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UAV Remote Sensing Image Mosaic and Its Application in Agriculture

Yinjiang Jia[1], Zhongbin Su[1※], Weizheng Shen[1], Jianqing Yuan[1] and Zhenan Xu[1]

[1]College of Electrical and Information, Northeast Agricultural University, Harbin 150030, China
jiayinjiang@126.com

Abstract

*UAV remote sensing image has the characteristics of higher spatial resolution, fine timeliness and high flexibility. It is widely used in many fields such as agriculture, forestry, soil resources and so on. Especially in agriculture, it plays an important role in information acquisition of agricultural production and agricultural condition monitoring. In the experiment, high-definition digital camera and multi-spectral camera are used to capture the visible light and near-infrared remote sensing image. Two pieces of 3m*3m calibration cloth is used for radiometric calibration and SIFT algorithm was used for image mosaic. This paper discusses the application of remote sensing image in agriculture, including rice lodging monitoring, diseases and pests monitoring, crop growth monitoring and crop nutrient diagnosis. The results show that UAV remote sensing provides an effective means for agricultural condition information acquisition, and has wide application prospect.*

Keywords*: remote sensing, UAV, multi-spectral image, image mosaic, SIFT algorithm*

1. Introduction

UAV is Unmanned Aerial Vehicle for short. UAV remote sensing is a new remote sensing means, with fast, flexible, low cost, high image resolution, etc [1-2]. UAV remote sensing as an indispensable means of satellite remote sensing, which can make up for the high cost of satellite remote sensing, the high-impact of weather conditions, long work cycle and so on. Due to the unmanned, UAV can avoid the risk of pilot's personal safety, and can reach the work area that vehicle and personnel can not reach.

UAV has been widely used in many fields such as agriculture, forestry, soil resources and so on. Especially in agriculture, it plays an important role in information acquisition of agricultural production and agricultural condition monitoring. UAV is widely used in rice lodging monitoring, pest and disease monitoring, crop growth monitoring and crop nutrient diagnosis [3], which has achieved an ideal application effect.

However, since the UAV remote sensing platform is limited by the flight height and focal length of camera, the acquired image size is smaller and single image often can't cover the entire target area, therefore, in order to obtain the entire target area image, more than one remote sensing image needs to get to splice into a panorama [4]. UAV remote sensing image mosaic is a process of automatically splicing some certain image sequences with the overlapping area into larger field of view panorama [5], which is the prerequisite for the implementation of agricultural remote sensing applications.

UAV remote sensing data is more dependent on true color image, even though it can truly reflect the data information, but only three channels of RGB data, spectral information is insufficiently, crop biophysical parameters can not be obtained and further analysis can not be in progress. In this paper, rice and corn is taken as the research object, UAV remote sensing platform is equipped with synchronous multi-spectral cameras and high-definition digital cameras to capture image. This paper first study the remote sensing

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image mosaic algorithm, then realize UAV remote sensing image mosaic based on SIFT algorithm, and finally discuss the application of UAV remote sensing in agriculture.

2. Materials and Methods

2.1. Overview of the Study Area

Experiments were done in Rice Research Institute, Fangzheng County, Heilongjiang Province. FangZheng county is located in the Middle East of Harbin city, Heilongjiang Province, geographical coordinates is east longitude 128°13′41″-129°33′20″, north latitude 45°32′46″-46°09′00″, the terrain is mainly plain, elevation is between 300-700 meters, the climate is cold temperate continental monsoon climate, average annual rainfall is 579.7mm, average annual temperature is 2.6℃, average frost-free period is 130d, annual sunshine hours are 2560 hours, planting structure is mainly rice.

2.2. Acquisition Platform and Sensors

2.2.1 UAV: Remote sensing image acquisition platform is TY-6 fixed-wing UAV of Nanjing Tianyi, UAV is as shown in Figure 1. UAV body length is 2.6 m and wingspan is 4m, flight altitude is 300-1000 meters, flight speed is 70-110 kilometers per hour, cruising time is up more than 6 hours, load weight is 8kg, driving mode is oil-driven, the control mode is automatically controlled program.

2.2.2. Sensors: To UAV sensor, there are high-definition digital camera and multi-spectral camera two types. The digital camera is Sony ILCE-5100, the sensor type is Exmor APS HD CMOS, the sensor size is 23.5mm*15.6mm, the maximum image resolution is 6000*4000, remote shutter and external GPS module are supported, which is used to obtain RGB true color image. There are two multi-spectral cameras, one is the ADC Lite and the other is Micro-MCA6 snap, they are all made by USA Tetracam Corp. For the ADC Lite, the sensor size is 4.92mm*6.55mm, the camera weigh is 200 grams, CMOS is 3.2 million pixels, image resolution is 2048*1536, image storage format is 10 bit lossless DCM format, 8 bit and 10 bit RAW format, Green, Red and NIR sensitivity with bands approximately equal to TM2, TM3 and TM4. For the Micro-MCA6 snap, as shown in Figure 2, the camera weigh is 700 grams, the sensor size is 6.66mm*5.32mm, CMOS is made up of six 1.3 million pixels, image resolution is 1280* 1024, six 9.6mm lens and six 16GB Micro SD card, the band wavelengths were determined by 10nm FWHM filters at the following wavelengths: 490, 550, 680, 720, 800, 900, in addition, according to the needs of the study, six alternative filters are equipped, wavelengths were 530, 575, 670, 700, 710, 730.

Figure 1. TY-6 Fixed-Wing UAV

Figure 2. Micro-MCA6 Snap Sensor

2.3. Experimental Data Acquisition and Processing

2.3.1. Experimental Data Acquisition: During July to August 2015, a number of UAV experiments were conducted in Rice Research Institute, Fangzheng County, Heilongjiang

Province, and a lot of experimental data were obtained. Figure 3 shows the UAV route plan in July 31, 2015. UAV carried Sony 5100 camera and ADC Lite camera in the first sorties, flight altitude was 670 meters, aerial average speed was 30m per second. For the Sony 5100, heading overlap rate was 75% and side overlap rate was 68%, the data format was JPG. For the ADC Lite, heading overlap rate was 65% and side overlap rate was 50%, the data format was RAW8. Micro-MCA6 snap multi-spectral camera was carried in the second sorties, flight altitude was 670 meters, heading overlap rate was 60% and side overlap rate was 45%, the data format was RAW10.

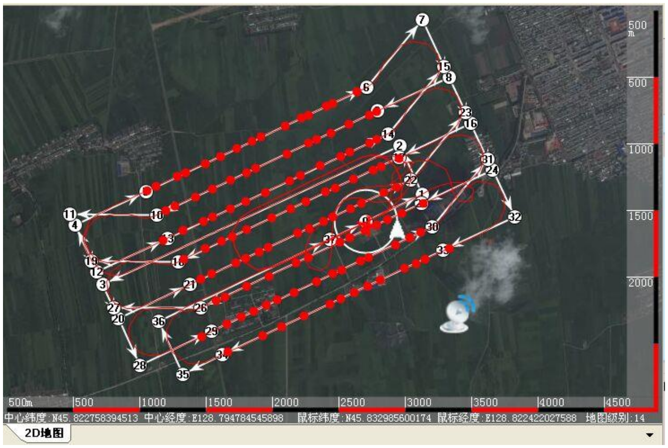
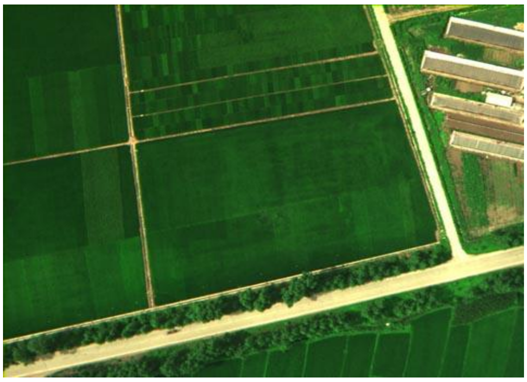


Figure 3. UAV Route Plan

2.3.2 Experimental Data Processing: During the experiment, in order to obtain the geometrical position of the object and the relationship between the corresponding points in the image, Sony 5100 camera was calibrated to obtain accurate data results. For ADC Lite and Micro-MCA 6 snap multi-spectral cameras, before the data acquisition, two pieces of 3m*3m calibration cloth were laid on the ground, the reflectivity was 3% and 48% respectively, FieldSpec Pro FR 350-2500(ASD) was used to measure the reflectivity of the fixed target when the UAV flew over the fixed target. In order to ensure the measurement accuracy, the average value of the 10 times spectral acquisition was used as the reflectivity of the calibration cloth to achieve the radiometric calibration of remote sensing images.

ADC Lite camera contained only a single lens that was designed and optimized for capture of visible light wavelengths longer than 520nm and near-infrared wavelengths up to 920nm. The resulting image was suitable for derivation of several vegetation indices. Micro-MCA 6 contained 6 factory-aligned multi-spectral cameras. With each exposure, 6 separate bands of visible or near-infrared radiation moved through each camera's lens and filtered to form a separate monochromatic image on the camera's sensor. The images from each camera in the array were simultaneously transferred to each camera's compact flash memory card for later access by the user. For the images of Micro-MCA 6, PixelWrench2 software supplied with the camera provided full camera control as well as image management and analysis. First, the RAW format files need to be converted into Multipage Tifs format. then, the data from 3 channels of 6 channels were selected to be synthesized into more common formats, such as BMP, JPEG, Tiff, PNG, etc, here TIF format was selected. Finally, the synthesized data could be used for agricultural remote sensing interpretation.

One single channel can not express a wealth of information. In order to obtain the desired image information, the image of multiple channels was selected. There were two kinds of composite methods, which were true color synthesis and false color synthesis. For example, the image of Micro-MCA6 snap acquisition, in PixelWrench2 software, if RGB three channel bands were selected as 680,550,490, then a true color image would be synthesized, as shown in Figure 4, if RGB three channel bands were selected as 800, 680, 550, then a false color image would be synthesized, as shown in Figure 5. The false color image contained near-infrared band and red band information. It could be used for a variety of vegetation index calculation.



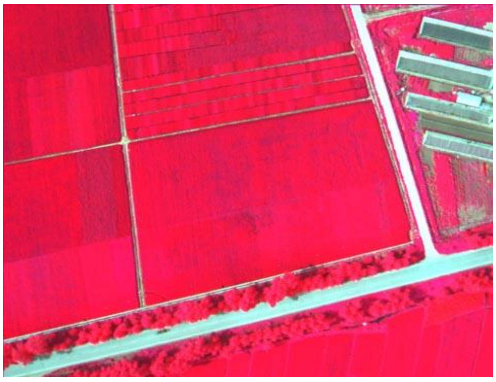


Figure 4. Synthesis of True Color Image Figure 5. Synthesis of False Color Image

3. UAV Remote Sensing Image Mosaic

3.1 UAV Remote Sensing Image Mosaic Process

UAV remote sensing image mosaic is the precondition of the UAV remote sensing image analysis. Image mosaic is composed of image preprocessing, image registration and image fusion [6].

The main purpose of image preprocessing is to correct the geometry and radiation distortion in the original image, as far as possible to reduce the impact of image distortion, to ensure the accuracy and accuracy of image registration. Image registration is one of the key technologies of image mosaic. Its accuracy largely determines the quality of image mosaic [7]. Image registration is the process of the best matching of two or more images acquired by different sensors, different sensors and different angles. Image fusion is an indispensable step in image mosaic. Due to the different shoot condition and the effect of illumination, after image matching, there exists obvious mosaic trace. The purpose of image fusion is to eliminate the image intensity or discontinuity of color, so as to achieve a smooth transition [8].

3.2. UAV Remote Sensing Image Registration Algorithm

There are three kinds of image registration algorithm, which is image registration algorithm based on gray information, image registration algorithm based on transform domain and image registration algorithm based on feature [9]. Image registration algorithm based on gray information is mainly aimed at the image of no remarkable feature, has the characteristics of large amount of calculation, poor stability and can not be scaled. Image registration based on the transform domain is usually performed by using Fourier transform, because of the characteristics of the Fourier transform, the effect of rotation, translation and scaling is ideal, however, for the more complex affine transformation, the effect is not good. Image registration algorithm based on feature can resist the influence of gray level change, shade and image distortion, which has a high accuracy, especially for UAV image sequences, it is suitable for UAV image matching. Feature extraction is a key step in feature matching process. Commonly used feature points extraction algorithms are SUSAN algorithm, Harris algorithm, SIFT algorithm, *etc.* SIFT algorithm has strong robustness to image scaling, rotation, light and noise [10-12]. This paper uses SIFT algorithm for feature extraction.

3.3. Realization of UAV Remote Sensing Image Mosaic

3.3.1. UAV Remote Sensing Image Read: Reference image and registration image is as shown in Figure 6, which is the experimental field of Rice Research Institute, Fangzheng County.

Figure 6. Reference Image and Registration Image

3.3.2 Gaussian Pyramid Building: Gaussian pyramid building first is Gaussian-smoothed and then is down-sampled. Figure 7 shows a forth order five layer Gaussian pyramid. As can be seen from the figure, with the number of layers increases, the image is gradually blurred so as to reduce image noise.

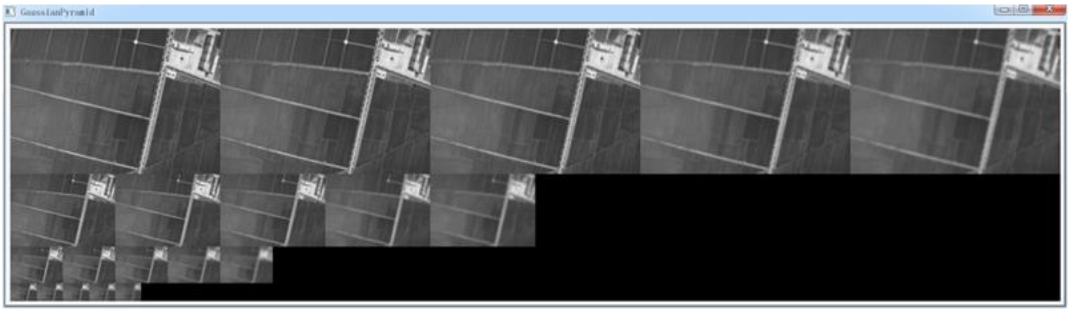


Figure 7. Gaussian Pyramid

3.3.3 Difference of Gaussian Pyramid Building: Adjacent Gaussian images are subtracted to produce the difference of Gaussian images based on the Gaussian pyramid. Figure 8 shows Difference of Gaussian pyramid. It is can be seen that the DOG image is a description of the target image contour.

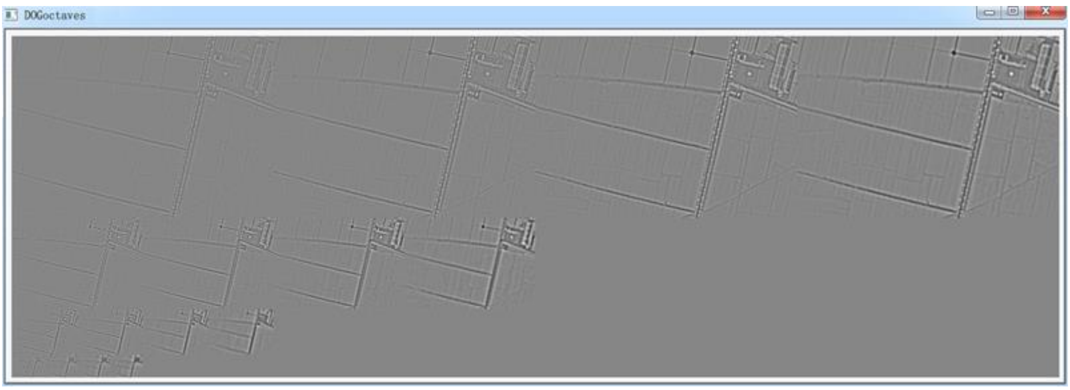


Figure 8. Difference of Gaussian Pyramid

3.3.4 Feature Point Extraction: Feature point extraction is to find extreme value in scale space. Feature point extraction image is as shown in Figure 9. In order to improve the image processing speed, as the difference of Gaussian pyramid construction, image equal scaling is to be done.

3.3.5 Determination of the Keypoint, Generation of Keypoint Descriptor: In order to have a rotation invariant of SIFT operator, the maximum gradient direction of the keypoint need to be determined. Gradient direction of the keypoint is statistics from the gradient histograms. The highest peak in the histogram representative keypoint main direction, then any other peak that is greater than 80% of the highest peak is used to an auxiliary direction of the keypoint. As shown in Figure 10, the length of each arrow is gradient magnitude and the direction of the arrow is the gradient direction.

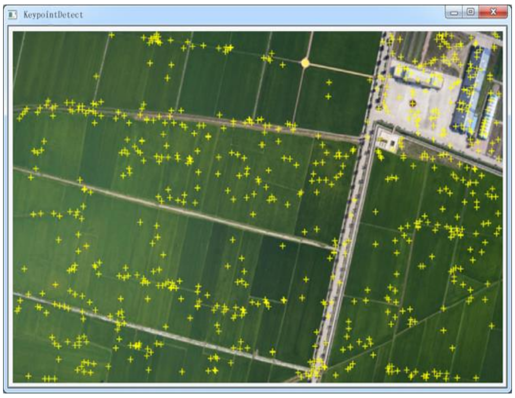


Figure 9. SIFT Feature Point Extraction

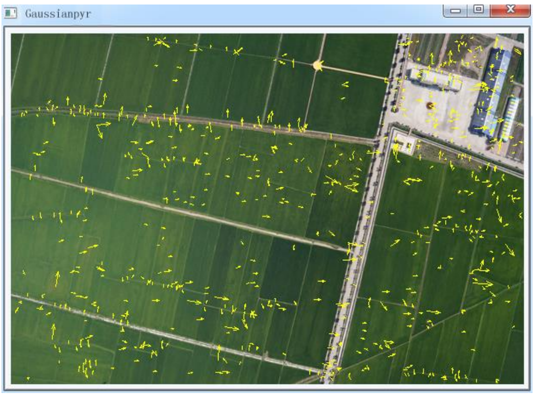


Figure 10. SIFT Feature Vectors

3.3.6. Feature Point Matching: This paper adopts Nearest Neighbor method for coarse feature point matching. If the ratio of the Euclidean distance between the current image feature points and another is less than a predetermined threshold value, the nearest feature point is considered as the matching point of the current feature point. Image of feature point matching is as shown in Figure 11.

3.3.7. Feature Point Purification: As can be seen from Figure 11, some matching points is wrong. It is necessary to deal with coarse matching feature point that obtained from the previous step for purification processing. RANSAC (Random Sample Consensus) algorithm is used to delete false matching points. Its idea is to design an objective function according to the specific problem, and then extract the minimum set of points by repeatedly estimating the initial value of the function parameters, all the data are divided into interior points and external points by using these initial values. In the end, interior points are used to recalculate function parameters [13]. The image by using RANSAC algorithm is as shown in Figure 12.

Figure 11. Feature Point Rough Matching

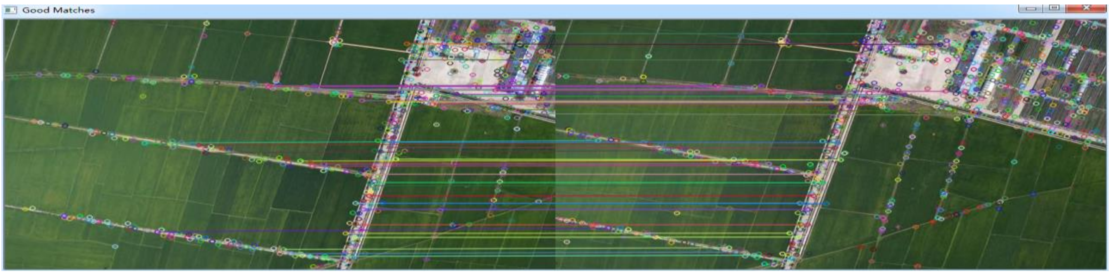


Figure 12. Feature Point Precise Matching

3.3.8. Feature Point Purification Image Fusion: If the two images in adjacent, there will be obvious mosaic trace, it is called seam or ghosting. This paper adopts weighted fusion algorithm to eliminate mosaic trace, weighted fusion algorithm achieves a smooth transition of two images overlapping regions, as shown in Figure 13.

Figure 13. Image Fusion

4. Agricultural Remote Sensing Application

4.1. Rice Lodging Monitoring

Rice lodging is a kind of agricultural disaster that effect rice yield and rice quality. Rice lodging is directly related to rice varieties, cultivation management, pest and strong wind [14]. It has a very important significance for high and stable yield of rice to understand the rice lodging timely and accurately. The UAV has obvious advantages in the monitoring of rice lodging, it has the characteristics of direct, prompt, accurate and efficient. One true color image obtained by Sony ILCE-5100 camera is as shown in figure 14, it can be seen from the figure there is a clear rice lodging phenomenon. Agricultural production staff can take active and effective measures to deal with rice lodging, so as to reduce the loss of production.

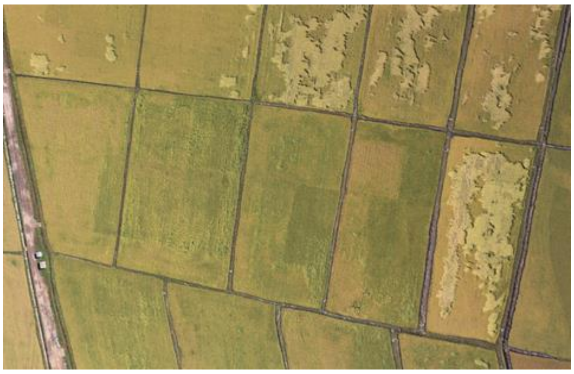


Figure 14. The Image of Rice Lodging

4.2. Crop Growth Monitoring

Crop growth means the crop growth status and trends. With the crop growth monitoring, the pest and disease, growing status and nutrition status can be known in time. Crop monitoring can not only provide timely and scientific basis for agricultural production, but also provide the necessary basic data for crop yield estimation [15]. At present, the commonly used method of crop monitoring are artificial observation, remote sensing, monitoring based on growing crop and growth model [16]. With the development of remote sensing technology, remote sensing monitoring has become the main means of crop growth monitoring.

Healthy crop in visible band of spectrum has a strong absorption rate and in near-infrared band has a strong reflectance. Based on the theoretical basis of the spectrum, crop growth monitoring can be achieve by extracting crop remote sensing indicators approach. Leaf area indexes (LAI), chlorophyll content (CHL) and normalized difference vegetation index (NDVI) are commonly used monitoring indicators. In the experiment, the experimental data are acquired by UAV, and monitored crop growth by extracting NDVI value.

NDVI is the most widely used vegetation index, which can reflect difference of vegetation coverage and growth status.

$$NDVI = \frac{NIR - R}{NIR + R} \tag{1}$$

Where NIR is the near-infrared band value for a cell and R is the red band value for a cell. The combination of red and near-infrared channels can greatly eliminate the interference of aerosol in the atmosphere. Values of NDVI can range from -1.0 to +1.0, but values less than zero typically do not have any ecological meaning, so the range of the index is truncated to 0.0 to +1.0. NDVI values can be obtained by band operation. One true color image of organic rice of Songnan Red Star farm is as shown in Figure 15, and the corresponding multi-spectral image is as shown in Figure 16. Because of the different sensor angle, there is a certain bias between the two images.

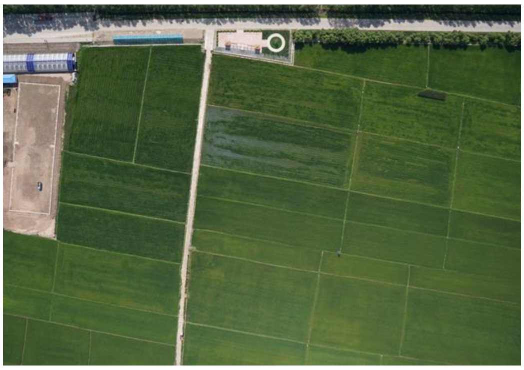


Figure 15. The True Color Image

Figure 16. The Multi-Spectral Image

Rice growth classification map by extracting the NDVI value of the rice is as shown in Figure 17. The rice growth was divided into five levels in ARCGIS, which were non-crop region, poor, fair, good and excellent. Different colors represent different growth conditions, and rice growth can be judged by rice growth classification map.

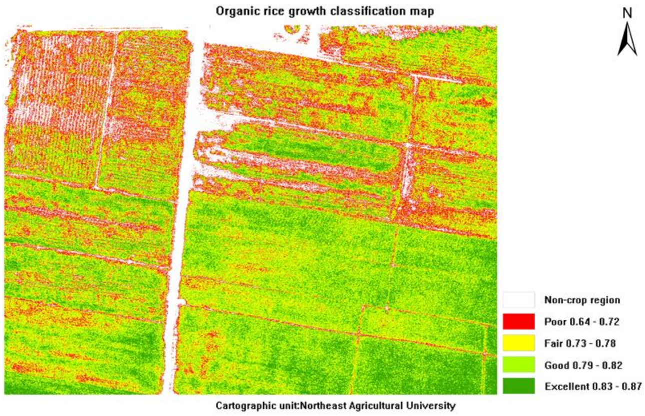
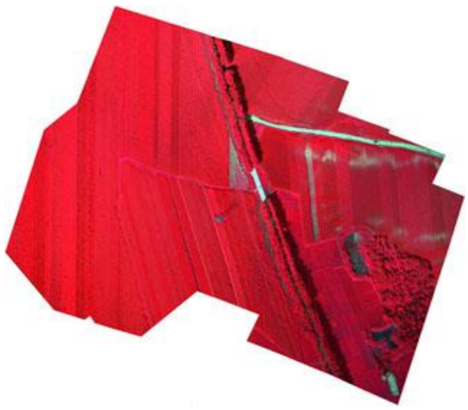


Figure 17. Organic Rice Growth Classification Map

4.3. Crop Nutrient Diagnosis

Nitrogen is the necessary nutrient elements for crop growth. There is a significant correlation between chlorophyll content and total nitrogen content of crop [17], so the nitrogen content of crop can be monitored by measuring the content. Because of the chlorophyll effective absorption of visible light, for healthy crop, the strong absorption band of chlorophyll is in 600-700nm, but in 700-800nm band, crop reflectance increased sharply, forming a steep and nearly straight edge, it is called the "red edge". The research shows that the position of "red edge" is based on the content of chlorophyll and the amount of biomass, moving along the long axis of the wave. When the crop chlorophyll content is high, "red edge" will move to the long wave direction, it is called the red shift.

Therefore, determining the sensitive crop physiological red edge position, establishing spectral diagnostic model crop nitrogen nutrition, it can quickly diagnose crop nitrogen status based on crop red edge position. One corn multi-spectral image of Anle garden experimental area was as shown in Figure 18. The corn leaves were acquired in the critical physiological period, nitrogen content was determined by chemical methods, the relationship between reflectance and nitrogen content of the multi spectral image was established, and the nitrogen content of maize was diagnosed, as shown in Figure 19.



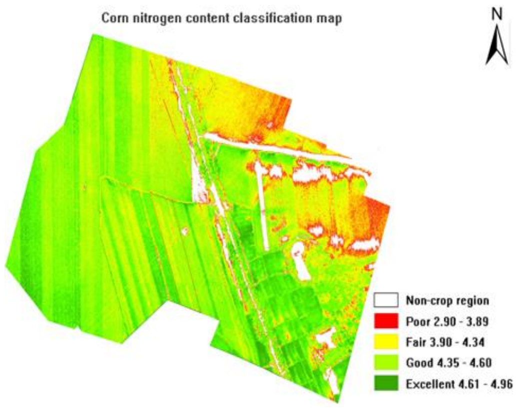


Figure 18. Corn Multi-Spectral Image Figure 19. Corn Nitrogen Classification Map

4.4. Crop Diseases and Pests Monitoring

Crop diseases and pests is an important factor affecting the stable and high yield of crop, it caused a great threat in yield of rice production safety, and how to get the information of crop diseases and pests in time is an urgent problem to be solved in agricultural production.

When crop diseases and pests occur, the chlorophyll level will appear different degrees of decline. The decline is usually expressed as a reflectance decrease in the near-infrared band, which can be detected in the near-infrared remote sensing images [20]. The reflectance spectral curve of crop diseases and pests is as shown in Figure 20. The more serious diseases and pests, the more chlorophyll level drops, it's near infrared reflectance decreased significantly, which provides a theoretical basis for diseases and pests by using remote sensing. Especially in the early stage of crop diseases and pests, although the structure of leaf blade is not obvious, the internal structure of the leaves may have been damaged, people can not identify it with the naked eye, but in the near-infrared band, the spectral reflectance of crop is significantly lower than the normal spectral reflectance. Therefore, spectral analysis is more suitable for early detection of crop diseases and pests, which is of great significance for the prevention and control of diseases and pests.

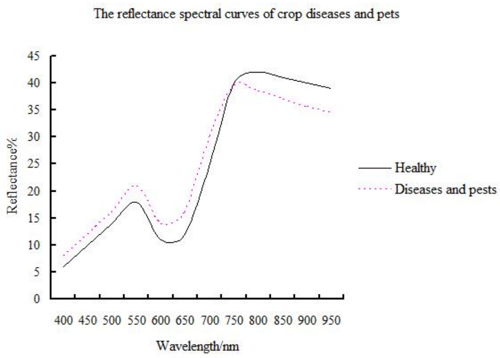


Figure 20. The Reflectance Spectral Curves of Crop Diseases and Pests

5. Conclusions

UAV Remote Sensing in agricultural information acquisition and monitoring has great advantages and broad prospects, compared to satellite remote sensing, with fast, flexible, low cost, high image resolution, *etc.* Because one single image can not cover the entire target area, so the UAV remote sensing image mosaic must be done. This paper discusses the SIFT algorithm for UAV remote sensing image mosaic and its application in agriculture, including rice lodging monitoring, diseases and pests monitoring, crop growth monitoring and crop nutrient diagnosis.

In recent years, the application of UAV remote sensing is more and more widely, but it needs to be further studied, including remote sensing image preprocessing, multi band data fusion, UAV remote sensing image mosaic algorithm, agricultural application of vegetation index optimization and data model optimization, which are the focus of the next step.

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Author

Yinjiang Jia (1977-), male, born in Harbin, Heilongjiang Province, China. he is a D.E. student in the college of Electrical and Information at northeast agricultural university. His research direction is agricultural remote sensing and information technology.

