, thus, the inverse of the line frequency is equal to the pixel dwell time.

PHI collects spectral images by using a grating. There are two kinds of diffraction grating used in the design of PHI. One is reflective grating and the other is transmission grating. The specifications of three kinds of PHI are listed in the Table 3.

Table 3 The specification of PHI

	PHI-1	PHI-2	PHI-3
Spectral Range	400-800nm	400-870nm	410-980nm
Spectral Bands	244	247	124
Spectral Samples Interval	1.8nm	1.9nm	
Spectral Resolution	< 5nm	< 5nm	< 5nm
Field of View	21o	23o	42o
Spatial Samples	376	652	1304
Instant FOV	1.5o	1.2o (0.6o)	0.6o
Dynamic Range	12bits	14bits	14bits
Maximum Scan Rate	60fps	50fps	50fps
Cooling	No	Yes	Yes
Grating Class	Reflective	Transmission	Transmissi on

Figure1 Principle of PHI



The PHI system is composed by sensor head and electronics system. The sensor head outputs image signal and line interrupt signal to electronics system. The electronics system outputs control signal to sensor head and record data into hard disk or tape. There is GPS and IMU interface in the system. The hyperspectral image preprocessing software is provided with PHI. PHI-2 uses fiber optics data transmission and thermal electronic cooler technology.

Figure 2a PHI-1 sensor

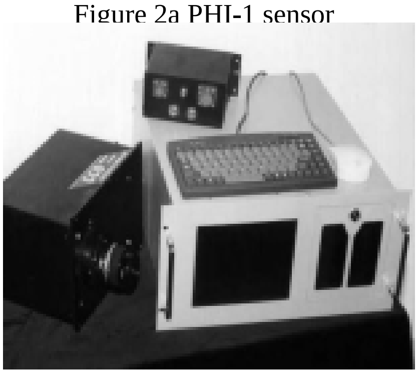
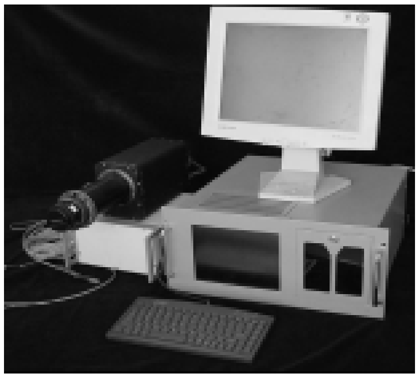


Figure2b PHI-2 sensor



PHI-III is newly developed based on the PHI-II. Compared with the former, it can provide higher spectral resolution and also higher spatial resolution because of the using of advanced optical components. And what is of most importance is that it has wider FOV up to 42o. Till now it has been used in many fields of remote sensing, including the digital city programming of Shanghai in last October.

Since 1994, PHI series sensors had been applied in the field of environment monitoring, vegetation, ocean observation, city layout, fine agriculture and so on. The experiment area covers over the mainland of China and Southeast Asia. Every year PHI is used in the different project supported by National 863 plan, district technology plan, ministries and commissions plan etc. The distributing of experiment places are showed in Figure3.

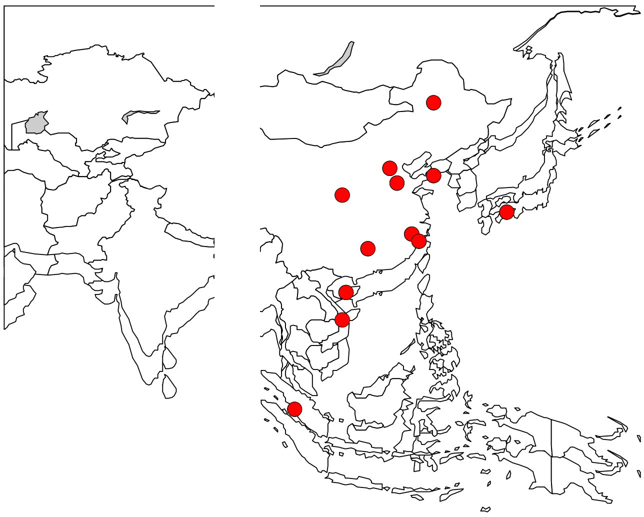


Figure 3 Distributing Map of PHI Application

Since May 2001, PHI-2 had been installed in the China Sea Scout Plane every summer. It is used for studying hyperspectral application on red tide monitor.

On November 2002, PHI was used for inspecting water resource of Huang Pu River in Shanghai. In the experiment, PHI was combined with a 2K×3K area CCD camera. The relationship between PHI and CCD camera was carried out by GPS time.

In October 2001, PHI was invited by National Remote Sensing Center of Malaysia. The experiment site is at the west of Malaysia.

The Table4 lists the flights of PHI and OMIS during 2001 to 2003.

Table5 Flights with PHI and OMIS during 2001 to 2003

Date	Where	Sersor	Aim	User
2001.4	Bei Jing	OMIS-I	agriculture	Institute of Remote Sensing Application,CAS
2001.4	Bei Jing	PHI-I	Fine agriculture	Beijing Academy of Agricultural Sciences
2001.5	Yan An	OMIS-I	Zoology programming of Yan River	Fei Tian Remote Sensing
2001.6	Yin Chuan	OMIS-I	Underground Coal Self-ignite Detection	Coal aerial survey Co.
2001.7-2001.9	渤海湾	PHI-II	Red Tide Detection	The First Institute of Oceanography.SOA
2001.8	Japan	OMIS-I	Fine agriculture	NTT DATA
2001.10	Malaysia	PHI-II	Rain Forest Dectection	Remote Sensing Center Of Malaysia
2002.4-6	Bei Jing	PHI-I	Fine agriculture	Beijing Academy of Agricultural Sciences
2002.5	Yi Xing, Jiang Su	OMIS-I	The Research of Resource Secondary Planet Application System	National Resource Ministry
2002.9	Zhao Yuan, Shan Dong	OMIS-I	Country Resource Investigation	National Resource Ministry
2002.10-11	Shang hai	PHI-1 PHI-2 OMIS-I 6000	Digital City Programming	Shanghai Council of Science
2003.4	Xi an	OMIS-II	Remote Sensing Archaeologize	Shan Xi Remote Sensing Center
2003.10	Shang hai	PHI-3 6000 3K×2K	Digital City Programming	Shanghai Council of Science
2003	Da lian, Tian jin,	PHI-2	Ocean Monitor	State Ocean Bureau

Multi-Sensor Integrated Remote Sensing System composed of one laser range finder and one PHI-III , then can provide many different kind of remote sensing data at one time. All those devices have been integrated by using optic, mechanical and electronics methods. To get a synchronized operation, all the sensors are driven by synchronized pulses which are generated by dividing a 1PPS signal from GPS information. The whole system is based on master-slaver network architecture. Every sensor has its own data capture system and is integrated in a star style LAN. A high performance computer is used as the center controller of the whole system, which is also the only machine that provides user interface to operators. Friendly interface make it very easy to control all the sensors, and network structure increases the modularity of the system. Users can select different sensors to work with as to their own requirement. Till now this system has also been used successfully in the digital city program of Shanghai in last October. The following is its specifications.

PHI-III	The same as those specifications of PHI-III above.
LASER SENSOR	5 points distance infomation per hyperspectral line, resolution 7.5cm
POS	Applanix POS AV 510
Stable Platform	Leica PAV30

2.2 Narrow Band Hyperspectral Camera

For rapid and steady collection of high spectral resolution airborne data, a narrow band hyperspectral digital camera system (HDCS) was developed and tested in 2000 by Institute of Remote Sensing Applications Chinese Academy of Sciences. The HDCS was built based on three 1024x1024 pixels, 12bits digitalized area CCD cameras, FOV and IFOV of which are about 20 degree and 0.34 mrad respectively. Precise exposure control and synchronic trigger control are provided in this system, and the problem of collection and recording of large digital image data has been well solved. The center

wavelength and bandwidth of the bandpass optical filters in this system can be customized to fit different application. The filter bandwidth can be changed from 10 to 25nm, and the filter center wavelength can be changed from 400nm to 900nm. The 10nm bandpass filters centered at 555, 650, 725nm and 650, 725, 825nm were used for agriculture research in the test phase. High
spatial-resolution hyperspectral images were acquired on December 5, 2000 with the HDCS. At an altitude of approximately 3500 meters, the spatial resolution was 1.2 meter. Image processing was made for improvement of the image quality.

The most useful feature of this system is its low overall cost and its flexibility to meet user needs. Because it is mounted in a small airplane, the HDCS can be flown over specific regions at varying altitudes to produce whatever spatial and temporal resolution. Researchers can now obtain hyperspectral data when and where they want it instead of being limited by relatively rigid imaging schedule of satellite. Users can do their hyperspectral band selection according to their application. And then, the only modification of the HDCS is to change the filters to fit the customized bandwidth and center wavelength.

3. HYPERSPECTRAL DATA PROCESSING AND APPLICATIONS

3.1 Hyperspectral Remote Sensing Data Classification Model

Many materials can be identified by unique absorption feature in their reflectance spectra. Consequently, hyperspectral image have been so widely used in the mineral mapping, vegetation classification and environment analysis, etc. Due to the complicated urban scene and relative disorder earth object in city, it is not easy to get a satisfactory classification result only depending on pixel-to-pixel spectral analysis, especially when the materials lacked strong absorption features and the remote sensing data have a low signal-to-noise ratio [11]. However, there are always very large requirement for urban mapping, particularly in China, whose city scene have been changing with almost each passing day. The airborne hyperspectral remote sensing technology can pay an important role in the urban landcover survey, particularly for the classification based on material composition difference.

This new method for classifying hyperspectral remote sensing data in urban area is described in this section, that combines the edge detection and spectral analysis together. Due to the varied surface scene in city and limitation of imaging spectrometer’s signal-to-noise ratio, normal classification based on pixels were not satisfied for thematic classification and mapping in urban area. Comparing with the classification on individual and isolated pixels, this classification on spectral polygons provides a great improvement of landcover mapping results in Beihai city. Because the appearance of the objects has been extracted from digital photographic data, the continuous spectral classification will not decompose the integration of object-classes. This is very important for the hyperspectral data usually with low signal-to-noise ratio and low spatial resolution. In addition, the spectral mean square deviation between different polygon-classes is larger than the deviation between different pixel-classes. Apparently, this approach has the advantage of increasing the diversity of different classes of spectra, which improve the accuracy of spectral classification. This technology could meet with the need of urban mapping in large scale.

3.2 POS Based Correction Model

Technology of airborne remote sensing is widely used in agriculture, geology, urban management and many other spheres. However, the problems of images’ quality stunt its development all along. Because the latitude of flying plane is low enough to be affected by air currencies, it is a challenge to keep flight flying stably, even if stable platform is put into use. As a result, airborne remote sensing images have more distortions and worse quality than images of satellite images. We have no high precise parameters and coefficients in airborne remote sensing system till now [12]. Usually, airborne images’ correction is done by registration of ground control points. This method needs too much ground work and cost a lot. It is not feasible well. Position and Orientation System / Direct Georeferencing (POS/DG) data is important to hyperspectral images, for it has much information of flight attitude, such as absolute position (x,y,z) and platform attitude parameters, which make it possible for geometric correction of airborne images with receiving POS/DG data. It can save much work and the cost of stable platform. It is an attempt in China that remote sensing images are corrected with airborne POS/DG data.

3.3. Mineral Diagnostic Spectra and Recognition

Mineral recognition is the initiatory application area of hyperspectral remote sensing. The field spectral measurement shows that the distinguishable spectral features for different minerals can be seen clearly in short-wave infrared region (Figure1). They are caused by the bending-stretching features of OH-, CO32-, Al2+-OH, Mg+-OH and SO42- borne minerals. The airborne hyperspectral data acquired in Tarim area Xinjiang China have been processed and analyzed for geological application. Very exiting results have been obtained in stratigraphic mapping of the studying area by hyperspectral technique. The different strata from Cambian-Ordovician, Silurian, Devonian, Carboniferous and Permain Periods in the Keping area West Tarim have been clearly separated and classified for its dominant minerals of each stratum. The limestone in Cambian-Ordovician and Permian strata almost has same display in the wide-band remotely sensed data such as Landsat and SPOT and it cannot be distinguished each other. Due to the different dominant minerals in these two strata i.e the calcite for Cambian-Ordovician and dolomite for Permian strata. Based on the mini. difference of mineral absorption location (2.331, 2.347 and 2.364 μm), two strata of Cambian-Ordovician and Permian have been clearly separated. The depth of the absorption band is closely related to the amount of the minerals in the rocks. By analysis of the wavelength location and intensity of the absorption, the distribution of clay and carbonate minerals in the area has been identified and then mapped.

3.4. Vegetation Red-Edge Spectral Feature and Recognition

Unlike minerals, all vegetation is composed of a limited set of spectrally active compounds. The relative abundances of these compounds, including water, are indicators of the condition of the vegetation and of the environment in which the vegetation is growing. Vegetation architecture has a very strong influence on overall characteristics of the reflectance spectrum. The spatial scale of the reflectance measurement is important in determining the observed reflectance. Its reflectance in visible and near infrared region (350 to 800 nm) is dominated by absorption from chlorophyll and other accessory pigments. Its reflectance in the SWIR (800 to 2500 nm) is dominated by absorption from liquid water in the plant's tissue and is additionally modified by minor absorption features associated with C-H, N-H, and CH2 bearing compounds such as starches, proteins, oils, sugars, lignin and cellulose. In addition, Scale dependence of vegetation spectra should be given more attentions in vegetation recognition. Generally the scales of vegetation include leaf/needle scale, branch scale, crown scale and canopy scale. Under current hyperspectral remote sensing technique, the canopy scale is the main sensing object. So, the mixed pixels mainly include three kinds of information: crown scale reflectance, crown density and background reflectance (soil, understory, litter, etc.)

In China, Pushbroom Hyperspectral Imager (PHI) was specially used for the vegetation precise classification and recognition. A solid state area array silicon CCD device of 780×244 elements is used as the detector of PHI. PHI has three parts: optic-mechanical system, signal process box and industrial control computer. This imager can acquire high spatial resolution because of its long focus length. High spectral resolution, light weight and relatively high spatial resolution, and low cost enabled PHI to be widely used in vegetation survey and recognition. In august of 2000, PHI was taken to Japan by Chinese scientists and completed a successful hyperspectral image data acquisition. Some main kinds of vegetables, such as Japanese cabbage, Chinese cabbage, radish, lettuce, pasture, yam, etc., were automatically recognized and mapped. Figure 2 shows the spectra extracted from hyperspectral reflectance image and Figure 3 shows the related continuum removed spectra.

The spectra of camouflage materials are most similar to vegetation and soils in the visible to near-infrared wavelengths (400 to 1000nms). In the SWIR, the positions and relative intensities of the major absorption feature associated with water are difficult to duplicate due to the complex architecture of vegetation. Absorption features associated with minor vegetation biochemical constituents are often not present or are not of the appropriate relative intensity. The plastic resins found in many camouflage materials have absorption features that are distinct from those of natural materials. The effects of wavelength dependence of optical path length on the liquid water absorption features in a natural vegetation canopy make it very difficult to create a good vegetation camouflage. Two examples are shown in figure 4, figure 5 and figure 6. In OMIS VIS image, natural and artificial plastic grass can not be distinguished. They are all in green color in RGB composition. From figure 4, the difference in NIR region is obvious. Additionally in N-dimension spectral space, the pixels of natural and artificial plastic grass distribute in different locations (figure 5).

3.5. Hybrid Decision Tree Model (HDT) for classification

According to the rice spectral features of hyperspectral image data acquired during the rice is growing, a hybrid decision tree classification algorithm dealing with the variety of rice is developed. The decision tree is defined as a classification procedure that recursively partitions a data set into smaller subdivisions according to a set of tests defined at each branch node in the tree. The tree is composed of many nodes, a set of inter-nodes (splits), and a set of terminal nodes (leaves). Each node in a decision tree has only one parent node and two or more descendant nodes[18]. A data set is classified according to the decision framework defined by the tree; a new class label is assigned to each object according to the leaf node into which the object falls. There are three sorts of decision tree. That is, univariate decision tree, multivariate decision tree and hybrid decision tree. Among them, hybrid decision tree is the most complex and flexible, where different classification algorithms can be used in different subtrees of a larger tree. So in principle, the hybrid decision tree should be more precise and more effective than the other two[19], which was verified in the study. The feature bands are selected according to the separability among bands, but the classification algorithm is selected according to its classification result. The separability among bands is calculated by the normalized mean value of each band. In the end, a classification experiment is done. In the experiment the hyperspectral image data acquired in Jintan rice breeding farm is used. A good classification result is achieved. The classification accuracy of test samples is reached 94.9 percent. Another classification test is based on OMIS data (128 spectral bands, acquired in Yayunchun, Beijing) under this model. Several spectral bands which are more sensitive to the building materials (metal, plastic, sand, cement etc.) were extracted for such objects identification.

3.6. Vegetation pigments extraction and dynamic analysis

Since new hyperspectral sensors now have become available to provide both high spatial resolution and high spectral resolution data. These characteristics combined with high signal to noise ratio allow that more possible to differentiate vegetation types and extract biophysical or biochemical information which are of great importance for precision crop management.

For the detection of vegetation pigment content per unit area, two main approaches are widely used, one focus on the narrow bands ratios, including ratios within visible and near-infrared region[20], ratios only in the visible region and ratios in the red edge region [21,22,23]. The other approach utilizes the characteristics of the first and second derivatives of reflectance spectra. The majority of researchers use the wavelength position of the red edge as the best predictor of chlorophyll [24,25], while others prefer to the amplitude of the first and second derivatives of reflectance at particular wavelengths,[26.27]. Some studies identify, when predicting chlorophyll content, first derivative spectra value can get same results with ratio vegetation index (RVI). Apart from pigment, LAI and percent cover were related to ratios of reflectance in narrow bands on the near-infrared plateau and red edge features of canopy reflectance spectra, as well as with the amplitude of the first derivative in the red edge and visible regions respectively,[26.28]. Some water absorption peaks (e.g. 970nm) were found useful to estimate the leaf water content[29]. Fouche[30], found that the single narrow band wavelengths 707nm and 589nm provide the better nitrogen (N) applications detection at different N-levels, based on the balloon hyperspectral image data with 8 filters digital camera. The airborne hyperspectral data was acquired in Changzhou by Pushbroom Area-array Hyperspectral Imager in high spectral resolution (less then 5nm). Especially, all the maps were achieved only by several channels. By this token, hyperspectral CCD camera with limited channels can play an important and independent role in the crop growth investigations.

In August, 2000, a set of reflectance spectra were gathered for two kinds of vegetables, eight distinctive growth stages for lettuce and seven for Japanese cabbage in Minamimaki area, Japan. The spectra were measured by an ASD FieldSpec FR spectroradiometer, which records a continuous spectrum between 350nm and 2500nm with a nominal sampling interval of 3nm (350-1000nm) and 10nm (1000-2500nm). In order to display the dynamic trend of all the indices in the same coordination, all the indices are normalized by the average of the corresponding eight or seven stages. These temporal index curves diagnostically embody pigment and biophysical parameters in crop periods of duration.

3.7 Spectral Recognition Based on Edge Search and Polygon Generation

Due to the varied surface scene in city and limitation of imaging spectrometer's signal-to-noise ratio, normal target spectral recognition based on pixels were not satisfied in urban area[4]. A method for object recognition in urban area is described in this section. At present, the hyperspectral RS satellite always take a panchromatic sensor but with high-spatial resolution. We can do the edge detection and polygon extraction with the high-spatial panchromatic data according to the difference of DN value. And then all spectral analysis are based on these polygons[1]. Because the appearance of the objects has been extracted from high-spatial resolution data, the continuous spectral classification will not decompose the integration of object-classes. Comparing with the classification on individual and isolated pixels, this classification on spectral polygons provides a great improvement of spectral identification results This is very important for the hyperspectral data usually with low signal-to-noise ratio and low spatial resolution. In addition, the spectral mean square deviation between different polygon-classes is larger than the deviation between different pixel-classes. Apparently, this approach has the advantage of increasing the diversity of different classes of spectra, which improve the accuracy of spectral recognition. This technology could meet with the need of urban mapping in large scale.

4. HYPERSPECTRAL IMAGE PROCESSING AND ANALYSIS SYSTEM(HIPAS)

In order to understand and design a system completely and efficiently, the primary goal of the system must be defined and detailed firstly. The design of HIPAS is a challenge because it is such a software system which incorporates a number of special algorithms and features designed to allow remote sensing scientist to take advantage of the wealth of information contained in large scale imaging spectrometer data easily and efficiently.

4.1 HIPAS Design Criteria

Based on researching into HIPAS V1.0 (written in IDL), we defined the following requirement for the new generation of imaging spectrometer software.

(1) The system should be not relate to any software and hardware platform. This means the software is dependent on IDL (the Interactive Data Language) no more and compatible for other platforms (Unix,Linux) with little modification.

(2) It should be independent of specific image display hardware.

(3) The system should allow routine analysis of imaging spectrometer data sets to include AVIRIS,GERIS, Eos HIRIS, Landsat MSS, Landsat TM and SPOT minimally. It should support the following data format straight: BSQ(band sequential), BIL(band interleaved by line) and BIP(band interleaved by pixel).

(4) The flexible and powerful utilities should be provided for data input, data formatting, data calibration and other common image processing tasks. Data visualization for rapid, exploratory spectra and image analysis should be established especially.

(5) The fundamental function of GIS(Geographic Information System) should be included in HIPAS. The analysis result can be exported via standard vector format to exchange with other common GIS software.

(6) The system should be easy-to-use and easy-to-understand.

4.2 System Structure

4.2.1 File Input and Output

The key classes for File I/O are HipasFileManager and ImageFileManager. HipasFileManager is the only way to access Hipas format Image data. For other external format Image files are accessed by ImageFileManager after decoder. The file I/O flow is shown in Figure1.

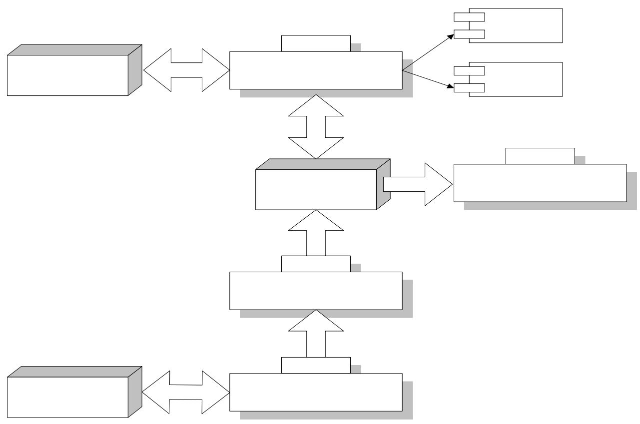


Fig 1. HIPAS File Input and Output

4.2.2 Image Tiling and Processing

Tiling is an efficient buffer method to improve the display and processing for the huge image. In general, it means the huge image will be divided into many small blocks. There two kinds of block in HIPAS: spatial block and spectral block.

Theoretically, the size of image in HIPAS should not be limited. The size of block is equal approximately under defined regulation. The finite Call-Back mechanism is adopted. A specific architecture of ROI (Region Of Interest) is designed and implemented. ROI is significant for HIPAS operation.

4.2.3 Execution Architecture

The errors of overflow and underflow is very common in such kind of software. In HIPAS ,every function has mechanism to handle those errors. ALL the processing of image can be concluded two kind operation: in-place and out-of-place. In-place operation is that this operation can change the source image. Out-of-place operation creates a new image on disk or in system memory vis-à-vis In-place operation.

4.3 Function description

According to the system detailed design, the programming language chosen for implementation was the standard C++ language. The system interface was designed to isolate with image processing function because this part has to use MFC (Microsoft Foundation Class) Partially. In order to be compatible for other UNIX platforms with little modification, the whole programming process was based on the modularized and object oriented software engineering construction. UML (Universal Modeling Language) was adopted to improve the implementation of system class in the process of object-oriented programming. The main function of HIPAS was described in the following figure2.

Compared with other RS image processing software, HIPAS is mainly for hyperspectral data processing mission. Its data pre-processing functions have some special tools for Airborne Hyperspectral Sensors made in Shanghai institute of technical physics, such as PHI-1, PHI-2, OMIS-1, OMIS-2. These special tools include data format transformation, radiance calibration, geometric correction based on POS data, etc.

5. CONCLUSION

It is obviously that Hyperspectral Remote Sensing in China has made big strides with the advance of technique. The progress has also enhanced the demand of its applications in resources inventory and environmental monitoring. The more programs and projects conducted in the late years, the more models developed or improved for hyperspectral image processing to promote its applications. As a result, the model development can strengthen the potential of the hyperspectral imagers and expand the market of hyperspectral imager application. And also, the hyperspectral imagers will have been perfected in the courses of these applications. This has led to a positive circulation, which is the main reason why hyperspectral remote sensing is booming in recent years in China.

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