Universidade do Minho

MAP-i: PhD Thesis Proposal

An assessment of heterogeneous computing platforms to efficiently process ATLAS events

Context and goals

Current research work is exploring different approaches to improve the performance of a scientific application that processes event data gathered by the ATLAS project at CERN, aiming the validation of a given model proposed by the High Energy Physics (HEP) researchers. The current version of the scientific application, *ttH_dilep*, was developed by researchers at the national LIP (the Associated Lab that acts as the CERN partner in Portugal) and has been adapted to take advantage of parallel homogeneous and heterogeneous systems, the latter with 2 different computing accelerators. The main goal was to evaluate the usability, performance and efficiency of the different systems and specific accelerators, as well as the structure of the physics application and libraries.

The scientific application, *ttH_dilep*, attempts to reconstruct the top quarks and Higgs boson that decay from a head-on collision of two protons, based on the resultant data collected in the ATLAS particle detector at the LHC. The quality of the reconstruction depends on the amount of partial reconstructions performed, where the event parameters are slightly varied, to overcome the experimental resolution of the particle detector and find the most accurate final reconstruction. Since the increase of the number of partial reconstructions directly affects the application execution time, therefore decreasing the number of events processed per time unit and impacting the research conducted by LIP, parallel implementation solutions have been developed, based on an identification of the critical region limiting the performance.

Two of these implementations target heterogeneous systems with accelerator devices, one using an NVidia GPU and other using the Intel Xeon Phi. Both implementations face many limitations, primarily due to the lack of a data structure holding all the event information on both the application and LipMiniAnalysis, restricting the performance gains and efficient use of the GPU. Also, due to these hardware limitations, only part of the application critical region was parallelized on the accelerator, increasing the amount of high latency memory transfers between CPU and GPU, and forcing the rest to be parallelized on the CPU.

A new work plan was devised to test the implemented versions of the parallel code and to overcome the identified efficiency limitations, that would start by porting the latest version of the scientific application, based on the LipMiniAnalysis library, and later improve its efficiency on heterogeneous platforms with both CUDA/GPU accelerator devices and the Intel many core Xeon Phi. The LipMiniAnalysis library is widely used by the HEP researchers in Portugal to validate other theoretical physical models and it will

be redesigned within the context of the current PhD proposal to accommodate the requirements of current and future computing platforms, highly parallel and heterogeneous.

Heterogeneous computing platforms have both high performance CPU-cores and massively data parallel accelerator devices. Automatic work and data balancing across all available resources requires integrated development frameworks, which still are under development within the scientific community; worth mentioning at this level the frameworks StarPU and its competitor DICE, a cooperative development between UMinho and UTexas at Austin. This work will also address the selection, test, validation and evaluation of an integrated development framework aimed at heterogeneous computing platforms, in terms of suitability and efficiency and productivity improvements in the design and execution of scientific applications within the ATLAS project at CERN.

Work environment

This cross-disciplinary project will be supervised by two academics from different research fields: **Alberto José Proença**, at the Group of Computing Science and Technologies at the Research Centre ALGORITMI, University of Minho, and **António Onofre Gonçalves**, a HEP academic at the LIP-Minho Research Unit, at University of Minho.

The main host institution will be University of Minho, namely the Research Centre **ALGORITMI**. The work will require further research contacts with HEP researchers at LIP in Coimbra and Lisbon, and eventually with computer experts at CERN.

External Researcher for the Monitoring Group

Adélia Sequeira, IST/UL, currently the Director of the Advanced Computing program in Portugal under the cooperation program between the Portuguese Universities and the University of Texas at Austin.

Braga, 17th January, 2014

The proposer

Alberto José Proença