PARALLEL ARCHITECTURES FOR PLANETARY EXPLORATION REQUIREMENTS

(P.A.P.E.R)

(Final Report)

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1. SUMMARY

Currently the project entitled Parallel Architectures for Planetary Exploration Requirements, acronymed as PAPER for short, is on a one-year, no-cost extension. Therefore, nominally the project would have ended on August 31, 1993. The main reason for the no-cost extension was to utilize funds that were still available for student support. To this end, with the extension, the project has helped with stipend support and tuition reimbursement for one graduate student, Ms. Angela Olagunju, during Spring 1994 and Summer 1994 semesters. This support, indirectly, helped support the new Master's program in Computer Science at Hampton University.

Since its first funding for calendar year 1989, the project has been well documented through interim and final reports, as well as the interim proposals submitted for continuation of funding. Thus, the reporting requirements set forth in the original conception of the project have been met with numerous reports on timely basis, as is shown in references [1-6].

Therefore, the aim of this report is to provide a map regarding the essential contents of past reports, and otherwise provide an overview. The details regarding the activities and accomplishments involving each project phase are to be found in the above-mentioned references.

Here, we give a summary and briefly describe the background of the project, including the funding and extensions. Afterwards, we give a very brief overview of the essential accomplishments in each phase. Finally, we conclude with the statement regarding the overall impact of the project on the computer science program at Hampton University, and for modest contributions to N.A.S.A.'s mission-oriented research efforts.

1.1 Background

Parallel Architectures for Planetary Exploration Requirements (**PAPER**) project is oriented towards technology insertion issues for NASA's unmanned planetary probes. Its basic aim has been to augment N.A.S.A's long-term efforts for space exploration, with particular reference to computational needs for planetary exploration missions of mid and late 1990s. A dual, and by no means less important, aim of the project has been to help develop research expertise for minority faculty and students.

The project has originally been conceived as a three-year project involving one or two faculty members as principal investigators, and two students as research assistants. For reasons explained in the concluding section, the students were primarily chosen from among the undergraduate computer science majors in the department.

In the first proposal [1], these three-years were conceived as constituting the three main phases:

Phase 1: Identify computing system architectures that are particularly suitable for planetary probes;

Phase 2: Investigate fault-tolerance and neural-network enhancements for the particular class of computer architectures deemed especially suitable;

Phase 3: Investigate architectural enhancements in terms of efficient operating system kernel software design (PI's main area of expertise).

Although the project was envisioned to last three years, due to funding delays, there were no-cost extensions, once for nine months, and once for twelve months, making the completion date August 31, 1994. However, in terms of focus, the phases were adhered to as set forth in the original proposal.

Phase 1, the first year, of the project was funded for the calendar year 1989. At the time, Dr. Ruknet Cezzar, a Visiting Professor from AT&T, served as the Principal Investigator, at no cost to either N.A.S.A or Hampton University. Subsequently, Dr. Ranjan K. Sen, a visiting Associate in the Department of Computer Science, has joined the project as a member of the Hampton University faculty, in the capacity as its Co-Principal Investigator. Two student research assistants, one a graduate student in Mathematics department, and the other, an undergraduate student in Computer Science Department has joined the project.

In accordance with what was proposed, the Phase 1 research efforts were focused upon the evaluation of space mission computer architectures. Qualitative and quantitative discussions and assessments of work in this area by Charles Stark Draper Laboratory, Jet Propulsion Laboratory, Ames and Langley Research Centers have been reported in interim and final reports [2,3].

Phase 2, which was approved for funding, was postponed until January 1991 with the first no-cost extension, due to limited HBCU funds. The actual funding for Phase 2 therefore corresponded to the calendar year 1991.

Meanwhile as discussed in the related interim report [4], the student researcher assistants, Ms. Marletta Snowden and Ms. Seema Farhad has graduated and left the project. Also, towards the middle of Phase 2, the Co-Principal Investigator, Dr. Ranjan K Sen, has completed his visiting assignment and returned to Indian Institute of Technology, Kharagpur, India.

Shortly after, two full-time undergraduate students, Mr. Lamont L. Jackson and Sherman R. White, were hired as student research assistants. They were both bright and promising computer science majors. This period was perhaps most productive of the project, as reported in the associated interim report [3]. At the end of this phase, Mr. Lamont Jackson has graduated and left the project.

Funding for Phase 3 of the project, has again been delayed due to lack of funds and funding rearrangements between N.A.S.A and Hampton University, involving large block grants versus small individual grants (such as PAPER). Accordingly, another extension at no cost to N.A.S.A was obtained pending the availability of funds. Meanwhile, another proposal was submitted for the purpose of clarifying proposed phase 3 plans and research activities [5].

Thus, with two no-cost extensions, Phase 3 which was envisioned for the Calendar year 1992, was postponed to calendar year 1993. Funding for phase 3 was obtained in August 1992, under the designation NAG 1-949, Supplement 7, at 75% of the originally requested amount. As soon as funding was obtained. At first, there did not appear to be any qualified student research assistants for the tasks on hand, mainly development of software. However, after one semester's delay, we have been enlist the assistance of Mr. Sherman R. White who was in his senior year. As is discussed in related interim report [7], Mr. Sherman White has continued to contribute to the project in several important ways discussed later.

Finally, successful installation of Alex Parallel Computer which runs a commercial version of the Trollius distributed operating system licensed from the Ohio State University as a research tool on transputer-based nodes, was done during the final no cost extension. During this period, we have also made further progress in porting the MIMD Simulator Software to Sun workstations, although that work has not yet been completed.

1.2 Overview

The project commenced at a time when the computer science department was just established, as an offshoot of the Mathematics department. There was shortage of faculty with proven research experience and even with terminal degrees. More importantly, there was no graduate program in computer science to supply graduate students as research assistants. Therefore, it was decided that the project utilize the time and talent of undergraduate computer science students. Although, during the initial phase, there were attempts to recruit graduate students from other departments, such as Mathematics. However, it was discovered early on that the graduate students majoring in non-computer sciences, were of little help because of lack of proficiency in programming, and also lack of knowledge concerning computer architectures which was the main focus of the project.

Enlisting the assistance of one or two undergraduate students throughout the duration of the project, was much more helpful to the project since much of the work involved systems and application programming. In addition, this gave the undergraduate students a good idea of scientific research process. Furthermore, several students chose to pursue graduate studies in computer science, either attending the Hampton University's program which came later, or at another university. In short, if the purpose was to expose the undergraduate students to the idea of research and at the same time support their educational efforts, the project has done well.

Another purpose of the project was to help establish a research expertise in the department in preparation for the planned graduate program which would be established with the help of the National Science Foundation's planning grants to minority institutions. That, of course, was achieved as the example of support for one graduate student in the last phase shows.

Finally, the project has provided the principal investigator knowledge and expertise in grantsmanship and theoretical research. Since, at the time the principal investigator was a visiting faculty member from a development organization at AT&T, gaining the expertise in assessing the needs of granting institutions and fulfilling the reporting requirements was valuable.

2. MAJOR ACHIEVEMENTS

Perhaps one important overall contribution of the project was its style. As was originally proposed, the project involved various systems engineering type of activities to gather together the knowledge and expertise in the area of computer system architectures to be used for planetary explorations. In other words, the proposal did not cite important scientific findings, clever algorithms etc., but rather articulated the need to have a more focused and coordinated efforts in this area. In other words, the original aim was to make sense of numerous efforts at various N.A.S.A. research centers, at Jet Propulsion Laboratory in particular, and synthesize the findings. Although this was too big and too ambitious of an aim for a project of this scope, it has highlighted the need for more coordinated, if not specifically mission oriented research efforts at N.A.S.A.

The more specific achievements are summarized in the following sections.

2.1 Phase 1 Accomplishments

In accordance with what was proposed, the phase I research efforts were focused the review of requirements such as those mentioned in AIPS study, and the evaluation of space mission computer architectures. In the requirements arena, the original and recent AIPS studies by CSDL and planetary rover requirements by JPL/CalTech were evaluated. Qualitative and quantitative discussions and assessments of five experimental architectures involving CSDL's AIPS-POC; JPL's MAX and F/T Snooping-Cache, Mark IV Hypercube, and Langley Research Center's VHSIC chips have been reported in the interim and final reports for that phase. Some of the associated references are reiterated here [7-14].

One of the highlight of this phase was our two-day trip to JPL/Caltech for the purpose of ascertaining the status of AIPS-related activities. At the time, we obtained highly detailed and at the time current information regarding experimental architectures for planetary explorations.

2.2 Phase 2 Accomplishments

As detailed in the associated interim report [4], important accomplishments for the first half were:

- o Presentation of an award-winning student paper entitled "Analysis of OS Kernel in A Shared-Memory MIMD Machine" at 8th Annual Minority Technical Student Symposium [15]

- o The completion of the MIMD Performance Simulator on VAX/VMS system and the preparation of the MIMD Simulator User Manual [16]

- o Presentation of a paper entitled "The Design of A Processor Architecture Capable of Forward and Reverse Execution," at Southeastcon '91, Williamsburg, Va. [17]

- o Attendance at IEEE Teleconference on Neural Nets, and the survey of recent publications in neural nets [18]

In the Remainder of Phase 2, we continued to focus on system software performance issues. To this end, an experimental software package on distributed operating systems, Trollius, was licensed from the Ohio State University Supercomputer Center. We have implemented and experimented with two versions of this software, one on a stand-alone Sun workstation, the other on an entire Sun network tied together with Sun's NFS (Network File System). At the same time, we obtained another package, P4 from the Argonne National Laboratories, which allowed experimentation with parallel FORTRAN running different program modules on different Sun workstations via UNIX remote execution facilities.

Unfortunately, due to breakdown of AT&T DSP BT-100 parallel machine where it was returned to the AT&T site in Whippany, New Jersey, we could not carry out research on distributed neural networks using this 15-node machine. However, another student, Mr. Alfred Thompson, who joined the project during the second half, has continued to investigate neural network research areas. In particular, he has contacted various sites at Langley Research Center doing neural network research and has sought collaboration. In particular, we have contacted Mr. Don Soloway's area to explore possibilities of joint research. Primarily due to the fact that much of their work was carried out on a stand-alone personal computer and could not be shared remotely, we abandon these efforts.

2.3 Phase 3 Accomplishments

Building upon the success of the simulator package which was successfully completed, and was being used as a main tutorial in several computer science courses, Sherman has continued to contribute to the project in this regard, in several ways. One was the main issue of porting the successful MIMD simulator from the VAX/VMS system to UNIX systems, which would require reprogramming in C language. The other was to utilization of the internetworking facilities that have become available to collect software related to distributed operating systems.

Moreover, the acquisition of software using internet facilities towards the end of Phase 2 has changed our attention towards network system performance issues. One issue, in particular, involved the execution of FTP commands locally to transfer very large files. The issue was the sensitivity of FTP performance to various local network configurations and to the presence of disk-less workstations versus workstations with sufficient disk capacity. At the same time, Mr. Sherman White was engaged in fine tuning of the expanded Hampton University Local Area Network (HU-LAN). The enhancements involved utilization of NSF funds to expand the network which consisted of three VAX machines connected via DECNET into a local network with several clusters: DECNET, Sun Network File System (20 workstations), Apple Appletalk (20 Apple IIc), and AT&T Starlan (20 AT&T 6312 IBM compatibles). All these clusters were to be tied together using Ethernet cable and TCP/IP protocol. We have presented our work in this area at 1992 MU-SPIN conference held at N.A.S.A. Goddard Space Center, Greenville, Maryland [19].

During the second half of Phase 3, as was envisioned in the associated interim report [5], we continued to explore the design and scope of the Trollius software. The aim was to see if its design could be used as basis for reworking and expanding the MIMD Simulator which was developed in-house. At the same time, we sought to make that package available on Sun network for easy access by the graduate students of the newly established graduate program in Computer Science, as well as by those undergraduates using the above-mentioned tutorial on parallel operating system performance.

To this end, Mr. Sherman White has used Pascal to C conversion utilities to port the system to a Sun workstation. Importantly, borrowing from the design of Trollius, he has utilized UNIX message-passing facilities to implement various internal queues of the operating system kernel which was being simulated.

Mr. Sherman White has completed the part involving performance statistics, but not the animation part involving highly complex X-window graphics. Before, finishing up the graphical part, he has graduated and left the project. We then sought to find another undergraduate student who is proficient in UNIX and C to continue and finish the work. Unfortunately, we were not successful in hiring a student, graduate or undergraduate, who is proficient with C language, knows UNIX system well, and has some knowledge of X-window utilities.

While porting the non-graphical portion of the software to the Sun workstation, and utilizing UNIX message passing facilities, we were also able to extend the scope of the simulator to distributed message-passing MIMD machines, in addition to the centralized shared-memory MIMD machines. Thus, the new design was based on UNIX message passing facilities for modularity and for support of message-passing MIMD systems.

At the time Mr. Sherman White left the project, we were also investigating the possibility of doing away with an important limitation of the software, namely the running of weather-prediction algorithm as the typical parallel computation. This was a challenging part, since parallel computations differed significantly in their algorithms, and mapping of those algorithms unto the MIMD architecture, in addition to investigating the OS kernel performance as the primary focus, was necessary.

We have submitted our results first to the 1992 Annual SIGCSE Symposium. Unfortunately, due to the special educational focus, SIGCSE Symposium did not accept the paper. Subsequently, we have resubmitted our findings to 1992 MU-Spin Conference held in Greenbelt, Maryland. There, we have summarized our activities involving the utilization of the newly established internet facilities to download various software packages, including the Trollius 2.2

software licensed from the Ohio State University.

In the second half of Phase 3, as well as during the no-cost extension period, Mrs. Angela Olagunju, a graduate student attending the newly established Master's program in computer science at Hampton University has joined the project. Her activities involved the installation of the 12-node parallel machine using transputers and supporting a commercial version of the Trollius distributed operating system. In addition, Mrs. Olagunju continued with the work of porting the MIMD simulator software from VAX/VMS system to Sun workstations.

As an intermediate step, Mrs. Olagunju first reworked the software, still using Turbo Pascal, to run on a personal computer. Once that is accomplished, the plan is to utilize Pascal to C conversion utilities to develop the programs in C language, and still using the MS-DOS personal computer platform. Finally, after the C version is fully tested, the software will be ported to the Sun workstations. The main reason for this strategy was the student's close familiarity with Turbo Pascal, but lack of expertise in C language. Mrs. Olagunju's report shown in Appendix A provides further details of her activities during Spring and Summer 1994.

3. CONCLUSION

The project's main contributions have been in the area of student support. Throughout the project, at least one, in some cases two, undergraduate students have been supported. By working with the project, these students gained valuable knowledge involving the scientific research project, including the not-so-pleasant reporting requirements to the funding agencies!

The other important contribution was towards the establishment of a graduate program in computer science at Hampton University. Primarily, the PAPER project has served as the main research basis in seeking funds from other agencies, such as the National Science Foundation, for establishing a research infrastructure in the department.

In technical areas, especially in the first phase, we believe the trip to Jet Propulsion Laboratory, and gathering together all the pertinent information involving experimental computer architectures aimed for planetary explorations was very helpful. Indeed, if this effort is to be revived in the future due to congressional funding for planetary explorations, say an unmanned mission to Mars, our interim report will be an important starting point.

In other technical areas, our simulator has pinpointed and highlighted several important performance issues related to the design of operating system kernels for MIMD machines. In particular, the critical issue of how the kernel itself will run in parallel on a multiple-processor system has been addressed through the various ready list organization and access policies.

In the area of neural computing, our main contribution was an introductory tutorial package to familiarize the researchers at N.A.S.A. with this new and promising field [20]. Finally, we have introduced the notion of reversibility in programming systems which may find applications in various areas of space research

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APPENDIX A: Alex Parallel Computer Installation

Research Activity Report

January thru September 1994

Porting the MIMD Simulator from VAX/VMS environment to the MS-DOS/Turbo Pascal

I looked at several books on operating systems and a book on queueing systems theory. I read thoroughly the literature given to me on the project (MIMD Simulator User Manual, Process Management Overhead in a Speedup-Oriented MIMD System, and Analysis of Operating System Kernel Overhead in a Shared-Memory MIMD Machine).

Dr. Cezzar gave at least two demonstrations of the MIMD Simulator.

I ported the script files and Pascal code from the VAX to MS-DOS. The VMS's script files and Pascal programs were modified or rewritten into a Turbo 7.0 Pascal file. Turbo graphics were used for the graphical displays. Redevelopment on the SUN workstation using ANSI C and PHIGS graphics under SunView Windowing System was another possible implementation.

The modifications made to the current program were as follows:

1) changed the order and appearance of the menu prompts
2) did not incorporate the animated graphical view of the cells
3) used Turbo Vision programming package to allow users to highlight different areas of the output for detailed information (output includes the Reports, Pie Chart, and Line Graph)
4) Did not keep the redundant abstract data types and nested records
5) Did not keep many of the pointer records
6) Greatly decreased modularization

Problems encountered during porting were:

1) Chunks of code were missing including data type and variable declarations
2) Redundant data type and variable declarations
3) The workings of the program and control flow was very hard to figure out
4) Some of the concepts were only familiar to me which caused confusion when porting the MIMD Simulator from VAX/VMS environment to the MS-DOS/Turbo Pascal

APPENDIX A: Alex Parallel Computer Installation (Continued)

I looked at two manuals on Alex Parallel Computers (Alex-Trollius 2.2.1, Alex XTrollius, and Alex-Brenda).

Assisted Mr. Cokus with the following:

1) relocating the Alex computer
2) connecting this front-end processor to the network
3) loaded the system software and appropriate drivers
4) troubleshot and diagnosed computer software and hardware problems

Problems encountered during installation were:

1) computer hardware had been damaged in shipping