Explicit Modeling and Concurrent Processing in the Simulation of Multibody Dynamic Systems

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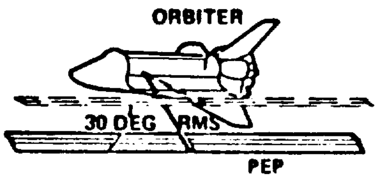
The objective is to present the activities at TRW in developing the capability to simulate the behavior of large flexible multibody space structures. The features of the simulation tools are (1) to accommodate all rigid/flexible body degrees-of-freedom which incorporate the control system models and external forces, (2) to provide the flexibility to incorporate engineering-defined models and to retain parameters of significance to the engineer, (3) to reduce the computation cost by one order of magnitude (two orders of magnitude compared to a CRAY 1S), and (4) to keep it versatile so that radical variations in anticipated space structures can be accommodated. The current computer tools to simulate multibody systems appear not only to be very costly and time consuming, but also do not produce the desired fidelity of the mathematical models.

The activities can be divided into the development of the models, the design and fabrication of a Custom Architectured Parallel Processing System (CAPPS), and the development of a balanced computational load distribution for concurrent processing. The development of the model, or the basic equations of motion, is defined by the engineer using a symbol manipulation program to obtain explicit equations of motion for the dynamic characteristics of the system with a reduced simulation time. The engineer can now fully participate in the derivation of the model to the degree required for a specific problem.

The CAPPS system contains any number of computational units, each being a high-speed digital computer capable of operating independently, i.e., each computational unit has its own memory devices, an arithmetic module, and a complete input/output capability. To establish the potential benefits of CAPPS, a benchmark problem (Orbiter-Remote Manipulator System-Power Extension Package spacecraft) was modeled using an existing program (DISCOS) and solved using 10 commercially available computing systems. The resulting comparisons are shown in FIGURE 1. The parallel processing capability of the CAPPS was demonstrated with a simulation of a despin maneuver of a whirling flexible beam with the first version of CAPPS, which had two computational units. The results indicated that this CAPPS exceeded the CRAY 1S by 100%, and the CAPPS measured performance exceeded the analytical estimate by 60 %.

A computational load distribution software is in development which consists of the following three iterative optimization subroutines: (1) partitioning, (2) assignment, and (3) sequencing, which together seek to minimize the execution time of the simulation problem in a manner transparent to the user.



41 DEGREES OF FREEDOM (RIGID - AND FLEXIBLE - BODY)
130 SIMULTANEOUS DIFFERENTIAL EQUATIONS
100 SECONDS MANEUVER IN REAL TIME

COMPUTER	VENDOR	CPU TIME/ REAL TIME	LENGTH OF RUN (CPU HRS)	COST OF RUN ($)	
IBM 3090/600E	IBM	157.17	4.37	7,170	
CRAY XMP	CRAY RESEARCH INC.	163.92	4.55		
CRAY 1S	BOEING COMPUTER SERVICE	183.12	5.09	8,433	
CRAY 2	CRAY RESEARCH INC.	272.86	7.58		
FPS 264/VAX 785	FLOATING POINT SYSTEMS	333.86	9.27		
CYBER 205	CDC	410.0	11.38	33,920	
XPI	CONVEX COMPUTER	710.11	19.73		MEASURED RESULTS
IBM 3081	IBM CORP.	792.3	22.01	39,329	
SCS-40	SCIENTIFIC COMPUTER SYSTEMS CORP.	905.91	25.16		
IBM 3033 (TRW)	IBM	1670.0	46.39	49,000	
CAPPS (20 CUs)		10.8	0.30	LESS THAN 50	ESTIMATED RESULTS

CAPPS COSTS ARE CONSERVATIVELY PREDICTED TO BE <1% OF THOSE OF THE BEST AVAILABLE MAINFRAME COMPUTER SYSTEM

FIGURE 1. Simulation Results for the Orbiter-RMS-PEP Spacecraft Benchmark Problem

In summary, a multibody simulation tool will be developed in the near future which will allow solution of the dynamics and controls of the deployment of the LDR backup structure, or the problem associated with the robotic assembly of the structure. The tools will allow the engineer to define the modeling technique and solve problems in less time and at reduced cost.