Satellite Ground Track Display on a Digitized World Map for the KOMPSAT-2 Mission Operations

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Abstract: Satellite ground track display computer program is designed and implemented for the KOMPSAT-2 mission operations. Digitized world map and detailed Korean map is realized with zoom and pan capability. The program supports real-time ground trace and off-line satellite image planning on the world map. Satellite mission timeline is also displayed with the satellite ground track for the visualized mission operations. In this paper, the satellite ground track display is described in the aspect of the functional requirements, design, and implementation.

Keywords: Satellite, Ground Track, Mission Operations, Digitized World Map

1. INTRODUCTION

Intensive human workload and comprehensive supporting hardware and software system are required to the satellite mission operations. The satellite mission operations system is designed to meet the functions including the antenna tracking of the satellite, telemetry reception and processing, command generation and transmission, mission planning and scheduling, spacecraft simulations and analysis, and flight dynamics support. Human-machine interface consideration is the most important aspect in the modern satellite mission operations system.

The KOrea Multi-Purpose SATellite-2 (KOMPSAT-2) will be launched in 2005 for high-resolution imaging of the Korean peninsula. The satellite mission is focused on the high resolution Earth imaging by 1 m in panchromatic scene and 4 m in multi-spectral scene while the KOMPSAT-1 has 6.6 m panchromatic scene[1]. The mission orbit is the same as that of KOMPSAT-1 except for phasing of the orbital position. This implies that two satellites can be separated in terms of time in the same orbit[2,3].

The satellite ground operation system is composed of two functional elements such as the Mission Control Element (MCE) and Image Reception and Processing Element (IRPE). MCE is responsible for the satellite mission operations such as telemetry monitoring, command transmission, orbit determination, and command validations. IRPE is responsible for receiving and processing of the image data. MCE communicates with the satellite upward and downward via S-band while IRPE only receives the X-band data. MCE is made up of four subsystems such as the Tracking, Telemetry, and Command subsystem (TTC), the Satellite Operations Subsystem (SOS), Mission Analysis and Planning Subsystem (MAPS), and the satellite Simulator subsystem (SIM)[4].

The MAPS provides the satellite mission planning functions such as the satellite event prediction, mission scheduling, command planning, and ground track display[5, 6]. It also provides the satellite mission analysis functions such as the orbit determination, orbit prediction, orbit maneuver, fuel accounting, and antenna pointing data generation.

Satellite ground track is a series of the sub-satellite points in process of time. The real-time satellite ground track display on a computer screen or wallboard shows the satellite operators where the satellite is presently located on the world or regional map. Off-line ground track display is also useful for the satellite mission operations planning. For that reason, the majority of satellite operations control system is provided with the satellite ground track display in a different level of functionality.

In this paper, satellite Ground Track Display (GTD) for the KOMPSAT-2 mission operations is described in the aspect of the functional requirements, design, and implementation.

2. DESIGN OF THE GROUND TRACK DISPLAY

An Object Oriented Design (OOD) approach[7] is used for the process of system analysis and design. System analysis is composed of Use-Case Model and Domain Model. System design consists of User Interface Design and Architecture Design. Logical View, Implementation View, Process View, and Deployment View are the four views of the architecture design.

2.1 Functional Requirements

The satellite ground track display provides the capabilities of displaying the sub-satellite points on a world map in real-time mode for satellite mission operations or in off-line mode for satellite mission planning. The detailed functional requirements are as follows:

- Satellite ground tracks up to 10 satellite shall be displayed at the same time
- Eclipse region at the satellite altitude shall be displayed on the world map
- Satellite coverage to the ground shall be displayed on the world map
- Ground station coverage to the KOMPSAT altitude shall be displayed on the world map
- Digitized world map shall be used for zooming capability
- The world map shall be panning by the operator's control
- Longitude of the world map center shall be changed by the user input
- Satellite imaging track shall be displayed along with the ground track
- Satellite mission timeline shall be displayed along with the ground track

- Satellite attitude tilt angle shall be calculated in imaging target planning
- Location on the world map by searching the name of the place shall be provided
- Different kind of digitized world map shall be provided in a different level of details.

2.2 System Analysis

System analysis is performed to define the users and the related services of the ground track display. An Unified Modeling Language (UML) is used[8]. Domain modeling is performed using class diagram and interaction diagram. Class diagram shows a static structure and relationship of the classes in the system. Interaction diagram presents the messages between the objects in the time frame.

Figure 1 shows the class diagram of the ground track display. Satellite Ground Track Display (GTD) consists of two parts. One is the ground track display and the other is imaging plan. The operator selects the applicable ground track data files to display in real-time or off-line. The operator requests the ground track display to the Ground Track Manager and Ground Track Manager requests the display to the Display Manager. Display Manager requests the zooming or panning the world map to Zooming Manager and Panning Manager. Zooming Manager or Panning Manager zooms or pans the world map by requests. In the imaging plan mode, the operator draw an image area based on the displayed ground track and image plan calculates the required tilt angle. The required tilt angle is saved in the repository.

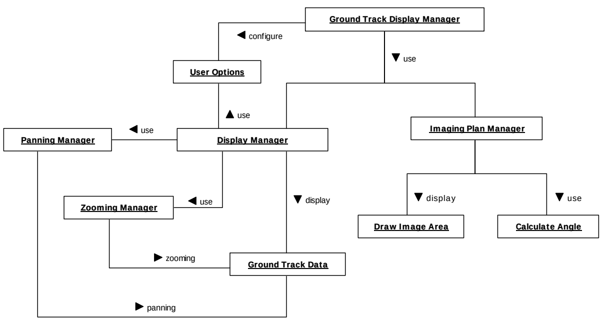

Fig. 1 Class diagram of the ground track display.

2.3 System Design

Four views of the ground track display such as logical view, process view, implementation view, and deployment view represent the architectural design. The logical view represents the end users functionality and supports the functional requirement of the system. The logical view of the MAPS describes all of the related packages in the system. Each package is composed of the related classes.

Logical View of the ground track display

In the logical point of view, the ground track display is composed of the four packages such as 'Mission Display', 'DrawX11', 'SHP Draw', and 'DXF Draw'. Mission Display package has the responsibility to display the imaging missions and manage the imaging plan files. DrawX11 package has the responsibility to provide the GDI interface from X11 window system, and draw the map, lines and curves in the map. SHP Draw package has the responsibility to read the SHP file and draw a map. DXF Draw package has the responsibility to load and display the DXF format map data file.

Table 1 shows the mapping of the objects in the domain model into the package in the logical view.

Table 1. Domain Objects to Logical Package Mapping of Mission Display

Domain Objects	Logical Package
Ground Track Display Manager, Ground Track Data, Display Manager, User Options, Imaging Plan Manager, Draw Image Area, Calculate Angle	Mission Display
Ground Track Display Manager, Ground Track Data, Display Manager, User Options, Zooming Manager, Panning Manager	DrawX11
Display Manager, User Options, Zooming Manager, Panning Manager	SHP Draw
Display Manager, User Options, Zooming Manager, Panning Manager	DXF Draw

Figure 2 shows the class diagram of the Mission Display package. Overall design is composed of the construction of the EocFile for managing the current reading and EocObj for storing the mission plan file.

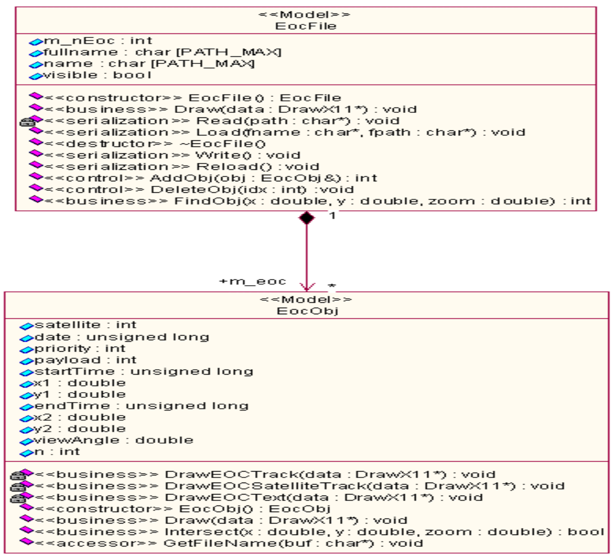

Fig. 2 Class design of mission display package.

Remaining View of the ground track display

Remaining three views, i.e. implementation view, process view, and deployment view are rather simple for the ground track display. Four logical packages in Table 1 are mapped into the four same implementation layers. And user interface package is applied to the graphical user interface layer. One process is used for the ground track display and the process is running in one computer hardware.

3. IMPLEMENTATION OF THE GROUND TRACK DISPLAY

The ground track display computer program was implemented in a HP-C3600 workstation on a HP-UX operating system. The program language of C++ was used.

The implementation of the digital map, ground track display, and image targeting will be described in this section.

3.1 Digital Map of the World

Digital map of the world is the most important part for the satellite ground track display. Base map of the world and the Korean peninsula was constructed. Two types of format such as the DXF format and SHP format were provided. The map for the Korean peninsula was scaled at least 1:1,000,000 and the rest of the world at most 1:1,000,000.

WGS84 reference system was used for the data vectoring. Each layer can be selectively displayed by the operator's choice. Selectable layers are coast border, national border, regional border, major cities, contour, islands, road, reservoir, lakes, river, sea, and longitude & latitude lattice.

Figure 3 shows the base map of the world. Three kinds of the world map were implemented with the inclusion of the different layers. The satellite operator can select one of three different kinds of the map for the details of display.

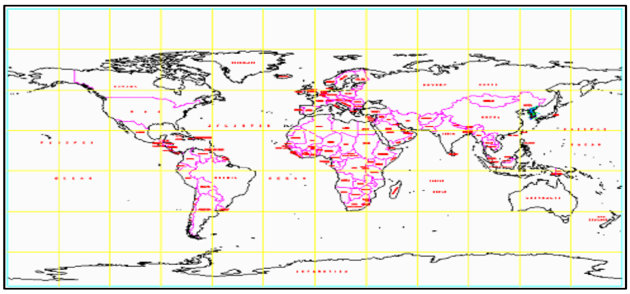

Fig. 3. Base map of the world (color inverted)

Figure 4 show the detailed map of the Korean peninsula. Layers used in the Korean map are administrative district boundaries and name of cities, express ways and local roads, reservoirs and rivers, and contours (altitude of 100m, 500m, 1,000m, and 2,000 m).

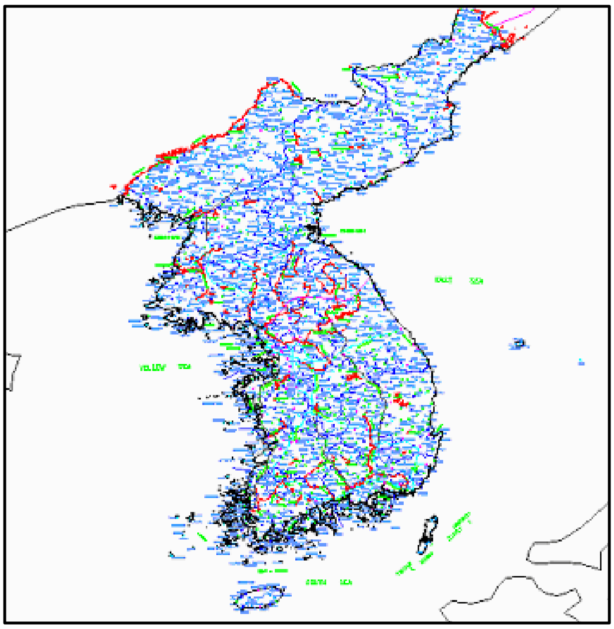

Fig. 4. Detailed map of the Korean peninsula (color inverted)

Figure 5 presents the Chung Cheong areas after zooming-in the Koran peninsula. Small cities, mountains, and roads are displayed in the map.

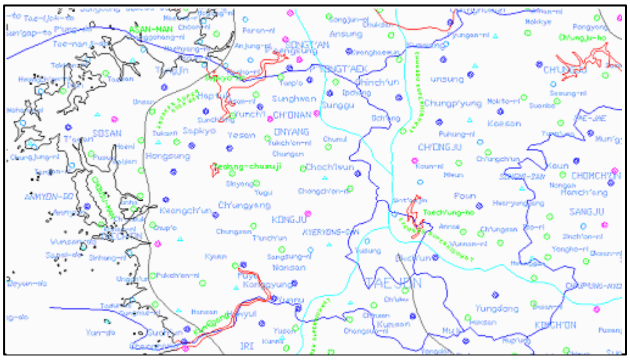

Fig. 5. Detailed map of Chung Cheong Area(color inverted)

3.2 Ground track display

Although up to 10 satellites can be displayed at the same time in the map, ground tracks of the two satellites, i.e. KOMPSAT-1 and KOMPSAT-2 will be displayed for the normal mission operations. Zoom in the Korean peninsula from the world map can be achieved by KOREA MAP button. The display can be saved as image file by SNAPSHOT button.

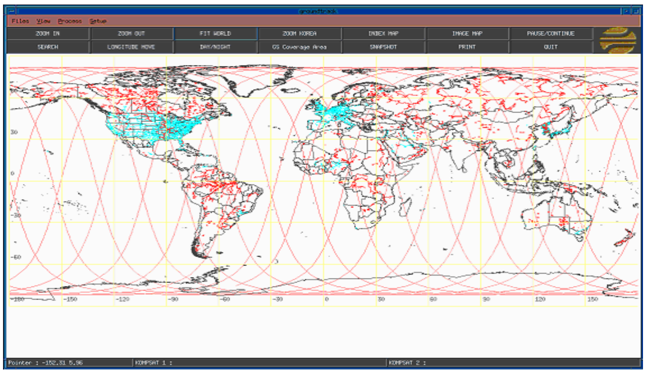

Fig. 6. Main windows of the satellite ground track display (color inverted)

3.3 Image target planning

In a normal operations, satellite camera operation plan for imaging is requested by the Image Reception and Processing Element (IRPE). However, independent satellite imaging plan can be accomplished in the ground track display program using the computer mouse and button operations. At that time, satellite tilt angle is calculated for targeting. Figure 7 shows the satellite ground track and imaging track. Figure 8 presents the detailed parameters for independent satellite imaging plan.

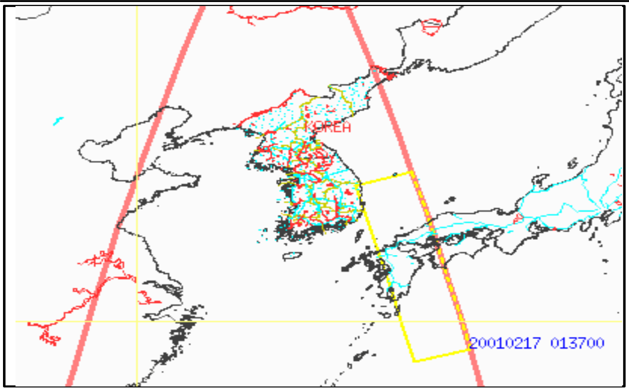

Fig. 7. Ground track and imaging track. Imaging start date and time are marked.

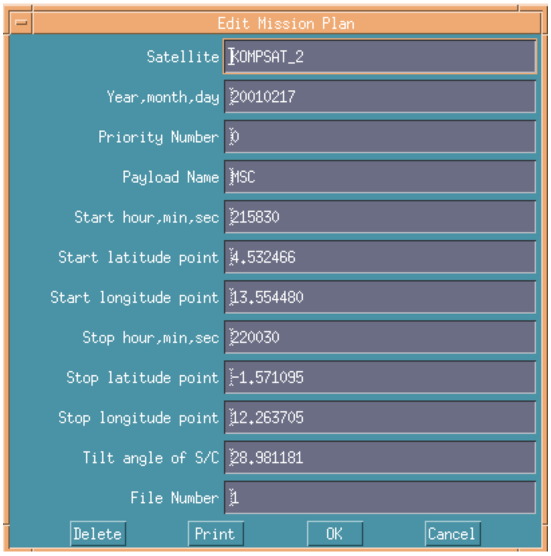

Fig. 8. Imaging plan parameters.

Satellite mission timeline is also marked in the ground track display for visualizing the satellite operations. Mission timeline includes the satellite imaging, playback telemetry dump, satellite image dump, and satellite ephemeris upload. Figure 9 shows the satellite ground track and mission timeline. Begin and end time of each mission is displayed.

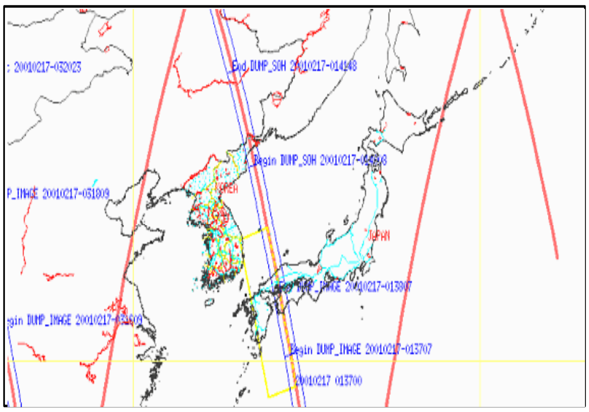

Fig. 9 Satellite mission timeline display.

4. CONCLUSIONS

The functional requirements, design, and implementation of the satellite ground track display have been explained. The object oriented analysis and design methodology were introduced in the development phases. For the independent satellite camera scheduling, the mission planning function for image targeting capability is also applied in the ground track display. The satellite operation schedule, i.e. mission timeline is marked in the satellite ground track for visualization. With various functional capabilities, the ground track display will be used as a vital tool in the KOMPSAT-2 satellite operations.

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