351

N90-20667

Animation Graphic Interface for the Space Shuttle Onboard Computer

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ABSTRACT

Graphics interfaces designed to operate on space qualified hardware challenge software designers to display complex information under processing power and physical size constraints.

Under contract to Johnson Space Center, MICROEXPERT Systems is currently constructing an intelligent interface for the LASER DOCKING SENSOR (LDS) flight experiment. Part of this interface is an graphic animation display for Rendezvous and Proximity Operations. The displays have been designed in consultation with Shuttle astronauts. The displays show multiple views of a satellite relative to the shuttle, coupled with numeric attitude information. The graphics are generated using position data received by the Shuttle Payload and General Support Computer (PGSC) from the Laser Docking Sensor.

Some of the design considerations include crew member preferences in graphic data representation, single versus multiple window displays, mission tailoring of graphic displays, realistic 3D images versus generic icon representations of real objects, the physical relationship of the observers to the graphic display, how numeric or textual information should interface with graphic data, in what frame of reference objects should be portrayed, recognizing conditions of display information-overload, and screen format and placement consistency.

INTRODUCTION

While much research is being funded to advance the state-of-the-art in realtime graphic workstations, these systems are not appropriate for onboard graphic displays to assist crew members in space. Hardware aside, issues concerning display content, efficiency and practicality must be addressed when considering graphic technology in space. MICROEXPERT Systems Incorporated is conducting research in the use of expert systems and graphical data portrayal on microcomputers to aid Orbiter crews in interpreting sensor data output in space. The application, funded by NASA Johnson Space Center, is to develop a human interface to the LDS. The LDS is a laser radar designed to measure the relative position between NASA's Orbiter (Shuttle) and a target (Space Station or satellite) during rendezvous and docking operations. The project software, called the Laser Docking Sensor Associate (LDSA), displays the LDS data under LDSA control. The system assists the crew by monitoring the data for fault and safety problems and provides crew input to the sensor. This paper outlines the approach taken in designing the graphic interface of the LDSA, and identifies peculiarities typical in designing graphic interfaces for flight qualified hardware.

SYSTEM CONSTRAINTS FOR FLIGHT QUALIFIED GRAPHICS

The new orbiter onboard computer that allows graphic displays is the Payload and General Support Computer (PGSC). The system is a GRiD CASE Model 1530 laptop computer. It is equipped with a 12.5 MHz 80386 32-bit processor with 80387 math co-processor. The display is a

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10 inch diagonal 640X400 pixel, backlit LCD display. The interface to external data is via RS-232 or RS 422 serial ports. The operating system is GRiD MS-DOS Version 3.21D.

The PGSC imposes the following limits on graphics applications and design:

o The processor size severely confines the amount of detailed graphic animation that can be displayed.

o The display does not support color graphics.

o The physical display screen size limits the detail in which the graphics can be presented.

o Communication via serial port restricts the amount of data available to the system. This limits the types of graphic applications the system can support. Graphic portrayal of externally digitized images for example, cannot be directly transferred in reasonable time.

o Input to the system is through the keyboard only. No mouse, track ball, voice or touch screen is available for the system. This limits user input to keyboard only and creates a need for menus, function keys and mnemonics.

o Because the PGSC is not currently connected to the orbiter General Purpose Computer (GPC), applications run on the PGSC are restricted to those which do not involve orbiter safety and mission data.

CHARACTERISTICS FOR ORBITER MMI DESIGN

As a prelude to building an Man Machine Interface (MMI) for the LDS, MICROEXPERT proceeded through a knowledge gathering process to learn more about the system being represented, the presentation preferences of users, and representation standards.

Gathering knowledge about a system yet to be built increases the difficulty of gathering definitive system information and expertise. In a large departmentalized organization it is always time consuming to locate the 'experts' with the proper knowledge required to impact system display design. When a new system is being built there is no expert and the knowledge has to be assembled from a variety of sources.

MICROEXPERT's knowledge engineers made several design trips to JSC to talk to the large variety of groups and departments with an interest in Shuttle displays. Personnel who participated in the design included four astronauts plus engineers from Proximity Operations and Shuttle Display Groups. We showed them preliminary designs and elicited comments. The final version of the display design resulted from iterative design and user input. In some cases, rules of display design yielded to astronaut expectations.

Our investigation into design preferences and requirements led to the following observations:

o Astronauts prefer graphical representation of data. Three dimensional graphic models that depict orientation are more meaningful to the astronauts than numeric data. Engineers prefer to see numeric and tabular data, and do not see the graphics as very meaningful.

o Numerical data should be displayed only to the accuracy that is relevant. Just because data may be available to three places after the decimal point, if the crew member can only affect a change in the data to the nearest integer, that is the only value necessary to display. The 'insignificant' significant figures only clutter the screen.

o Although uniformity of numerical data makes for a symmetrically pleasing display, crew members prefer receiving the exact data as required.

o Critical data, for example range and range rate in our application, can be emphasized by displaying them in large numbers on the graphic screen in head-up display fashion. Not only does this permit the crew member to easily find numeric data without changing the graphic view, but allows other crew members to monitor the values over the shoulder of the prime user.

o Critical information that appears as a demon or warning should require positive confirmation by crew members using the system.

o Displays should be stuffed with as much information as possible to avoid changing display screens. However, astronauts should be able to declutter the screen during certain operations of the display.

o Information displayed graphically on the screen should be placed in multiple or selectable frames of reference. Astronauts prefer that most graphic displays be in shuttle coordinate orientation. For proximity and docking, all readouts should be 'fly-to' oriented. This means that the goal of the display should be to put the target in the middle of the crosshairs, or zero out all the numerical data.

o A conflict arises between generic graphic displays, and mission specific displays. Generic displays have the advantage of providing ease of training, standardization, and reusability of software. Graphics that pertain to a single mission requirements can provide a much greater level of detail and specificity to the graphics, and impart more information to the crew member. In other words, there are no absolutes for screen design in real space applications.

GRAPHICS APPLICATION: LASER DOCKING SENSOR

The above considerations were incorporated into the design of the graphic interface to the LDS. The purpose of the LDS is to improve measurement accuracy over the current docking methods using the KU band radar, the Crew Optical Alignment Sight (COAS) and external telemetry. The system goal is to achieve soft docking with a target, reduce docking time requirements, and conserve fuel while maintaining safety.

The LDS measures range, azimuth, elevation, roll, pitch, yaw and associated rates to a docking target. To achieve accuracy over a dynamic range, the LDS design calls for a complex integration of several measurement systems,including the Distance Measuring Equipment subsystem, which is a laser radar with multiple tones to measure the range and a doppler to measure range rate and the Long Range Bearing System (LRBS), consisting of an illuminator and camera to capture a video image of the target for determining bearing beyond 80 feet, Short Range Bearing System (SRBS) for calculating bearing and attitude, and several optic and microprocessor subsystems.

The LDS communicates with the PGSC via an RS-232C link. It outputs fixed formatted data packets at a 1HZ update rate. The PGSC can send to the LDS the following mode commands: STANDBY, SEARCH, BREAK TRACK, SELF TEST, CALIBRATE, and SEND VIDEO. Normally the LDS operates autonomously without input from the PGSC. The LDS also sends the data packet to the Payload Data Interface (PDI). The LDS connects to the aft flight deck switch panel via panel discrete mode selection input.

PGSC DISPLAY DESCRIPTION

The PGSC runs MICROEXPERT's realtime LDSA program. The LDSA has four main functions:

- o Communication with LDS
- o Display of the LDS data
- o LDS data analysis using expert systems
- o Satellite target recognition.

The LDSA MMI presents the LDS data in graphical and tabular form with critical data enlarged. The relative position of the target is presented from more than one perspective and coordinate system. The menu enables user input.

The LDSA expert system checks the data for validity, trends and dangerous situations. The target recognition software validates the target and calculates its attitude.

MICROEXPERT designed two interfaces for this system: one mission specific, the other a generic proximity operations display. Both

MMI's were designed around the knowledge gained from on site interviews, MICROEXPERT's experience in complex displays for tutoring, and general principals of display and expert system design.

The mission specific interface consists of several full screen graphical views with scales and numerical readouts. These windows are:

- o The front view from the perspective of the LDS (see Appendix A) displaying a three dimensional wireframe model of the target vehicle. The model is scaled, transformed and oriented in roll, pitch and yaw from the LDS measurement. The model appears in real time as the satellite would to a mission specialist observing it through the COAS.

- o The side view depicting the position of the shuttle and the target vehicle from a point on the azimuth axis.

- o The readout screen, listing all the data, sensor status and a history of the LDS status and mode changes.

The generic interface (see Appendix A) consists of one main display screen with six main windows. In the graphics windows icons portray the relative positions of the vehicles. The target icon always includes a halo to indicate the deadband. Scales to the side of the graphics indicate the measurement, its rate, and direction of change. The windows are:

- o Side view indicating the Z and X coordinates of the target in graphics and a linear scale.

- o Top view graphing the target relative to the shuttle in X and Y as seen from above the shuttle (-Z). The field of view of the LDS is outlined by a dashed box.

- o Sensor data listing measured parameters (range az., el., etc.) sent from the LDS in a columnar readout. The values are converted to the cartesian coordinate system of the shuttle and displayed.

- o P/L Relative displaying target attitude values in columnar readouts with corresponding rate values.

- o LDS FOV plotting the target in the LDS's field of view.

- o Status and Warning indicating the mode of the LDS and suggestions from the expert system.

CONCLUSIONS

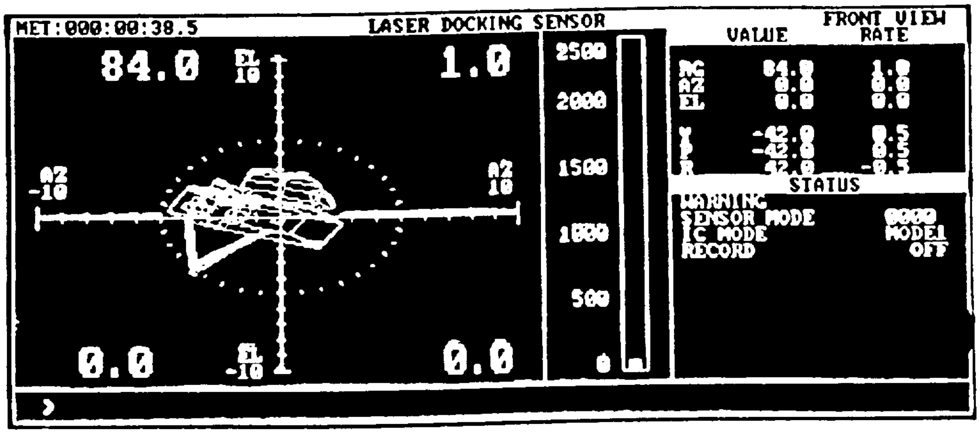
Designing animation graphic interfaces for space applications creates considerations that may impact the design of the interface and disallow the current state-of-the-art in color animation graphics. In spite of this, graphic interfaces can be applied to onboard, realtime software applications with strongly positive results.

The 80386 processor in the PGSC is capable o running a variety of sophisticated programs that could aid Orbiter crews. The terminate-and-stay-resident display, interface software, and data analysis routines in the PGSC run "simultaneously" by servicing interrupts to share processor time. Displaying multiple 2D views, or 3D wireframes can provide a graphical representation, while omitting detail prohibited on small machines.

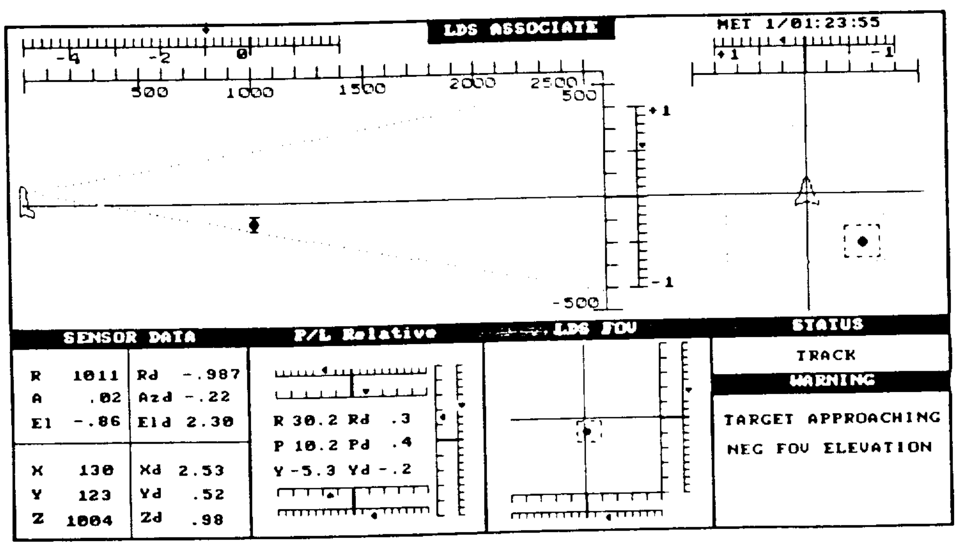
On board graphic software for data representation is relatively new to the Shuttle program. Animated graphic representation o data brings a more intuitive understanding of the data to crew members, and should be carried into more onboard software systems. Integrating crew member desires into the display design creates an efficient, tailored display that is will provide graphics to better aid the crew. Because different players have different needs and display interests, graphics standards should be created for the PGSC and adapted for all payload support software. This will improve and reduce the cost of display design, increase acceptability, and enhance training.

ACKNOWLEDGEMENTS

Our thanks to Silvio Nunes, Jane Chang and Dave Stevens for their programming support.



CGA Mission Specific Display



EGA Generix Proximity Operations Display