AC 2009-1657: EDUCATING THE EDUCATOR: COMPUTATIONAL SCIENCE AND ENGINEERING TRAINING WORKSHOP FOR FACULTY FROM UNDER-REPRESENTED AND MINORITY SERVING INSTITUTIONS

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Educating the Educator: Computational Science and Engineering Training Workshop for Faculty from Under-Represented and Minority Serving Institutions

Abstract

Computational science and engineering (CSE) and high performance computing (HPC) have now become an integral part of several engineering and science disciplines. However, there is still a very small participation from minority and under-represented population within US. To attract minorities to these critical technical areas and to the field of CSE and HPC, we have followed a complementary approach by exposing and training the faculty members from several under-represented and minority universities in the areas of CSE and HPC through a one-week annual workshop conducted at the campus of North Carolina A&T State University (a major historically black college and university (HBCU)) with a strong computational science and engineering graduate program. This workshop enabled the participant faculty members from under-represented and minority serving institutions who are generally involved with minority undergraduate students at their institutions to be educated and exposed about various aspects of the CSE and HPC techniques and opportunities in these areas.

This paper highlights the development of this educating the educator annual workshop on computational science and engineering and high performance computing *for the past three years (2006 – 2008)*. The experiences and feedback from the participating minority university, and the impact of expanding CSE and HPC education outreach to the community of faculty members and students at the under-represented and minority serving institutions are discussed. This educating the educator workshop has enabled the participating faculty members to not only get trained and exposed in these areas, but is also enabling to act as a catalyst to propagate their knowledge to their students. This is potentially serving a larger minority population and providing future work force needs of qualified minorities in these critical areas.

Introduction

Computational science and engineering (CSE) and high performance computing (HPC) have now become an integral part of several engineering and science disciplines. Still the number of students from under-represented universities and minority institutions, who are involved and exposed to these fields, is very minimal. Several high performance computing training programs funded by the National Science Foundation, the Department of the Defense, etc., has traditionally focused on summer training in HPC for minority students from these minority serving universities. In spite of several such programs, the number of minority, especially African American students, graduating and entering CSE and HPC professional areas has remained really low. There is a great demand of graduates and working professionals in the areas of computational science and engineering that are trained not only in the technical domain areas but also in the computational aspects and high performance computing areas, the related technology, tools, paradigms and approaches. This expertise demand is not only from the US federal engineering and science laboratories where modeling and simulation have already become integral part of many activities but also from the private and commercial sectors.

In spite of the demand, the number of minorities and the prospective graduates in these fields are significantly low. The need for trained and educated under-represented and minority US citizens are critical in these technology areas. Such demand can only be met by the introduction of these technologies, education and mentoring of the under-represented and minority students at various levels. This can be accomplished by an early introduction of these technology areas from the undergraduate level. It would be best if the undergraduate students are exposed to such areas by their own faculty advisors, teachers and educators at their own institutions. This would permit this exposure to reach a larger segment of the minority student population than that are reached by the current HPC summer student programs. In most cases, the students also loose continuity and nurturing after the completion of the summer programs due to lack of local faculty expertise and interest in these areas at most of the minority serving institutions. It is thus imperative that faculty members themselves at these minority and under-represented serving institutions be exposed and trained in the field of high performance computing, and the related technologies that enable the computational modeling and simulations, and the application of the high performance computing techniques, methodologies and paradigms.

Our experiences indicate that the practical high performance computing knowledge expertise and skills are generally learned during their working use and practice by most scientists and engineers. Even at major computationally strong universities with significant high performance and supercomputing expertise, and facility availability, these expertise and skills are learned by the students and faculty members (with no prior exposure to high performance computing) through workshops and courses tailored and offered locally. At any minority institution, most of the faculty members have expertise and formal training in their own fields, and in the domain area courses they teach. Some of the faculty members who have graduated a while ago may not have any prior formal training in the area of computational science and engineering, and high performance computing. It is thus essential that the faculty members at these minority serving institutions are exposed and trained in the areas of computational science and engineering, and high performance computing. It is expected that this method of educating the educator will facilitate exposing and training the minority university faculty members in these areas. This would allow these trained faculty members to spread their knowledge to a larger minority student population at their institutions.

In this regard, over the past three years, we have followed a complementary approach by exposing and training the faculty members from several under-represented and minority universities in the areas of CSE and HPC through a one-week annual workshop conducted at the campus of North Carolina A & T State University with a strong computational science and engineering graduate program. Our experiences, findings, and data indicate that the workshop participant faculty members from under-represented and minority serving institutions have not had any prior exposure to various aspects of the CSE and HPC techniques and opportunities. This workshop facilitated and provided such training to nearly 45+ faculty members from 40 different minority serving institutions over the past 3 years.

This paper highlights the development of this educating the educator workshop on computational science and engineering and high performance computing for the past three years (2006 – 2008). The experiences and feedback from the participating minority university and the impact on

expanding CSE and HPC education outreach to the community of faculty members and students at the under-represented and minority serving institutions are discussed. This educating the educator workshop has enabled the participating faculty members to not only get trained and exposed in these areas but also to act as a catalyst to propagate their knowledge to their students. This has a potential to serve a larger minority population and future work force needs of qualified minorities in these critical areas.

The paper is structured as follows. The development and the structure of the workshop are discussed first. Our experiences indicate that even with a terminal doctoral degree in their field, several participating faculties do not have prior exposure to the several enabling areas of CSE and HPC. Our experiences about our initial assumptions of the faculty members' background in some of the enabling required aspects of high performance computing and the actual observations are highlighted. This is followed by the presentation of the feedback received from the participating faculty members on the workshop and its impact.

Workshop Development and Content

Computational science and engineering and high performance computing are techniques that are applicable in several scientific, technical, engineering and mathematics (STEM) disciplines as well as of relevance to several non-scientific disciplines. In addition to the technical domain area expertise, CSE and HPC require the individuals to be educated and familiar with various core areas. The workshop content was formulated with these different core components to provide the participating MSI faculty members exposure and training in various core areas of CSE and HPC during this week long workshop. The core areas that are relevant to CSE and HPC are:

- Knowledge and familiarity with the operating systems that are found in the HPC resources. The use of the HPC resources in the domain application areas require a working knowledge of the operating system that are commonly used in these HPC machines, as well as the practical aspects of access and utilization of these resources.
- Knowledge of the HPC hardware architecture models to understand the physical layout of the processor and memory configuration as these relate to the computational performance of the multi-processor application software.
- Knowledge of HPC software paradigms and programming models that allow the utilization of the multi-processors in the computations and in the implementation of multi-processor algorithms. The applicability of different programming models depend on the application specific needs and the computational algorithms employed.
- Knowledge of cluster and grid computing that would enable the coupling of net-worked computers (for example, several desktops) available at their universities to form a distributed computing system.
- Knowledge of techniques used in visualization. Domain area applications require intelligent visualization for analysis and interpretations. The techniques and tools for visualization of varied data sets and synthesis form a required core for CSE and HPC.
- Knowledge and working principles of data mining that allow the information gathering from several modes of data.

Technical Lectures

The foundational background of these different core areas listed above were covered through focused, short technical lectures and associated hands-on workshops. The purpose of these lectures is to provide exposure to these technical core areas. These are followed by short hands-on workshop in the relevant areas. The technical lectures covered the various enabling technologies components that are relevant to every CSE and HPC educator and researcher. These included lectures on:

- Introduction to UNIX and HPC operating systems
- Introduction to HPC hardware architectures
- Programming for HPC/Multi-Processors
- Introduction to cluster and grid computing
- Introduction to data mining
- Introduction to visualization

CSE Application and Technology Overview Presentations

The participants in this MSI faculty workshop have a diversified background and to motivate and educate them on the role of CSE and HPC in several application areas, we also included several overview presentations discussing the role of CSE and HPC in several application and domain areas. These were presented by key practicing scientists and leaders in the field from federal laboratories and Universities. These presentations are generally one hour in length and provided the participants an understanding of the role of CSE and HPC in several practical applications and facilitate relating these to their area of expertise.

Hands on Workshops

In addition to background classes as described earlier, hands on training sessions were also conducted to introduce the participants the concepts and actual development and execution of parallel programs; visualization and data mining exercises. The feedback from the first year of conducting this workshop guided us in further refining and expanding these workshops. The participants from the first workshop in 2006 had indicated that these hands on workshops were very helpful in the learning process, and had requested to increase the time allocated to these workshops and reducing the time for the lectures and other presentations. The 2007-2008 CSE-HPC workshops conducted thus increased the amount of time allocated to the hands on portions with additional exercises that enabled an increased level of participant interaction. These hands on workshops are designed to be interactive with the participants actively engaged through various activities and learning exercises relevant to the background material covered in these core area lectures. For example, the hands on workshop on parallel programming trained the participants on implementing the parallel algorithms, evaluation of their performance; introduce the concepts of communication and computational loads as well as scalability and speed-up issues in parallel computing. These practical sessions kept the participants engaged while giving them illustrative examples that they can add and enhance in their own courses. These interactive

hands on workshops were conducted in the core areas that are relevant to high performance computing and computational science and engineering. They are:

- UNIX, Linux, How to access HPC systems?
- Programming for HPC/Multi-Processors
- Grid/Cluster computing
- Visualization
- Data mining

UNIX, Linux Workshop: The UNIX/Linux workshop is a core component of CSE-HPC and discussed the operating system that is commonly used in HPC systems. Our experiences indicate that majority of the participating faculty members over the three years of conducting this CSE-HPC workshop were not exposed to this. Most of their computing experience stopped with PC based systems. Few that had prior exposure were able to assist other participating faculty members during the workshop.

Grid/Cluster Computing Workshop: The grid/cluster computing hands on workshop not only introduced the concepts and programming paradigms for cluster/grid computing but also provided the required concepts and the software tools necessary for setting up a distributed computing environment using the net-worked computing systems available within a university. This would potentially enable the participating faculty from minority institutions to setup their own computational grid and harness the un-used computing power available with their office machines as well other net-worked computer systems in the campus. The grid based system is an effective low cost way of introducing the parallel, multi-processor computing systems and concepts to the students by the faculty members. This does not require the high power and expensive HPC computational resources, but uses effectively the unused computational cycle times at their institutions.

Visualization Workshop: "Seeing is Believing". This is one of the most popular hands on workshops. The participants were introduced to visualization concepts and several freeware visualization software resources that help to visualize, analyze and understand various types of data drawn from different disciplines. The participants were introduced on the use of these visualization resources as well as extracting feature information from the various data sets. The participants not only learned these visualization tools but were also able to apply them to their own data. Several participants expressed their usefulness and were planning to employ and introduce these visualization tools in their work as well as in the classes they teach. The freeware nature of these visualization software resources makes it easier for their introduction to the classroom and use by undergraduate students. These freeware resources were well received by the participants and several indicated their interest in their introduction in their own courses.

Programming for HPC/Multi-Processors: Hardware resources are no use without the application software that can optimally utilize all the hardware resources. As the hardware complexity increases leading to better performance, an understanding of the parallel programming paradigms and the factors that influence their performance are critical. This workshop provided hands on training on the parallel programming models, had students develop simple parallel programs and analyze their performance such as scalability, efficiency, etc.

Data Mining Workshop: Large scale data sets are created in several applications whether it is scientific, business or other fields. Intelligent data deduction, query and inferences are critical. The concepts of the data mining were introduced in the lectures and the hands on workshop focused on the introduction and training of a data mining resource tool Weka. This was a well received workshop by the participant. Several of the participating faculty members expressed interest in introducing these data mining tools in their research as well as in their courses.

Source of Computing Resources

The HPC computing resources available at North Carolina A & T State University through our established computational science and engineering graduate program were employed for the practical hands on exercises. The availability of resources is necessary for the participants to employ the learned concepts in their own classes and curriculum. The availability of the HPC resources for the potential use by MSI faculty members through programs such as UNCFSP (United Negro College Fund Special Programs) was presented in 2007. Details of other HPC resource availability through other NSF centers and HPC modernization programs were also presented through technical presentations from the HPC center resource personnel in all the years of the workshop. The participants were also provided details of other continuing education through programs such as the Joint Educational Opportunities for Minorities (JEOM) through the Department of Defense High Performance Computing Modernization Office (HPCMO) and other HPC activities available to their students. Many of the HPC student summer programs had limited number of participating minority serving institution. However, the participant MSI-faculty members for our workshop came from a much broader range of minority service institutions. The CSE-HPC workshop thus had a positive outcome of not only educating and training the faculty participants but also provided a potential to attract new HPC student workshop participants from a larger number of under-represented and minority serving institutions.

Social Programs

"All work and no play make Jack a dull boy". The workshop was developed and arranged for all the participant faculties stay in Greensboro at the same hotel. This and the social programs helped to enhance the interactions and camaraderie among the workshop participants. The participants not only gained technical education but also developed longer friendships and plans for future partnerships and collaborations. New research and educational partnerships were fostered and are continuing due to these interactions.

Our Experiences

The development of course content for faculty member training posed some interesting dilemmas. Some of our experiences and observations are presented next.

1. Most of the participant faculty members were experts in their field and majority had a terminal doctoral degree in their domain. Our general thought was that courses and workshops in the area of "Introduction to Unix and HPC Operating Systems" may not be

necessary. Based on their advanced degrees and educational training, we initially thought they may have prior UNIX operating system exposure. However, our experiences indicated that most of the participating MSI faculty members had limited computer resources, and primarily PC based systems. Most have not had prior experience in the Unix/Linux operating systems that are commonly used in HPC systems. We consistently had similar experiences in all three years of the workshop.

2. In the first year of conducting this faculty training workshop, we had allotted a longer time for the lectures and a higher number of presentations. This reduced the available time for the practical hands on workshop portions and was generally rushed. The participant feedback from the first year indicated a large preference and liking for the hands on workshops and reducing the pace of the workshops for the participants to complete the assignments and hands-on exercise to follow through the concepts. Based on this recommendation, the time for hands on workshop segments were increased in the second and third years. Further and continued refinements are necessary.

3. All three years of the workshop had about 15+ faculty member participants. The smaller class size providing good interactions between the participants and teaching faculty. The most recent workshops had a much large pool of applicants from nearly 40+ different minority institutions including an American Tribal College. This clearly indicates that there is a need for this type of training. There are several who are interested in attending and learning from these workshops that benefit the MSI educator. An informal survey of 15 participants from the 2008 workshop indicated a demographic breakdown of 5 African Americans, 1 Hispanic, 7 of Asian origin from MSI, and 2 others with a gender break down of 12 men and 3 women.

4. The informal and formal feedback from the participants clearly elucidates the need for follow-on activities, a framework for continued collaborations and partnerships from the organizing institution to make this workshop a further success.

5. Educating the faculty in CSE-HPC areas is an effective way to encourage and increase minority and under-represented student participation in these critical areas. If each participating faculty member would mentor, educate and encourage 10 students in a year about the CSE and HPC areas, the indirect benefits can reach about 150+ students a year. Since the faculty member will be in the school even after the students have left, this is a perennial benefit. This expanded outreach to younger minds can definitely foster interest in CSE/HPC and can result in educating and training a diversified workforce for the nation in this important and critically needed field.

6. The positive outcome of the faculty training is seen in the fostering of collaborative efforts among the participant faculty members and recommendation of their undergraduate students for our CSE graduate program.

Feedback from CSE – HPC Workshop Participant Faculty Members

This section presents a sampling of the feedback from the participant faculty members of this workshop that benefits and educates the faculty members from minority serving institutions in the area of computational science and engineering and high performance computing. The feedback comments relate to the contents of the workshop and life after the workshop.

CONTENTS OF WORKSHOP

-"Build in some flexibility to allow continuation of exercises at night for those interested in further exploration. This is an excellent, well-organized workshop. Choice of presenters was excellent. WILL SUGGEST: Inclusion of presenters representing different funding agencies (Possibly in addition to DOD). Discussion time period after the presentations. This period will be good for general comments and involved comments. As much as possible, presenters link their subject matters to applications in different fields as represented by the workshop participants:"

"I enjoyed the workshop. It was filled with very good information. I learned a lot abut high performance computing. It would appear that the (Our University) Program is among the state of the art. It is also evident that a great investment has been made in the effort from all aspects, fiscally, commitment on the part of the faculty and staff. You are to be commended on your effort. I hope to continue my connection with you as well as work to implement some aspect of the knowledge that I have gained. Thank you for accepting me as a participant."

"Complete examples of problems where parallel processing is necessary for completion. Invite at least two faculty from each school, so that communication is fruitful after returning to university. (Even if fewer schools are represented)."

LIFE AFTER THE WORKSHOP

How I intend to use what I learned:

"Explore funding possibilities in computational materials science, chemistry. Generate interest in computational technologies and introduce same to students. Generate faculty interested in computational technologies in order to promote and cultivate interest in students. Develop initiatives so that interested students can continue in computational science engineering at "*Organizing Institution*"."

"Intend on creating exercises around Para Vein [*sic*] and Vol Vien [*sic*] as was given in the workshop. I also want to use UNIX in some way.

"The workshop was invaluable. It allowed me to be exposed to some very useful concepts and software. I can see myself incorporating these

materials into my courses because I am always looking for practiced industrial material for the students."

"I want to implement clustering, visualization, and data mining for my students. I want to pursue more knowledge in this area".

"1) Will try to start at least associate level degree 2) Will conduct workshop with support of NCAT to generate awareness and interest."

"I intend to use the learning that I received to enhance the learning of students that I teach. My hope is to help them learn how to learn and strive to be new self starters encouraging them to begin to assume full responsibility for their learning. I hope to focus initially on the grid concept in taking advantage of domain compute labs."

"● establish a cluster (poor man's super-computer) ●establish HPC Lab● study parallel programming and try to implement it ●use visualization ● apply what I have learned to the research areas of my interest."

What can "we" do to help you achieve your goals?

"Need further assistance with modeling and simulations- finite element "crash" course. Keep informed of Organizers computational science engineering program/activities such as student internships, collaborative efforts and funding opportunities."

"It would be good if we were given access to your system for at least three months so we could practice some of the things we got training in. We should be allowed to keep out ID and password for a while so we could access the system."

"Please keep the channels open. Help us persuade our institutions about the importance of these subjects. Help us help ourselves. Every presentation was excellent. Thank you for a great workshop!"

"It will help if we can get some support, later during the year when we use this material for our classes (follow up support)."

"●stay I touch and electronic mentorship ●permission to use our account ●research collaboration ●proposal writing collaboration ●student sharing collaboration ●joint publications"

Concluding Remarks

The CSE-HPC workshop at North Carolina A & T State University has enabled the training of several faculty members from minority serving institutions (currently 45+ faculty members from more than 40 minority serving institutions including tribal colleges) in the areas of computational science and engineering and high performance computing. The development of this educating the educator workshop on computational science and engineering and high performance computing are discussed. The experiences and feedback from the participating minority university and the impact on expanding CSE and HPC education outreach to the community of faculty members and students at the under-represented and minority serving institutions are presented. The anonymous feedbacks from the participants clearly indicate that this educating the educator workshop has enabled the participating faculty members to get trained and exposed in these areas. In addition these faculty members also act as a catalyst to propagate their knowledge to their students. This serves a larger minority population and has a potential to provide future work force needs of qualified minorities in the critical technical area of computational science and engineering and high performance computing. The workshop is not only enabling the MSI faculty member improvement and exposure to new areas but is also benefiting the student education and mentoring at minority serving institutions. This can be further augmented with follow on activities as pointed out by the participants after the workshop.