Forest Fire Detection Solution Based on UAV Aerial Data

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Abstract

This software provides functions on processing UAV (unmanned aerial vehicle) aerial image data according to the requirements of forestry area application on UAV platform. It gives a real-time and remote watch on fire in Greater Xing' an Mountains, simultaneously the UAV is flying and getting the aerial data, helping users quickly master the number and location of fire points. Monitoring software covers functions including fire source detection module, fire location module, fire range estimation module, and report generation module. Mutual cooperation among the various modules improves operational efficiency and detection reliability of the system. What's more, user-friendly visual interface is provided to give a convenience in user operation and interaction.

Keywords: Forest Fire Detection, UAV Aerial, monitoring software

1. Introduction

Real-time fire monitoring has always been an important difficulty in protecting forests, especially for the big forest, because monitoring out of time often causes significant economic losses. So "Early Detect and Early Rescue" is the purpose of forest fire prevention and control for forestry sector. With the development of the UAV technology, remote sensing, and information processing technology, it has been feasible to real-time process and analysis image, which can detect the fire by using the aerial images of large forest areas.

UAV, shorted of unmanned aerial vehicles, is also called as Aerial Robotics. It is composed of vehicle internal automatic control system for autonomous control and execute task or external control by remote station transmits the control instruction to operation mission , mainly by the aircraft carrier, power systems, navigation and control system, the take-off and the recovery device and other electronic, and also can carry the detection equipment *etc.* **Error! Reference source not found.**.

There are many kinds of UAV. According to the mode of flight, UAV can be divided into fixed wing unmanned aircraft, Rotor UAV, unmanned airship etc. And according to the characteristics of the design and task classification, UAVs generally include persistent type without one aircraft, tactical UAV, a miniature unmanned aircraft, pocket UAVs and so on. Because the miniature unmanned aircraft vehicle has the advantages of low cost, small volume, light weight, flexible, landing with relative few restrictions, and can adapt to the complicated and changeable environment advantage, make it become the main research directions of the current air robot research, and in the practical application, because of the high flexibility and strong adaptability, the miniature unmanned aircraft in the military and civilian have a wide application prospect. So miniature unmanned aircraft is used as the UAV for our application of forest fire detection.

UAVs are widely used in many kinds of applications. UAV is mainly used for low altitude reconnaissance; electronic jamming task in military .It not only can reduce the casualties during reconnaissance process, but also can greatly improve fight efficiency. In addition, unmanned vehicle can also be used for target indication and biochemical weapons detection. The unmanned vehicle's advantage is particularly prominent when it fights in the city. It can fly in slow speed, in order to avoid hitting buildings; it can fly to large buildings on hold for urban reconnaissance mission in the civil context. The UAV can be used to the communication relay, environmental studies, natural disasters monitor and support; the UAV can also be used for border patrol, agricultural survey, and large-scale ranch and forest fire detection.

Fire is a regular occurrence in forested landscapes throughout the world. Worldwide, a large number of fire disaster annually happened in fire-adapted ecosystems in large areas of Africa south of the equator, central Asia, southern South America, Australia, and many areas of the boreal forest in Russia and Canada. Therefore, the use of UAV to detect fire source becomes exceptionally significance. Many foreign researchers took deeply research and experiments in the recent twenty years. According to the advocacy of the NASA many universities in the United States and personnel carry out the research and application on UAV and have made breakthrough progress.

By 1990, the usefulness of high elevation aircraft in monitoring large fires and multiple fires in North America had been demonstrated. Aircraft, as opposed to satellites, have the ability to survey as needed without fixed trajectories, and can loiter at fires with flight altitude adjustable to satisfy resolution and coverage requirements. By 2000, the potential for collecting, transmitting, and converting thermal infrared data from aircraft into a GIS format in near-real time had been demonstrated. However, manned flights have limitations in terms of mission duration, mission safety, and cost. In the late 1990's, NASA and the US Forest Service (USFS) began studying the application of unmanned (sometimes termed uninhabited) aerial vehicles (UAV) to support fire mitigation efforts **Error! Reference source not found.**. UAVs, also known as unmanned aircraft systems (UAS), have the ability to operate in areas that are dangerous for manned observation and the ability to operate for flight periods of 24 hours or more. A civil industry has begun to emerge around UAS technology. Due to relative newness of the industry and the heavy restrictions on flights, relatively few wildfire application studies have been published. However, research and development efforts for UAS applications to wild land fire management are ongoing. The United States (US) federal government, specifically the USFS, stands at the forefront of wildfire UAS application development. In 2001, Ambrosia et al. **Error! Reference source not found.** reported the results of a USFS and NASA funded experiment using an ALTUS II UAS to collect thermal imagery over a controlled burn. In 2006, Rest as **Error! Reference source not found.** reported the findings of Szendro Fire Department's experiment using a UAS helicopter to conduct air reconnaissance of two forest fires at Aggtelek National Park in Hungary. In 2009, The University of Alaska-Fairbanks (UA-F) was issued an emergency COA by the FAA allowing the use of the Insitu Scan Eagle UAS to be flown in support of wildfire monitoring and mapping at the Crazy Mountain fire in Alaska. This is significant because UA-F was the first non-government entity afforded this opportunity by the FAA **Error! Reference source not found.**.In 2010, Barado et al. **Error! Reference source not found.** proposed a communication system that used tethered balloons equipped with Wi-Fi repeaters to create an adhoc network in a remote location to facilitate data transfer between firefighters, a UAS, and a control station. In July 2010, The Association for Unmanned Vehicle Systems International (AUVSI) hosted a Fire Fighting Tabletop Exercise (FF-TTX) in July 2010 **Error! Reference source not found.**.

Fire localization based on the parallel binocular stereo vision is proposed in [8] to improve the real-time and accuracy of the fire localization, the application is very important. The technology of parallel binocular stereo vision and 3-D information

reconstruction is used to determine the fire 3-D coordinate of the large space building. In the light of the problem of monitoring fire is in large buildings. The design strategy and practical implementation of establishing the auto-locating and fire –fighting monitor system based on image information of CCD are proposed. The system is based on the CCD dynamic characteristics and color information to detect and locate fire [9]. In [10] an identification method for fire smoke based on a neural network is discussed. The neural network's input used three couples of extinction coefficient ratio of three laser beams with wavelengths of 670 nm, 1060 nm and 1550 nm respectively. The network's output used fire smoke and non-fire smoke factors. Experiments of multi-wavelength lasers attenuation by typical fire smoke and non-fire smoke factors were conducted, resulting in twenty six network sample pattern definition tables acquired from selected data. Three hundred and ninety one times of simulation training resulted in an output error less than 0.0001.The verification experiments prove that this method is effective in distinguishing between fire smoke and non-fire smoke factors. This identification method has practical application for solving fire smoke recognition and other similar non-structural problems. A fire detection method based on the visual characters of images is proposed in [11]. According to the characters of fire images near to near infrared, near infrared images are collected. And making use of the changing information of the fire at the earlier period, the characteristic value is picked up by the image process as the input signal and identified by the genetic neural network to distinguish the fire. This is the idea of the fire identification system. The result is indicated that the system can decrease the error rate further, respond more quickly and monitor more widely than traditional system. Processing the image which is taken by camera, people can get its color feature & wavelet feature, then, using neural network & supervise learning; people can establish relations between image feature vector and three dimension fire vectors achieve the purpose of using image to detect fire [12]. In [13] author used the fuzzy neural network to establish the model of fire detection, Flame characteristics will be extracted as the input, in order to classification of the fire image. The simulation results show that the algorithm on different scenarios of fire detection with high accuracy. In [14] describes the system on theory base, System design, and hardware implementation. It's an Innovation that we using the CCD camera to collect infrared image, the Wave length of infrared filter mainly depends on the spectroscopy theory. In [15] a new method for naval vessel fire detection based on artificial neural network is presented. By designing a model of three layers back propagation artificial neural network, the improved BP arithmetic–LM arithmetic, is applied to the intelligent process of data synchronously detected by the multi sensor. In [16] a fire detection method of marine engine room based on infrared vision is introduced. First, we project the infrared flame images in the sliding windows onto a projection plane. The grey values of pixels in the Projection image signify the spatial distribution of the flame. The author use the invariant moments of the projection image describes the dynamic distribution of the flame. Second, we use support vector machines to distinguish flame object from fake object based on the projection moments. In experiments, we adopted two kinds of flames and two kinds of fake targets. In [17] establish the fire source clustering positioning method based on dynamic Clustering idea with the sensor arrays. The output of the traditional fire source localization method based on wireless sensor array was randomness and uncertainty, which cannot be a better guide to actual fire-fighting. First this paper gives a dense region selection algorithm based on dynamic clustering idea, and then selects the dense region of each output of the traditional methods, and finally each selected area is estimated as a fire source region and the regional centers as the point estimate of the fire location.

Our software meets the requirements of fire detection, analyzed and identified by real-time transmission infrared and visible light of video data. According to the telemetry data, it completes the situation assessment and the geographical location of the fire, and ultimately generates fire detection report for the command and control center. The

software shows the characteristics of high detection speed, high precision, wide measurement range, can effectively provide helpful guidance for the forestry sector, save manpower and material resources and improve work efficiency.

The second part introduces the overall design of the software; the third part give a real knockdown to the design of each module; and the fourth part is to introduce the system use case, and the fifth part is the summary.

2. The Overall Design of the Software

2.1. Software Interface Relationship
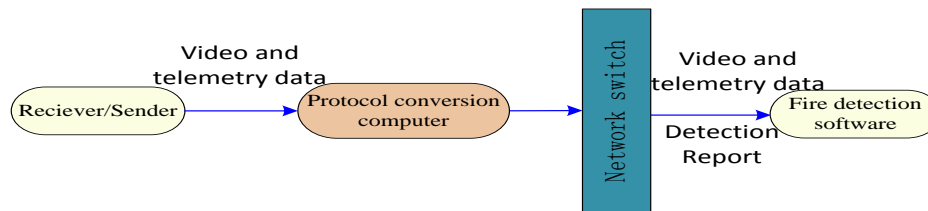
Figure 1. Software Interface Relationship

Network communication using TCP/IP protocol, transceiver transfer remote image data from the plane through the net export to the protocol conversion computer, then transfer image data to fire monitoring software by switch, or by optical fiber network (Figure 1).

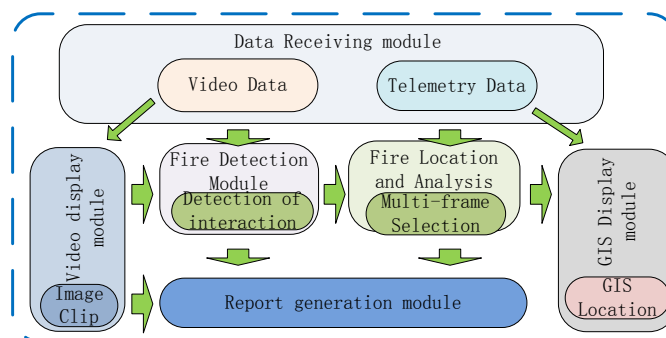### 2.2. The Information Flow of Software Modules

Figure 2. The Information Flow of Software Module

The software includes data receiving module, fire detection module, a video playing module, the fire source location and analysis module, GIS display module and report generation module. The information flow between the modules showed in Figure 2. Data receiving module receives the video and telemetry data from the UVA; Video play module decode video and refresh display. According to the user need to call the fire detection module, display real-time detection results in the video and provide screenshot function; the fire source location and analysis module calculate the geographic coordinate of fire source according to the test results and the telemetry data.

Software design tool

This software is developed using C++ language in Microsoft Visual Studio 2010 platform, dependent on the open cv image processing library and Kakadu video decoder.

The interface

Software main interface as shown in Figure 3, consists of four parts of A, B, C, D and

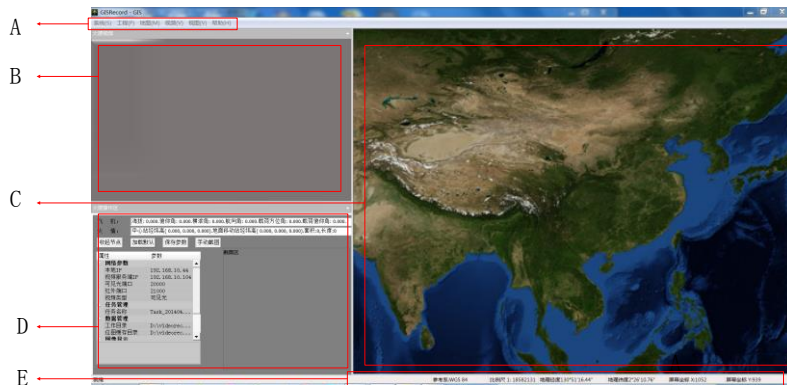E, Respectively is the menu, fire source video display area, GIS map display area and status bar.

Figure 3. The Interface

3. Module Design

3.1. Data Receiving Module

Via TCP\IP protocol, it continually receives raw data of telemetry image from fixed station. And then these data, including infrared and visible light data, are saved to local disk in mj2k format.
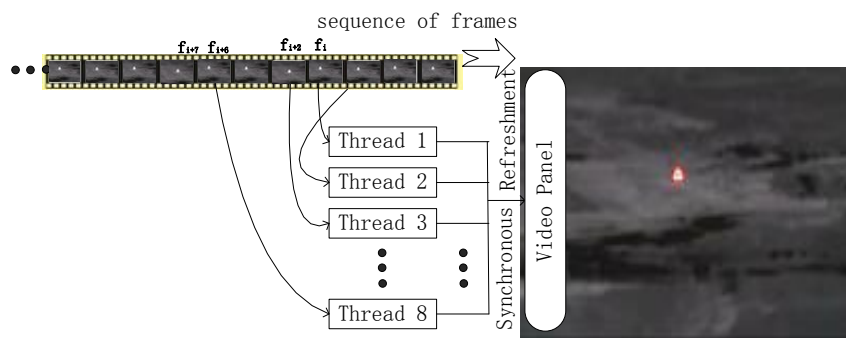

Figure 4. The Video Refreshes Method

3.2. Video Play Module

In the video play module uses 8 threads on the playing area to refresh the display interface. At first, Each thread decode frame of the new mj2k format video, then transform into a same size picture, and call the fire detection module, circle the fire source area in the picture if there exist , finally paste it into the video refresh area. All the threads of video refresh zone are synchronous (Figure 4).

Video play module also provides a screenshot function which can be used to generate test report.

3.3. The Fire Detection Module

The Fire detection module is called before in the video refresh, according to the user interaction, the working mode of the Fire detection module can be divided into the automatic detection and artificial auxiliary detection (Figure 5). Automatic detection mode detects the whole picture under the condition of user not to circle source area, segment and highlight the edge of the suspected source area. Auxiliary detection is performed by fire detection in a rectangular box user circled; this method can further

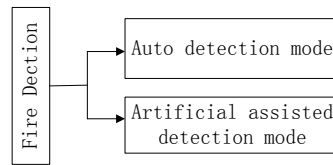confirmation of the suspected source of fire, segment and highlight the edge if the fire source is confirmed.

Figure 5. Fire Detection Method

3.4. The Fire Source Location and Analysis Module

The fire source location and analysis module converted fire source position and size information to the latitude and longitude, the size and altitude information under the geodetic coordinates. According to the aircraft telemetry data location and height information, the module calculates the image pixel scale, and then transforms the fire source position into the geodetic coordinate, also calls the GIS display module positioning to the interface view (Figure 6).
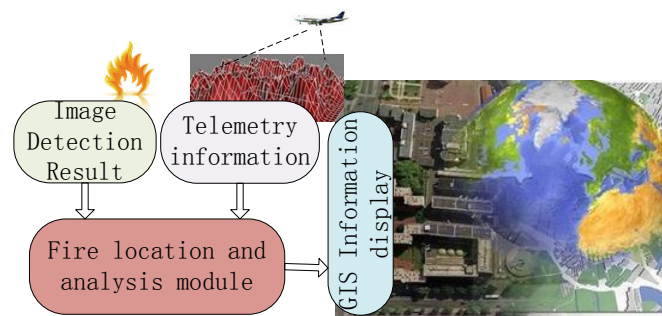

Figure 6. The Information Flow of Fire Location and Display

The module also provides frame selection mechanism, updating the longitude and latitude, altitude and other geographic information according to the effective frame that user confirmed.

3.5. The GIS Display Module

The GIS display module is integrated with software that display geographic information of the earth satellite image, the software also provides a drag, zoom, and positioning and measurement operation for the user. When the fire is detected, GIS module will display real-time fire location to the GIS interface, the user can also carry on the monitoring to remote areas that is not easy to reach due to the software expanse the user's perspective.

3.6. Report Generation Module

Report generation module form the fire monitoring report in detail according to the fire location, analysis and other data, it mainly includes the following aspects: Fire geographical position display, show fire state on the map in detail; given the latitude and longitude of fire source, fire area, the length of the fire line and other data; according to the distance and range of fire analysis the required of firefighting resources.

4. The System Use Case

The use cases of the system includes a user login, system parameter setting, real-time

video switch, fire detection switch, interaction switch, multi-frame selection, load the GIS layer, the GIS map operation, interface view shift, screenshots, reports generation and exit (Figure 7).

Three kind of user are allowed to login and operate the software. The administrator is able to access all of operations. The Inspector is allowed to access system parameter setting, real-time video switch, fire detection switch, interaction switch, and interface view shift. The reporter is allowed to access multi-frame selection, load the GIS layer, GIS map operation, interface view shift, screenshots and reports generation.
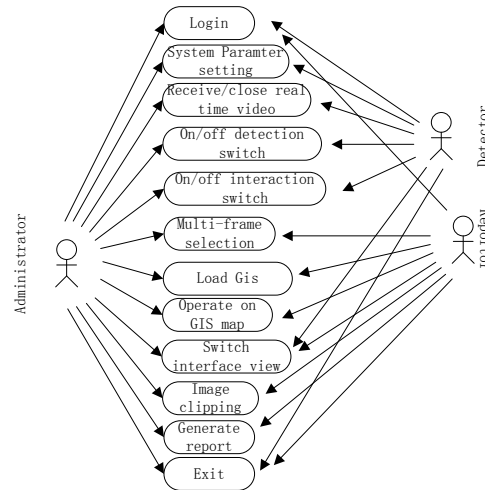
Figure 7.Software Use Case Diagram
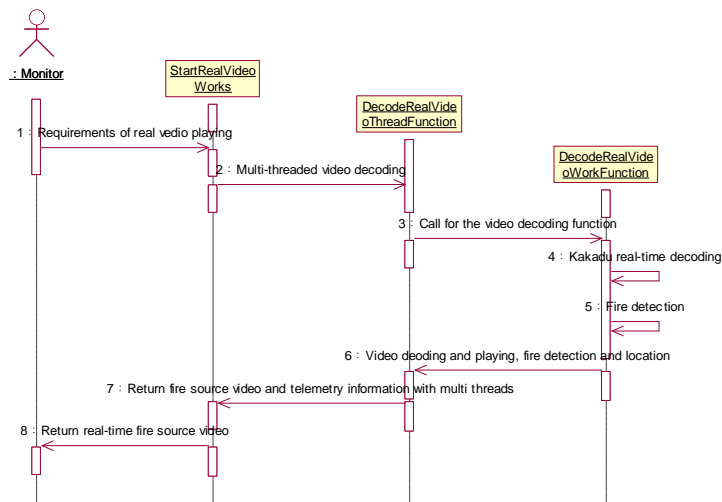
5. Sequence Chart

Figure 8. Real Time Video Detection Sequence Chart

Figure 8 shows the sequence chart of Real Time Video Detection. The process of real time video detection module comprises a video decoding process, a video playback process and a real-time video fire detection process. When the monitor has a requirement of real-time video playback, the function Start Real Video Works () will start multiple threads and call the Decode Real Video Work Function () to detect fire and play video.

Reference to the producer consumer model, the whole process requires synchronization and asynchronous with the video receiving thread. The video receiving thread receives a video frame and sequential storage, processing and display of video frames have been receiving real time video detection thread. When the real-time video detection thread receives a video frame, the Kakadu technology is needed for video decoding firstly, then the fire detection process is underway on the decoded video frames and the new video frame is output. At last, the function gives back the new video frame to the monitor and displays the picture.
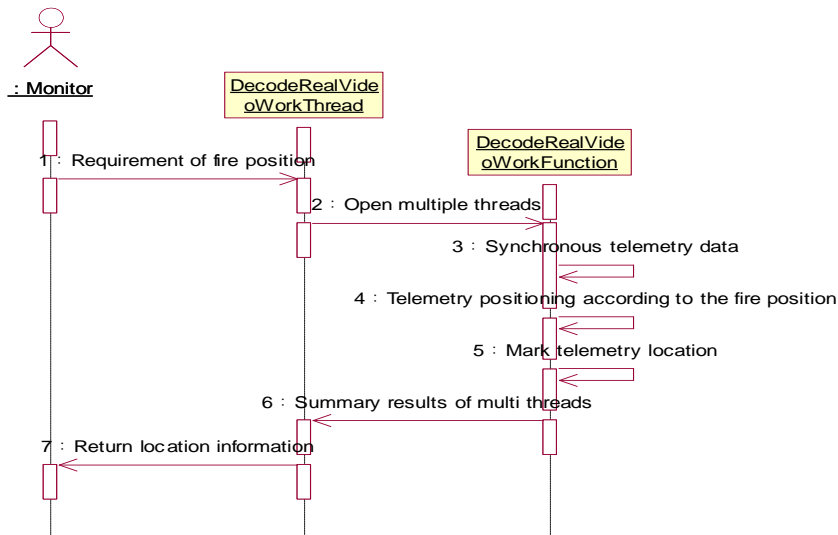

Figure 9. Fire Location Sequence Chart

Figure9 shows the sequence chart of Fire Location. The fire positioning module is positioning telemetry according to the telemetry information and video frames, and it shows the latitude to the users in real time. When the monitor requests fire location, multiple threads and a fire location function will be started. When the fire detection function has detected fire in the real-time video, the telemetry information of latitude and longitude is estimated with the fire location information and the received telemetry information. This information will be marked on the topographic map and returned to the monitor.

For the sequence of Report generation, the fire report generation module contains the information of instant time, the district of the fire, the wire length, fire area and the fire image. When the monitor requires generating report, a new thread and a function for report generation will be started and the report will be sent to the monitor with Word 2010.

6. Tree-Crown Reconstruction Based on UAV Aerial Images

A tree-crown reconstruction method is proposed according to the characteristics of UAV aerial image sequences. In the method, we extract feature points based on segmentation, and then match feature points based on regional correlation coefficients. For imaging model of UAV aerial camera, the feature points set are determined by a suitable parameter estimation method. Finally, a modeling method is presented to build the tree-crown model.

UAV aerial is an important way to capture spatial data, and is an important technology

shooting ground by optical imaging sensor. Because of its low cost, flexible use, and short operation cycle, etc. The UAV aerial has become an irreplaceable surveying and mapping technology in the field of military and civilian. At present, there has been a great progress in the applications of UAV aerial technology, which is widely used in the national ecological environmental protection, climate monitoring , investigation of land use, urban planning and municipal management, plant diseases and insect pests in the forest protection and monitoring, etc.

For forest fire controlling, the tree is complex in morphological structure, and this makes it difficult to reconstruct the tree model. Among the methods of reconstruction, binocular stereo vision method has greatly developed, and is now able to stably achieve better reconstruction effect. However, most of the methods rely on accurate horizontal section, which the UAV aerial images can't content. Therefore, we obtain very detailed model by using two images so as to benefit the UAV images.

It is a crucial step to extract the feature points in good matching, as feature points completely reflect the structure characteristics of the target. For feature extraction and matching method, there are two main methods based on feature and on regional correlation. For the former, Scale Invariant Feature Transform (SIFT) algorithm is widely used, which is invariant to size, rotate and radiation of object. For the latter, method based on correlation coefficient is usually adapt to extract and match feature points. The method based on regional correlation coefficient has good performance, but has a complex calculation, resulting in a slow speed, and poor real-time performance. So it is weak to adapt to the change of the image. Generally, we need the algorithm need not the complex image preprocessing, and is able to obtain correlation well representing the similarity of two images. Thus, it can remain most information in image, and it relies on efficient scanning way based on choosing appropriate feature area or feature point extraction method.

Tree reconstruction effect can be directly displayed by the visual modeling scattered points. At present, in the field of tree reconstruction, the commonly used modeling method is the triangular mesh for space scatters. Under a particular resolution, triangular mesh can express more complex surface more accurately using less space and time with the structured model. But the feature points the aerial images can extract is very limited. Using the grid to create three-dimensional tree model is too rough, which also cannot construct the branches structure of the tree-crown well. Our method simulates the branches growth structure of the tree, which can build the complex models of the trees well. Modeling space feature points is effective in the limited UAV environment.

6.1. Camera Parameter Estimation

The aerial camera intrinsic parameters can be set up every time before the UAV aerial photographing, Table.1 shows parameters.

Table 1.Camera Parameters Available

Parameter name	Parameter value	remark
x0	0.0949mm	Camera principal point coordinate x component
y0	0.2426mm	Camera principal point coordinate y component
f	33.8568mm	focal
e	0.00641mm	principal pixel size
h	800m	UAV flight height
Time	8s	time interval of capture

According to the camera imaging model, the camera intrinsic parameters can be calculated. In order to simplify the experiment, this paper uses the camera intrinsic

parameter matrix including 4 parameters, which means we think there is no distortion in camera. As for the camera extrinsic parameters, because the camera rotation is ignored in this experiment, we only need camera's translation vector. According to the known air distance and flight height of UVA, we map the translation vector in image to world coordinate system.

6.2. Matching Tree Feature Points

To get the bright and dark area of tree-crown, we do watershed region segmentation. Therefore, we statics the area represented by the number of pixels as in Table 2. It is found that most segmented areas exist between 40 and 150, and that there only are few very large area and very small area: the number of areas existing in [1,39] and [150,181] is just 8. In general, the areas segmented by watershed are uniform.

Table 2.The Result of Water Region Segmentation

project	value	proportion
The biggest value of interval, unit: pixel	181	-
The smallest value of interval, unit: pixel	1	-
The sum of interval	47	1.000
[1,39]	5	0.106
[40,99]	26	0.553
[100,149]	13	0.277
[150,181]	3	0.064

6.3. Tree Reconstruction and Modeling

According to tree feature points scattered, the information of branch and crown can be calculated which can be applied to create the three-dimensional tree model of crown by our method. In order to obtain the structure of crown as completely and accurately as possible, we take different threshold value to match feature points in experiment and compare the corresponding result. Under the case of choosing several representative threshold value extracting feature points set and constructing skeleton construction and three-dimensional model of trees.

The UAV aerial is great significant in area of forestry fire controlling. As tree reconstruction has great advantages in obtaining the depth information from 2D images, our approach on UAV aerial images based tree reconstruction is of great usefulness. In our method, we solve the difficult feature points match problem for aerial images based on the watershed segmentation and regional correlation coefficients, and extract enrich structure points for target tree-crown.

7. Fire State Detection Platform

As shown in Figure 10, in the fire detection under the state of fire, video area real-time broadcast remote video and display fire detection results, GIS display marked fire location in the satellite map; In the fire operation area, real-time display altitude, pitch angle and other remote sensing information of the aircraft and latitude and longitude and

other geographical information detected by the central station and moving station.
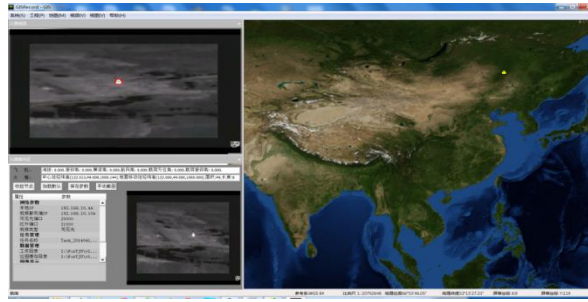

Figure 10. Fire State Detection Software

This software implements analysis, processing, and fire detection on UAV aerial image. It can real-time detect a widely range of forest, and locate the potential forest fire fast and accurately, and help staff eliminate the hidden danger. In the future, the technology of UAV aerial will be popularized in many fields like agriculture, forestry, sea .etc. The image processing software based on UAV aerial will greatly promote the development of these industries and enlarge the application scope of UAV.

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