Dr. Salmon
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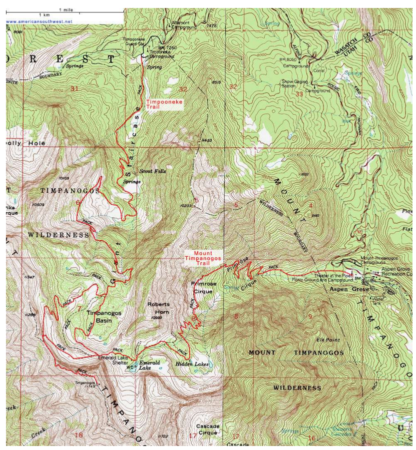
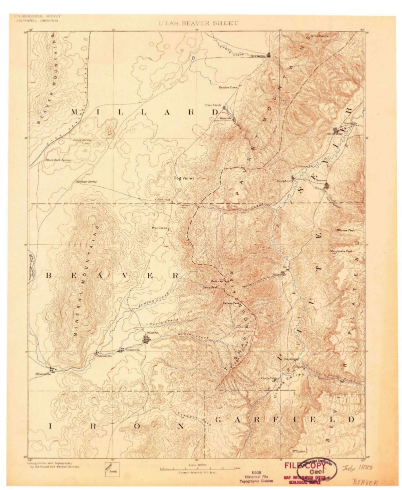
ME EN 575 - Homework 1

1.1 Familiarization with Contours and Constraints

(a) Mountain Peak
Location: Mt. Timpanogos Peak
Coordinates: 40.39089, -111.64596



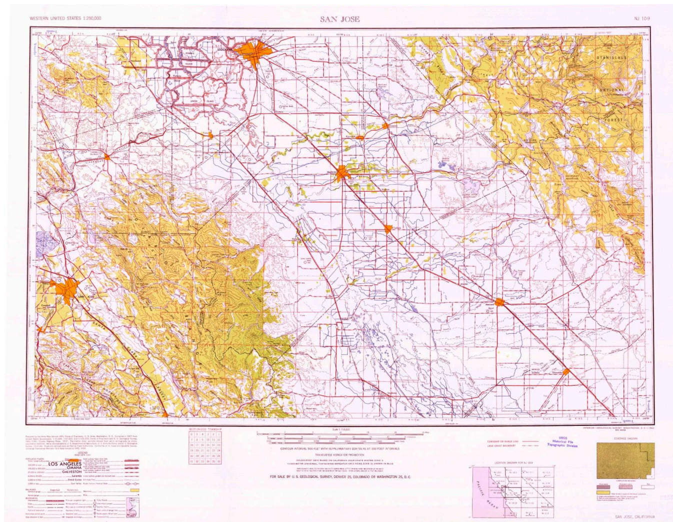
(b) Basin/ Bowl
Location: Dog Valley, UT
Coordinates: 38.6650, -112.5799



(c) Long Valley

Location: San Joaquin Valley

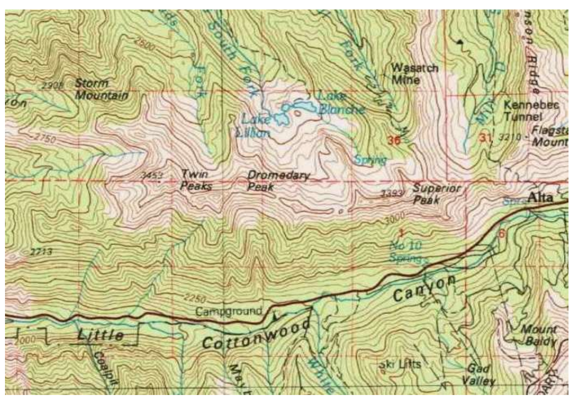
Coordinates: 37.9833, -121.8677



(d) Saddle Point

Location: Twin Peaks/ Dromedary

Coordinates: 40.5527, -111.6541



(e) Equality Constraint

Location: Playa Organos Shoreline

Coordinates: 9.7976, -84.9035

Explanation: Walking along the shoreline constrains the user to an elevation of h = 0.

(f) Inequality Constraint

Location: Waipio Valley

Coordinates: 20.1116, -155.5965

Explanation: The steep terrain acts as a boundary that is difficult or impossible to cross.

1.2 Unconstrained Brachistochrone Problem

Problem Overview: This problem required finding the path of a wire that minimizes the travel time of a bead sliding with friction (mu_k = 0.3) from (0,1) to (1,0).

Numerical Results (n = 12):

- **Optimal Travel Time:** 0.8920
- **Design Variable:** 10 interior y-coordinates

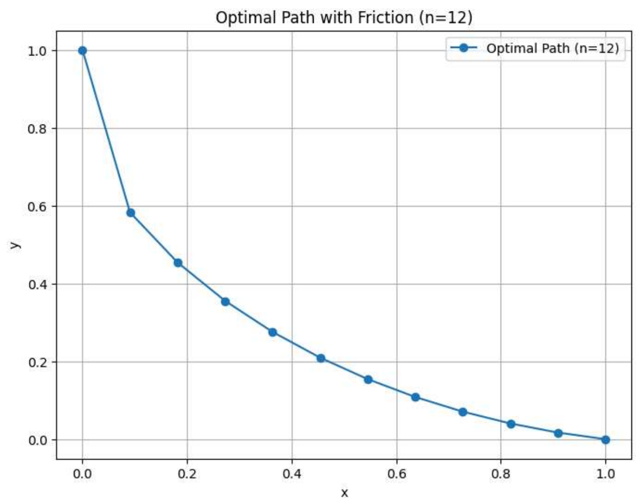


Figure 1: Brachistochrone curve with friction.

Dimensionality Study: The problem was solved for n = [4, 8, 16, 32, 64, 128]. As dimensionality increased, both the total number of function evaluations and the CPU wall time grew significantly. This illustrates the computational cost associated with higher-resolution discretization in optimization.

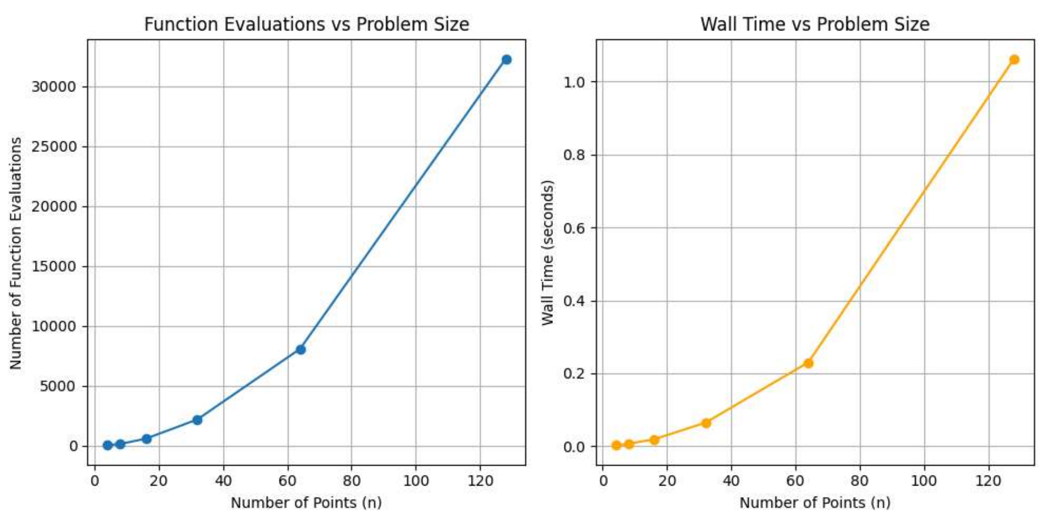


Figure 2: (a) Function evaluations versus the number of points. (b) Evaluation time versus the number of points.

Learning Summary:
This problem was a good first practical introduction to discretization, and helped teach me how to approximate a continuous path by dividing it into linear segments. Implementing the objective function required summing the travel time across these segments, where I learned that the magnitude of gravity affects the final time but not the coordinates of the optimal path. Also, I learned a bit about warm starts from the hint in the homework. It was interesting to learn that starting from a lower-dimensional case can improve the efficiency of the optimization.

1.3 Constrained Truss Problem

Problem Overview: The goal was to minimize the mass of a 10-bar truss subject to yield stress constraints and a minimum area bounds.

Optimization Results:

- **Optimal Mass:** 1497.60 lbs
- **Total Function Calls:** 255

Member	Area (in2)	Member	Area (in2)
Bar 1	7.9000	**Bar 6**	0.1000
Bar 2	0.1000	**Bar 7**	5.7983
Bar 3	8.1000	**Bar 8**	5.5154
Bar 4	3.9000	**Bar 9**	3.6770
Bar 5	0.1000	**Bar 10**	0.1414

Table 1: 10-Bar truss optimal cross-sectional areas.

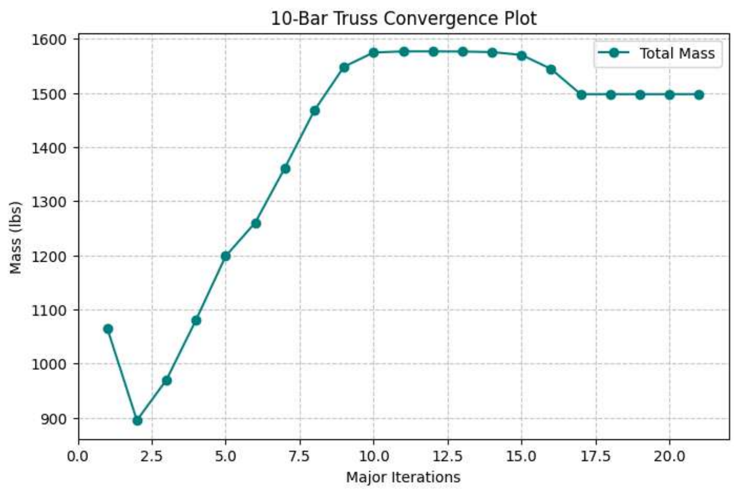


Figure 3: Convergence plot of major optimization iterations versus 10-bar truss total mass.

Learning Summary:

Solving the ten-bar truss problem taught me how to work with constrained optimization, where the objective is to minimize the structural mass while still considering failure limits. I learned how to integrate a structural analysis function into an optimizer to evaluate stresses in each member based on their cross-sectional areas. The provided code was very helpful in all of that.

Looking at the final results, it was clear how the bound constraints like the minimum limit the feasible region to the minimum. Finally, creating the convergence plot helped me visualize how the solver iteratively refines the design variables to reach the optimal mass while still taking into account the constraints.