Development of Interoperable Multi-Satellite Operations Platform

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Abstract

FORMOSAT-2, an earth observation remote sensing satellite has been launched and operated by National Space Organization, National Applied Research Laboratories (NARLabs-NSPO) of Taiwan since 2004. Its unique daily revisit feature with 2-m GSD has demonstrated tremendous benefits in various applications especially in disaster response and continuous change detection monitoring. NSPO is determined to become one of the high resolution image providers in the world. Therefore a follow-on FORMOSAT-5 satellite is being developed and targeted to launch in 2015.

From the demand perspective, with growing variety of space resource availability in recent years, horizontal interoperability of satellite programming operation is crucial to provide decision-support platform for users with different purposes. Based on experience operating FORMOSAT-2 satellite, NSPO is developing a satellite multi-mission programming system prototype with web service interface. This system, Formosa SPS (sensor planning system), can be used for determining the feasibility of an intended sensor planning request and it features a common platform of sharing satellite resource. Meanwhile, due to the orbit feature, there are different chances that a specific AOI (area of interest) lies within the field of view for different satellite in certain period of time. Therefore, systematic analyses are performed in real-time for multi-satellite scenario. 3D simulation system using free application programming interface (API) technology is also being developed. In this paper, we will introduce the background and objective of this system development and present its mechanism and function. Formosa SPS 1.0 is OGC Compliant certified.

1. Introduction

It is estimated that there are nearly 200 Earth observation satellites will be launched by 2017 and satellite-based Earth observation activity is entering a new expansion phase (Adam Keith, 2014). In order to getting maximum benefit and using the satellite resource efficiently, the coordination of satellite activity will become more and more important. The Multi-Satellite Operations Platform developed by NSPO was performing the prediction of satellite track, simulation the coverage and viewing angle of satellite observation. The estimation of satellite revisit frequency and cloud forecast are also provided to assist the user to seek the possible opportunity to observe the area for the constellation of satellite.

This web-based technology enables users to understand the satellite position in real-time and identify the area of interesting either by themselves or ingesting from the internet WMS site. Meanwhile, because each satellite is operated by different individual organization, the standardized protocol is adapted for commutation between system and satellite operation center. This makes interoperability become possible.

2. Feasibility analysis for satellite mission tasking

The system was designed to perform primary feasibility study according to the satellite orbit, AOI, requested viewing angle and weather condition. Base on this information, the user could choose the reasonable AOI for each satellite. It has ability to significantly improve the coordination among the user and different satellite operation agencies.

2.1 Geographic information platform

In case of emergency, government institutions, civil society organizations, and development agencies will create a common platform for public agencies to share information and publish map-based services for the affect area. On the other hand, the crowd sourcing geographic data by lots of non-professionals volunteer is also available in the public. Usually, those data has feature of large data volume, and abundance information and low cost. By taking advantage of those open source information, the system has been implemented to retrieves a map from Web Mapping Services (WMS) site and display in Google Earth. It allows the user to specify distinct layers, the spatial reference system, the geographic area, and other parameters describing the returned map format.

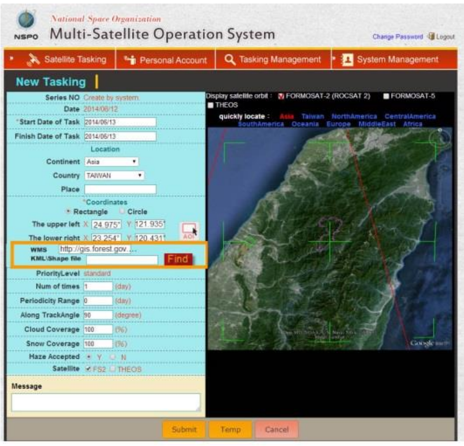


Figure 1 WMS layer as AOI

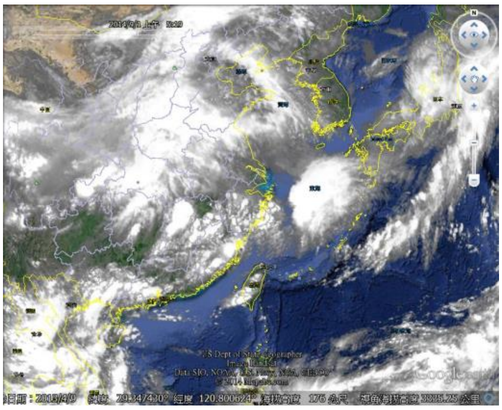


Figure2 Cloud forecasting layer

On the other hands, the usage of image is also influence by the weather condition for optical instrument. The system makes use of cloud forecasting information to aid user to understand the weather condition to avoid acquiring the unsatisfied data. The original data was obtained from Global Forecast System which operated by NCEP (National Centers for Environmental Prediction). This data together with the information from the observation by ground instrument, environmental circumstance and empirical knowledge are regards as initial forecasting data. By implementing well–known MM5/WRF model, the numerical cloud prediction was made. This data also could be displayed in the Google earth platform. It seeks to make use of flexible combination of information layer in order to fulfill various needs for the satellite observation.

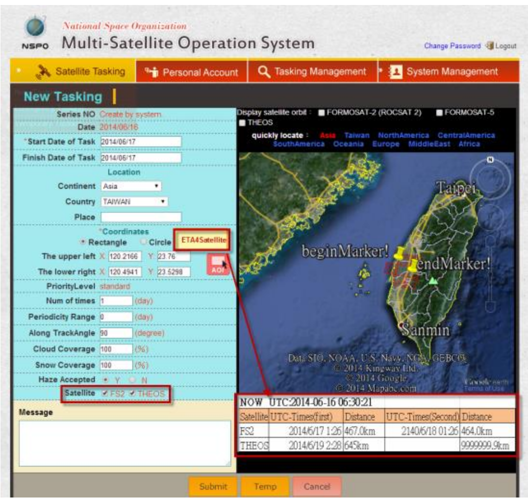
2.2 Estimated Time of Arrival for Satellite

According to the application, users look for available satellite resource to deal with. The system uses a Simplified General Perturbation 4 (SGP4) propagator (Hoots 1998) and concept of Kepler elements to determine the past and future orbit position of the satellite every second by using published Two-Line Orbital Element (TLE) sets that are typically available every few hour from CelesTrak. The system updates and interprets TLE data every day to ensure the accuracy of the estimated satellite orbits due to the factors of gravity or resistance etc. This study implements the prediction analysis of satellite revisit rate and possible footprint in case of lacking of precise ephemerides.

The concept of the elevation mask (Hwang *et al.* 2010) was used to decide the satellite opportunity window for a given target. It defines a circle of radius γ of the geographic area for target with a specific view angle α for a satellite to image a target.

$$\gamma = \frac{\pi}{2} - \cos^{-1}\left[\sin\frac{r_e+h}{r_e}\right] - \alpha \qquad (1)$$

Where h is the satellite altitude and r_e is the radius of the earth. Figure 2 is an achievement of the revisit time prediction via the locations and satellites. This study calculates the next revisit time and the distance from current satellite position. Users will know the date of revisit same site through analysis of satellite revisit rate and it helps obtain resources of satellite images. Once the satellite access time was decided, the system will give the forecasting cloud percentage for the AOI.



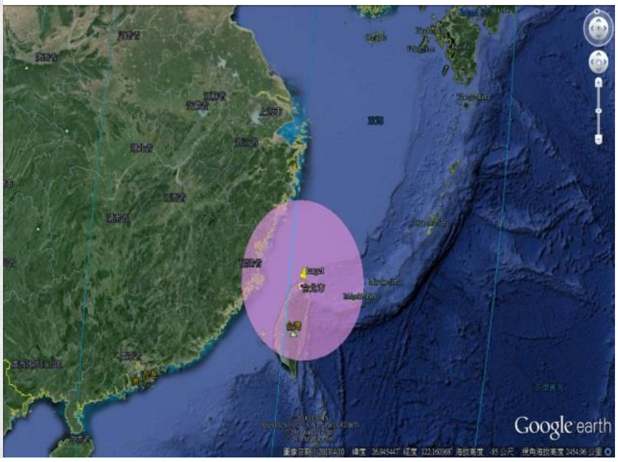


Figure 2 Time of Arrival for Satellite **Figure3 elevation mask of target**

2.3 Satellite forecasting coverage and acquisition footprint

The satellite instrument is able to scan not only through the nadir but also perpendicular to the satellite's motion. The swath of cross-track scanners is the potential zone which satellite has ability to acquire the data. To analyze the global coverage, the swath from adjacent pass has to be taken into consideration. The swath width is related to the viewing zenith angle, radius of earth and attitude of orbit. The higher the orbit the bigger the coverage area and the width it is given by

$$\mathrm{w} = 2\left\{\varepsilon - \sin^{-1}\left[\left(\frac{r}{r_e}\right)\sin\varepsilon\right]\right\} \qquad (2)$$

where ϵ is the zenith viewing angle, r_e is radius of earth and r is the attitude of satellite as show in the figure 5(kidder *et al.* 2004). The system enables the user to request to display the swath of every single daytime pass for different instrument.

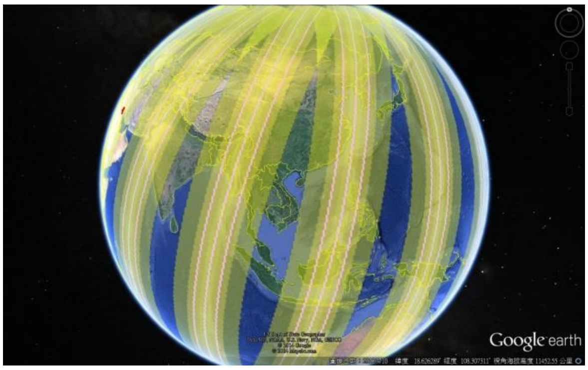


Figure 4 Potential Satellite Instrument Coverage

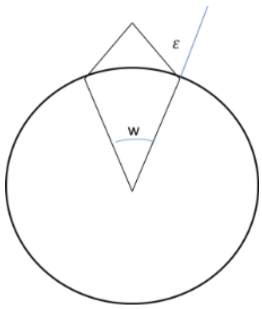


Figure5 Satellite Viewing Geometry

3. System architecture

3.1 Achievement of dynamic satellite simulation in three-dimension

To make the tasking of satellite images close to the needs of the user senses, this study intends to shows satellite tasking situations from two-dimensional to three-dimensional dynamic simulation in 3-D platform. Google earth has been used as user-friendly graphical interface to pinpoint geo-reference truck locations (SUN et al 2009). In order to dynamic satellite tasking simulation in three dimensions, the information needed to contain each time point, satellites location, rotation angle, orbital position and ground position. This study processes three-dimensional models manipulating simulation with Google Earth three-dimensional model API because the Google Earth API supports COLLADA format and import three-dimensional models into Google Earth platform. In addition, the dynamic tasking simulation is used with Javascript to control object movement, rotation and enlargement. Based on orbit and the range of simulated image information, this study adopts Google Earth three-dimensional model API and Javascript technologies to achieve displaying dynamic satellite simulation with a three-dimension. The application is used with these technologies and information to implement displaying dynamic satellite tasking simulation in three-dimensional. It shows satellite flight and tasking with three-dimensional dynamic way to deal with scheduling and users can understand more about the process of satellite tasking. However, in practical satellite operation, there are several constraint has to be consideration such satellite maneuver time, duty cycle which is related to the design of satellite. The system is lack of those constraint rules, the animation may not be achieved.

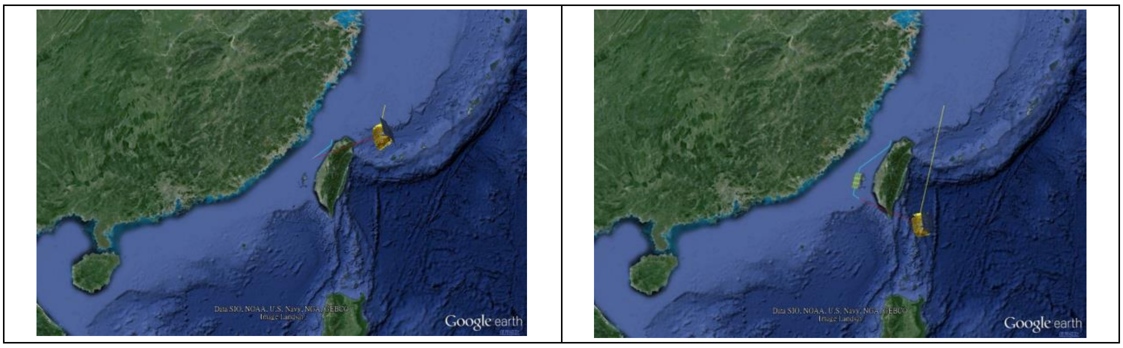


Figure 6　Satellite tasking simulation in three-dimensional dynamic display

3.2　The architecture of Notification server

For the sake of improving service efficiency, the notification mechanism has been developed including the notification of progress, the status and the results etc. If it can be established a single notification mechanism to meet all the needs of information notifications, it simplifies the structure and improves efficiency of maintenance.

This system intends to establish the Notification Server, as unified notifications of each SPS Server as shown in Figure 7. When a task has been completed, the notification server adopts the Series No. as Primary Key to notify the end user and update the status in MSOS (interface platform) including the task number, the coverage of images, Notification Server url and so on. Through the establishment of this framework, this study improves the efficiency of information collection for end user and MSOS.

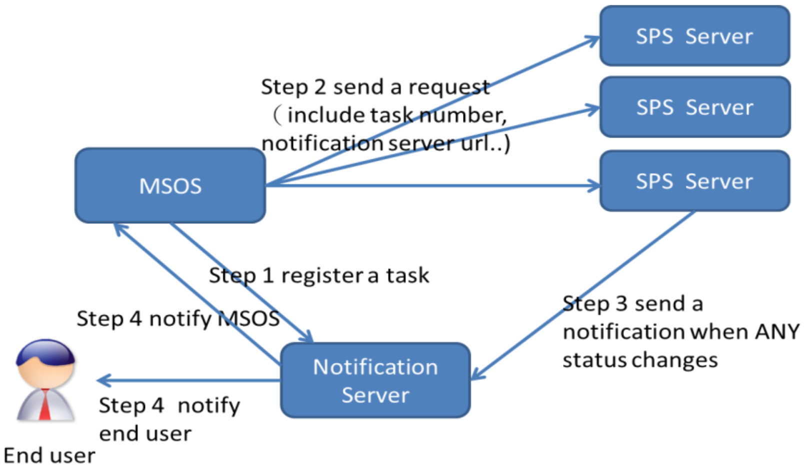


Figure 7 Notification server frameworks

3.3 OGC Standard Interface

The framework of multi-satellite operation is in charge of communicating between system and satellite order management system. The communication protocol is use the OGC® Sensor Planning Service (SPS) standards which make it easy to request imaging tasking to different satellite and receiving the processing status. The protocol is including the parameters of satellite tasking, status of mission plan and its acquisition result. The information is defined in the tag of SPS xml file format. Each satellite operation is able to extract the information, operate the tasking, and feedback the status in the same way.

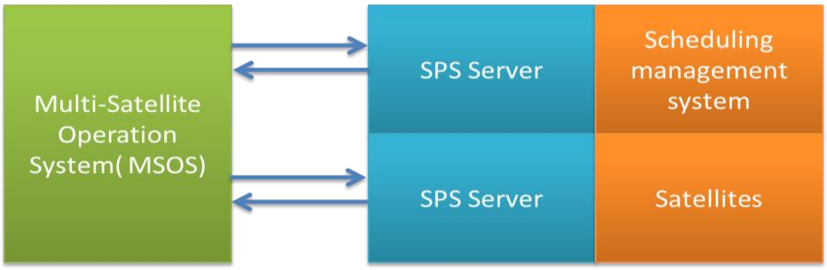


Figure 8 Multi-satellite operation framework

The framework is show as in the figure 8. The SPS server is responsible for interpret the information instead of telephone call and emails between user and satellite operation. The result also responds to the platform through the server.

Conclusion

Formosa SPS is a web-based system that utilizes the Google Earth to display area of interest, satellite position and sensor coverage area. The satellite available in the system was form a “virtual constellation”. It enables the user to select the timely and proper data regardless the practical satellite operations, the system provide the environment to allow different user share the same visualized data and as if they collaborated in the same platform. It helps to build social networks connecting users, satellites, and algorithms to establish an internationally coordinated operational framework and efficient exchange of information that facilitates interoperability. The system function and mechanism intend to fulfill international cooperation.

REFERENCE

Adam Keith, 2014. European Association of Remote Sensing Companies Newsletter, http://www.eomag.eu/articles

F. Hoots and R. Roehrich, 1988. Models for Propagation of NORAD Element Sets.

F-T Hwang, Y.Y Yeh and S-Y Li, 2010. Multi-Objective Optimization for Multi-Satellite Scheduling System, ACRS 2010

Kidder, S. Q., and T. H. Vonder Haar, 2004: A satellite constellation to observe the spectral radiance shell of earth. 13th Conference on Satellite Meteorology and Oceanography, Norfolk, Virginia, 20-23 Sept.

OpenGIS® Sensor Planning Service Application Profile for EO Sensors,
from http://www.opengeospatial.org/standards/sps

SUN En-ji, NIETO Antonio, 2009. Zigbee/Google Earth based assisted driving system in mining, Mining Science and Technology, Volume 19, Issue 5, September 2009, Pages 626–630.