CAN LAY USERS DIRECTLY UTILIZE SATELLITE-IMAGE INFORMATION IN THE NEAR FUTURE?

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ISPRS FIEOS Special Session, Commission I

KEY WORDS: Users, Satellite, Image, Information, Future, and Intelligence

ABSTRACT:

Why are today's TV users able to receive different programs in their homes using different channels with a remote control? Why have lay users of satellite images not been able to receive satellite information directly for their applications until today? What is the future of earth observing satellite systems? These questions make us contemplate whether or not future Earth observing satellite systems can become so intelligent, that a lay user can directly receive the satellite image information that they specify for their applications. We believe that the Earth observation satellite has passed the threshold of maturity as a commercial space activity, and the next generation of satellites will be highly intelligent. This paper reviews the development of Earth observing satellites, and presents a vision of future intelligent systems. This system is a space-based configuration for the dynamic and comprehensive on-board integration of earth observing sensors, data processors and communication systems. It will enable simultaneous, global measurement and timely analysis of the Earth's environment in real-time by mobile, professional, and lay users for meeting their demands, which have migrated from basic imagery to temporal, site specific, update image-based information. Data and information revisions will be requested more frequently, that is, analogous in many ways to today's weather updates. Lay users may soon be able to directly access data in a manner similar to selecting a TV channel.

1. INTRODUCTION

We believe that the Earth observation satellite has passed the threshold of maturity as a commercial space activity after the satellite family experienced significant development in technologies and applications during the past decades of year. The current generation of satellite development is of high-resolution, multi-/hyper-spectral satellite systems, which are being marketed and widely applied to a wide variety of Earth sciences (Zhou 2001). The development of the satellite can be roughly divided into the following periods: (Zhou and Baysal 2004)

- Early satellites era (early 1960's thru 1972)
- Experimentation and initial application of satellites (1972 thru 1986)
- Wide application of satellites (1986 thru 1997)\
- High-resolution satellites (1997 to "2010")

Zhou and Baysal (2004) concluded that there is a significant jump in the technology of earth observing satellites about every 13 years. Based on this cycle, it is estimated that the current generation of earth observing satellites will be replaced by another generation by the year 2010. This leads us to ask, "What will characterize the next generation of Earth observing satellites?, and "What is the NEXT next generation of Earth observing satellites beyond 2010?"

An interesting answer may be one that is constructed by asking, "Why do today's TV users receive different programs using different channels with a remote control at home?" "Why can cell phone users directly communicate with each other in real-time?" "Why does a lay user of satellite images not receive the satellite information directly for their applications until today?" These questions make us contemplate whether future Earth observing satellite system can become so intelligent that a lay user can directly receive the satellite image information that they specify for their applications in a manner similar to selecting a TV channel using a remote control. To this end, will future Earth observing satellite systems enable simultaneous global measurement and timely analysis of the Earth's environment in real-time, by mobile, professional, and lay users to meet their demands. Demands have migrated from basic imagery to temporal, site-specific, update image-based information. Will the data and information revisions be updated more frequently analogous in many ways to today's weather updates (Zhou and Baysal, 2004)?

This paper presents our vision for the architecture of the future intelligent earth observing satellite and part of its current progress.

2. MULTI-LAYER SATELLITE SYSTEMS

2.1 Simulation of Multi-layer Satellite Networks

We designed and simulated a two-layer satellite network called first intelligent earth-observing satellites (FIEOS). This satellite network, consisting of two layers, is enough to reach all functions required by users (Figure 1). In contrast, more than a two-layer satellite network will add the load of data communication of cross-links. Thus, FIEOS configuration is conceptually designed into a two-layer satellite network. The first layer, which consists of many earth-observing satellites (EOS) viewing the entire earth, is distributed in low orbits ranging from 300 km to beyond. Each EOS is small, lightweight and inexpensive relative to current satellites. These satellites are divided into groups called *satellite groups*. Each EOS is equipped with a different sensor for collection of different data and an on-board data processor that enables it to act autonomously, reacting to significant measurement events on and above the Earth. They collaboratively work together to conduct the range of functions currently performed by a few large satellites today. There is a lead satellite in each group, called *group-lead*; the other satellites are called *member-satellites*. The group-lead is responsible for management of the member-satellites and communication with other group-leaders in the network (constellation), in addition to communication with the geostationary satellites. This mode of operation is similar to an *intranet.* The group-lead looks like a local server, and the member-satellites look like the computer terminals. The local server (group-lead) is responsible for internet (external) communication in addition to management of the intranet (local) network. This design can reduce the communication load and ensure effectiveness of management and coverage of data collection.

The second layer is composed of geostationary satellites because not all EOSs are in view of or in communication with worldwide users. The second layer satellite network is responsible for communication with end-users (e.g., data downlink) and ground control stations, and ground data processing centers, in addition to further processing of data from group-lead satellites.

All of the satellites are networked together into an organic measurement system with high-speed optical and radio frequency links. User requests are routed to specific instruments maximizing the transfer of data to archive facilities on the ground and on the satellite (Prescott *et al.*, 1999). Thus, all group-leads must establish and maintain a high-speed data cross-link with one another in addition to uplink with one or more geostationary satellites, which in turn maintain high-speed data cross-links and down-links with end users and ground control stations and processing centers.

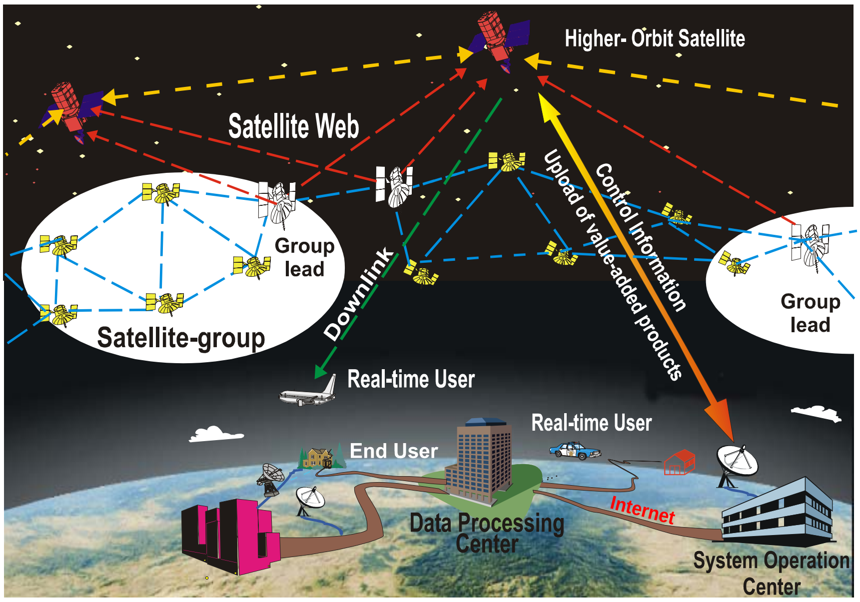

Figure 1. The architecture of a future intelligent earth observing satellite (FIEOS) system.

2.2 Performance of Satellite Network

The normal operating procedure is for each EOS to independently collect, analyze and interpret data using its own sensors and on-board processors. These collected data will *not* be transmitted to ground users, the ground station, or geostationary satellites unless they detect changed data after the data reprocessing is carried out onboard. If scientific users want raw data, they can directly uplink their command for downlinking the raw data. When an EOS detects an event, e.g., a forest fire, the sensing-satellite rotates its sensing system into position and alters its coverage area via adjusting its system parameters in order to bring the event into focus (Schoeberl *et al.*, 2001). Meanwhile, the sensing-satellite informs member-satellites in its group via cross-links, and the member-satellites autonomously adjust the attitudes of their sensors to acquire the event. The different sensors of a satellite group are located in different height, different position and with different spectral coverage, resulting in a multi-angle, -sensor, -resolution and -spectral observation and analysis of the event. These data sets are merged to a geostationary satellite that assigns priority levels according to the changes detected. Following a progressive data compression, the data is then available for transmission to other geostationaries. The links between the geostationary satellites provide the worldwide real-time capability of the system. Meanwhile, the geostationary further processes the data to develop other products, e.g., predictions of fire extend after 5 days, weather influence on a fire, pollution caused by a fire, etc. These value-added products are then also transmitted to users.

If the geostationary cannot analyze and interpret the directly collected data, the "raw" data will be transmitted to the ground data processing center (GDPC). GDPC will interpret these data according to user's needs, and then upload the processed data back to the geostationary satellites. In the satellite network, all satellites can be independently controlled by either direct command from a user on the ground, or autonomously by the integrated satellite-network system itself.

The satellite transmits the image in an order of priority, where the more important parts of the data transmitted first. For example, the multi-spectral imagery of a forest fire may have higher priority than the panchromatic imagery. Panchromatic imagery for 3D mapping of a landslide may have priority over the multispectral imagery. Of course, the autonomous operation of the sensors, processors and prioritization algorithms can be subject to override by system controllers or authorized users.

The FIEOS will perform much of the event detection and response processing that is presently performed by ground-based systems, through the use of high performance processing architectures and reconfigurable computing environments (Alkalai 2001, Armbruster et al. 2000, Bergmann et al. 2000). FIEOS will act autonomously in controlling instruments and spacecraft, while also responding to the commands of the user interested to measure specific events or features. So, users can select instrument parameters on demand and control on-board algorithms to preprocess the data for information extraction.

Various Users		Illustration
Mobile user	A real-time user, e.g., a mobile GIS user, requires a real-time downlink for geo-referenced satellite imagery with a portable receiver, small antenna and laptop computer.	
Real-time user	A mobile user, e.g., a search-and-rescue pilot, requires a real-time downlink for geo-referenced panchromatic or multispectral imagery in a helicopter.	
Lay user	A lay user, e.g., a farmer, requires geo-referenced, multispectral imagery at a frequency of 1-3 days for investigation of his harvest.	
Professional user	A professional user, e.g., a mineralogist, requires hyperspectral imagery for distinguishing different minerals.	
Professional user	A topographic cartographer, e.g., a photogrammetrist requires panchromatic images for stereo mapping.	

Figure 2. Examples of future direct end-users in the land surface remote sensing (images are courtesy of other authors available on the web).

The design concept for FIEOS is flexible because any additional satellites can easily be inserted without risk to the infrastructure, and the instruments and platforms are organically tied together with network information technology. A two-layer satellite network insures that global data is collected on a frequency of decade minutes base or shorter; event-driven data are collected with multi-angle, multi-resolution, multi-bands, and users can acquire images of any part of the globe in real-time. This design concept provides a plug-and-play approach to the development of new sensors, measurement platforms and information systems, permitting smaller, lighter, standardized satellites with independent functions to be designed for shorter operational lifetimes than today's large systems so that the instrument technology in space can be kept closer to the state-of-the-art.

2.3 End-user operation

End users expect directly down-linked satellite data (in fact, the concept of data means image-based information, rather than traditional remotely sensed data) using their own receiving equipment. All receivers are capable of uploading the user's command, and mobile and portable receivers have GPS receivers installed, i.e., mobile user's position in geodetic coordinate system can be real-time determined and uploaded to satellite systems. The on-board data distributor will retrieve an image (scene) from its database according to the user's position (Figure 2).

In this fashion, an ordinary user on the street is able to use a portable wireless device to downlink/access the image map of the surroundings from a satellite system or from the Internet. Homes in the future are also able to obtain atmospheric data from the satellite network for monitoring their own environments. The operation appears to the end-users as simple and easy as selecting a TV channel by using a remote control (Figure 3). The intelligent satellite system will enable people not only to see their environment, but also to "shape" their physical surroundings.

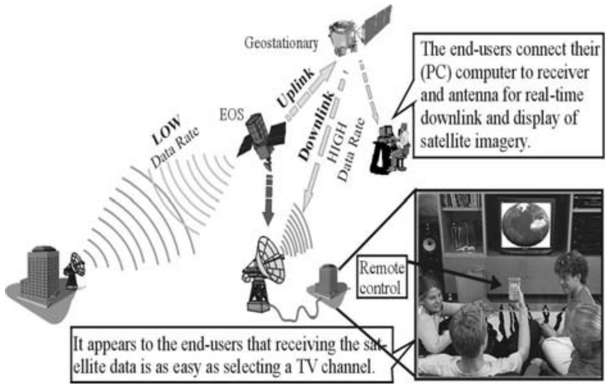

Figure 3. End-user operation akin to selecting a TV channel.

3. STATUS OF PROGRESS AT ODU

Realization of such a technologically complex system will require the contributions of scientists and engineers from many disciplines. In the present paper, we report our progress on two topics: (1) Relative and absolute navigation of formation flying of satellites, and (2) On-board "GCP" identification based on GIS data.

3.1 Simultaneous Determination of R/A Position and Attitude of Multi-satellites

The simultaneous determination of R/A and attitude of multi-satellites is based on the photogrammetry collinearity as follows:

$$x_g^c - x_o^c = -f\frac{r_{11}(X_G^M - X_E^M) + r_{12}(Y_G^M - Y_E^M) + r_{13}(Z_G^M - Z_E^M)}{r_{31}(X_G^M - X_E^M) + r_{32}(Y_G^M - Y_E^M) + r_{33}(Z_G^M - Z_E^M)}$$

$$y_g^c - y_o^c = -f\frac{r_{21}(X_G^M - X_E^M) + r_{22}(Y_G^M - Y_E^M) + r_{23}(Z_G^M - Z_E^M)}{r_{31}(X_G^M - X_E^M) + r_{32}(Y_G^M - Y_E^M) + r_{33}(Z_G^M - Z_E^M)} \qquad (1)$$

where $r_{i,j}\,(i=1,2,3;\ j=1,2,3)$ are elements of the orientation matrix R_c^M, which includes the direction cosines of 3 rotation angles, ω, φ and κ. G denotes the geodetic coordinate of ground points, and E denotes the geodetic coordinates of exposure stations. It should be mentioned that Eq. 1 is based on a frame sensor. If the onboard camera is a linear sensor, Eq. 1 can be modified accordingly. The detailed description can be found in Zhou *et al.* (2000). With Eq. 1, we can simultaneously determine the six absolute DOF and six relative DOF separately.

3.1.1 Simultaneous Determination of Six Absolute DOF

Equation 1 is traditionally used to determine absolute position and attitude of a single sensor/satellite, if the appropriate calibration (sensor interior elements, offset between GPS antenna and exposure center) is finished. If we connect many overlapping single images/satellites into a block, and extend Eq. 1 for a block situation, we can simultaneously compute the instantaneous absolute position and attitude (absolute 6 DOF) of all satellites from a number of GPS-based navigation data and a number of tie points (conjugate points), which connect adjacent images. The basic principle of this technique is to tie overlapping images together without the need for ground control points (GCPs) in each image stereo-model. The input to the aerial model includes measured image coordinates of tie points that appear in as many images as possible and the GPS-based navigation data (or ground coordinates of GCPs). The system outputs the absolute position and attitude (absolute 6 DOF) of all the satellites (imaging sensor) as well as the ground coordinates of the tie points. Theoretically, this computational model can link several hundred satellites (imaging sensors) together.

The satellite absolute state includes the position, attitude, and velocity, which are expressed in the ground-frame. All calculations and integration are also performed in the ground-frame. Support that the ground point G_1 and G_2 are imaged into g_1^1, g_1^2 and g_1^4 as well as g_2^1, g_2^2 and g_2^4 in the image plane 1, 2, and 4 are acquired by the satellites 1, 2, and 4, respectively. Also support that the absolute position and attitudes for the satellite 1 and 4 are provided by GPS-based navigation system. (We also assume that the calibration between the EO sensor exposure center and the GPS antenna are implemented.) The absolute position and attitude (6 DOF) of satellite 2 (and all satellites) can be determined as follows:

For G_1 in satellite 1:

$$\begin{aligned} v_{g_1^1}^{x1} &= a_{17}^1 dX_{G_1}^T + a_{18}^1 dY_{G_1}^T + a_{19}^1 dZ_{G_1}^T - l_{G_1}^{x1} \\ v_{g_1^1}^{y1} &= a_{27}^1 dX_{G_1}^T + a_{28}^1 dY_{G_1}^T + a_{29}^1 dZ_{G_1}^T - l_{G_1}^{y1} \end{aligned} \qquad (2)$$

For G_1 in satellite 2:

$$\begin{aligned} v_{g_1^2}^{x2} &= a_{11}^2 dX_E^2 + a_{12}^2 dY_E^2 + a_{13}^2 dZ_E^2 + a_{14}^2 d\omega_E^2 + a_{15}^2 d\varphi_E^2 + a_{16}^2 d\kappa_E^2 + a_{17}^2 dX_{G_1}^T + a_{18}^2 dY_{G_1}^T + a_{19}^2 dZ_{G_1}^T - l_{G_1}^{x2} \\ v_{g_1^2}^{y2} &= a_{21}^2 dX_E^2 + a_{22}^2 dY_E^2 + a_{23}^2 dZ_E^2 + a_{24}^2 d\omega_E^2 + a_{25}^2 d\varphi_E^2 + a_{26}^2 d\kappa_E^2 + a_{27}^2 dX_{G_1}^T + a_{28}^2 dY_{G_1}^T + a_{19}^2 dZ_{G_1}^T - l_{G_1}^{y2} \end{aligned} \qquad (3)$$

For G_1 in satellite 4:

$$\begin{aligned} v_{g_1^4}^{x4} &= a_{17}^4 dX_{G_1}^T + a_{18}^4 dY_{G_1}^T + a_{19}^4 dZ_{G_1}^T - l_{G_1}^{x4} \\ v_{g_1^4}^{y4} &= a_{27}^4 dX_{G_1}^T + a_{28}^4 dY_{G_1}^T + a_{29}^4 dZ_{G_1}^T - l_{G_1}^{y4} \end{aligned} \qquad (4)$$

For point G_1, we have obtained 6 observation equations, 9 unknowns (6 absolute navigation elements, 1 tie point ground coordinates). Similarly, for point G_2, we can obtain the 6 observation equations. In total, we have 12 observation equations, containing 12 unknowns (6 absolute DOF, 2 tie point coordinates). Combining these observation equations, we can solve the 6 absolute position and attitude of the satellite 2 through least square method. This principle demonstrates that absolute navigation parameters (absolute 6 DOF) of multi-satellites can simultaneously be determined, resulting in high and symmetric accuracy and high-reliability of multi-satellites. Moreover, not all satellites in the formation flying are required to mount a GPS receiver.

3.1.2 Simultaneous Determination of Six Relative DOF

The relative states between the satellites are of much greater interest for formation flying. The goal of the relative navigation is to estimate the relative state of the formation, i.e., where the satellites are located with respect to each other. To this end, a specific GPS antenna on one of the satellites is typically selected as a formation reference point. The satellite associated with this reference point will be referred to as the "master" or "reference" satellite, with the rest called "followers". For relative state estimation, the selection of the reference is arbitrary (it can be any satellite in the formation).

The determination of relative state (position and orientation) can be conducted by coplanarity condition. For example, suppose that there is a ground point *G*, the imaged points in the "master" image plane acquired by the "master" satellite (satellite 1 in Figure 1) and the second image plane acquired by the follower (satellite 2 in Figure 1) is g_1 and g_2. The coplanarity states that the "master" and "follower" exposure stations (E_1 and E_2), the object point (G), and the "master" and "follower" imaged points (g_1 and g_2), all lie in a common plane. The mathematical model of coplanarity in an established auxiliary coordinate system, E_1-UVW is given by,

$$F = \overrightarrow{E_1E_2} \times (\overrightarrow{E_1g_1} \cdot \overrightarrow{E_1g_2}) = \begin{bmatrix} B & 0 & 0 \\ X_{g_1} & Y_{g_1} & Z_{g_1} \\ X_{g_2} & Y_{g_2} & Z_{g_2} \end{bmatrix} = \begin{bmatrix} Y_{g_1} & Z_{g_1} \\ Y_{g_2} & Z_{g_2} \end{bmatrix} = 0$$

where
$$\begin{bmatrix} X_{g_1} \\ Y_{g_1} \\ Z_{g_1} \end{bmatrix} = R_{g_1}^{E_1} \begin{bmatrix} x_{g_1} \\ y_{g_1} \\ -f_1 \end{bmatrix}, \qquad \begin{bmatrix} X_{g_2} \\ Y_{g_2} \\ Z_{g_2} \end{bmatrix} = R_{g_2}^{E_1} \begin{bmatrix} x_{g_2} \\ y_{g_2} \\ -f_2 \end{bmatrix} \qquad (5)$$

Moreover, $R_{g_1}^{E_1}$ and $R_{g_2}^{E_1}$ are functions of the direction cosines of the three rotation angles, $(\omega_{g_1}^{E_1}, \varphi_{g_1}^{E_1}, k_{g_1}^{E_1})$ in the "master" image, and $(\omega_{g_2}^{E_1}, \varphi_{g_2}^{E_1}, k_{g_2}^{E_1})$ in the "follower" satellite.

Because the three rotation angles in the "follower" satellite are the rotation from the "follower" image space to auxiliary coordinate system space, thus the relative orientation of the "follower" satellite to the "master" satellite is $(\omega_{g_2}^{E_1}, \varphi_{g_2}^{E_1}, k_{g_2}^{E_1})$. The relative position of two satellites can be determined by exposure center coordinates of two satellites, which have been described in Section 3.1.1. The final basic formation relative state is given by the following:

Relative position $[B_1, \Delta B_{12}, \Delta B_{12}, \bullet\bullet\bullet\bullet, \Delta B_{16}]$, and relative orientation

$$\begin{bmatrix} \omega_1, & \Delta\omega_{i,j}, & i = 1-5;\ j = 1-6 \\ \varphi_1, & \Delta\varphi_{i,j}, & i = 1-5;\ j = 1-6 \\ \kappa_1, & \Delta\kappa_{i,j}, & i = 1-5;\ j = 1-6 \end{bmatrix}.$$

We have experimented the simultaneous determination of six absolute DOF and six relative DOF when satellites are various flying heights, in-track overlap, cross-track overlap and analyzed the influences factors to accuracy and reliability of absolute and relative navigations.

3.2 Onboard "GCP" Recognition Based on GIS Data

Formation fly of a satellite cluster requires the high accuracy determination of relative position and absolute position and attitude. Because of the low accuracy and reliability of navigation information by navigation sensor (Alonso *et al*. 1998, Gill *et al*. 2001), a few GCPs are necessary for highly accurate and reliable geocoding. An algorithm, which recognizes GCPs onboard via the support of a geo-database (GIS database), is now investigated. The steps in this algorithm will be presented next.

3.2.1 Landmark Vector Data(base) Management System

It is impossible to provide traditional photogrammetric target points at real-time during most satellite observing missions. We propose to use natural landmarks (e.g., a crossroad center) to replace the traditional GCPs; and we denote these *landmark GCPs* by LGCPs. They are stored on the onboard computer (Figure 2). The creation of an LGCP database includes landmark selection, data structure/model for 3D coordinates storage, reference frame datum (e.g., WGS84), and datum transformation, fast query and retrieval algorithms. These algorithms and methods on ground have been implemented before and the details can be found in Zhou and Jezek (2000).

3.2.2 Identification of LGCPs using Optical Correlator

For onboard geocoding of remotely sensed satellite images, image coordinates corresponding to LGCPs must be known. The LGCPs stored in the onboard computer can be retrieved at real-time; thus, the core task is to precisely determine the pixel coordinate of corresponding LGCPs from onboard sensor images. The basic steps are: (1) create a template image of the LGCP from LGCP database; (2) determine the AOI (area of interest) in the sensor imagery via back-projection; and (3) match the template image and the sensor image via JTC for pixel coordinate determination of the LGCPs. Next, these steps will be described in more detail.

a. Creation of Template Image of LGCPs (Figure 4): The creation of a template image for LGCP is to convert landmark vector data into raster image data form. The gray values of vector landmark data in template images are assigned 255, and the background is assigned 0. The size of template mainly depends up the texture content around the landmark, navigation errors, and image GSD (ground sample distance). In our study, when the size of template is typically 50X50 pixels^2 to 100X100 pixels^2; GSD=1m, then the error of orbital position is 3~6 meters and the error of sensor attitude is 0.002 degree.

b. Area of Interest (AOI) Determination (Figure 4): In order to increase matching speed, we can narrow the search space of the match processing. By the "coarse" EOPs (position and attitude) provided by onboard navigation sensors and priori calibrated IO parameters, we can back-project 3D coordinates of *LGCPs* into the sensor image plane via Eq.1 for the approximate location of landmark. Based on this approximate location, we can design an area of interest (AOI) in the sensor imagery. The size of AOI mainly depends upon the GSD, navigation error (other errors, e.g., atmospheric refraction, lens distortion, etc., are relatively less). A larger AOI increases the load of computation, and a smaller AOI cannot ensure sufficient search space. In fact, the prior EOPs and all distortions of the imaging system can be used to predict the search range. In our study, the AOI is determined using 200 by 200 pixels^2, because the offset between the ideal and actual positions of the same feature is about 18 m (about 18 pixels due to 1-m GSD), when the position and attitude error of the sensor are 3~6 m and 0.002°, respectively. Whatever the Earth observing satellite's specification is, the size of AOI should be ensured to provide sufficient search space for matching processing.

c. Landmark Match using Optical Correlator: We will use Joint Transform Correlator (JTC) to realize the matching between the landmarks stored in the landmark database and the same landmarks in the sensor imagery, because the processing rate of the JTC can reach 300 pts/s (Janschek *et al.* 1999, 2000). Moreover, the JTC can also work under some scale and perspective distortions between compared images. The matching procedure, when the JTC consists of one processor, is briefly described with the following steps.

(1) During one cycle of matching, a temple image and an AOI image (the current image) from the sensor imagery are simultaneously entered into the optical system of the Optical Fourier processor (*OFP*) by a spatial light modulator (SLM).
(2) In the focal plane of the lens, the image of the Joint Power Fourier Spectrum (JPS), which is detected by a square-law image sensor (usually CCD) and entered into the same SLM during read out of the CCD, is formed. Then, in the focal plane, the image of the correlation function is formed with two symmetric bright points - correlation peaks - if that current image contains even a part of the temple image. The position of the peak corresponds to the mutual shift of the current and temple images. The correlation image is processed by the digital processing unit (DPU) in order to detect the correlation peaks and calculate their position.

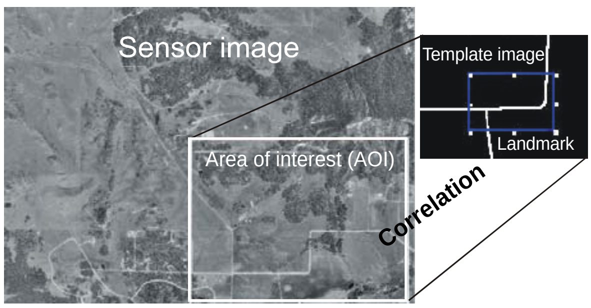

Figure 4. LGCPs and correlation algorithm via JTC.

3.2.3 Onboard Geocoding

After the image orientation parameters are determined via the algorithms/methods that we have discussed so far, the geocoding of each satellite image scene still will consist of the following steps: (1) determination of the size of the geocoded image; (2) transformation of pixel locations from the original image to the resulting (geocoded) image; and (3) resampling of the original image pixels into the geocoded image for assignment of gray values. The whole processing procedure of geocoding of satellite images contains from the determination of the sensor's exterior orientation parameters to the transformation of the original imagery to the geocoded product. The software and algorithms of geocoding, except onboard EOP determination, have been developed by Zhou (2002). The future investigation of this proposed project will be migrating these algorithms to onboard satellite platform with special consideration of the onboard processing environments, e.g., limited storage space and power.

4. CONCLUDING REMARKS

The present paper provides the concept design and the architecture of a future intelligent earth observing satellite (FIEOS) system. The proposed system is a space-based architecture for the dynamic and comprehensive on-board integration of Earth observing sensors, data processors and communication systems. The architecture and implementation strategies suggest a seamless integration of diverse components into a smart, adaptable and robust Earth observation satellite system. It is intended to enable simultaneous global measurements and timely analyses of the Earth's environment for a variety of users. Common users would directly access data in a manner similar to selecting a TV channel. The imagery viewed would most likely be obtained directly from the satellite system.

To this end, real-time information systems are key to solving the challenges associated with this architecture. Realization of such a technologically complex system will require the contributions of scientists and engineers from many disciplines. Hopefully, this revolutionary concept will dramatically impact how earth observing satellite technology develop and conduct missions in the future.

Since the spatial information sciences are maturing, it is time to 'simplify' our technologies, so that more users can directly obtain information from satellites. The future is promising for the photogrammetry/remote sensing/GIS communities. A thorough feasibility study addressing the key technologies of each of the components, the necessity, possibilities, benefits and issues, and exploration of specific funding opportunities for implementation will be performed in Phase II of our investigation.

ACKNOWLEDGMENTS

This project was partially funded by the NASA Institute of Advanced Concepts (NIAC), under contract number NAS5-98051. We would like to thank all those people who were kind enough to discuss a number of topics that were crucial to complete this work. We are grateful to those satellite development scientists who have provided us with helpful advice, encouragement and relevant materials.

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