Investigation of the Programming Capabilities of the HAL-15 Hypercomputer

Neha Reese Dandawate
Olaf O. Storaasli (Mentor)

Research Performed on Virginia Governor's School NASA Summer Mentorship
Analytical and Computational Methods Branch
NASA Langley Research Center
Hampton, VA
July 18, 2002

Significance Report

Previous Research

The National Aeronautics and Space Administration Langley Research Center first began its research with the HAL-15 hypercomputer in March 2001, when Langley received the hypercomputer from Star Bridge Systems (Uher). Senior aerospace research scientists Dr. Olaf Storaasli and Dr. Robert Singleterry have been the foremost leaders in this study, who, in conjunction with their associates, have spent the past 18 months developing programs and debugging the system. All findings and discoveries were reported back to Star Bridge Systems, which, in turn, incorporated them in updated versions of the program.

The effect of previous research on my study is analogous to the construction of a building; initially, the groundwork must be laid out, and subsequent construction takes place by building atop prior construction. Similarly, the development of arithmetic and transcendental functions is the antecedent in my attempt to build vector and matrix algorithms, and the assurance that my programs are correct and will work under nearly all, if not all, situations lies in the implementation of various new data types. Thus, the amassing of previous research serves as the basis for my work with the HAL-15 hypercomputer, just as mine will do the same for future researchers.

Uses for the HAL hypercomputer within NASA

NASA has high hopes for this radically new technology. Once fully developed, the astonishing speed of the HAL hypercomputer will be fully exploited throughout various NASA projects.

One of the primary hopes for HAL is its implementation in satellite and spacecraft control centers. The hypercomputer would allow the space technologies to perform a more diverse group of tasks, allowing NASA scientists to learn a great deal more about space through significantly fewer spacecrafts and monetary efforts (Thomson). This ripple effect would be furthered as the leftover money will be used to finance other projects, leading to new discoveries and findings.

Moreover, the HAL hypercomputer will be used for the exploration of solutions of structural, electromagnetic, fluid analysis, and radiation analysis for astronaut safety, atmosphere science, digital signal processing, pattern recognition, and acoustic analysis (Uher).

HAL in the Community

The HAL hypercomputer has the potential to have enormous effects on the community outside of NASA as well, revolutionizing nearly all aspects of life. Most obvious is the technology's establishment in mainframe and personal computers on a massive scale, allowing for much faster telecommunications and information processing (Star Bridge Systems).

Star Bridge Systems has entered several agreements with companies and organizations in hopes of developing and utilizing the HAL hypercomputer. One such deals is the collaboration with the Smithsonian Astrophysical Observatory at Harvard University to execute the largest virtual supernova experiment ever performed. Another partnership includes the National Security Agency to build a large-scale hypercomputer for cryptography, and potentially one with Cold Springs Harbor Laboratory to further genetic exploration (Thomson).

The following is a breakdown of additional uses for the HAL hypercomputer currently either in consideration or in the preliminary steps of execution.

- Circuit-based telecommunications
- Internet servers
- Chemical databases
- Computer chemistry/molecular modeling
- Printing and publishing
- Complex data management
- Visual simulations
- Database, data storage and data mining
- Geo-spatial imaging
- Distribution servers
- Manufacturing
- Engineering analysis
- Distributed supercomputing
- Industrial design
- Interactive entertainment
- 3D animation and rendering
- Media management and distribution
- Asset management
- Network and system management
- Broadcast graphics
- Building design
- Real-time video compression for conferencing and distribution
- Context accurate natural language translation
- Video-on-demand
- High data-rate adaptable satellite and terrestrial communications
- Immersive virtual reality
- New forms of artificial intelligence
- Adaptive motion control systems for robotics and industry
- Pattern recognition for fingerprint/voice/image identification
- Voice over IP

- Motion picture special effects (Star Bridge Systems)

Despite all these potential uses, Star Bridge Systems plans to emphasize its technology on military, aerospace, bioscience, and telecommunication industries because these trades present the greatest need for the HAL hypercomputer (Thomson).

Abstract

A recent new technology in the computer field is the Hyper Algorithmic Logic hypercomputer (HAL). Created by Star Bridge Systems, this hypercomputer is built with Field Programming Gate Arrays (FPGAs) that allow this computer to be the leader in reconfigurable computing. Reconfigurable computing refers to FPGAs' ability to be reconfigured an innumerable amount of times specifically for the task on hand, inevitably allowing for parallel information processing. This parallel nature gives the HAL hypercomputer unparalleled speed, its primary advantage over its traditional CPU counterpart that uses serial data processing. Other advantages include price, efficiency, size, potential, and optimal silicon use.

In order to expand HAL usage to a greater number of users, Star Bridge Systems created the graphical programming language VIVA. By use of this icon-based language, users are able to create programs and algorithms for their needs.

The HAL hypercomputer is a relatively new technology and naturally demands extensive exploration into its potential. Consequently, for the past 18 months, NASA has been developing programs and debugging the HAL-15 hypercomputer via VIVA. During my experience at NASA, I was given the opportunity to develop vector and matrix programs while searching for any errors in the system. Through continuous work on the HAL and VIVA, I worked under the supervision of Dr. Olaf Storaasli and with the aid of his other students to develop these programs.

Introduction

The HAL hypercomputer

The HAL hypercomputer has been causing a great deal of excitement in the computer science field. Acclaimed as the fastest, most flexible computer in the world, it is most likely the technology of the future (Wermer).

The Hyper Algorithmic Logic (HAL) hypercomputer is the product of Star Bridge Systems, a small Utah-based company. Its primary advantage over its peers is speed; whereas the fastest IBM supercomputer can process 3.9 trillion calculations per second, HAL can handle 12.84 trillion calculations per second (Martinez).

HAL's astonishing speed lies in its massively parallel software. Rather than being confined to serial processing as standard computers are, it is able to execute multiple tasks at once. This is possible because HAL utilizes Field Programming Gate Array chips, also known as FPGAs. FPGAs are silicon chips with millions of gates capable of being reconfigured as a custom chip, meaning it can reconfigure itself almost instantaneously based on the demanded task. In other words, HAL is able to create a sort of specialized computer based on the specific task called upon by the user (Brownstein). An FPGA may be reprogrammed a thousand times per second and automatically takes full advantage of all an algorithm's inherent potential for parallel computing. If a task does not use all FPGAs, the remaining ones may be reconfigured to fulfill another task simultaneously. In addition to this parallel nature, another advantage an FPGA offers is its ability to be programmed in an analog computer style that does not require the development of the solution algorithms of the governing equations of the problem. This allows for not only maximum silicon use, but for a significant reduction in the time necessary to perform tasks as well (Singleterry Jr., Sobieszczanski-Sobieski, and Brown)
.

In order to make this technology accessible to a wider range of people, Star Bridge Systems created VIVA, a graphical programming language that was created especially for this massively parallel structure. VIVA allows users to rapidly develop software based on their specific needs through icons that can be connected to create a wiring-like diagram (Techmall). Once the algorithm is created, it can then be compiled to formulate an object that performs a specified task. This object can then be placed in the VIVA library, which houses all the objects. In this manner, a user may create many intricate programs by using basic objects from the library.

The Creators of HAL: Star Bridge Systems

Kent Gilson, CEO of Star Bridge Systems, is the key individual responsible for the development of the HAL hypercomputer. His experience with FPGAs dates back to 1984, when he began to explore a new branch of computers that he labeled "reconfigurable computing". In December 1997, Gilson created Star Bridge Systems, a company dedicated to the production of reconfigurable computing in technology (Thomson).

In March 2001, Star Bridge Systems enacted a Space-Act agreement with the National Aeronautics and Space Administration in which HAL hypercomputers were given in exchange for research and information on the system. Through this partnership, Star Bridge has been able to rapidly develop the HAL hypercomputer while NASA has been given access to explore one of the most revolutionary breakthroughs in the field of computer science in recent times.

HAL vs. Traditional CPUs

The HAL hypercomputer presents several significant advantages over today's conventional computers, ranging from the components of the computers to their potential.

The most obvious advantage the HAL hypercomputer offers is a drastic reduction in time necessary to process information, possibly handling data up to 60,000 time faster than an IBM 300 MHz computer (Techmall). In addition, HAL also provides monetary and energy savings. According to Kent Gilson, HAL hypercomputers will be able to present the public with a data processing technology that is a thousand times less expensive and that much more efficient (Thomson). This advantage of efficiency lies in the fact that conventional computers utilize only about 10%-20% of its silicon, while the HAL hypercomputer maximizes silicon use. Additionally, the typical CPU has a fixed word, a wasteful use of energy, whilst HAL has variable data types that allow the hypercomputer to adapt to its task (Star Bridge Systems).

The HAL hypercomputer also is much easier to program for many than its traditional counterpart. VIVA allows for graphical programming, a promising alternative to the standard keyboard-based language. This not only allows for a wider variety of users, but it also allows programs to be developed in parallel form rather than serial (Thomson).

There is a great disparity between the potential of CPUs and FPGAs. Conventional computers are limited to serial processing, and thus cannot offer much efficiency or speed for some of the complex problems presented by scientific breakthroughs; rather, as the problems become increasingly complex, today's CPUs slow down. This makes them poor factors in such important findings as the decoding of DNA and gene sequencing. The HAL hypercomputer, however, can process complex problems in the same amount of time as simple problems, making it a wise choice for projects such as genetic exploration and artificial intelligence (Star Bridge Systems).

My Purpose with HAL

In my time at NASA, the purpose of my experiment was evaluating and debugging VIVA and developing of programs, namely vector, matrix, factorial, and computational programs for the HAL-15 hypercomputer. Under the supervision of Dr.

Olaf Storaasli and with the aid of his associates, I had been working towards creating such VIVA programs for five weeks.

Literature Review

1. **"Creating the Real HAL" Michael Martinez, ABC News article**: This article is a general overview of Star Bridge's HAL hypercomputer. It gives a brief introduction to the structure of the hypercomputer, its advantages and disadvantages, potential, and a comparison with traditional CPUs. This article was also one of the few that addressed the possibility that HAL may not live up to its hype and may perhaps be simply an overlyin the computer industry.

2. **"A $1000 Supercomputer?" Mark Brownstein, CNN News article**: This CNN articles focuses primarily on the HAL hypercomputer and its functional potential. It gives a general background on how the computer works, but does not comment on its current state or future uses. This article emphasizes the belief that the HAL hypercomputer is the way of technology of the future.

3. **"Star Bridge Systems announces World's Fastest Supercomputer HAL-300GrW1" Techmall**: This piece of information places the HAL hypercomputer in context with the economy and its potential effect of the computer industry. Much is said about Star Bridge Systems and its practices, and although this article does not give a technical explanation of FPGAs, it was one of the only ones to speak of VIVA.

4. **"New computer technology: The Hypercomputer" Lompoc Record**: This is a rather technical report of HAL, aimed for most likely someone with experience with computers. It talks of the revolutionary ways of VIVA and FPGAs, but does not comment on HAL's current state or Star Bridge Systems.

5. **“Computing faster than engineers can think” Bill Uher, NASA**: This article deals primarily with NASA’s interaction with the HAL hypercomputer. It gives a brief introduction to HAL, but draws particular attention to the computer’s valuable uses, especially for scientific discoveries.

6. **“Star Bridge claims changes supercomputers to hypercomputing” Sandra Wermer, Primeur**: A radical view of HAL is given in this article, claiming that is the amazing technology of the future. It reiterates the belief that the HAL hypercomputer will redefine everyday life and technology in the future. Not surprisingly, this article is not a technical one and fails to explain how the hypercomputer functions.

7. **“Field-Programmable Gate Array Computer in Structural Analysis: An Initial Exploration” Robert C. Singleterry Jr., Jaroslaw Sobieszczanski-Sobieski, and Samuel Brown, 43rd AIAA Structures, Structural Dynamics and Materials Conference**: This is a technical paper that gives an in-depth evaluation of FPGAs, their uses, and potential. Several experiments were carried out, and the results indicated that FPGAs have great potential to reduce the time needed to solve a variety of solutions. The paper also examines the differences between conventional CPUs and FPGAs, how to program FPGAs, and problems that arise when using FPGAs. Although this paper does not concentrate specifically on the HAL hypercomputer or VIVA, these were the tools that were used to carry out the study.

8. **“SBS Unleashes VIVA” Kimball Thomson, Wasatch Digital IQ**: This article is a comprehensive look at both Star Bridge Systems and the HAL hypercomputer. It gives a thorough story about the development of Star Bridge Systems, going back to Kent Gilson’s first work on computers in 1974. It details the road the company has taken and its plans for the future, both monetarily and technologically. The article also looks at the HAL hypercomputer, its conception,

current state, obstacles, and potential. The article hints that hypercomputing is the way of the future through numerous interviews and comparisons.

9. **Star Bridge Systems Webiste, Star Bridge Systems**: This website is the Star Bridge company website and serves to introduce potential customers to the products of the company. Naturally, a great deal of bias occurs, and while many of the claims are not substantiated with hard evidence, this website does offer a wide list of potential uses for the HAL as well as a great deal of technical information on the hypercomputer.

Research Questions

The following is a list of some of the questions I had during my work pertaining to me research.

- What is the HAL hypercomputer? Why is it so important?
- What is a FPGA? How does it differ from a CPU?
- What is VIVA and how does it work?
- What are some problems with the system?
- What is the most efficient method to create a dot product?
- What is the most efficient method to create a vector-by-vector multiplication product?
- How can I create a computational program?

Methods and Materials

Materials: HAL-15 hypercomputer
VIVA software

Method:

Begin by turning on the HAL-15 hypercomputer. Log in to Network Neighborhood as Starbridge. Open the VIVA program, load the FAI system, the MetaLib sheet.

Open Composite Folders in the VIVA library. Open Jacobi file. Open I/O subfolder and drag Write_D icon and Read_D icon to main screen. Open Primitive Objects sheet from the library and drag an Input icon onto the screen. Cut this icon. Paste and attach this icon to the Data, i, size, and Go nodes on Write_D. Double click on the piping connecting the Input icon and the Data node. Take the resulting piping and attach to the Dtype node on the Read_D icon. Double click on the piping connecting the Input icon with the i node and take the resulting pipeline and attach to the i node of Read_D. Double click on the piping connecting the Input icon and the Go node and attach this new pipeline to the Go node of Read_D. Right click on the Input icon for i of Write_D. Set the Data type as MSB004. Do the same with the Size input icon. Open Vectors folder from Jacobi folder and drag Dense icon onto screen next to Write_D and Read_D icons. Attach D_I of Write_D icon with D_I_O node on Dense icon. Attach D_I of Read_D with D_I_1 node of Dense icon. Drag another Input icon from Primitive bits folder and attach to S node of Dense_icon. Right click on this icon and set name to Write/Read. Under the Jacobi file, open PackUnpack folder. Drag Unpack_D_O icon and place next to Dense icon. Connect D_O node of Dense with the only node on the left side of Unpack_D_O. Open Registers folder in VIVA library and drag out six RegEn icons, placing them on the extreme right of the screen in a vertical line. Attach the Data node of Unpack_D_O to the first RegEn D node. Double click on this piping and attach it to the third and fifth RegEn's D node. Open Data Info folder in VIVA library and drag out three Equal icons. Attach one node of each other these to the i piping of Write_D. Drag out three Input icons from the VIVA library and attach one to each of the remaining nodes on the Equal icons. Right click on the Input icon of the first Equal icon. Set data type to MSB004, attributes to constant, and values to *1. Right click on the Input node of the second Equal icon. Set data type to MSB004, attributes to constant, and values to *2. Right click on the Input node of third Equal icon. Set data type to MSB004, attributes to constant, and values to *3. Go to VIVA library and drag three AND icons from the

Primitive Objects folder. Attach the right node of the first AND to the En node of the first RegEn icon. Attach the right node of the second AND icon to the En node of the third RegEn icon. Attach the right node of the third AND icon to the En node of the fifth RegEn icon. Attach the right node of the first Equal icon to one of the left nodes of the first AND icon. Attach the right node of second Equal icon to one of the left nodes of the second AND icon. Attach the right node of third Equal icon to the one of the left nodes of the third AND icon. Attach the Done node of the Unpack_D_O icon to the unattached node of the first AND icon. Double click on this piping and attach to the unattached nodes of the second and third AND icons. Go to VIVA library and drag three AND icons onto main screen. Attach right node of the first AND icon to the En node of the second RegEn icon. Attach the right node of the second AND icon to the En node of the fourth RegEn icon. Attach the right node of the third AND icon to the En node of the sixth RegEn icon. Attach one left-side node of the first AND icon (attached to the second RegEn) with the En node of the first RegEn. Double click on this piping and attach it to the D of the second RegEn. Attach one left-side node of the second AND icon (attached to the fourth RegEn) with the En node of the third RegEn. Double click on this piping and attach it to the D of the fourth RegEn. Attach one left-side node of the third AND icon (attached to the sixth RegEn) with the En node of the fifth RegEn. Double click on this piping and attach it to the D of the sixth RegEn. Go to library and drag an Equal icon to main screen. Attach one left-side node with the Write/Read piping of the Dense icon. Drag an Input icon from library and attach to the other left-side node of the Equal icon. Right click on this Input icon and set data type to Bit, attributes to constant, and values to *1. Take the right-side node and attach to the AND icon attached to the second RegEn. Double click on this piping and attach the Equal to the unattached nodes of the other two AND icons. Under Primitive Objects folder, drag out six Output icons and attach one to each of the RegEn. Right click on the first Output icon and specify name as Data1. Right click on second Output icon and specify name as Data1Done. Right click on the third Output icon and specify name as Data2. Right click on fourth Output icon and specify name as Data2Done. Right click on the fifth Output icon and specify name as Data3. Right click on sixth Output icon and specify name as Data3Done. Save sheet. Convert Sheet to Object with title Vectorwreg.

Open a new sheet. Drag two Vecwreg icons onto main screen from library.Attach Input icons to each of the nodes on the left side of each icon. Let the first vector icon be called vector A. Right click on each of the Input icons attached to the first vector icon and add an A to the end of each Input name. Let the second vector be Vector B. Right click on all the Input nodes of Vector B and add a B to the end of each name. Open the Math folder under the Composite Objects Folder. Open the Arithmetic subfolder and drag six multiplication icons onto the screen, placing them in a vertical line. Open Convert File and pull out twelve Dynamic Out icons. Attach one to each A and B of the multiplication icons. Open Control folder and drag six OneShot icons. Attach one to each of Go on the multiplication icons. Drag out six AND icons from the Primitive Objects folder. Attach the right-hand side of each of the AND icons to the I node of the OneShot icons. Attach Data2 of Vector A (Data2A) to the first Dynamic Out of the first multiplication icon. Attach Data3 of Vector B to the second Dynamic Out of the first multiplication icon. Connect the respective done nodes of these data to the AND icon of the first multiplication icon. Repeat this process with the rest of the multiplication nodes, attaching Data3A and Data2B to the second multiplication icon, Data1A and Data3B to the third multiplication icon, Data3A and Data1B to the fourth multiplication icon, Data1A and Data2B to the fifth multiplication icon, and Data2A and Data1B to the sixth multiplication icon. Pull out six StaticOut icons from the Convert folder and attach the data node of each to the P node of the multiplication icon. Double click on the piping connecting the Input node of DataA to the Vectorwreg icon. Pull the piping and connect to type node of each other StaticOut icons. Pull out six Output nodes from the library and attach one to the blank node of the left-side of the StaticOut function. Right click on the Output icon and specify the name as the name of the two numbers that were multiplied (i.e. for the first multiplication icon, the output name is 2A3B). Go to library and drag six RegEn icons from Registers file. Attaching one RegEn icon to each multiplication vector, attach the Done node of the multiplication icon to the D and En nodes of the RegEn icons. Drag six outputs from the VIVA library and attach one to the Q node of the RegEn icon. Right click on each of the Output nodes and specify the name as the two numbers being multiplied and Done (i.e. for the first RegEn, the name is 2A3Bdone). Save sheet. Convert this to an object called vectormult.

Open a new sheet. Drag the icon vectormult from library. Drag two OneShot icons from the VIVA library and attach one to each of the Gos on the vecturmult icon. Attach Input nodes to each of the nodes on the left side of the vectormult icon and the I node of the OneShot icons. Drag three Sub icons from Arithmetic folder (subfolder of Math in Composite objects). Drag three OneShot icons from the convert folder and attach the Pulse node to the Go node on each Sub icon. Drag three AND icons from the Primitive Objects folder and attach each one to the I node on the OneShot icons. Attach the first two Data from the vectormult icon to the data input of the Sub icon, making sure the data is kept in order (i.e. Data2A3B is data A and Data3A2B is data B for the first Sub icon). Attach the respective dones of each data of vectormult to the AND icon of the corresponding Sub icon. Drag three RegEn from the Registers folder. Attach the Done node of the first Sub icon to the D and En of the RegEn. Repeat this operation for the remaining Sub and RegEn icons. Drag six Output icons from the VIVA library. Attach one to each of the S nodes of the Sub icons and one to each of the RegEn icons. Right click on each of the Output icons. Name the output icons of the Sub icons I,J, or K, respectively. Name the output icons of the RegEn icons Done I,J, or K, depending on the name of the Sub output. Save sheet. Convert Sheet to icon.

Results

Please refer to attached pages for results.

Conclusion

At the end of my five weeks, I was able to create a vector function. By use of Cramer's Rule, I was able to create a vector cross product. However, I am not sure if the method in which I created the algorithm is the most efficient. I was also unable to write the answer in vector format. Another problem I had with the function was the data type; the function can only be used if the data type is integer. Floating point was too large for the hypercomputer to compile, something that needs to be changed in the future.

Overall, the function I created does take advantage of the HAL's parallel nature and remarkable speed. It can be applied to many physical concepts and thus presents great potential to be used in various NASA projects. If this project were to be continued, I would like to see other data types used as well as experimenting with other ways to create this function.

Acknowledgements

I would like to thank Dr. Olaf Storaasli for giving me the opportunity to work with him. It has been a unique opportunity in which I have learned not only about math, science, and technology, but also about myself as a person and the world around me. Thank you for always being ready to help and your positive attitude during these five weeks.

Thank you to William Fithian and Siddharta Krishnamurthy for explaining VIVA and helping with my project. None of my research could have been done without either of you. I am sure both of you will have much success in your futures.

Roland Cabanos- Thank you for all your understanding and compassion. You were a major factor in the completion of this paper and my survival for the past month. I also hope that you begin to lead a healthier lifestyle so you do not die at the age of 35.

My deepest appreciation goes out to Pete Thomas and Cheryl Simmers for selecting me for this opportunity and giving me such a wonderful experience. I will never forget what I have learned here. This has truly been a life-changing experience.

To all my teachers, I would like to acknowledge all the hard work and dedication you put into teaching my peers and me. Because of your undying resolve, I was able to come here and have this amazing opportunity.

Finally, to all my fellow governor's school students. For the past five weeks, we have grown together and become a family. Thank you for teaching me about myself and helping me to become a better person. None of you will be forgotten.

Bibliography

Brownstein, Mark. "A $1000 supercomputer?" CNN.com 15 June 1999. 8 July 2002 <http://www.cnn.com/TECH/computing/9906/15/supercomp.idg>.

Martinez, Michael. "Creating the Real HAL." ABCNews.com 8 July 2002 <http://abcnews.go.com/sections/tech/CuttingEdge/hypercomputer990217.html>.

"New Computer Technology: The Hypercomputer." Lompoc Record 14 February 1999. 8 July 2002 <http://www.countdown.org/end_articles/tec_new_computer_technology_the_hypercomputer.htm>.

Singleterry Jr., Robert C., Jaroslaw Sobieszczanski-Sobieski, and Samuel Brown. "Field-Programmable Gate Array Computer in Structural Analysis: An Initial Exploration." 43rd Structures, Structural Dynamics and Materials. 22-25 April 2002. Denver, Colorado.

Star Bridge Systems Website. Star Bridge Systems. 8 July 2002. <http://www.starbridgesystems.com>

"Star Bridge Systems Announces World's Fastest Supercomputer, HAL-300GrW1." Techmall 8 June. 8 July 2002 <http://www.techmall.com/techdocs/TS990610-8.html>.

Thomson, Kimball. "SBS Unleashes VIVA." Wasatch Digital IQ 1 (2001): 58-63.

Uher, Bill. "Computing faster than engineers can think." NASA 01-021. 26 March 2001. 9 July 2002 <http://larc.nasa.gov/news_and_events/inside_pages/2001/01-021.html>.

Wermer, Sandra. “Star Bridge claims changes supercomputers into hypercomputing.” Primeur 9 June 1999. 8 July 2002 <http://www.hoise.com/primeur/00/articles/monthly/SW-PR-07-99-41.html>.