Promoting a Research-Based Education through Undergraduate Research Experience for Students

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Abstract

Involving undergraduate students in research has proven to be an essential experience that enhances the learning outcome of students [1,2]. When exposed to research world at an early stage of their career, they acquire new skills that also guide them in tailoring their experience and choosing their future career. The High Energy and Medical Physics Group at Texas A&M University at Qatar (TAMUQ) has been supporting and engaging undergraduate students in different research projects in the areas of High Energy Physics and Medical Physics for the past six years. It attracted students from all four majors offered at TAMUQ, Electrical, Mechanical, Chemical and Petroleum Engineering shortly after the launching of its research activities. Many projects conducted within the group were awarded by the Qatar National Research Fund which is a governmental funding body that provides funding to highly competitive projects that address national priorities and contribute to capacity building [3]. Students were trained to use a high performance computing facility, different programming languages, software and Monte Carlo based platforms for their simulation. As for the outcomes, they participated and presented at international conferences, many of them attended CERN summer internship program. Some of the published journals in international peer-reviewed scientific journals.

In this paper, we present some of the projects that our students completed, the different tools that were used, as well as the research outcomes. Then, we will discuss the impact of this experience on their learning and undergraduate education as well as their career path, especially their postgraduate studies.

1. Selected projects

Students are integrated into the research team and proposed one of the research areas of the group: High Energy Physics and Medical Physics. In the past five years, 20+ students have been involved in our research projects in both fields. Six students have been accepted and completed the CERN summer internship program (2 month duration each).
At this stage of their academic career, students would have enough knowledge in physics (mechanics, electromagnetism and modern physics) to fulfil the research requirements and efficiently contribute to the activities.

1.1. Monte Carlo modelling of a clinical Positron Emission Tomography scanner

In this project students were involved in modelling and validating a Positron Emission

Tomography (PET) scanner. PET is a nuclear imaging modality used for diagnostic purposes. Students were trained to use the high performance computing facility at TAMUQ, C++ programming language as well as GATE, a simulation toolkit adapted to the field of nuclear medicine [4]. The simulation consists of building a model of the scanner given the specifications from the manufacturer and obtaining the performance metrics of the modelled scanner in order to compare to the published measurements. Statistical analysis was also used to analyse output data of the simulation. Figure shows a screenshot of PET scanner as modelled by students. The figure also shows a line source that is used for sensitivity studies.

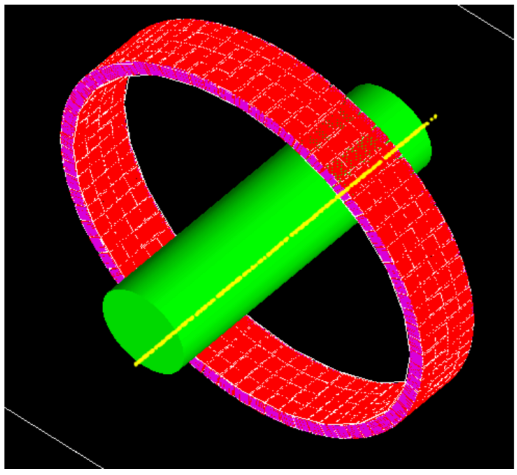

Figure 1 *GATE geometry model of a clinical PET scanner with the phantom and the line source.*

1.2. Modelling of radiation therapy systems

This project introduces students to the field of Radiation Therapy (RT) used to treat cancer. Students used GATE software adapted to the high performance computer to model and validate a linear accelerator that produces the X-ray beam used in Radiotherapy (RT) treatment. Students are asked to simulate the different elements of the RT system shown in Figure 2: electron beam, target, filters and collimators. The dose distribution profile is then calculated and compared (figure 2 right a and b).

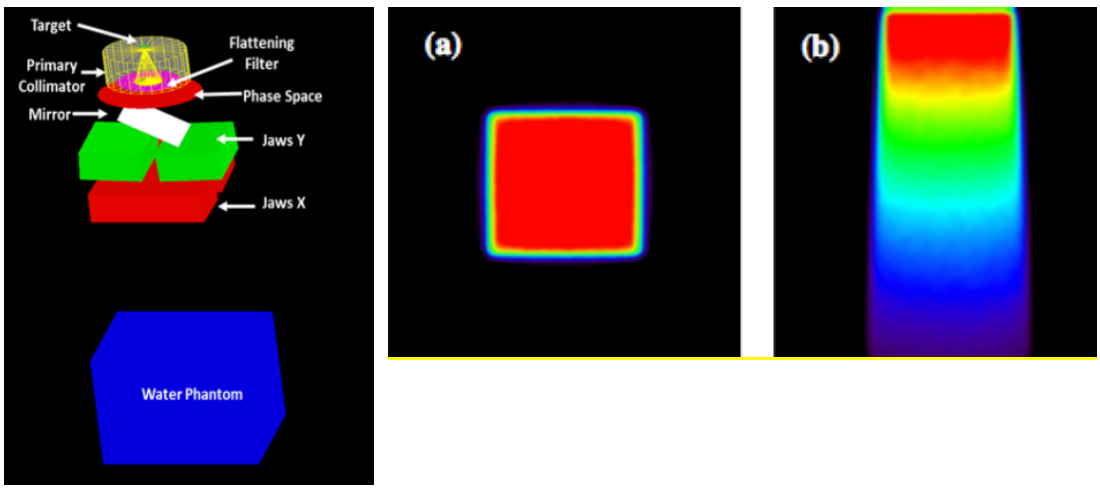

Figure 2: *Right: screenshot of the GATE interface of the RT system. Left: Transvers (a) longitudinal (b) dose distributions*

1.3. Using and mastering the HPC system

Most of the projects mentioned above require tremendous computing capabilities. The Raad2 supercomputer facility, installed at Texas A&M University at Qatar, has been used. It is a is Linux based system equipped with CRAY cutting edge blade servers with a total of 4,128 traditional CPU cores of the Intel Haswell architecture. All compute nodes contain 2 processors per node with 12-cores each and 128GB of RAM. The system is running SLURM as workload manager to efficiently allocate and manage compute resources.
RAAD-2 is paired with 800TB parallel storage system from DDN. The DDN EXAScaler(Lustre) system is connected to the cluster's ARIES network allowing research applications to access and process large amounts of data at higher speed. System peak aggregated read bandwidth is 16GB/s; whereas a single client peak concurrent bandwidth is 2.5GB/s read and 2.5GB/s write.

2. Research Outcomes and Impact on career path

The undergraduate research opportunity that was provided to the engineering students at TAMUQ through these projects was strictly beneficial and quite enlightening to many of them and a turning point to others. Below is a summary list of the main research outcomes of this work:

- Expanding knowledge in courses that they use in their respective engineering curriculum such as statistical analysis and programming.
- Learning to access and use a high performance computing facility, in order to speed up the simulation involving heavy computation. This was also useful for some of their engineering projects.
- Presenting (oral/poster) at international conferences.
- Interning/training at CERN and getting exposed to lab work with Scientists and Engineers.
- Learning to work independently as well as in a team.
- Training in Medical Imaging and Radiotherapy departments at hospitals.

As for the impact on their career path, many students were positively influenced by the undergraduate research experience, and decided later to pursue a career in research in various prestigious universities such as Stanford University, Columbia University and University College London. Moreover, according to them, the choice of their postgraduate studies program was made easier after their involvement in research activities at an early stage of their education.

3. Acknowledgements

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4. References

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