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Joan Wyzkoski Weiss
Fairfield University, weiss@fairfield.edu

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COMPUTER GRAPHICS APPLICATIONS TO CREW DISPLAYS

Joan Wyzkoski
Assistant Professor
Department of Mathematics
Bradley University
Peoria, Illinois 61625

ABSTRACT

Astronauts are provided much data and information via the monchrome CRT displays on the orbiter. For this project two areas were investigated for the possible introduction of computer graphics to enhance and extend the utility of these displays. One involved reviewing the current orbiter displays and identifying those which could be improved via computer graphics. As an example, the tabular data on electrical power distribution and control was enhanced by the addition of color and bar charts. The other dealt with the development of an aid to berthing a payload with the Remote Manipulator System (RMS). This aid consists of a graphics display of the top, front and side views of the payload and cargo bay and point of resolution (POR) position and attitude data for the current location of the payload. The initial implementation was on an IBM PC clone. This program previews the demonstration software installed in the Johnson Space Center Manipulator Development Facility (MDF). Due to current hardware limitations, the MDF version is slow, i.e. about a 40+ second update rate and, hence, not "real-time." Despite this fact, the evaluation of this additional visual cue as an RMS operator aid indicates that this display, with modifications for speed, etc., can assist the crew. Further development is appropriate.

INTRODUCTION

Color and graphics, if carefully selected, enhance the display and understanding of data. Computer graphics, in particular color graphics, furnishes an excellent means to improve the presentation of information. This, in turn, encourages quicker interpretation and, hence, response to data. More efficient response to information facilitates man-machine interaction.

Orbiter computer CRT displays provide much data and information to the crew. Reviewing these displays and identifying those which can be enhanced via computer graphics was one facet of the project. The other area of investigation involved the development of an aid to facilitate payload berthing by the Remote Manipulator System (RMS) operator.

Displays

Numerous CRT displays are selectable by the crew during each flight of the shuttle. These show data and information in a variety of formats. Some are quite specific and apply to the ascent and reentry of the orbiter. Others indicate the status of the various shuttle systems and typically are in tabular form.

All the displays were reviewed. A display of the data on electrical power distribution and control was chosen to demonstrate a possible enhancement of displays. Color and bar charts replace tabular digital data. Most entries have a high(H), medium(M) or low(L) range. Red, green and yellow, respectively indicate each range. In order to respond to the high range of a particular portion of the electrical system, spotting a "red" condition is easier than spotting an "H".

Payload Berthing Aid

To berth a payload the RMS operator, working in the aft flight deck, currently uses several visual cues. In most cases a portion of the payload can be viewed from the two aft payload bay viewing windows. Starboard and port TV cameras are positioned on the fore and aft bulkheads of the cargo bay. Two others are located at the elbow and wrist, respectively, of the manipulator arm. On monitors, located in the aft flight deck, the operator can select views from up to four of the cameras. Digital information about the position and attitude of the point of resolution (POR) of the payload (This is explained in the Theory section.) is also available.

An additional visual cue to aid in payload berthing was developed. This aid consists of a computer graphics display of the top, front and side views of the payload and cargo bay along with the POR position and attitude data. See figures 1 and 2.

THEORY

The choice of colors and the selection of an appropriate graphic played major roles in the implementation of an enhanced display for the orbiter.

Developing the software to display the updated views of the payload required some mathematical analysis and computation. As shown in figure 3, the orbiter coordinate system is a right-handed system. The positive x-axis is forward, the y-axis is starboard and z is down. The POR is a preselected point within the payload. The position is indicated as x, y, z values in the orbiter coordinate system. The attitude of the payload, or the pitch, yaw and roll of the payload which would orient it into its present attitude, is a series of rotations about lines passing through the specified control point and parallel to the appropriate orbiter axis. Pitch is a rotation about the orbiter y-axis in a clockwise direction. A counterclockwise rotation about the orbiter's z-axis produces yaw. While a clockwise rotation about the x-axis of the orbiter causes the payload to roll.

Three dimensional data bases along with the appropriate move/draw specifications were defined for the cargo bay and payload, respectively. These data points are placed in n(# of data points for the cargo bay or payload) by 3 matrices. The updated position of the payload is a translation by the change in x, y and z, respectively. These changes are added to the respective coordinates of each data point for the payload. The rotations to accomplish pitch, yaw and roll are easily represented as 3 by 3 matrices (See Foley and Van Dam, 1982, pp. 255-258. Note, 4 by 4 matrices are not necessary for this application.). Composition of these matrices and then a matrix multiplication of the data set with the POR centered at the origin of the orbiter coordinate system, create new, transformed data points of the payload.

To show the top view, the x,y values, transformed to screen coordinates, are plotted. The front view is a plot of the y,z values and the x,z values are drawn for the side view.

IMPLEMENTATION

The sample orbiter display, the current and enhanced versions, and the RMS berthing aid were implemented in color on an IBM PC clone. These programs are basically for demonstrations, although much potential exists for application of computer graphics on the orbiter. Using the POR data from an actual berthing procedure, the berthing display updated approximately every 12 seconds. See figures 1 and 2.

In order to evaluate the effectiveness of this payload berthing aid, the displays were implemented on a Z80 microprocessor equipped with a Microangelo card and displayed on a monochrome graphics monitor. This is interfaced with the SEI computer which controls and monitors the Manipulator Development Facility (MDF). [The MDF is a JSC training facility for RMS operators.] During a payload berthing maneuver, current POR data is sent to the Z80 microprocessor, which draws the appropriate display for the operator to view. Due to the limitations of the hardware, especially the 8 bit processor, the update rate is about 40 seconds for a full display.

RESULTS

The sample displays appear to have potential but have not been adequately evaluated. This is mainly due to the emphasis and time devoted to the MDF berthing aid.

The response by the MDF/RMS operators to the payload berthing aid has been very favorable. The present system was developed with the hardware which was on hand at JSC and costs less than $4000. Viewed as an initial step in the development of a close to real-time berthing aid, the current system shows much potential. The slow update rate of the display, except as a demonstration, is not acceptable. This is easily remedied by a better, more powerful processor which is readily available.

FUTURE ENHANCEMENTS AND DIRECTIONS

An obvious direction of the orbiter display portion of the project is additional review of the displays in order to identify specific categories of the displays and the corresponding color computer graphics enhancements. This review will also benefit current definition of space station systems display requirements.

The utility of the payload berthing aid has been demonstrated. It is apparent that speeding up the refresh rate of the display is the first goal. Other enhancements could include graphical indications of the collision of the payload with the cargo bay and the ability to select, via keystrokes, light pen or some other interactive device, a portion of the display on which to zoom. Zooming in on a particular segment of the display would allow the operator to see the fine detail that is helpful in the final stages of berthing. Further development of this computer graphics payload/cargo bay display will certainly indicate additional refinements and enhancements.

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3. Rogers, David F. and J. Alan Adams, MATHEMATICAL ELEMENTS FOR COMPUTER GRAPHICS, McGraw-Hill, NY, 1976.

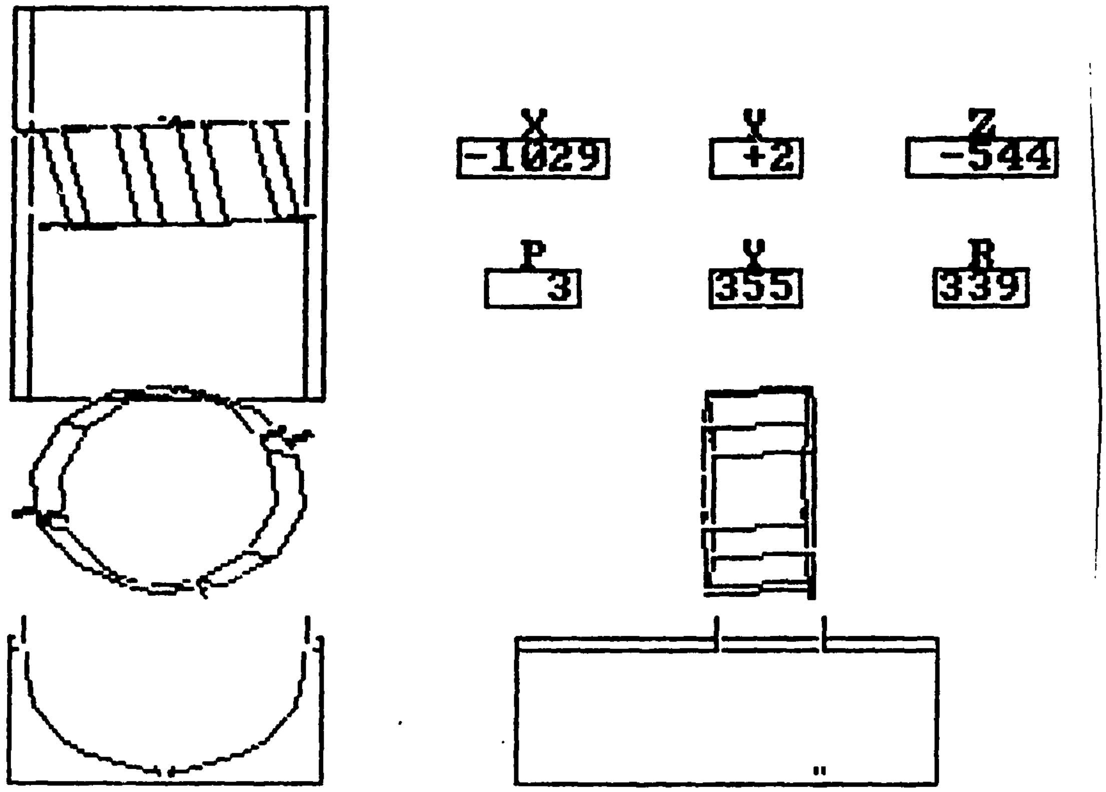

Figure 1. IBM PC demonstration of a typical payload berthing display. Beginning in the upper left-hand corner in a counterclockwise direction, the top, front and side views of the payload and cargo bay, and the point of resolution position and attitude data are displayed

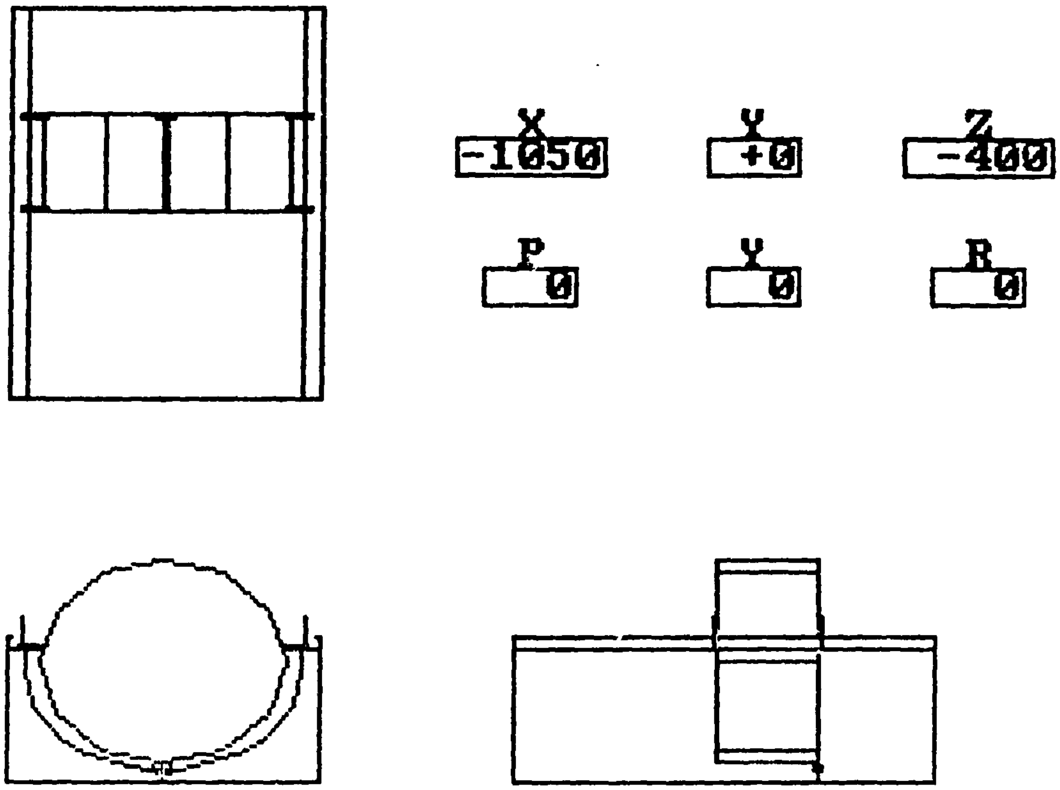

Figure 2. IBM PC demonstration of a berthed payload display. Beginning in the upper left-hand corner and moving in a counterclockwise direction, the top, front and side views of the payload and cargo bay, and the point of resolution position and attitude data are displayed.

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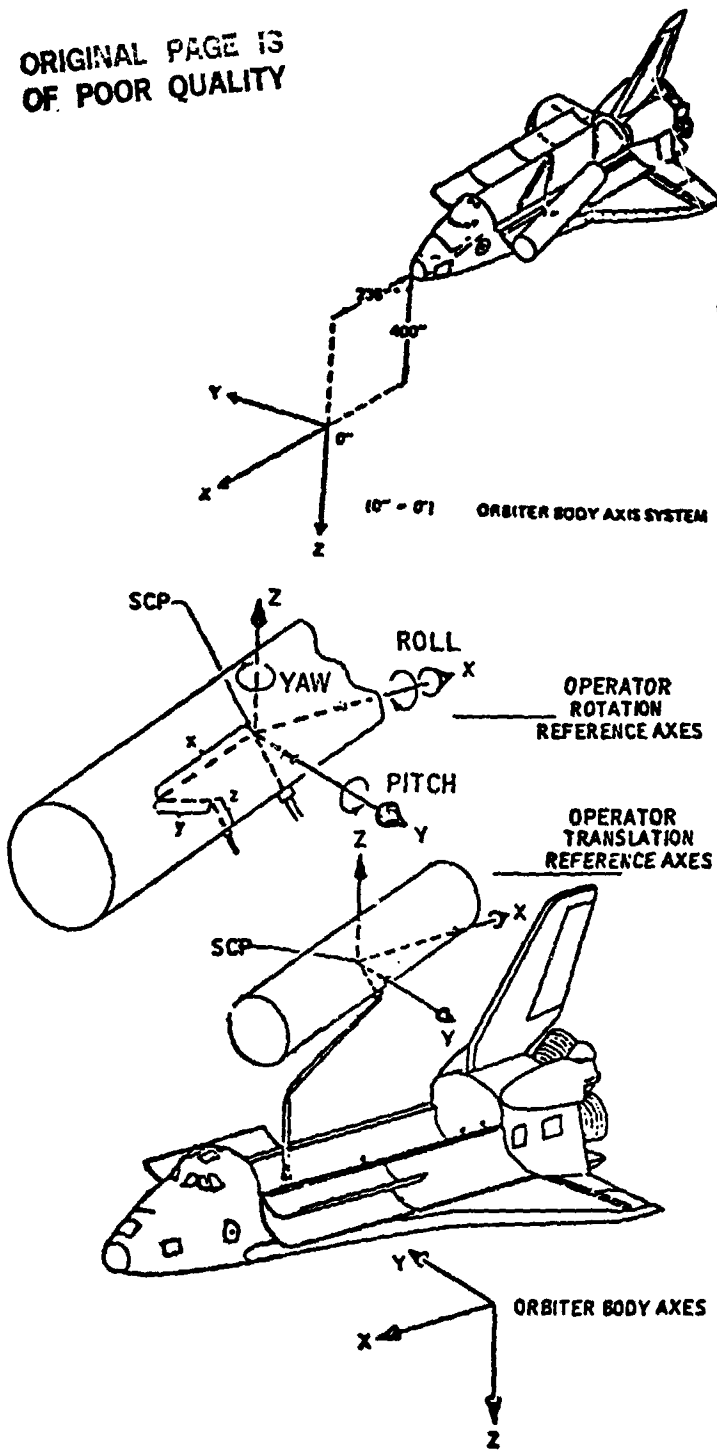

Figure 3. Orbiter Body and Payload Reference Axes