Performance of Heart Modelling Application (CARP) 20x Faster after Optimisations by HECToR dCSE Team

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HPC experts from EPCC, working under NAG's Computational Science and Engineering (CSE) support service for HECToR, the UK's national academic supercomputing facility, have optimised the Cardiac Arrhythmia Research Package (CARP), a widely-used software package designed for large-scale simulation studies of hearts. As a result of this project, a monodomain simulation of a human heartbeat (1 second activity) is now possible in under 5 minutes, a 20-fold improvement in performance.

CARP is a widely-used software package designed for large-scale simulation studies of hearts. The aims of these studies are to provide detailed personalised therapies for treatment of medical conditions such as cardiac arrhythmias or heart failure. The areas where incorporation of in-silico modelling into the clinical workflow are feasible include cardiac resynchronization therapy (for treatment of heart failure); drug trials (looking for possible side-effects); and development of better defibrillators.

Commenting on the dCSE project success, Gernot Plank (the Principal Investigator) said "*The progress achieved during the 8 month dCSE project led to a step change in code performance. For the large problem we are interested in, that is the simulation of a human heart beat, the code performance improved by a factor of 20 which enables us to simulate one cardiac cycle in less than 5 minutes. This opens entirely new perspectives for cardiac modelling in the context of clinical applications where simulations are expected to play an important role in the future to optimize planning of therapies.*"

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HECToR is managed by EPSRC on behalf of the participating Research Councils with a mission to support capability science and engineering in UK academia. The Cray XT supercomputers, located at the University of Edinburgh, are managed by UoE HPCx Ltd. The CSE Support Service is provided by NAG Ltd and ensures users have access to appropriate HPC expertise to effectively exploit advanced supercomputers for their science. A critical feature of the CSE Support Service is the distributed CSE (dCSE) programme which, through lightweight peer review, delivers dedicated performance and scalability projects on specific codes in response to proposals from users. The dCSE programme now consists of over 50 focused projects complementing the traditional HPC user applications support and training also provided by NAG.

The dCSE projects completed so far have delivered outstanding examples of the cost savings and new science that can be enabled through dedicated CSE effort. The CARP project reported here adds to these success stories with a successful performance improvement.

Project Background

The goal of this dCSE project was to enable the CARP code to run efficiently on large HPC platforms. The parallel decomposition scheme resulted in high levels of load imbalance giving poor performance, and the output routines caused a significant bottleneck in simulations of large systems. The objectives were thus to improve the strong scaling of CARP, first by improving the decomposition used, and second by optimising the output routines.

Gernot Plank of Oxford University was the Principal Investigator on the project. Lawrence Mitchell, of EPCC at the University of Edinburgh, carried out the 8 person-month project in collaboration with the NAG CSE team and the CARP developers.

Dr Plank estimates that the usage of CARP on HECToR will be up to 10 million AUs (allocation units) in 2011, at a notional cost of £140,000.

Project Results

The dCSE project implemented an improved parallel mesh decomposition scheme together with an asynchronous parallel output capability. These code enhancements resulted in performance improvements of around 250% for small systems, rising to 1800% for large simulations. As a result of these speedups a monodomain simulation of a human heartbeat (1 second activity) that previously took around 75 minutes to complete can now be completed in less than 5 minutes.

The results of this work have been merged back into the central CARP repository and are now available to users worldwide. Dissemination of the work and results is ongoing: a paper was presented at CUG 2010 and articles are currently under review. A conference paper on this work has been published (L. Mitchell, M. Bishop, A. Neic, M. Liebmann, E. Hoetzl, G. Haase, G. Plank. Modeling Cardiac Electrophyiology at the Organ Level in the Peta FLOPS Computing Age. AIP Conference Proceedings, 1281(1):,407-410, 2010).

A full technical report can be found at http://www.hector.ac.uk/cse/distributedcse/reports/

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