Postgraduate Studentships Queen's Doctoral Training Programme on Secure Connected Intelligent Design and Manufacturing

School of Electronics, Electrical Engineering and Computer Science

PhD Studentship 2020/21

Proposed Project Title: DTP: Large-scale numerical optimisation on graphics processing units	
Principal Supervisor: **Dr Pantelis Sopasakis** **Contact Details:** Dr Pantelis Sopasakis **QUB Address** Ashby Building, Stranmillis Road, Office No. 07.013 **Tele No:** +44 (0) 28 9097 4663 **E-Mail:** p.sopasakis@qub.ac.uk	**Research Area** High performance computing, Numerical analysis, Parallelisable algorithms, Big data technologies, Computer Science **Proposal open to other School (indicate area of Interest)** Electrical Engineering and Computer Science, (Applied) Mathematics, Mechanical, Aerospace and other engineering schools
Degree linked to ELE	
Degree linked to CSC	

This project is part of the Queen's Doctoral Training Programme in Secure Connected Intelligent Design and Manufacturing. Many of today's industrial approaches require transformative changes to ensure long term societal, economic and environmental resilience and sustainability. PhD projects in this programme explore the potential of emerging digital technologies, such as artificial intelligence, robotics, and the Internet of Things, to transform the way we design, manufacture and operate products and services.

The programme offers a bespoke research and training programme that aims to develop students into cross-disciplinary, industry-conscious thinkers and leaders who will influence the roadmaps of future advanced manufacturing technologies and their applications. They will have a balanced understanding of ICT (security, communications and data analytics) in the context of their application to Advanced Manufacturing and High Value Design.

Project Description:

Under the hood of most control, machine learning, data analytics and other engineering applications, one can often find an optimisation problem. Modern applications such as deep learning, stochastic model predictive control, moving horizon estimation, molecular modelling and risk-averse portfolio optimisation give rise to problems often involving millions of decision variables and constraints. Our ability to solve such problems in **real time** will be a determining factor for the development of next-generation applications including autonomous vehicles and collaborative robots. To that end, it is imperative that we devise appropriate numerical algorithms to harness the unparalleled computation power of **graphics processing units** (GPUs).

In case of convex optimisation problems, there has been remarkable progress over the last few years that has led to speed-ups of **two orders of magnitude**. For instance, by exploiting the structure of stochastic optimal control problems, problems involving more than 2 million variables can be solved in a few seconds by means of a massively parallelisable first-order gradient-based methods (Sopasakis et al., 2018; Sampathirao, Sopasakis et al., 2018). More recent developments have afforded us an additional three-fold acceleration (Sampathirao, Sopasakis et al., 2017, 2020). It is becoming evident that a wide spectrum of engineering applications has a lot to gain from this ongoing research on GPU-accelerated algorithms.

When it comes to massively parallelisable methods, the terrain of nonconvex optimisation (e.g., deep learning) is largely unexplored. The lack of sufficiently fast numerical algorithms is impeding the industrial uptake of highly promising technologies such as **deep neural networks**. This interdisciplinary PhD project will make a significant academic and industrial impact by proposing novel methods for solving very large scale nonconvex optimisation problems on GPUs by leveraging recent theoretical results such as the proximal averaged Newton-type method.

Objectives:

The PhD candidate will devise massively parallelisable numerical optimisation algorithms for solving convex and nonconvex large-scale optimisation problems that may will involve millions of decision variables and constraints. The main objective of this PhD project is to reduce the solution time by about two orders of magnitude compared to existing methods. Particular objectives of the project are:

1) To explore different numerical optimisation methods – including, but not limited to proximal Newton-type methods and block coordinate-type methods – that will enable the solution of large-scale optimisation problems on GPUs and propose a generic and re-useable parallelisation scheme,

2) To develop code-generation software that will automatically discover and exploit the structure of given optimisation problems,

3) To devise algorithms for nonconvex large-scale optimisation problems, including, but not limited to deep learning and risk-averse optimal control problems,

4) To demonstrate the effectiveness of GPU-based parallelisation methods for solving optimisation problems, by performing extensive benchmarks and comparisons with state-of-the-art methods and implementations.

The successful candidate will publish the outcomes of his/her research in top-tier journals and will present their work in some of the most esteemed scientific conferences in the field of optimisation, control engineering and/or machine learning.

Academic Requirements:

A minimum 2.1 honours degree or equivalent in Computer Science or Electrical and Electronic Engineering or relevant degree is required.

GENERAL INFORMATION

This 3.5 year PhD studentship, potentially funded by the Department for Employment and Learning (DfE), commences on 1 October 2020.

Eligibility for both fees and maintenance (approximately £15,000) depends on the applicants being either an ordinary UK resident or those EU residents who have lived permanently in the UK for the 3 years immediately preceding the start of the studentship. Non UK residents who hold EU residency may also apply but if successful may receive fees only.

Applicants should apply electronically through the Queen's online application portal at: https://dap.qub.ac.uk/portal/

Further information available at: https://www.qub.ac.uk/schools/eeecs/Research/PhDStudy/

Closing date for applications: 15 March 2020