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: Nonlinear model predictive control for safe proactive collaborative robotics

Principal Supervisor:
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Research Area

Control engineering, Learning-based control, numerical optimisation, stochastic control

Proposal open to other School (indicate area of Interest)

(Applied) Mathematics, Computer Science, Mechanical Engineering

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:

A wide range of industrial applications requires the combination of the speed and efficiency of robots in performing repetitive, heavy or dangerous tasks and the judgement and intelligence of human operators. Relevant examples arise in applications of packaging and palletising, quality inspection, assembly lines, gluing and welding to name a few. However, robots are powerful machines which, if not controlled properly, can be extremely dangerous - often lethal - to human operators. For that reason, in current industrial practice, robots are kept is isolation. The aim of this PhD project is to devise methodologies that will allow the deployment of collaborative robots (cobots) and has the potential to revolutionise existing production lines.

Safety is number one concern when it comes to the deployment of cobots. This poses significant design challenges since humans tend to move in a non-deterministic fashion, which can be difficult to predict. As a result, cobots are required to act proactively by anticipating the motion of human operators and account for the associated uncertainty in order to avoid collisions. This can be achieved by optimally readjusting the cobot's planned trajectory online following the model predictive control (MPC) approach.

In particular, given the stochastic nature of human motion, cobots are required to construct a contingency plan in real time to take into account different possible trajectories of humans, which can be computed based on historical data and using machine learning models. The cobot is required to solve an optimisation problem that leads to collision avoidance in high probability. This can be achieved by the recently proposed framework of risk-averse MPC (Sopasakis et al., Automatica 2019 and Sopasakis et al., ECC 2019).

Objectives:
The PhD candidate will devise design methodologies for nonlinear MPC formulations that meet the safety requirements of collaborative robotic systems without compromising the robot's performance. Particular objectives of this PhD project involve the development of :
1) data-driven model predictive control methodologies that lead to theoretical safety and stability guarantees
2) appropriate stochastic control methodologies to deal with uncertain collaborative robotic systems exposed to an inexactly known probability distributions
3) data-informed stochastic dynamical models of humans
4) a game-theoretic control framework where robots will be able to predict how their actions will affect the behaviour and motion of humans around them
5) numerical algorithms and appropriate high-performance high-throughput implementations which are suitable for robotics and are able to meet their stringent runtime requirements; these can involve implementations of GPUs or FPGAs

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