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OTBSAF Scalability on Pentium III/4 and Athlon 64/XP3000 Architectures

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Abstract

Effective use of embedded simulation requires assessment of critical tradeoffs between processing power and simulation scope/fidelity. This paper addresses that concern by providing recent benchmarking results of entity scaling capabilities for the One Semi-Automated Forces Testbed distributed simulation environment on currently available processor architectures. Results indicate that processors which are now available in laptop computers have sufficient capability to simulate the quantity of entities required for Battalion-sized force-on-force training exercises.

1. Introduction

Embedded Simulation [Abate 1999] capabilities can be incorporated into modern combat vehicles to enhance crew performance by using simulation to train, plan, and rehearse within the combat platform. Rather than developing a completely new set of applications to implement these capabilities, a preferred approach is to reuse the same application code within stationary vehicles in the motor pool, vehicles enroute to the combat destination, or vehicles on the move in a training exercise. *One Semi-Automated Forces Testbed (OTBSAF)* [SAIC 2001A] is one such simulation application being adapted for embedding training. Hence, OTBSAF has been selected here as the benchmarking environment to evaluate various personal-computer-class processors for potential use in Embedded Simulation.

2. OTBSAF as a Prototyping Testbed and Simulation Framework

OTBSAF is a large-scale constructive simulation system developed to portray elements down to the individual platform or entity level [SAIC 2001A]. Although it is a *constructive simulation*, it provides both logical and real-time clocks so it can be used for real-time interactive simulation to portray additional elements in an exercise beyond those represented by manned simulators. For communicating with manned simulators, it uses the *DIS protocol* [SAIC 2001B]. Each entity is simulated by instantiating the appropriate model for that entity. Initially, each entity assumes the default values for each parameter that can be modified by the *SAF operator*. Below we describe the OTBSAF distribution to explain its operation and application as a scalability testbed.

OTBSAF version 1.0 [SAIC 2001A] is distributed with over 5,000 pages of documentation describing 636 libraries and 5 applications. The libraries have over 1 million lines of executable code with 80% written in the C-language and the majority of the balance in *Finite State Machine (FSMs)*. The FSM [SAIC 2001B] code generator is an AWK script that translates the FSM source files into corresponding C-language constructs.

Semi Automated Forces (SAF) a simulation system that can provide operator-controlled semi-automated entities that can maneuver on the simulated battlefield similar to a manned simulator. The goal of OTBSAF is to replicate the outward behavior of simulated units and their component vehicle and weapon systems to a level of realism sufficient for training and combat development [SAIC 2001C]. Utilization of OTBSAF takes advantage of a large range of domain knowledge to model all simulated systems, implementation knowledge including networking, and user interfaces, available from the various organizations that use and adapt the SAF to their needs.

3. OTBSAF Scalability on Modern Processor Architectures

The question of how much processing power is required to execute a training exercise has existed since the introduction of OTBSAF and its predecessors. One such study for the *Modular Semi-Automated Forces (ModSAF)* platform Version 3.0 was conducted in 1998 by Roberts et al [Roberts 1998]. These results for ModSAF scalability study are summarized in Table 1. This study was based on a 16-node Silicon Graphics Origin 2000 computer where separate SAFsims were invoked on each processor for the number of processors shown from a minimum of 1 processor to a maximum of 15 processors.

Table 1: ModSAF 3.0 Benchmark Results [Roberts 1998]

Number of SAFsims (Processors)	Total Entities Modeled by all SAFsims	Average Entities Per Processor
1	160	160
2	264	132
4	384	96
8	640	80
15	720	48

These results were obtained by executing the intrinsic entity measurement benchmark in ModSAF via the "`-benchmark`" option. All the CPUs used in this study were identical within the Origin 2000 machine. Roberts attributed the major source of this nonlinear scaling behavior to the situation that each processor had to dedicate more and more processing time to the increased number of *Protocol Data Units (PDUs)* exchanged between *SAF simulators (SAFsims)* as more processors are added to the distributed simulation.

To update similar results for modern processor architectures now being considered for Embedded Simulation, a similar set of tests using the OTBSAF "`-benchmark`" option were conducted. This execution option allows one to specify the number of platoons to use in the benchmark, which thus increments the number of vehicle entities by four for each platoon. A heterogeneous system with three computers was used. Host "bahrd" was a Dell Inspiron 8000 laptop using a Pentium III processor running at 1 Ghz. It

Table 2: OTBSAF Benchmark Results - Part I

	Number of Processors		
Host Machine	1	2	3
Bahrd	180	0	100
Bahr2	256	188	168
Bahr3	280	200	176
Total vehicles	280	388	444
Incremental		108	56

utilized 0.5 Gbytes memory and was running the Linux 2.4.20 kernel. Host "bahr2" was a generic desktop using an Athlon 2400+ processor with 0.75 Gbytes memory running the Linux 2.4.22 kernel. Host "bahr3" was another generic desktop using an Athlon 2600+ processor with 2.0 Gbytes memory running the Linux 2.6.7 kernel.

Table 2 lists the results obtained for these benchmarks. The test was conducted by iteratively changing the entity quantity values until the threshold between `pass` and `fail` was discovered. The entries in Table 2 reflect these results, where the first column identifies the computers by their host-name and the second column shows the maximum number of vehicles for each computer was operated separately. The third column reflects the results of taking two computers at a time, and likewise the fourth column represents taking all three computers at the same time. The "Total Vehicles" row reflects the maximum number of vehicles that could be generated by the respective number of computers. The "Incremental" row reflects the number of vehicles that were added to the exercise with the addition of another processor. These results again reflect similar nonlinear scaling behavior that was encountered in Roberts' earlier report.

There are number of techniques to address scalability issues. For instance, the final report of the Synthetic Theater of War experiment conducted in 1994 [Tiernan 1995], identified similar problems with scalability, reporting the maximum number of entities on a common network occurred with 10 computers. They overcame the scaling problems by isolating portions of the network and only sharing the necessary PDUs between the different network segments. Other reported solutions reported making changes to the OTBSAF/ModSAF architecture using for example only one copy of the PO database in a shared memory common to all processors.

Nonetheless, one item to note from Table 2 is that the faster processor continued to support more entities, implying that increased throughput can contribute to the scalability of entities that can be simulated. Another item discovered in the experiments is that the speed of the LAN between the computers did not impact the results, as both a 1 Gbit/sec and a 100Mbit/sec LAN were evaluated using "Bahr2" and "Bahr3". The laptop was restricted to a 54 Mbit wireless link. At least at this level of entity counts, the current LAN technology was not a limiting factor.

Table 3: OTBSAF Benchmark Results - Part II

	Number of Processors		
Host Machine	1	2	3
Redscull	268	0	148
Bob	412	276	244
Rednight	412	280	256
Total Vehicles	412	556	648
Incremental		144	92

To update the current state of the art even further, we had the opportunity to test a cluster of gaming machines. Two of these machines were based on AMD 64 Processor, an XP3000+ model, and a Pentium-4 Processor. All three of these machines had a 1 Gigabyte of main memory, and ran at a 2 GHz clock speed. Table 3 provides the results of this benchmarking effort. Clearly, the two AMD 64 machines identified as Bob and Rednight were faster than the Pentium, however the Pentium fell midway between the 2 Athlon Processors although their model numbers indicated they would be faster in a standard office benchmark. The two AMD 64 machines actually did perform more than 1.5 times faster as proposed by their 3000+ model number.

4. Conclusion

Modern microprocessor architectures have the capability to simulate 400 or more entities with acceptable fidelity for embedded training exercises. This simulation capacity coupled with the prioritized execution strategy introduced in [Bahr 2004B] provides sufficient capabilities to interact with all entities in the platform's field-of-view and monitor those likely to enter its field of view in OTBSAF. However, it was seen repeatedly that the number of entities feasible to simulate scales sub-linearly in terms of the number of processors utilized. Nonetheless, the required processing power is currently available in notebook computers which is sufficient for embedded simulation applications, thus enabling new dimensions of portability for the M&S community.

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