# DEEP LEARNING AND OPTIMIZATION WITH PDES (MATH 689)
# HARBIR ANTIL, MATHEMATICAL SCIENCES

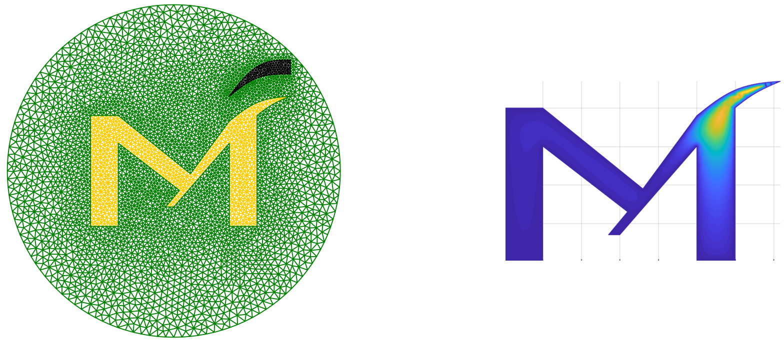

FIGURE 1. *Goal:* Control the temperature profile (described by PDEs) inside the sub-region M (left) with the help of a control which is applied on the black sub-region. Left: A finite element mesh. Right: Optimal state. (Antil. et al 2018).

Partial differential equation (PDE) models are widely used to model physical phenomenon. One example where PDEs have shown their effectiveness over the last three decades is image processing. Recently deep convolution neural networks (CNN) have become common in machine learning problems such as image processing and speech recognition. Despite their recent successes, the learning algorithms such as deep ResNets still face immense challenges associated with their design, memory requirements, and tremendous computational costs. The purpose of this course is to understand such learning algorithms using well-established PDE and optimization techniques.

This is a two semester course but each semester is standalone.

**Fall 2018:** Deep Learning and Optimization with PDEs

Monday, 7:20 pm - 10:00 pm, Exploratory Hall 4106

*Prerequisite.* Basic knowledge of PDEs and numerical analysis (both undergraduate level).

*Course topics:*

(1) Cast machine learning problems in an optimization framework with PDE constraints (cf. Fig. 1).
(2) Theory of weak solutions for nonlinear elliptic, parabolic, and hyperbolic PDEs.
(3) Optimization problems with elliptic and parabolic PDE constraints.
(4) Numerical methods and algorithms to solve PDEs and optimization problems in higher dimensions.

**Spring 2019:** Deep Learning and Optimization with PDEs Under Uncertainty

Uncertainty stems from inherent randomness in the environment, unknown precision of physical models, algorithmic errors, and noisy, corrupt, or incomplete data. More fundamentally, algorithms we develop today will face varied uncertain circumstances in the future. Our algorithms need to respond and adapt to those changes. We will address how to

(1) Quantify uncertainty and how to create solutions that are resilient to uncertainty.
(2) Adapt concepts from risk management to optimization problems with PDE-constraints by making use of *risk measures* or *risk functions*.
(3) Design algorithms to solve such PDEs and optimization problems.
(4) Implement algorithms and develop software.