Dissertation Topic Ideas

Approximating a Differential Model from Data

Goal: Identify best approximation techniques for constructing models of a truth function $f : \mathbb{R}^d \to \mathbb{R}^b$ of the forms:

$\hat{f} : \mathbb{R}^{d+\nabla d} \to \mathbb{R}^b$
Position + change → new response value.

$\hat{f} : \mathbb{R}^{d+b} \to \mathbb{R}^{\nabla d}$
Position + new response → necessary change.

where $\mathbb{R}^{d+\nabla d}$ denotes the real vector space $\mathbb{R}^{2d}$ in which the fist half of the vector is the current position and the second half of the vector is the "change" in position. The approximation techniques will be constructed given a row-vector matrix of n nodes $X^{(n \times d)}$ and response values $Y^{(n \times b)}$ associated with each node.

Target: either TOMS or Mathematics journal depending on which is more feasible (provable properties or quality math software).

Steps:

– Analyze basic theoretical properties of a model with this form given minimal assumptions (real vector space, Lipschitz continuous truth function, well spaced nodes)

– Pick data (VarSys) to do initial empirical study and convert data into differential form (distance between all pairs)

– Construct models with different approximation techniques (Delaunay, Voronoi, Box, NN) and analyze results

– Use empirical results to write a (few) paper(s)

– Develop deeper theory on performance of models and what model characteristics lead to what outcomes.

– If theoretical results are interesting enough, begin targeting math journal publication, otherwise target math software implementation.

Provable Properties of Box/Voronoi Meshes for Functional Approximation

Goal: Extend my existing mesh-based approximation techniques to functional interpolation and study meaningful provable properties about them.

Target: a Mathematics journal publication.

Steps:

– Establish new method for approximating functions with a function as response value other than forcing weights to be convex (or perhaps not, if it turns out that my current approach is acceptable?)

– Study theoretical properties of the various approximations, what can be maintained and what can't?

Box/Voronoi Meshes for Functional Approximation Math Software

Goal: Extend my existing mesh-based approximation techniques to functional interpolation and generating an optimized and robust code-base for computing them.

Target: TOMS publication.

Steps:

– Establish new method for approximating functions with a function as response value other than forcing weights to be convex (or perhaps not, if it turns out that my current approach is acceptable?)

– Identify most likely use-case scenario for the routines, develop robust optimized and stable implementation of algorithms (studying potential optimizations in the process)

Mixed Integer Programming for L_0

Goal: Use mixed integer programming and real math-software to perform the same optimization tasks as being done in the Machine Learning (ML) community for reducing model size.

Target: a series of publications (conferences, journal) in the ML community.

Steps:

– Read on recently literature surrounding L_0, standard use case, assumptions about the problem at hand

– Read up on mixed integer programming, identify connection to current work

– Identify optimal approach to solving the standard L_0 problem being faced by the current ML community

– Identify and apply existing math software to the L_0 problem