TECHNICAL DATA BULLETIN

Packard Bell Computer
2700 SO. FAIRVIEW STREET
P.O. BOX 5158
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TRICE DDA/PB250 HYBRID COMPUTING SYSTEMS SOLVE FOUR KEY SPACE VEHICLE SIMULATION PROBLEMS FOR NASA-LANGLEY AND NASA-HOUSTON

INTRODUCTION

Four space vehicle simulation problems were performed by PBC and Computer Usage Company personnel on TRICE/PB250 computing systems as part of the acceptance tests for two of these systems delivered to NASA's Langley Research Center and Manned Spacecraft Center. These solutions were performed in realtime or faster and the results were compared with independent solutions computed on a large General Purpose Computer. The problems are described together with the method of solution and the results.

1. Four Body Lunar Orbit

This problem describes the motion of a space vehicle in a trans-lunar orbit with reference to an earth-centered three-dimensional Cartesian coordinate system. Gravitational effects of the earth, moon and sun are included.

The equations solved were of the form:

$$dx_p = \frac{-GM_e x_p}{r_{ep}^3} + \frac{GM_m (x_m - x_p)}{r_{mp}^3} + \frac{GM_s (x_s - x_p)dt}{r_{sp}^3} + \frac{f_x dt}{M_p}$$

$$dr_{mp}^2 = d(x_m - x_p)^2 = d(y_m - y_p)^2 + d(z_m - z_p)^2$$

for r_{mp}, r_{sp}, r_p

(more)

In this problem the equations were solved entirely on the TRICE with the exception that the second derivatives of the sun and moon positions were supplied from a table in the PB250 at 12 hour intervals. These values were integrated on the TRICE to obtain the position coordinates of the sun and moon.

For purposes of checking against GP computed runs Fx, Fy, and Fz remained constant, however, the problem was mechanized so that these values could be provided in analog form through the system Analog to Digital converters. The problem was run with a fast time scale with respect to realtime of 2:I. At the end of a two hour run in problem time values of x y z and $\dot{x}$ $\dot{y}$ and $\dot{z}$ matched those computed by the GP to better than one part in 10^5 (0.273 parts in 10^5 worst value).

2. Three Body Lunar Orbit

This problem is similar to the Four Body problem except that it was solved using polar coordinates, the gravity effect of the sun was neglected, and the moon was assumed to have an elliptical orbit.

Because of the nature of the polar coordinate system and the extreme range of the variables from the near earth to the near moon case, an automatic rescaling method was used to maintain the desired accuracy.

The method was originally developed at the NASA Marshall Space Flight Center. Eight different overflow signals corresponding to each of the eight blocks of computing modules can be sensed by the PB250. The overflow signal may be caused by overflow of the Y register of any of the computing modules in that particular block. The problem is mechanized so that the critical variables on which rescaling depends are distributed over six of the eight module blocks. On overflow, the TRICE is halted and the required modules are rescaled by the PB250 according to a table corresponding to the particular block overflow signal. Six such tables are stored the PB250. The rescaling operation requires a fraction of a second and is barely detectable by the operator. The tables contain lists of modules to be rescaled and the number of bits by which the scaling is to be changed. The rescaling can thus be performed as many times as needed to maintain the required accuracy. The program for rescaling is completely general requiring only the distribution of the critical variables during mechanization and entries in the tables of the mdoules whose scaling is affected.

3. Soft Lunar Landing

This problem is a zero velocity lunar impact beginning from a lunar orbit with an altitude of 264,000 feet. The problem is mechanized for both pilot and programmed control of thrust in three dimensions.

The equations mechanized were of the form:

$$d\dot{x} = \frac{-T\dot{x}}{mv} dt - G_m R_m^2 \frac{X}{r^3} dt$$

for $\dot{x}$ $\dot{y}$ and $\dot{z}$; and

$$rdr = xdx + ydy + zda$$

for r and V; and

$$dm = - \frac{Tdt}{v}$$

for change of vehicle mass.

For the check solution thrust, T_1 was programmed:

$$T = \begin{cases} T_1 & o < t < 483 \text{ sec} \\ T_2 & 483 \text{ sec} < t \end{cases}$$

After completion of the check run (955 seconds) the values of X Y and R (Z = 0) checked with the GP computer solution to one part in one hundred thousand.

4. <u>Six Degree of Freedom Reentry</u>

This problem involved the reentry from 400, 000 feet of an aerodynamic vehicle including the necessary axis transformations to provide latitude, longitude, range and heading angle to destination. The aerodynamic equations were solved in body axis with constant coeefficients. The gravitational forces included oblateness terms. All of the equations were solved on the TRICE with the exception that air density used in the generation of dynamic pressure and the speed of sound used in the generation of Mach No were provided by the PB250 from tables versus altitude. These values were computed on a sampled data basis as rapidly as possible by the PB250 (approximately every 50 msec).

Check solutions were made with the large GP computer for both a constant "q" and q as a function of altitude and velocity. The constant q case checked to better than one part in one hundred thousand for the velocities, angular rates, altitude angles, altitude heading, latitude and longitude. For the variables q case accuracies degraded to one part in 10^4 for velocities and angular rates. The loss of accuracy was attributed to the speed at which the air density was up dated by the PB250.

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