Project #1 Mathematical Modelling and Optimal Control Theory in Industrial Driers

Industrial drying - a seemingly dry subject if ever there was one – is an area of research where there is still much to learn. There is also much to be gained, as understanding various drying processes in the food industry can help to optimize them, and hence, cut energy usage while maintaining product quality. Describing drying in a quantitative way requires the use of a surprisingly wide range of mathematical and physical concepts.

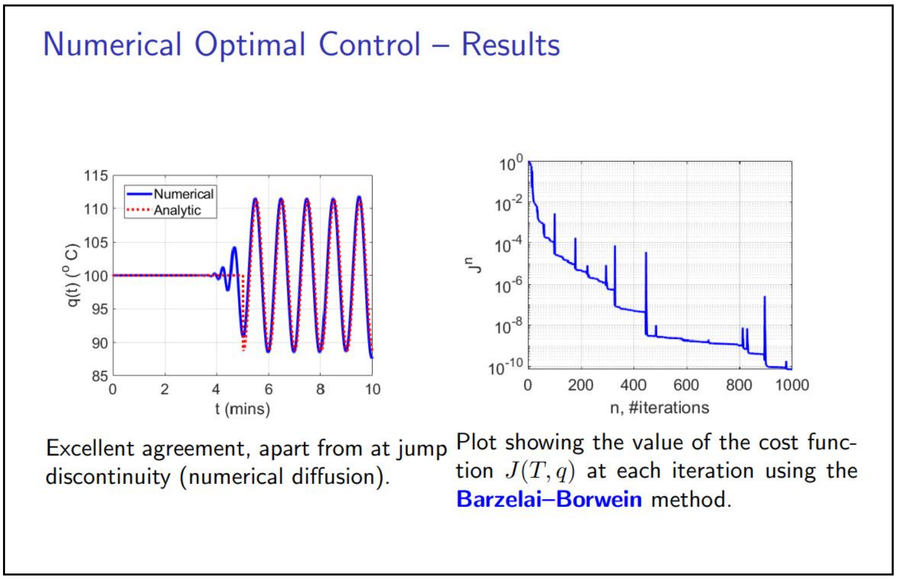
In this project, students will learn these concepts, and apply them in the context of simulation and optimization. The modelling is based on Partial Differential Equations (PDEs) - there is no escaping the fact that lot of dryers are basically a hyperbolic system, which convects moist product at the inlet to (hopefully) dry product at the outlet. Maintaining the outlet variables in a target state requires optimal control theory, which for PDEs is formulated as a kind of constrained optimization in Banach spaces. There are some standard results that guarantee the existence of an optimal control, students may look into this theoretical approach if it is of interest. There is also a lot of Physics involved in the problem, including the modelling of the evaporation rate and the drying rate

In this project, the student will take an existing code package that implements such a model of industrial drying (as well as implementing the optimal control). The aim of the project will be to improve the model and bring it to a state where it is a practically usable tool in industry. The project will involve:

- Improvements to the drying-rate model using experimental data as a guide;
- Adding extra physics to the model to make it more realistic;
- Developing a control-theory model using a Kalman filter.

This is collaborative project with the University of Edinburgh (experimental data) and a small enterprise working in the area of control theory for industrial processes

Key skills: mathematical modelling, partial differential equations, programming in e.g. Python or Matlab



Project #2 Mathematical Modelling of Water Flow through Soil Structures

The aim of this project is to develop a data-driven Mathematical Model of Soil Compaction. This will be done through the following steps:

- Formulate Computational Model of Soil Compaction using OpenFOAM software
- Configure model using data from UCD X-ray CT facility
- Implement model on Irish High-Performance Computing Platform ICHEC

The application here is to better understand the flow of water through soil, with a view to developing predictive models of soil compaction. Work on this topic will produce long-term benefits to society, for instance, improved crop yields. This is joint work with Dr Saoirse Tracey in the School of Agriculture and Food Science, who is an expert on X-Ray CT scanning.

Methodology: The student will establish a data pipeline from the UCD X-ray CT facility to ICHEC, the Irish Centre for High-End Computing. Specifically, the student will extract 3D structures of soil via the creation of *.stl files from previously scanned soil cores. This data will then enter the modelling pipeline, firstly via the OpenFOAM fluid software and then uploaded to ICHEC for modelling simulation of hydrological parameters. This will allow the actual geometries from the CT scans to be used in simulations and questions about water movement through soil and quantification of soil physical parameters to be deployed

Key skills: mathematical modelling, partial differential equations, fluid mechanics, a love of programming. The project will be based on the OpenFOAM fluid simulation software. This can be learned using online tutorials, however, the student should love "hacking" at code to turn existing bits of code into usable simulations.

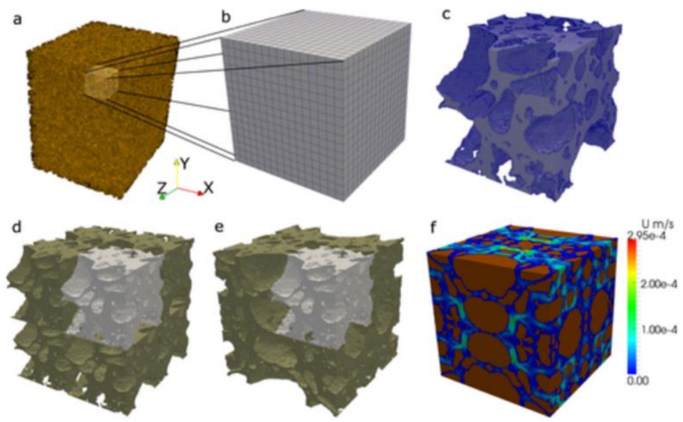


Figure 1: Outline of steps used in the subsampling, meshing, and solution of cell problem (a and b). The subsampling of a 1.2 mm side length cube of the segmented .stl file (c). The mesh generation. The generation of a truly periodic geometry through (d) translation and (e) reflection, the original volume mesh is shown in a lighter shade (f). The numerical solution for the local velocity magnitude in the subsampled soil.