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The Application of New Software Technology To The Architecture of the National Cycle Program

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As part of the Numerical Propulsion System Simulation (NPSS) effort of NASA Lewis in conjunction with the United States aeropropulsion industry, a new system simulation framework, the National Cycle Program (NCP), capable of combining existing empirical engine models with new detailed component-based computational models is being developed. The software architecture of the NCP program involves a generalized object-oriented framework and a base-set of engine component models along with supporting tool kits which will support engine simulation in a distributed environment. As the models are extended to contain two and three dimensions the computing load increases rapidly and it is intended that this load be distributed across multiple work stations executing concurrently in order to get acceptably fast results.

Central to the NCP architecture is the concept of "components", a set of software objects which interact with one another while carrying out the engine simulation. The importance of a component lies in the ability of NCP to replace a component representing one engine module with a different but compatible component representing a different design of that engine module. This allows different engine manufacturers to use the NCP system but incorporate models of their own engine modules while still taking advantage of the NCP system to build and carry out the simulations.

The research carried out was directed toward performance analysis of the distributed object system. More specifically, the performance of the actor-based distributed object design I created earlier was desired. To this end, the research was directed toward the design and implementation of suitable performance-analysis techniques and software to demonstrate those techniques.

There were three specific results which are reported in two separate reports submitted separately as NASA Technical Memoranda. The results are:

1. Design, implementation, and testing of a performance analysis program for a set of active objects (actor based objects) which allowed the individual actors to be assigned to arbitrary processes on an arbitrary set of machines. This analysis included the competition of actor objects for the processor and the complex state of these objects. The methodology used a full queuing theory model which automatically generates the global balance equations and solves them. The program was completed and demonstrated and has been submitted as a NASA Technical Memorandum. The title is "Performance Analysis of an Actor-Based Distributed Simulation". The report includes detailed descriptions of the actor models and their states, the program design, example results, and complete listing of the program.

2. The global-balance-equation approach has the fundamental limitation that the number of equations increases exponentially with the number of actors. These actions are very well behaved and special solution techniques make them practical for moderate sized sets of actors executing in several machines. It major advantage is that no approximations are used in the solution. Its major disadvantage is that large sets of actors cannot be analyzed. An entirely new approach to the problem was formulated. I have called it the "nearest-neighbor" approach and it is based upon decomposing the global balance equations into sets associated with pairs of actors. Fundamental to this approach is that it involves the solution of balance equations but since these are the balance equations of subsets of actors, their number does not increase exponentially. The approach is approximate but has the advantage that the solution yields actual state probabilities which can be checked using global balance equations. Hence, unlike many approximate approaches to this problem, the nearest-neighbor approach allows checking of the solution and an estimate of the error.

The technique was demonstrated in a prototype analysis program as part of this research. The results of the program were checked against the global-balance solution discussed above. The results were quite encouraging though based upon a rather ad-hoc approximation used in the program. Late during the grant, a much better approximation was developed and this is discussed in result below. As a consequence, a proposal was submitted to continue the research by developing the new approximation including development of a complete program from the prototype.

3. The source of approximation in the nearest-neighbor algorithm is the requirement for estimating some joint probabilities from some marginal distributions. A completely ad hoc estimate was used in the prototype. I found a much better approach to this problem by using a separable queuing theory model constrained to match the marginal distributions of the interacting sub-networks into which I decompose the overall problem. The computation becomes very straightforward because the joint probabilities can be sequentially calculated without the solution of simultaneous equations. Moreover, the approximation becomes exact if the model actually satisfies the conditions for separable

queuing centers and hence is a credible basis for the approximation. Preliminary calculations using this approximation were done and the entire approach submitted as a NASA Technical Memorandum. Its title is " The reconstruction of joint probabilities of separable queuing networks from individual queuing center distributions".