

Briefly outline the background to and the aims of the project (500 words max):

Diamond Light Source is the UK's national synchrotron, a particle accelerator that is capable of producing extremely bright light. Beams are generated by accelerating electrons near the speed of light around a ring more than half a kilometre in circumference. They are then directed into laboratories, and used to analyse samples in a variety of research and industry applications, ranging from fossils and solar panels to viruses and vaccines.

In order for this light to be collimated and focused appropriately onto samples, the resulting beam has to be stabilised; this is a large-scale disturbance rejection problem, with 173 outputs, 172 inputs and sampled at frequencies that exceed 10kHz [1]. The Oxford Control Group has developed a model predictive control (MPC) system to perform just this task. They also developed several "solvers" (OSQP, Clarabel, Cosmo), that often involve the use of machine learning (ML) algorithms, where a common challenge is often presented by finding Euclidean projections onto convex sets.

To reduce computation time and memory usage in the beam stabilisation algorithm, the group proposed to use the fast gradient method, where the Euclidean projection step is solved using Dykstra's scheme [2]. This is an iterative algorithm for finding the projection onto the intersection of two closed convex subsets in Hilbert space. It is efficient and fast, but can stall under certain conditions [3][4]. Hence, Dykstra's method must be modified to avoid stalling, with a focus on polyhedral sets that are encountered in most engineering applications.

Under which conditions does the method not converge for these polyhedral sets? Once the conditions for stalling are identified, how could stalling be prevented? Answering these questions would be the primary focus of this project.

A theoretical approach would be initially required to identify the initialisation parameters and overall conditions that lead to stalling. Subsequently, the stalling conditions would be reproduced for small polyhedral sets, both analytically and via simulations. Finally, we would try to develop solutions to ensure convergence and improve the MATLAB implementation of the MPC system. My work would be embedded in solvers, with the aim of improving computation times by ~10 times. In addition, considering how popular the use of Dykstra's method is in various ML applications, this project would have a high degree of relevance even outside of the domain of Diamond Light Source.

Indicate briefly why you would like to take part in this scheme (500 words max):

Throughout my nearly two years of undergraduate study at Oxford, the control theory submodule, along with its associated laboratory exercises (including the rocket controller in the first year and the Quanser Aero experiment in the second year), has consistently captivated my interest and reaffirmed my conviction in pursuing engineering as my chosen field of study.

Participating in this scheme offers an exciting opportunity to bridge theory and practice in the field of engineering. Throughout my academic journey, I've gained a strong theoretical foundation, but I'm eager to see how these concepts play out in real-world applications, particularly in control theory and programming. Control theory is a field I'm particularly passionate about, so being able to work on practical applications is incredibly exciting. This project provides a hands-on learning experience that goes beyond traditional coursework, allowing me to develop new skills and work closely with a diverse team of researchers.

Collaborating with experts in the department is a key aspect of this scheme that I'm looking forward to. Working alongside others with different perspectives and areas of expertise will not only enhance my technical skills but also help me grow personally, improving my ability to communicate and work effectively in a team. The prospect of cooperating with my supervisor Stephen Duncan, as well as members of the control group (Paul Goulart, Jack Umenberger and Idris Kempf) and researchers from Diamond Light Source is extremely stimulating, and I eagerly anticipate the opportunity to contribute to research within the field of control theory.

Additionally, there's the potential for this project to evolve into a larger endeavour, such as a 4YP (fourth-year project), or the EPSRC Vacation Internship. This possibility motivates me to fully invest myself in the scheme, knowing that the skills and experiences gained will be valuable for future projects in engineering.

Overall, I see EUROP as a chance to expand my horizons, learn new things, and contribute to meaningful research. I'm excited to dive in and make the most of this opportunity to grow both personally and professionally.

References

1. I. Kempf et al., [“Model Predictive Control for Electron Beam Stabilization in a Synchrotron”](#), arXiv, 2021.
2. I. Kempf et al., [“Fast Gradient Method for Model Predictive Control with Input Rate and Amplitude Constraints”](#), IFAC, 2020.
3. H. H. Bauschke et al., [“On Dykstra’s algorithm: finite convergence, stalling, and the method of alternating projections”](#), arXiv, 2020.
4. C. Perkins, [“A convergence analysis of Dykstra’s algorithm for polyhedral sets”](#) Soc. Ind. Appl. Math. J. Numerical Anal., 2002.