Rory Clune. MAS.864 Project Proposal

Structural Optimization

I have experience with structural optimization from my Masters research work in Civil Engineering. In that work, I used commercial closed-source optimization packages to optimize the configuration (member sizing and nodal geometry) of truss structures. I aim to move beyond that work in my MAS.864 project. At a minimum, it would be useful for me to write an optimization routine with similar capabilities to these commercial solvers. The insight I will gain from this should take my understanding of structural optimization beyond its current level. It would be natural to work with beam-based structures since the basic building block for their analysis was developed in the finite element homework assignment. I have written solvers for assemblies of beams in the past, so the generalization of our solution method for a single beam to a frame (consisting of multiple connected beams) should not take too long. This will allow me to focus primarily on the optimization. The first goal of the project would be the implementation of an optimization routine that can find, say, the minimum weight frame structure to support a given loading, given a topology that defines the assembly of beams and a set of boundary conditions. The variables would be the sectional properties of the beams (area & moment of inertia) and the coordinates of the start and end nodes of the beams.

However, part of the specification for this project is that it goes beyond an implementation of someone else's work. Some originality is required. I will now outline a few possibilities for a small piece of original work that would be roughly equal to a week's homework assignment.

One interesting thing I can do is be to implement a (presumably small) number of optimization methods, and run them out on different problems. The original contribution of this work would then be an identification of some features of frame optimization problems that make them amenable to solution by a certain method. The main pitfall would be not being able to find any such features.

Alternatively, I could try to do something technically novel. I have recently been reading about clustering techniques, and think there may be a potential for application in the design of structures. The traditional goal of optimization is to find the best possible design to fulfill a stated purpose. Civil Engineering is different to other disciplines that build structures in that subjective criteria such as aesthetics and constructability play a large role in design evaluation. Since these concepts are difficult to express mathematically, they are often left out of the optimization process. I have seen quite a few papers on 'multimodal optimization', proposing population-based evolutionary methods like Genetic Algorithms and Particle Swarm to find multiple solutions which are different in character from each other but better than all close neighbors (i.e. they are locally optimal). An engineer can then choose among these, implicitly accounting for the subjective evaluation criteria. A measure of success of the algorithms in these papers is whether or not they find many possible locally optimal solutions, with failure being manifested in the convergence to a single, global, optimum. I think that clustering could be used to split the design space early in the exploration into regions containing local optima for a highly nonlinear structural optimization problem. Each cluster could then be isolated and the optimum within it be found.