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A Demonstration Platform for Small Satellite Constellation Remote Operating and Imaging

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ABSTRACT

A new platform 'Satellite Remote Operating and Imaging Demonstration System for Small Satellite Constellation' is presented in terms of platform architecture, design, as well as experiment, etc. The platform will allow realistic obtaining on-demand satellite imagery in a timely and persistent manner for pre-mission planning. Development of the system was motivated by interest in multi-task scheduling for satellite imaging, as small satellite constellation in LEO is an attractive way to provide rapid imaging in disaster response, etc.The platform consists of three devices, including Satellite Emulator, a Mobile Terminal system and Global Geographic Image Displaying System (GGIDS). The entire system works as follows, the user needs first to start the app, add or remove satellites. Then the user can select a target by the embedded Google map API. With the position of the target, the terminal app can predict the overpass time for each satellite. The satellite with shortest overpass time will be selected. The corresponding orbit elements, system time and target position will be sent to both the emulator and GGIDS. The emulator will then propagate the dynamics of the chosen satellite and perform attitude maneuvering according to the demanded angle, which is used to drive the pan tilt unit. The camera will take a picture of the projected image by the triggering signal. Finally, the acquired image will be sent back to the tablet. With these settings, the users can specify various properties of the platform and carry out a fast trial. Experiments are provided to verify the effectiveness of the system. The developed platform can significantly reduce the risk of space mission, and will provide a useful tool for evaluating algorithms for satellite image acquisition scheduling and multi-task operational planning.

[1)] Associate Professor

1. INTRODUCTION

Space technology is a comprehensive advanced technology for space exploration, development and utilization, and has significant benefits in military application, scientific and technological progress and economic development. In the current world, the space technology is an important symbol to measure the comprehensive national power of each country. Therefore, every country puts the development of space technology into an important position and has carried out numerous space projects. In recent years, many countries and regions are hoping to establish low-cost regional coverage satellite system with non-geostationary orbit (Feng 2010 and Crossley 2000). Compared with GEO satellite system, the MEO and LEO satellite system has the following advantages: short propagation delay, low transmission loss, low launch cost and can effectively improve the payload resolution, etc. Satellite constellation is composed of a number of satellites running with certain rules, and has benefits include higher coverage performance, short revisit time interval while comparing with single satellite. The satellite constellation can satisfy the application requirements of communication, navigation, positioning, space exploration, hot area imaging and scientific experiments, etc. Therefore, the MEO and LEO satellite system has unlimited potential for political, economic and disaster rescues application, etc. (Li 2010)

In the civil aspect, major natural disasters occurred frequently all over the world in the past decades. For example, about 160 thousand people died in the India Ocean tsunami in December 26, 2004; About 70 thousand people died in the Wenchuan earthquake in May 12, 2008. These major disasters have caused huge casualties and property losses to the country. Disaster information acquisition is an urgent need for disaster rescues and post-disaster reconstruction. Using a satellite constellation to achieve continuous imaging of the disaster area, it can provide timely and accurate information for the rescue forces to race against time for rescuing the wounded, and reducing the loss caused by the lag of information (Sweeting 1996).

The above application demands put forward more requirements for remote-sensing system: fast platform establishing, quick information acquisition, short revisit observation period and large coverage rate, which are difficult to be achieve for the existing on-orbit imaging satellite in the short term. With the development of small satellite technology, it can be very convenient, rapid and flexible to achieve these functions, and has become a very important means of emergency remote-sensing. For example, the SeeMe project proposed by DARPA is a tactical reconnaissance satellite program (Yang 2013 and Li 2013), and it can provide reliable and continuous remote-sensing information. Using imaging small satellite for emergency network can reach the effect which other methods cannot achieve, such as the flexibility of launching small satellite, the rapidity of networking small satellite.

This paper aims at the requirement of the fast imaging of the future micro-satellite constellation for the hot area, and develops a user-oriented ground simulation platform satellite remote sensing and operating. This paper focuses on the design of the platform general framework, and sub-systems scheme and hardware-in-the-loop simulation, etc. The developed platform can significantly reduce the risk of space mission, and will provide a useful tool for evaluating algorithms for satellite image acquisition scheduling and multi-task operational planning. The rest of the paper is organized as follows. In section 2, platform architecture and its main functions will be discussed in detail. An experiment that demonstrates the functionality of the platform will be presented in section 3. Finally, section 4 presents the conclusion.

2. GENERAL SCHEMEOF THE DEMONSTRATION PLATFORM

The remote operating demonstration system is composed of three parts, including a Satellite Emulator, a Mobile Terminal system and a Global Geographic Image Displaying System. The three subsystems use WiFi to achieve communication. The system block diagram is shown in Fig. 1.

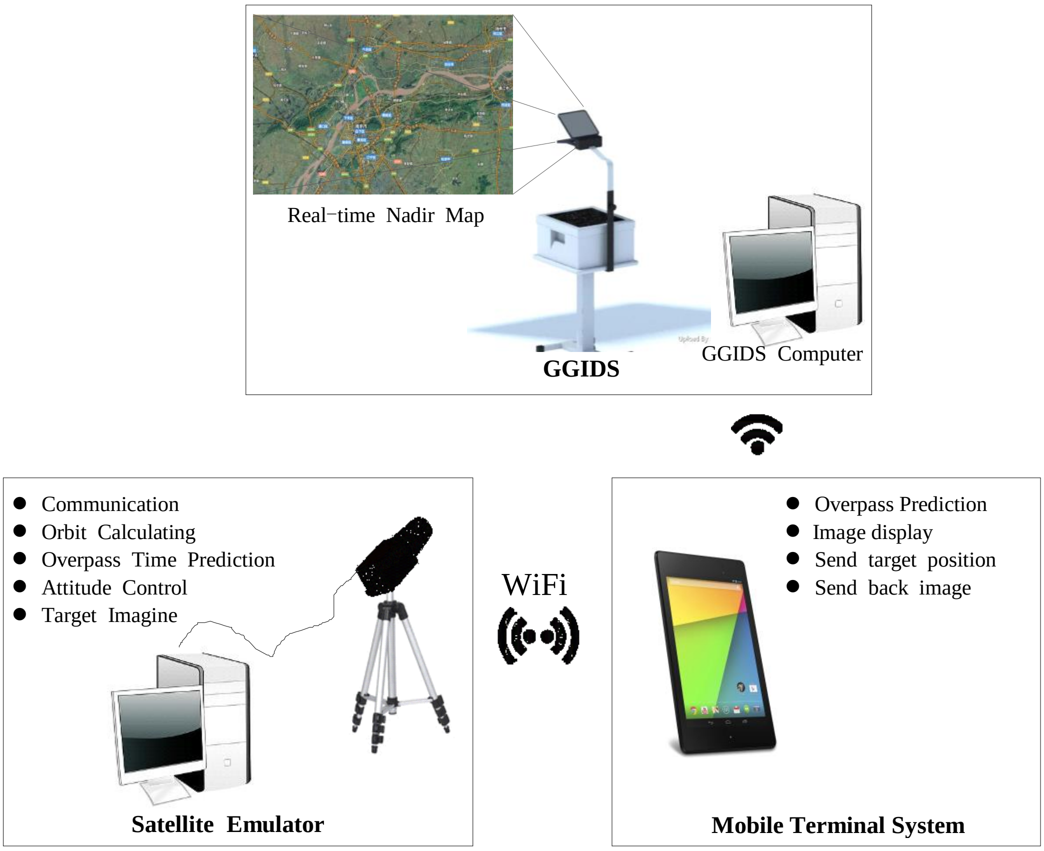

Fig. 1 System Block Diagram

The Satellite Emulator is composed of a satellite dynamics simulation computer, real-time dynamics simulation software, an image acquisition camera, a camera control pan tilt unit and a support. Its main functions are as follows: communicating with the Mobile Terminal system, receiving instruction from the Mobile Terminal system, setting simulation parameters, calculating satellite orbit, predicting overpass time, calculating attitude maneuvering angle, controlling attitude maneuver, driving pan tilt unit and camera, imaging target area and transmitting target image to the Mobile Terminal system.

The Mobile Terminal system is composed of a mobile terminal and terminal App. In order to obtain the image and geographic latitude and longitude of the target, the PC Table needs to install navigation software (such as Google maps) in advance and has the wireless communication capability. The main functions of the Mobile Terminal system include: calculating and displaying the three dimensional orbit of the satellite constellation, inputting and editing satellite orbit, displaying target area image and acquiring geographic position, predicting satellite passes, sending target geographic position, receiving target image from Satellite Emulator.

The GGIDS is composed of the image displaying computer, real-time image display software and a image projector. In order to ensure the operation of the GGIDS system, the experiment environment should have internet. The main functions of the GGIDS system include receiving satellite orbit parameters and target geographic position information from the Mobile Terminal system, acquiring global geographic information online, updating nadir geographic image in real time and projecting the real-time geographic image to a appropriate plane.

The general scheme of each subsystem will be introduced in detail later.

2.1 Scheme of Satellite Dynamics Simulator

The dynamics simulator software of this paper is developed in LabVIEW. In order to achieve the operation of the hardware, such as camera driving, image acquiring and pan tilt unit controlling，the dynamics simulator needs to run in real time. The operation period and the orbit/attitude dynamics calculation period are both 0.5 seconds. The dynamics simulator uses a common PC computer or a mobile notebook with the following basic configurations: the CPU is Intel Core i5, the memory is 4G, and the disk capacity is 120G. The software version is Labview2011 or above, Microsoft Visual Studio 2010. The GUI interface of satellite Emulator is shown in Fig. 2.

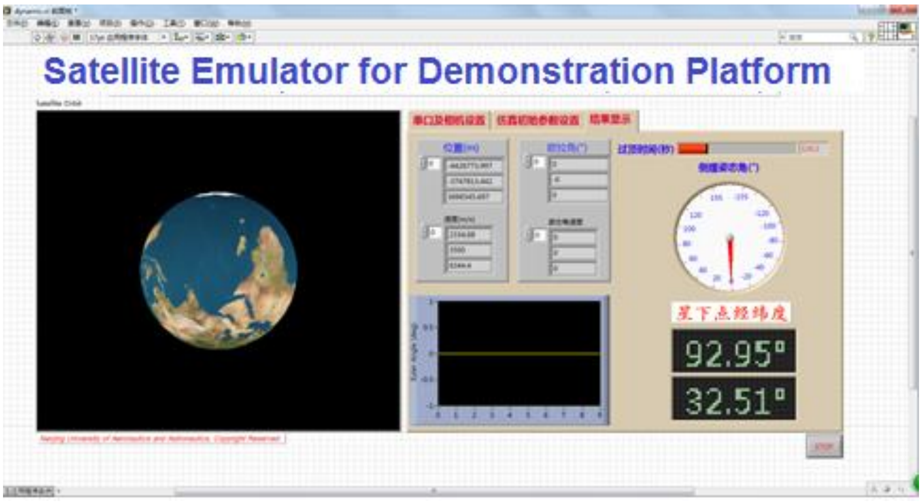

Fig. 2 GUI Interface of the Satellite Emulator

The GUI interface of the simulator is divided into two parts; the left side is the 3D animation of the satellite orbit, while the right side is the parameter setting and the result display window. The parameter setting includes serial port and camera parameters configuration, initial simulation parameters. The operation flow chart of satellite dynamics simulator is shown in Fig. 3.

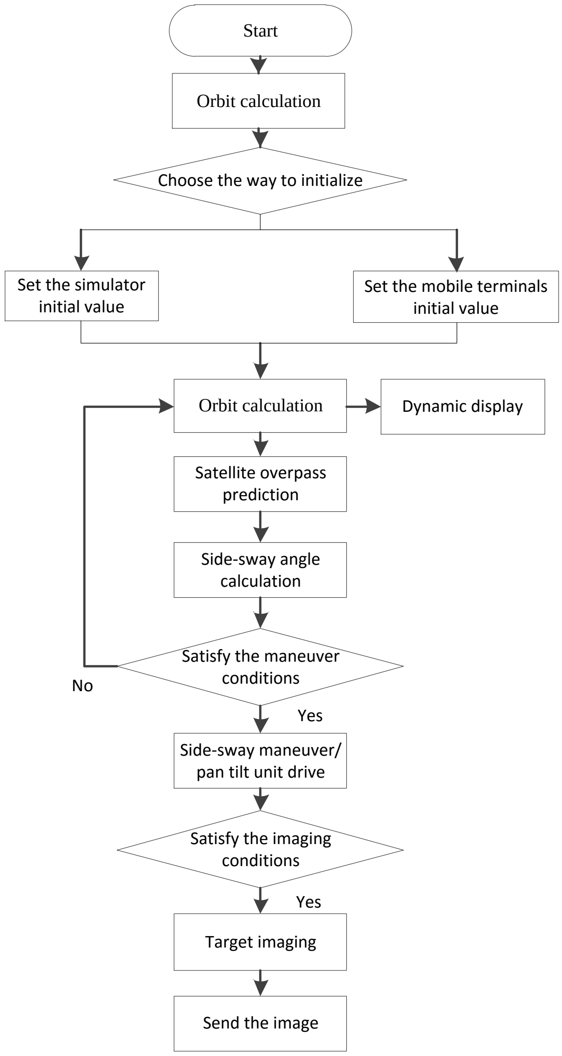

Fig. 3 Operation Flow Chart of the Satellite Emulator

To run the Satellite Emulator, we need to first select the initialization mode, using the initial value of the simulator or from the Mobile Terminal system. Then, the orbit of the selected satellite is propagated and displayed during each period. The satellite overpass prediction and maneuvering attitude angle will be calculated. The satellite will conduct attitude maneuver while the target area can be seen, and perform target imaging if the target is in the Field of View of the camera. Finally, the image acquired will be send back to the Mobile Terminal system. In this process, the satellite overpass prediction method can refer to Palmer (2000) and Yan (2001), and satellite maneuver control method can refer to Tang (2010) and Li (2011).

2.2 Scheme of the Mobile Terminal System

The Mobile Terminal System uses a PC tablet or a smart phone. Its application software is developed in Android. The software interface is adapted with size of the tablet and phone. The relation of the main interface and the sub-interfaces for Mobile Terminal system software is shown in Fig. 4.

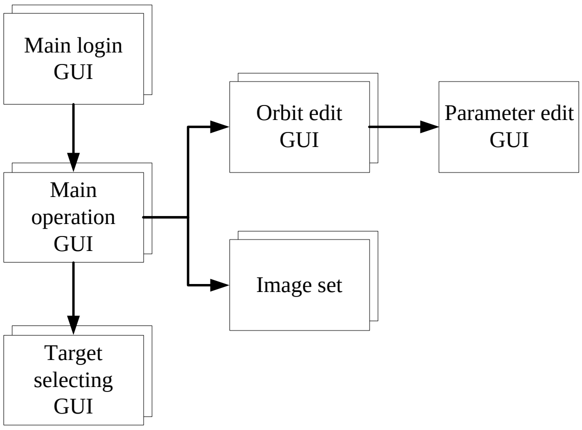

Fig. 4 Mobile Terminal System APP Interface Relation

2.2.1Main login module

The main login module is used for the user to login and set the network parameters, and its interface is shown in Fig.5 with its port as shown in Fig. 6. Projection management machine and satellite dynamics simulator's IP can be set in the main login module. After login successfully, these parameters will be stored in the database and can be called directly for next operating.

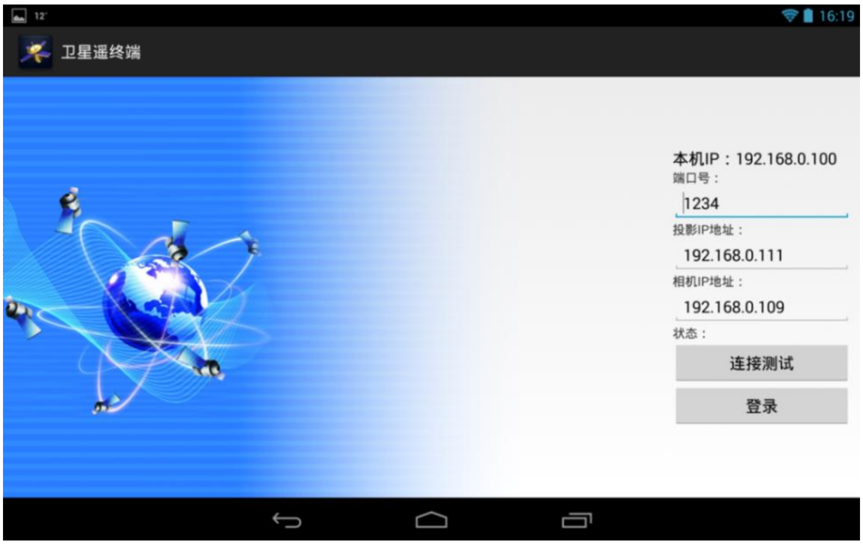

Fig. 5 Main Login Interface

2.2.2 Main display module

The main display interface is the main interaction interface for the user, and is used for displaying the 3D orbit and the related information for the satellite constellation. The visual angle and size can be adjusted through touching operation. After selecting a target, the related parameters of the task can be displayed. The interface is shown in Fig. 7 and the port is shown in Fig. 8.

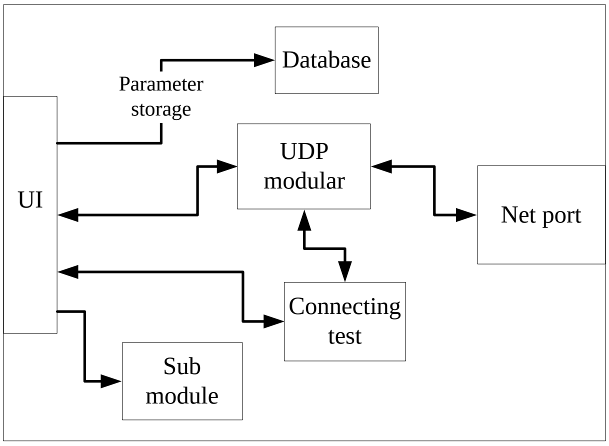

Fig.6 Main Login Module Port

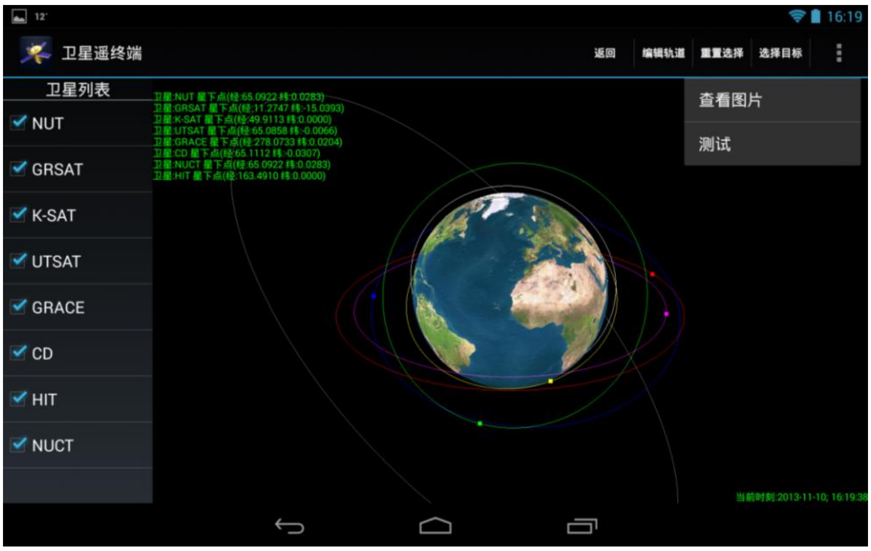

Fig. 7 Main Display Interface

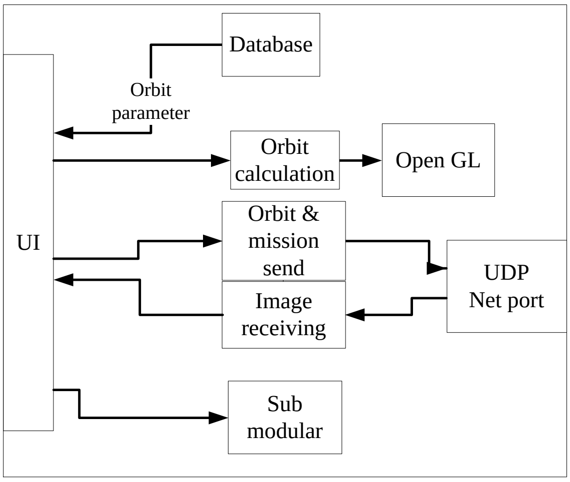

Fig. 8 Main Display Module Port

After the module is activated, all the satellite orbit parameters will be loaded from the database firstly, and all the satellite will be listed in the list for users to select. After selecting the satellite, the orbit and related information will be displayed in the center of the interface as well as the nadir information.

Interface title bar is a menu item. The “Edit Orbit” item is used to add or modify the satellite orbit parameters that have been stored in the database. “Reset Selection” item is used for the user to give up the task and to choose a new satellite after the user has selected a target for imaging and the software is in the imaging schedule mode. “Select Target” item is used to enter the interface to select target to be imaged. “View Image” item is used to enter the interface to browse the saved images.

After selecting the target to be imaged, returning from “Select Target Interface”, it will still stay in this interface. Because the imaging target has been selected, the information of the imaging target, the time node when each selected satellite can participate in the imaging task and nadir information will be displayed in green area in the picture.

After this module receiving the signal that satellite image was accomplished by the Satellite Emulator, it will call image display module to receive image from the Satellite Emulator and then to display it.

2.2.3 Orbit Edit Module

The interface of the orbit edit module is relatively simple. Its main function is loading satellite orbit parameters from the database and updating or inserting new data to the database. The orbit data will be presented to the user in the form of a list, and the user can long press the list item to pop up "modify" and "delete" menu. The menu item is in the upper right corner of the interface and “Add Orbit” is used to add a new orbit.

2.2.4 Target Select Module

The interface of the target select module is shown in Fig. 9, while its port is shown in Fig. 10.

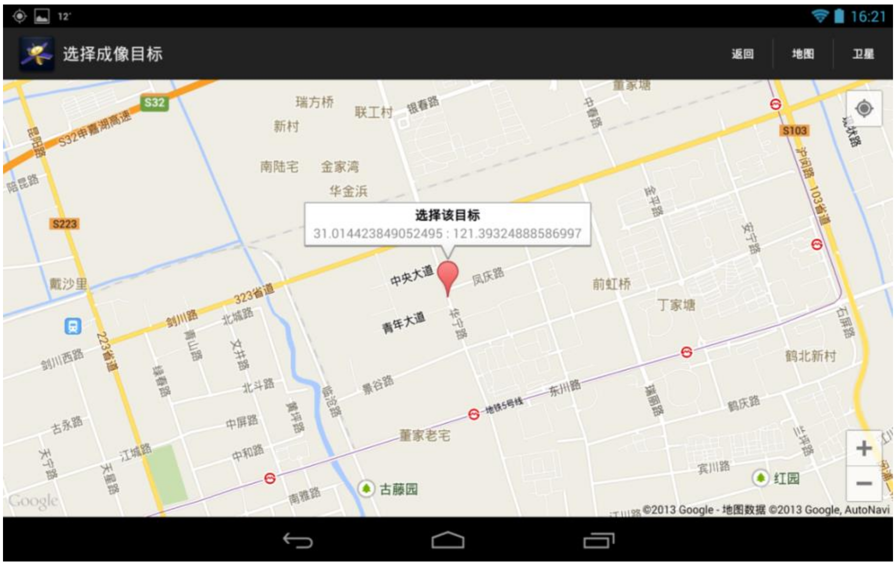

Fig. 9 Target Select Module

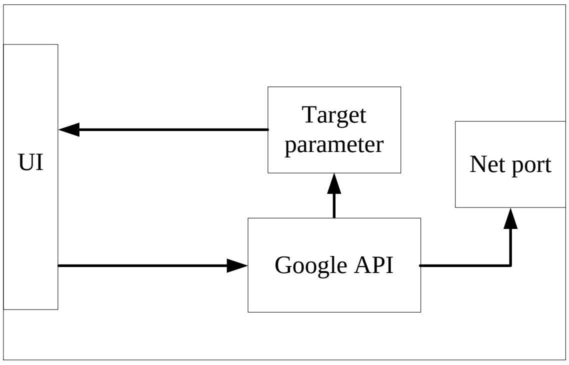

Fig. 10 Target Select Module Port

The target select module is to provide a function for the user to select the area to be imaged. The Google map API is embedded in this module and it provides interactive operation interface. The User can long press to select the imaging target, and the corresponding latitude and longitude information of the target will be sent back to the main display module after selecting the target.

2.2.5 Image Browse Module

The image browse module will display the acquired images in the form of a list. The corresponding image file name is the time when received the image. And the user can click to view the image.

2.3 Scheme of Global Geographic Image Displaying System

The GGIDS software is developed in Microsoft's C# and with UDP communication module. Its interface is shown in Fig. 11, and its port is shown in Fig. 12.

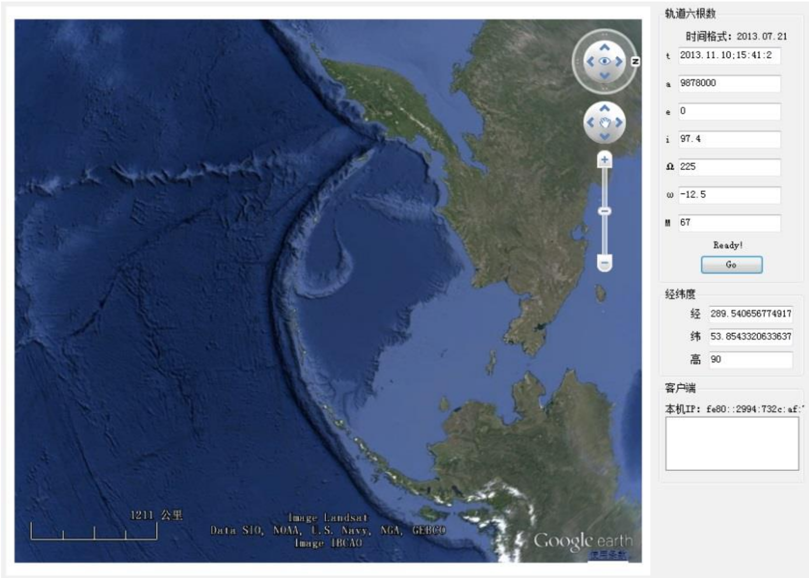

Fig. 11 GGIDS Software Interface

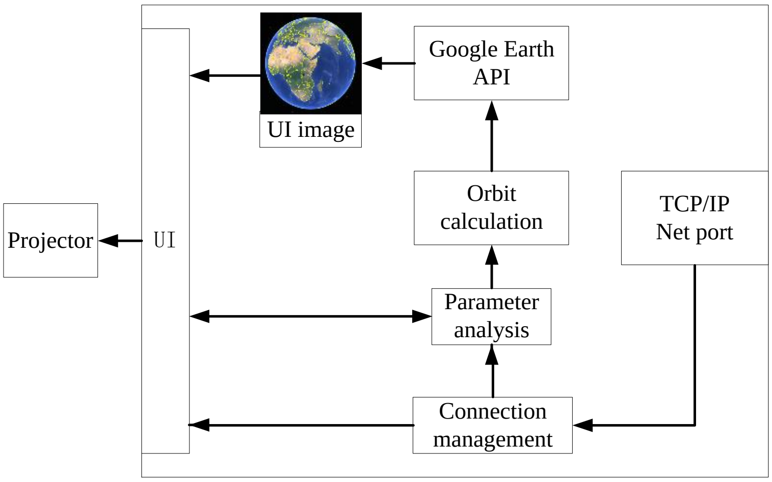

Fig. 12 GGIDS Software Port

The Google map API is embedded in the GGIDS software. The image is deduced by latitude, longitude and height of nadir which is calculated by orbit elements. Before the Mobile Terminal sends orbit data, the software will propagate with any orbit parameters the user inputted. After receiving orbit data from the Mobile Terminal, it will then receive orbit parameters automatically. Connection management is used to receive the satellite orbit parameters sent from the Mobile Terminal and send the parameters to orbit calculation module. The display interface of the software is provided by the projector.

Google Earth API adopts HTML service based on java script. Therefore, in order to use the Google Earth API, the software needs to use WEB control to call HTML web site. At the same time, in order to be able to generate the local HTML address, the IIS service is embedded in the system in Windows. And the java script code which adopts Google Earth API is called by IIS service, and is put into google_earth.html file center. Its system block diagram is shown in Fig.13.

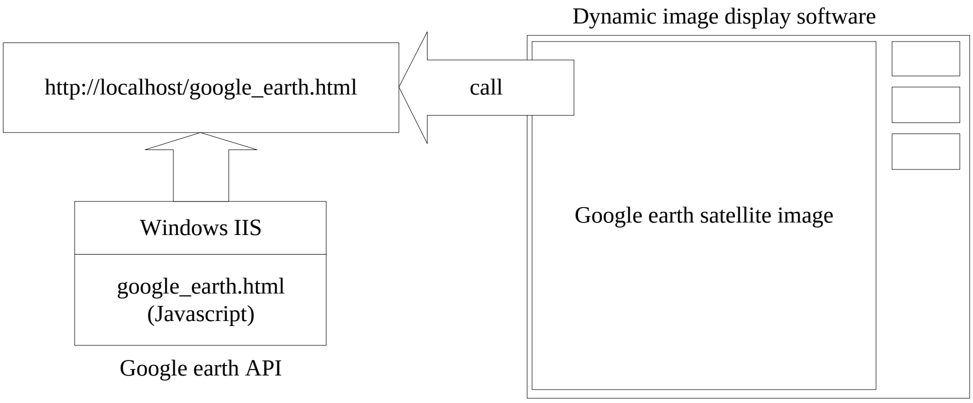

Fig. 13 System Block Diagram

The function of part of the Google_earth.html code is updating the camera view and getting the new Google earth satellite image.

3. Hardware-in-the-loop EXPERIMENT

In order to verify the function of the demonstration platform developed in this paper, hardware-in-the-loop simulation is required. The required equipments including a dynamics simulator computer, an earth image processing computer, two Mobile Terminals, a projector, a image acquisition camera, a step-motor, a suit of tripods, a step-motor DC converter, a USB-serial port adaptor and a laser pen. Test equipments connection block diagram is shown in Fig. 14.

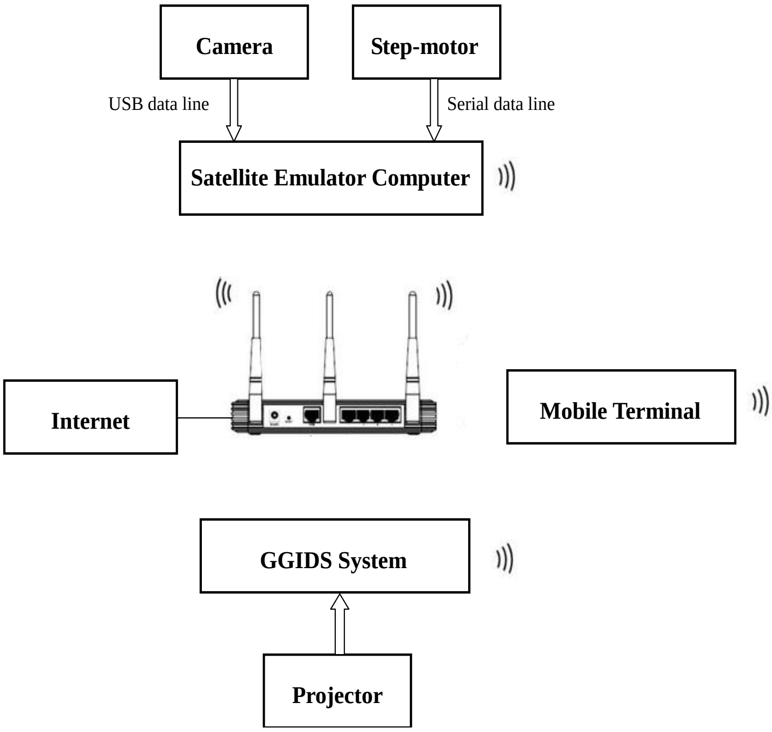

Fig. 14 Test Equipments Connection Block Diagram

To accomplish the comprehensive test of the remote operating demonstration system to be successfully, we need firstly to test the Satellite Emulator, the Mobile Terminal system and the GGIDS system, respectively. Then integrating the system and carrying out a comprehensive test. All the steps have been completed during the test, such as task satellite choosing, imaging target selecting, satellite parameters sending, orbit predicting, camera controlling, and image saving and returning. The selected satellite orbit parameters are shown in Table 1. The imaging target's longitude and latitude are 46° and -101° respectively.

Table 1 Satellite Orbit Elements

Reference Time	2014-01-09; 14:00:00					
Orbit Parameters	a(km)	e	i(°)	Ω(°)	ω(°)	M(°)
	6878	0	97.4	225	12.5	20

Hardware-in-the-loop Integrated Testing Site is shown in Fig.15.

Fig. 15 Hardware-in-the-loop Integrated Testing Site

The Mobile Terminal orbit prediction overpass time is after 208 seconds, select the above satellite to perform the task and send the parameters to the Satellite Emulator. The camera starts maneuvering 40 seconds before the imaging time, and completes the imaging task in the imaging time. Then the image is sent back to the Mobile Terminal, which is shown in Fig. 16.

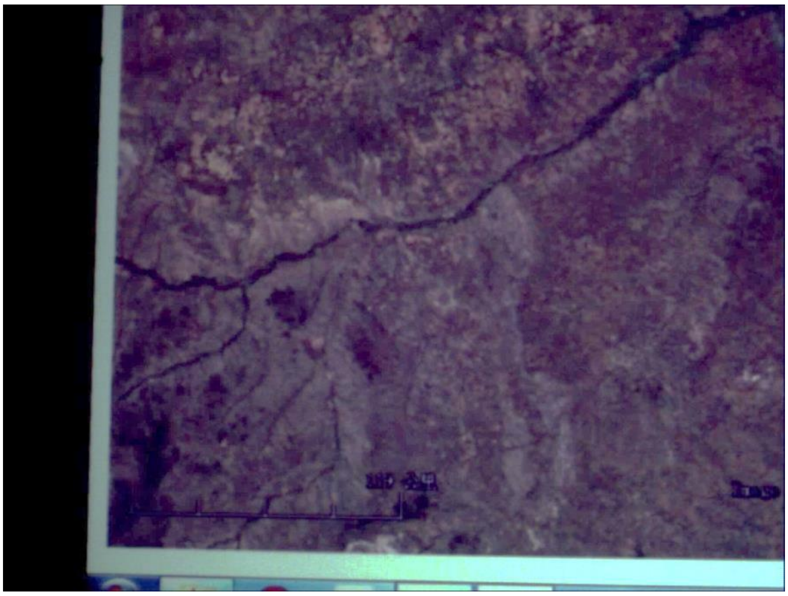

Fig. 16 Acquired Image

4. CONCLUSIONS

The global response space mission such as disaster rescue requires the remote sensing system possess the ability of high coverage and fast revisit period for any position on the Earth. Based on the background of spacecraft response imaging of hot area for future micro-satellite constellation, this paper developed a platform "Satellite Remote Operating and Imaging Demonstration System for Small Satellite Constellation". The platform consists of three devices, including Satellite Emulator, a Mobile Terminal system and Global Geographic Image Displaying System. The platform allows realistic obtaining on-demand satellite imagery in a timely and persistent manner for pre-mission planning. Finally, hardware-in-the-loop simulation was carried out to verify the basic function of imaging mission acquisition, task scheduling and image fast download of the platform. The developed platform can significantly reduce the risk of space mission, and will provide a useful tool for evaluating algorithms for satellite image acquisition scheduling and multi-task operational planning for system engineers.

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