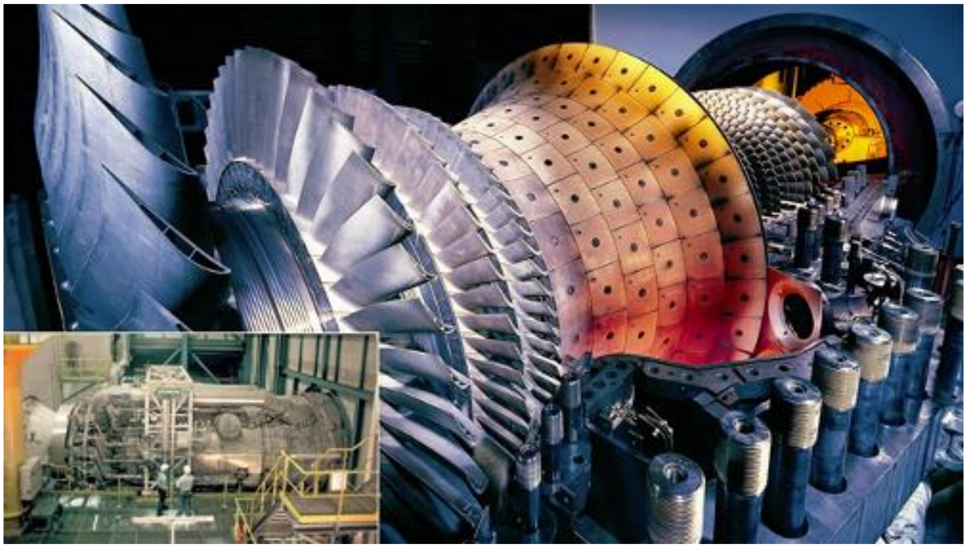
This is a call for MEng students who may be interested in pursuing an international research project. Please review the information below

Project Title: Solving Transient Inverse Heat Transfer Problems in Complex Geometries using Physics Guided Neural Networks

Background:

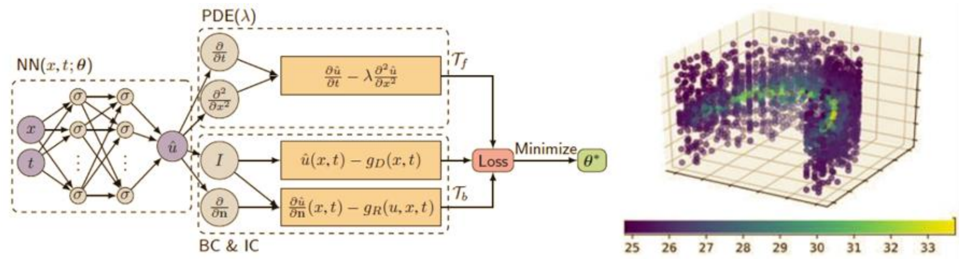
Temporally and spatially unstable thermal conditions lead to transient or inhomogeneous thermo-elastic behavior of workpieces during manufacturing or geometric inspection. Especially in large-scale manufacturing with high unitary costs of components, inevitable temperature inhomogenities of workpieces result in thermal-induced errors, which impact final product quality and incur serious resource and economical loss due to long temperation times. Temperature monitoring by means of sensors consign transient surface temperature fields, but do not yield information about inner workpiece temperatures or heat flows acting as relevant boundary conditions for thermal simulation models.

FEM, as commonly used numerical approach to perform multi-physics simulations, is a suitable tool to predict thermally induced workpiece deformations, offering the opportunity to consider multiple varying temperature loads, such as thermal energy from the manufacturing process, heat conduction between clamping surfaces or variable ambient temperatures. Although it is possible to simulate and numerically solve virtually any process, the efficient application often suffers from defining correct initial (IC) and boundary conditions (BC), since they have to be known and set up in the simulation model in advance. Most commonly information about heat fluxes are heuristically estimated, which represents an uncertainty for common forward simulation methods.



Impact:

Deep learning has achieved remarkable success in diverse applications; however, its use in solving partial differential equations (PDEs) has emerged only recently. To combine the benefits of analytical methods with the advantages of machine learning techniques, Physics-Guided Neural Networks (PGNN) were introduced recently. The basic idea is to apply physical laws into a neural network, whereby the most common approach is to add certain physical laws into the loss function in order to force the neural network to comply with them.



First prototype implementations have indicated that PGNNs are generally capable of solving direct as well as inverse heat transfer problems even for large and complex geometries. Nevertheless, there is still huge potential for improvement related to the efficiency, generalizability and accuracy of the method.

Pushing the research further, the following subtopics were identified and addressed:

1. Fine tuning of the prototype related to neural network architectures, loss weights and point sampling schemes
2. Application and testing of the method to a real-world demonstrator
3. Scientific benchmark between PGNN and FEM for dedicated use-cases

Research Problem Addressed:

At this point, the need for methods to solve inverse heat transfer problems (IHTP) arises. In this context, inverse posed problems address heat fluxes, which are the cause of a temperature distribution and can be quantified by temperature measurements. In fact, inverse calculations belong to optimization problems. Providing additional observation data besides a partial differential equation system (PDE), the aim is to derive the unknown parameter of heat flux.

In order to solve inverse problems, e.g. the Conjugate Gradient Method (CGM) is a commonly used approach to retrieve unknown parameters through minimizing the discrepancy between observations and the solution of PDEs. CGM is a computationally intensive procedure, seeking for an iterative solution for the direct problem using the current assumption of unknown parameters. Additionally, it involves the effort to calculate the gradient in conjugated direction and to formulate and solve the adjoint problem. Therefore, CGM has limited scope to carry out real-time prediction and diagnosis, especially as it comes to complex or even large workpieces.

Supervisors:

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Program: M.Eng, Mechanical and Industrial Engineering

Technical Expertise Required:

- Interest in Artificial Intelligence and Simulations

Availability: September 2021 – April/August 2022

Application Deadline: Open until filled

Interested students are encouraged to apply by sending the documents listed below, as a **single PDF** with the subject line: “InVEST Project Application - **Project Title**” to info.invest@utoronto.ca and CC tobi.edun@mail.utoronto.ca.

1. Resume/CV
2. Copy of your most recent transcript (does not need to be official transcript, ROSI copy acceptable)
3. Statement of Interest demonstrating your motivation for pursuing the project and what you will bring to this collaborative project