Rethinking RAM: Testing alternative models of computation (Progress)

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1 Project Summary

General Area: Models of Computation in Algorithms

Keywords: RAM model, computational models, benchmark

Question: The RAM model of computation is the traditionally assumed environment of most algorithm analysis, but it is questionable whether it serves as an accurate model of modern computers. This project will experimentally test the RAM model versus the recently proposed Virtual Address Translation (VAT) model. *Is Jurkiewicz and Mehlhorn's Virtual Address Translation model experimentally superior to the traditional Random Access Machine for modeling computational complexity?*

Responsibilities:

LACHUT Benchmark Algorithms, Write/Edit Reports, Analyze Algorithms with VAT Model, Assist K. Lahiri

LAHIRI Compare Models/Experiments, Analyze Algorithms with VAT Model, Write/Edit Reports, Assist D. Lachut

Budget: $6,165.92

Deliverables: Progress Report, Final Report, Presentation Slides

2 Original Schedule

The project's original schedule was:

Submit Project Proposal	27 February 2013
Benchmark Procedures	13 March 2013
Be Competent to Use VAT Model	20 March 2013
Submit Progress Report	27 March 2013
Algorithms Analyzed with VAT Model	10 April 2013
Submit Draft Report & Presentation	17 April 2013
Oral Presentation	29 April 2013
Submit Final Report	15 May 2013

3 Status

Using the original schedule as a plan, the project team began work on the project. They here note the progress in carrying out the plan, and discuss the work they will accomplish moving forward.

3.1 Progress

The team's primary accomplishment thus far is in implementing a set of standard reference algorithms as procedures in C. By selecting algorithms such as heapsort, permute, binary search, etc., they bypassed need to analyze these procedures under the RAM model, as these algorithms are already well understood and well documented.

Additionally, the team has attended to it's overhead responsibilities by delivering this progress report with its accompanying outline of the final report.

3.2 Remaining Work

Much remains to be done. The step of benchmarking the procedures on real hardware has taken longer than intended, as has the task of understanding the VAT model of computation. However, these difficulties were forseen and the next section of this report comments more fully on them.

Also remaining is the work originally scheduled for the next several weeks. The selected algorithms must be analyzed using the VAT model. Following such analyses, the team will present its findings in draft and final reports and, possibly, in a presentation.

4 Issues

In the project proposal, the project team noted two primary difficulties to be overcome for the completion of the project. They were:

VAT Analysis: As the Virtual Address Translation computing model is very new, little can be known about it. Prior to starting this project, the investigators know of only two people who currently understand the model and have done work with it. This entails some things.

Will the model work: Prior to beginning the project, the investigators cannot know if algorithm analysis under the new model will be a tractable problem in every attempted case.

Complexity: Even the tractable analyses will be substantially more complex than the corresponding analyses done with the RAM model.

Lack of helpful resources: There is necessarily a lack of resources to assist the investigators should the model prove especially difficult to master or the analyses especially difficult to formulate.

Benchmarking: It may be difficult to devise the most correct way to benchmark the running times of the implementations of the selected algorithms. Each tested procedure must run multiple times on multiple, varied inputs, and perhaps even on different operating systems to determine if there is a single model of computation that is superior.

These two areas remain the two primary difficulties being overcome.

5 Revised Schedule

In light of the team's progress and difficulties, the revised schedule is as follows:

Submit Project Proposal	27 February 2013
Submit Progress Report	27 March 2013
Benchmark Procedures	3 April 2013
Algorithms Analyzed with VAT Model	10 April 2013
Submit Draft Report & Presentation	17 April 2013
Oral Presentation	29 April 2013
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Final Outline

Draft outline of the final report follows.

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Abstract

This is where the abstract will briefly summarize how great our project is. After all, we discovered that the VAT/RAM model is superior to the RAM/VAT model of computation.

Keywords RAM Model, computational models, benchmarks, algorithms

1 Introduction

We solved the problem of demonstrating whether the Virtual Address Translation (VAT) model of computation–presented by Jurkiewicz and Mehlhorn–is a better model than the Random Access Machine (RAM) model for analyzing the performace of algorithms when implemented on modern computing hardware.

The novel contribution includes not only the benchmarking of these procedures, but also the comparative analysis of the two models.

This work could be very significant if VAT is indeed superior to RAM. We would be the first to independently verify this and we would be contributing some of the first analysis of common, reference algorithms.

2 Motivation

Analysis of algorithms on abstract machines serves as a crucial element of computer science, which allows incredible increases in the speed and utility of

computer programs. Until now, computer scientists have used the RAM and the EM models to perform algorithmic analysis accurately. But Jurkiewicz and Mehlhorn observe discrepancies with some experimental findings and attempt to push forward the VAT model to account for these discrepancies.

Before algorithm analysts shift to this new model, they must carefully verify its claims and correctness, it's utility. This is where Jurkiewicz and Mehlhorn's contribution falls short. Their paper does mention that experimental findings tally with the theoretical predictions of the new VAT model, but it does not clearly represent these findings. Additionally the number of test cases is limited. So before scientists readily accept this new model for theoretically analyzing the running time of algorithms the test set must be broadened to verify and compare the experimental results with the model's predictions.

If it can be verifed by experimental comparison that the new VAT model is more accurate, then this will serve as an incentive to researchers to use the proposed model for more accurate estimations of running time of algorithms. More accurate algorithm analysis will help maintain the pace of innovation enjoyed by computer science for a generation.

3 Previous Work

It is evident that most papers on algorithms tend to ignore the cost of virtual address translation, though researchers recognize these costs. This is because of the model that researchers follow, and that is the classic RAM model without virtual memory. Papers like "The cost of virtualization" by Ulrich Drepper and other materials like "AMD64 Architecture Programmer's Manual Vol 2" describe the implementation of virtual memory and its associated costs during translation; but no study has tried to develop a model that considers these costs for algorithmic analysis prior to the recently proposed VAT model.

Keeping this trend in mind, it is not surprising that there has been little related work that carefully verifies the experimental results and strengthens the new model that accounts for these costs. Our contribution, experimentally examining and comparing the proposed model to the older model, will fill this gap.

4 Methods

Here we describe in excruciating detail what we did.

4.1 Implementations

We took a set of standard reference algorithms including permute, and heapsort. We turned them into C procedures. We ran each one a dozen times on each of a wide variety of sizes of inputs. On each run, we timed the execution. We then took those running times and figured their growth rates. This gives us real world running times.

4.2 VAT Model Analysis

We learned how to use the VAT model. We overview how to do that here, but point you to the J&M article to explain it. We used the VAT model to analyze our set of algorithms.

5 Results

We need actual results to write this section, but it will be divided into three subsections.

5.1 Benchmarks

This subsection will have some text explaining several charts that show empirically discovered running times of our various procedures.

5.2 RAM

This subsection will be fairly brief, with a table listing the runtimes every one 'knows' these reference algorithms have.

5.3 VAT

This subsection will have a little more to it than the RAM section. There will be a table telling about the calculated running times of our algorithms. There might also be some text describing some of the difficulties or nuances of doing the analyses with the new model.

6 Discussion

This is where we discuss results.

6.1 RAM vs Reality

Here is where we will compare the benchmark results with the standard runtimes. This will need a table to compare the two algorithm-by-algorithm.

6.2 VAT vs Reality

Here is where we will compare the benchmark results with the new model's runtimes. This will need a table to compare the two algorithm-by-algorithm.

6.3 VAT vs RAM

The big finale, old vs new, here is where we will declare a winner between RAM and VAT. This will likewise need a table. Really all three tables could be combined into one good chart for the whole section.

7 Future Work

There still remains work to be done making our mathematical models better reflect reality.

8 Conclusions

We did the experiment, because reasons. We found a result, and thought it was pretty nifty.

9 References

The final paper will include our references duly cited using Bibtex. I have to remember how to compile them properly. But from our proposal

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5. T. Jurkiewicz and K. Mehlhorn, "The cost of address translation," presented at the ALENEX13, New Orleans, Louisiana, 2013, pp. 148–163.

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7. R. K. Ahuja and J. B. Orlin, "Use of Representative Operation Counts in Computational Testing of Algorithms," *INFORMS Journal on Computing*, vol. 8, no. 3, pp. 318–330, 1996.

8. U. Drepper, "What every programmer should know about memory, Part 1 [LWN.net]," 21-Sep-2007. [Online]. Available: http://lwn.net/Articles/250967/. [Accessed: 27-Feb-2013].

Appendix

We will include an Appendix for our source code and data. We might include our efforts at employing VAT analysis. For now, all our materials can be found online at:

https://github.com/dslachut/adv-algo-project