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3D DISPLAY OF SPACECRAFT DYNAMICS USING REAL TELEMETRY

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ABSTRACT

3D display of spacecraft motion by using telemetry data received from satellite in real-time is described. Telemetry data are converted to the appropriate form for 3-D display by the real-time preprocessor. Stored playback telemetry data also can be processed for the display. 3D display of spacecraft motion by using real telemetry data provides intuitive comprehension of spacecraft dynamics.

Keywords: 3D display, satellite motion, telemetry

1. INTRODUCTION

KOrean Multi-Purpose SATellite-1(KOMPSAT-1) had been launched in December 1999 and has been being operated normally by Mission Control Element(MCE), which was developed by Electronics and Telecommunications Research Institute(ETRI). KOMPSAT-1 MCE consists of TT&C, SOS(Satellite Operation Subsystem)(Mo et al. 2000), MAPS(Mission Analysis and Planning Subsystem)(Won et al. 1999), and SIM(SIMulator)(Choi et al. 2000). KOMPSAT-1 has been operated by using the MCE so far without any problem. Now, we are in implementation phase of MCE for KOMPSAT-2, which equipped Multi-Spectral Camera (1m panchromatic and 4m multi-band). For KOMPSAT-1 MCE SIM, we developed three-dimensional display of spacecraft motion by using simulation data for better comprehension of spacecraft dynamics and spatial motion of spacecraft. The motivation of this paper is some needs to display spacecraft motion using telemetry data in real-time for providing intuitive comprehension of spacecraft dynamics in real-time to operators and subsystem engineers during KOMPSAT-1 operation. In this paper, three-dimensional display of spacecraft motion using real telemetry data in real-time(emulated) and playback is presented.

2. KOMPSAT SIM

The KOMPSAT spacecraft simulator (SIM) is a comprehensive application software system to simulate the KOMPSAT and one of the four subsystems of the KOMPSAT mission control element (MCE) as shown in Fig. 1. Major functions of the SIM are as follows.

The main improved functions of KOMPSAT-2 EGSE are as followings:

- Validation of telecommand

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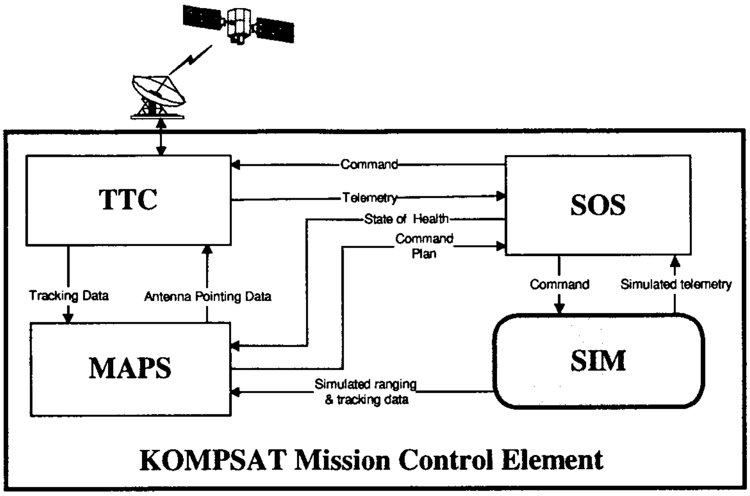

Figure 1. KOMPSAT Mission Control Element Schematics.

- Functional validation and operation check of the SOS
- Satellite operator training
- Anomaly analysis and simulation for resolution
- Functional validation of the on-board flight S/W

2.1 Hardware Configuration of SIM

Fig. 2 shows the H/W structure and Table 1 is specifications of H/W elements for KOMPSAT-1 SIM. The SIM communicates with the SOS and the MAPS via MCE LAN employing the TCP/IP. The HP J210 workstation is the main computer system of the SIM. World Tool Kit (WTKTM) as VR tool was employed for 3D graphic display of the attitude and orbit of the satellite, and it interfaces with the SIM main computer via RS232C. By the way, a PC server which has 1 GHz CPU, 512MB main memory, and high performance graphic card is used for KOMPSAT-2 SIM H/W platform.

Table 1. The SIM Hardware Elements.

SIM H/W	Specification
HP J210 Workstation	• Main Memory: above 128MB
	• Hard Disk: above 5GB
	• 4mm tape cartridge
	• 176 MIPS
PC for VR Display	• Main Memory: above 32MB
	• Hard Disk: above 1GB
	• Graphic board for VR
I/O device	• Color graphic monitor (20")
	• Color monitor for 3D display
	• Line printer
	• Laser printer
Interface	• LAN transceiver
	• LAN card

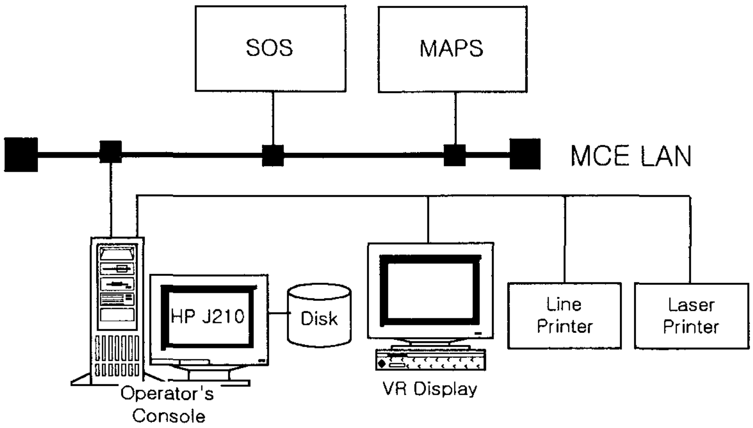

Figure 2. SIM H/W Structure.

2.2 Scope of Simulation

The SIM provides the following scope of simulation.

- Telecommand(TC) and Telemetry(TM) simulation
- Flight dynamics simulation, i.e. orbit and attitude dynamics
- Earth and Space environment simulation
- Spacecraft subsystems simulation, i.e. AOCS(attitude Orbit Control Subsystem), TC&R(Telemetry Commanding & Ranging) and EPS(Electric Power Subsystem)
- Ground Station simulation, i.e. KOMPSAT ranging & tracking data generation with respect to the specified ground station.
- 3D Display of Spacecraft Dynamics Comprehension.

3. 3D DISPLAY OF KOMPSAT-1 SIM

An independent PC was assigned to 3D graphical display for KOMPSAT-1 SIM and it was directly connected with SIM main computer by RS232C for the sake of reducing burden of the main computer. Every quarter seconds, the 3D display PC received data packet from main computer to display 3D motion of KOMPSAT-1. The data packet consists of time, spacecraft position and velocity, attitude information, solar array deployment status, solar array rotation angles, Greenwich angle, Sun and Moon position, etc.. The 3D display program can support recording received data packet from simulator and playback display of spacecraft 3D motion with the recorded data. Figure 3 shows 3D Display of KOMPSAT-1 SIM.

4. 3D DISPLAY OF KOMPSAT DYNAMICS BY TM

By the way, 3D Display of KOMPSAT-1 SIM did not support the display by using TM from spacecraft because TM did not provide enough information for the 3D Display. Demand to 3D display of spacecraft dynamics using TM was raised during the KOMPSAT-1 operation periods.

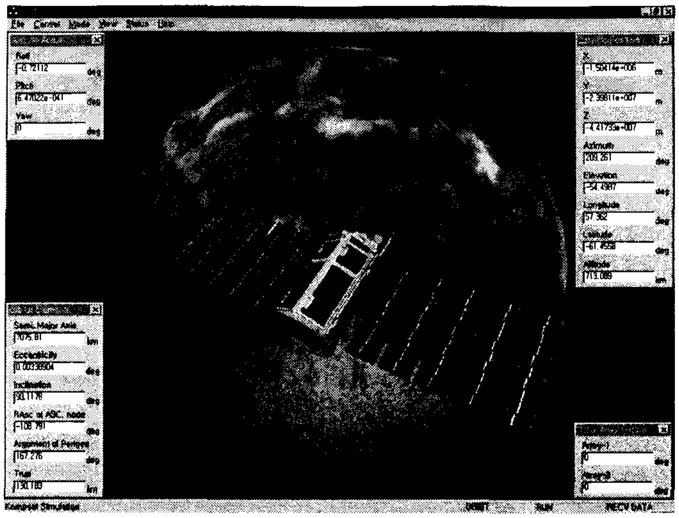

Figure 3. 3D Display of KOMPSAT-1 SIM.

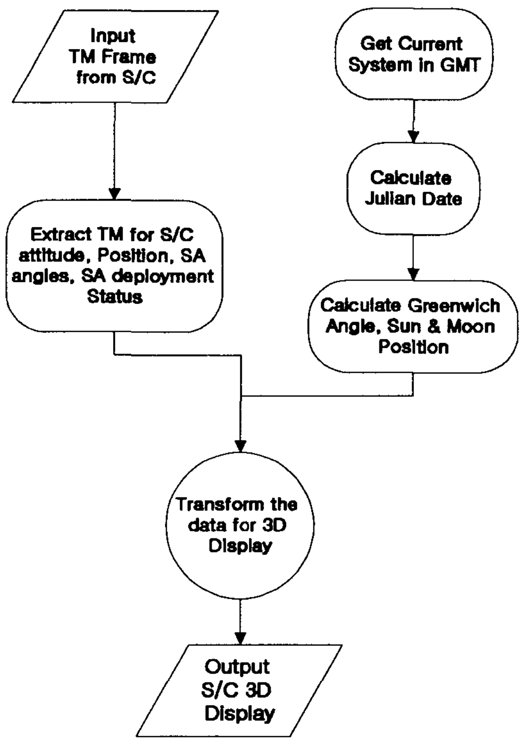

Figure 4. The procedure of real-time preprocessor.

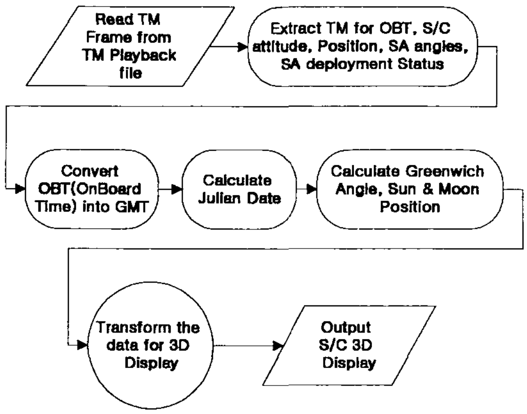

Figure 5. The procedure of playback preprocessor.

A preprocessor to convert from spacecraft TM into data required for 3D Display is introduced in this paper. The preprocessor can be divided into two. The one is real-time preprocessor and the other is playback processor. Ground control system of KOMPSAT receives real-time TM and playback TM during pass time. Real-time TM is distributed into SOS GUI and other network computers to display TM and subsystem engineers monitor state of health of spacecraft. High-speed playback data is stored into playback data file for later analysis purpose.

4.1 Real-Time Preprocessor

Real-time preprocessor consists of step-by-step procedures described in Fig. 4 for the 3D display of spacecraft dynamics by real-time TM. TM packet from spacecraft via SOS is fed into real-time preprocessor. TM manager routine extracts the individual TM items such as spacecraft attitude & position, SA (Solar Array) angles, SA deployment status required for 3D display. Also, current time in GMT is required to calculate Julian Date(JD) and this JD is used to calculate Greenwich Angle(GA), Sun and Moon Position in Earth Centered Inertial(ECI) coordinates. These are combined to TM items extracted from TM frame and coordinate transformation or Filtering is performed to generate data for 3D display. For the KOMPSAT-1 & KOMPSAT-2, attitude information in TM is described as quaternion and rotation sequence of them is 1-2-3. The transformation from body quaternion into Euler angles (1-2-3 sequence) is required for KOMPSAT 3D display.

4.2 Playback Preprocessor

Figure 5 shows the step-by-step procedures for playback preprocessor for the 3D display of spacecraft dynamics by using playback TM. The playback preprocessor reads TM packet from playback TM file. TM manager routine extracts the individual TM items such as On-Board Time (OBT) in GPS constellation time format, spacecraft attitude & position, SA (Solar Array) angles, SA deployment status required for 3D display. The OBT extracted from TM frame is converted into GMT. The converted time in GMT is required to calculate Julian Date (JD) and the procedure followed is the same with that of real-time preprocessor.

5. RESULTS

The program for 3D display of spacecraft dynamics is implemented by using Open GL for plat-

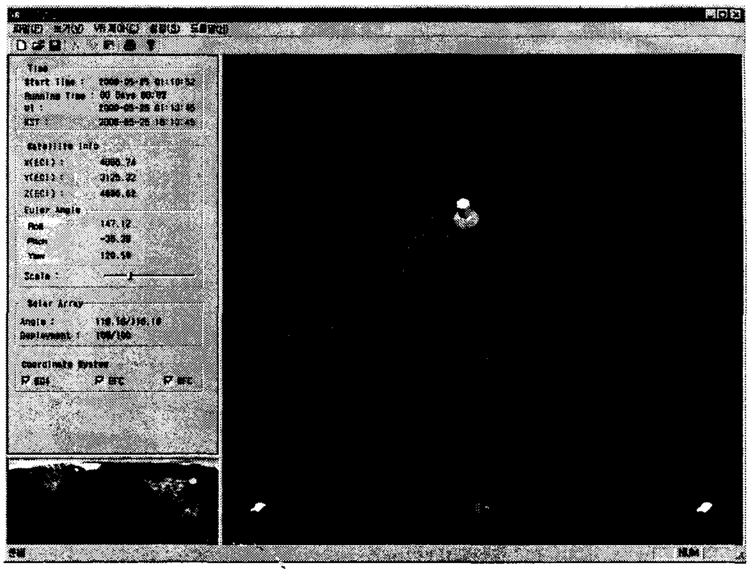

Figure 6. 3D display of spacecraft motion by playback preprocessor.

form independency. This program, also, has spacecraft ground track view for better comprehension of spacecraft dynamics. In order to test their functions, we used KOMPSAT-1 playback data. Firstly, several playback data was used to test playback preprocessor and the 3D display gives the expected view of spacecraft dynamics at speed of more than ten times faster than real-time. Figure 6 shows the example view of 3D display by using playback preprocessor Secondly, we set the computer system time as the time, which is the time for first frame of playback TM file and run the program for emulation of real-time display. The resultant view of the 3D display gives the expected view of spacecraft dynamics too. The telemetry frame is received every quarter seconds and 3D display of S/C dynamic motion is displayed one quarter second behind. If we want to reuse this program for other spacecraft system, an appropriate filter to produce spacecraft attitude and position and a TM manager for a spacecraft are required.

6. CONCLUSIONS

The program for 3D display of spacecraft dynamics using proposed two preprocessors, real-time and playback preprocessor, is implemented by Open GL and tested them successfully. Even though KOMPSAT-1 TM manager was used for the both preprocessors, a TM manager for a spacecraft is required for reusing this 3D display tool. We did not use a filter to produce spacecraft attitude and position of KOMPSAT-1.

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