Image-Based Rock-Climbing Simulator

Artificial Intelligence Final Project

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CS 151

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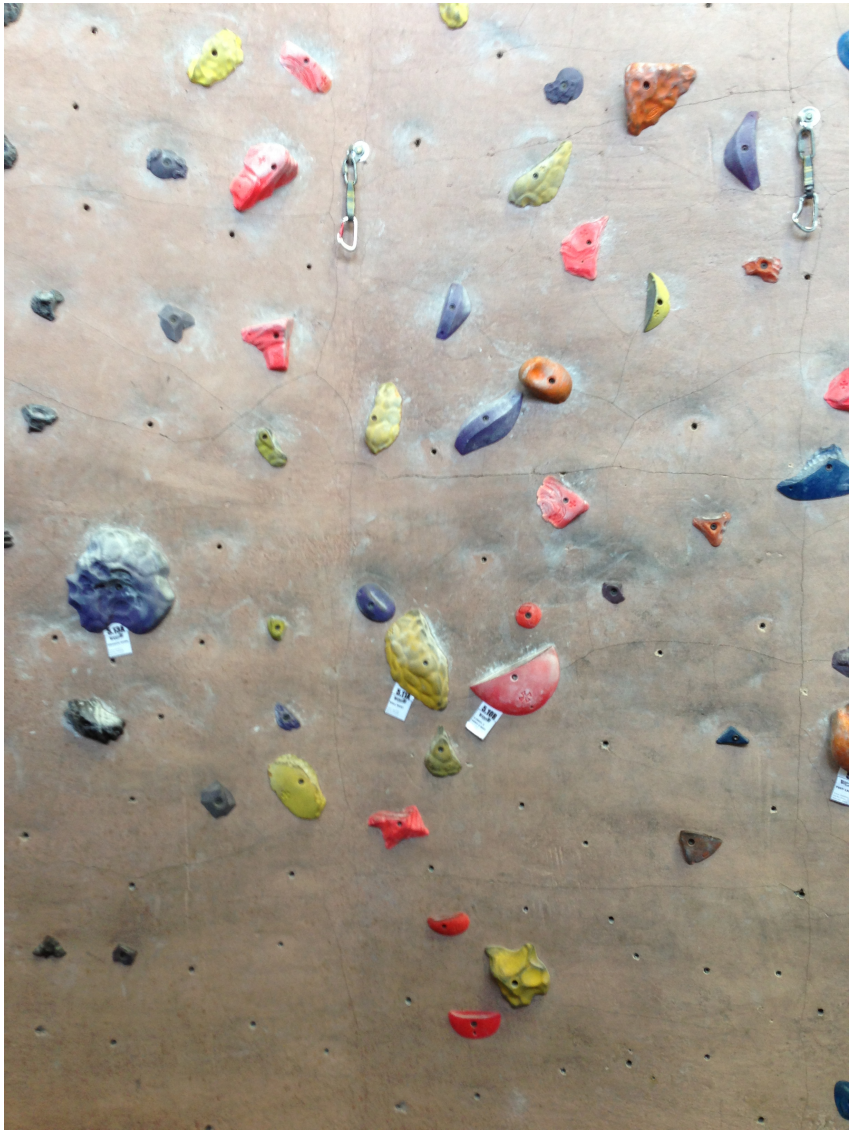
Rock Climbing



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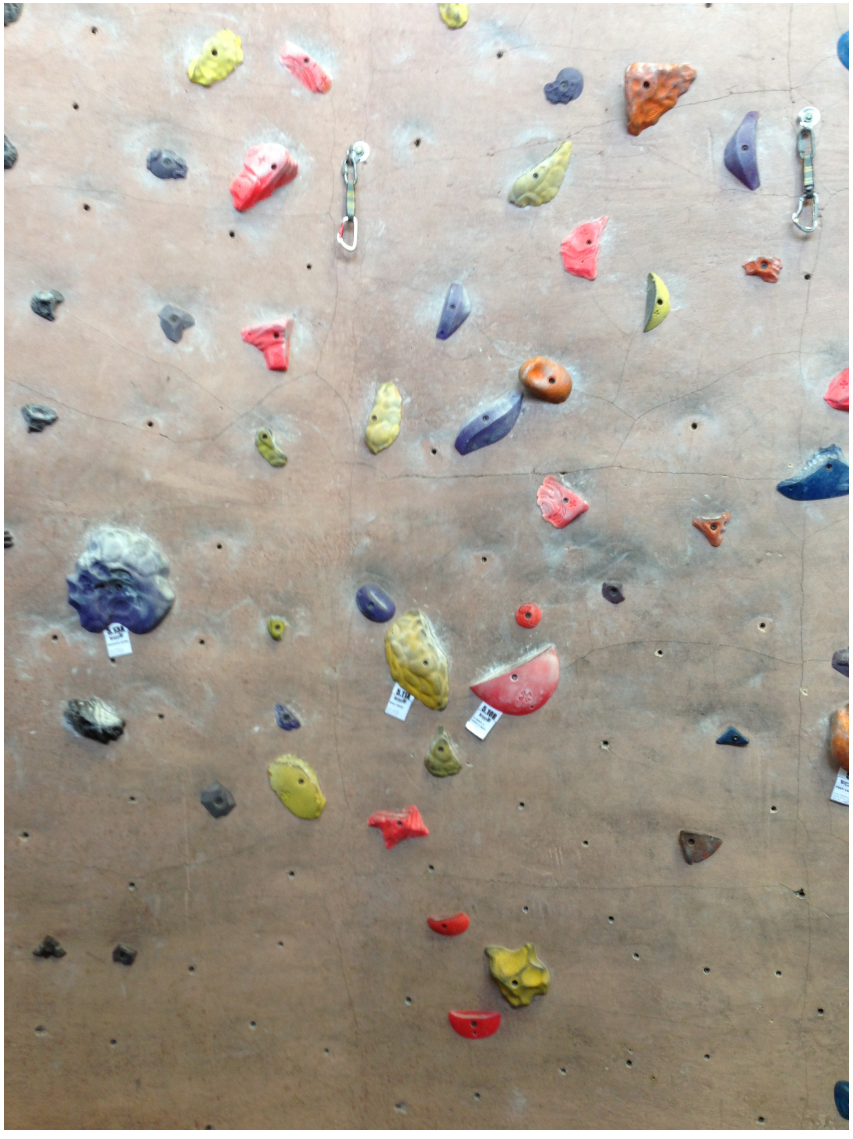
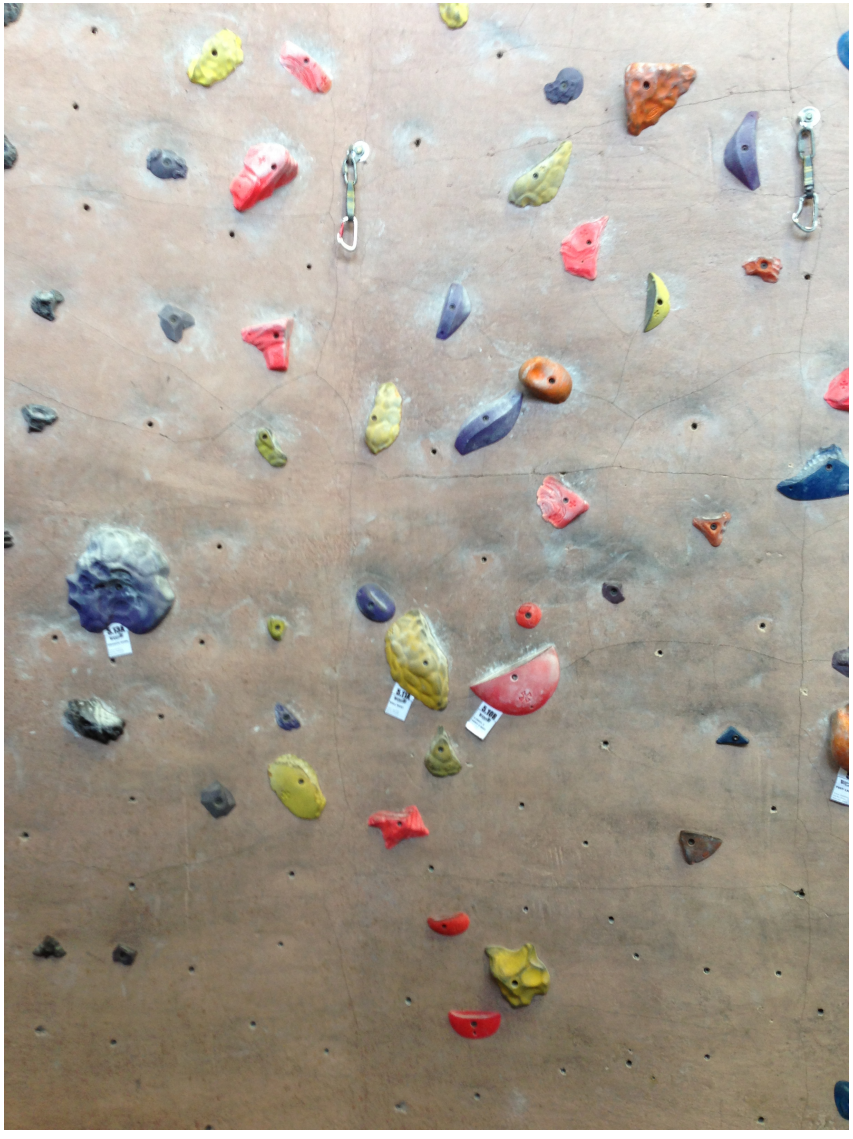


Problem Definition

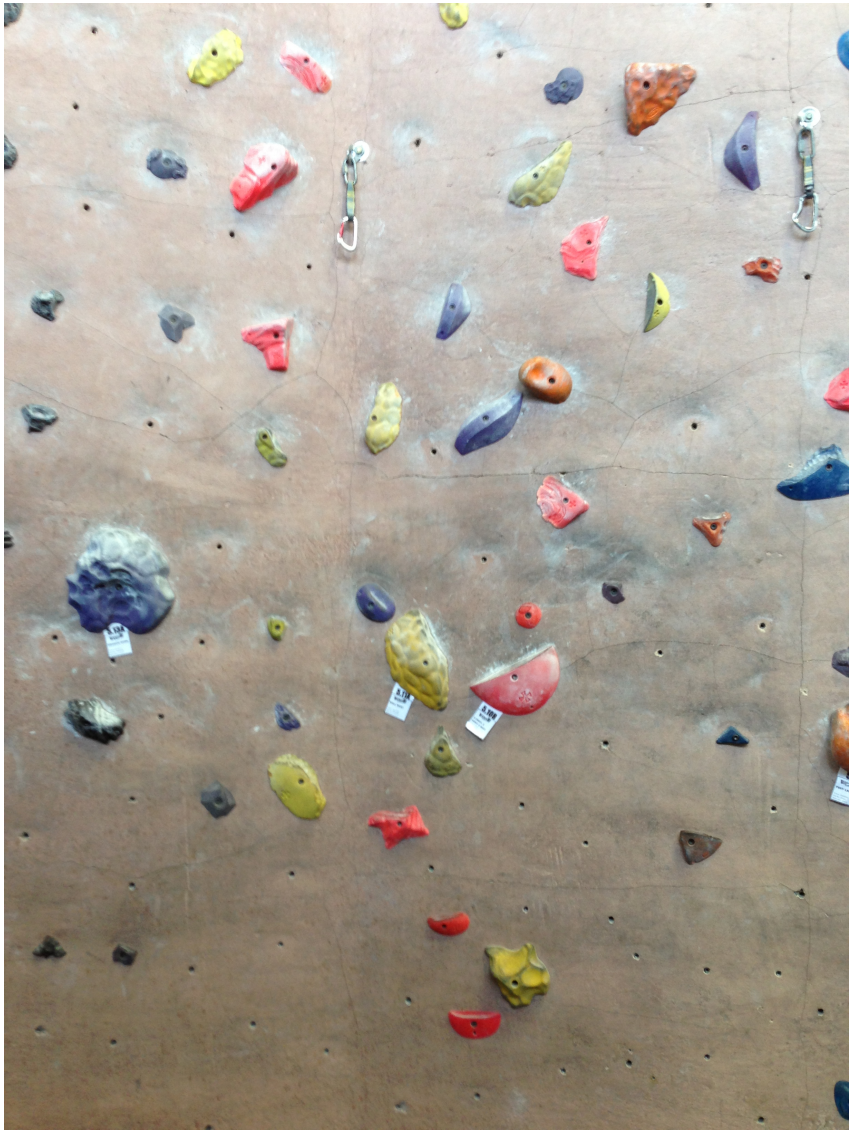
- Routes are color-delimited
- Use any subset of designated grips to get to the top
- Difficulty determined by size, spacing and surface properties of the grips
- Climbers have to determine a path

Rock Climbing



Challenges

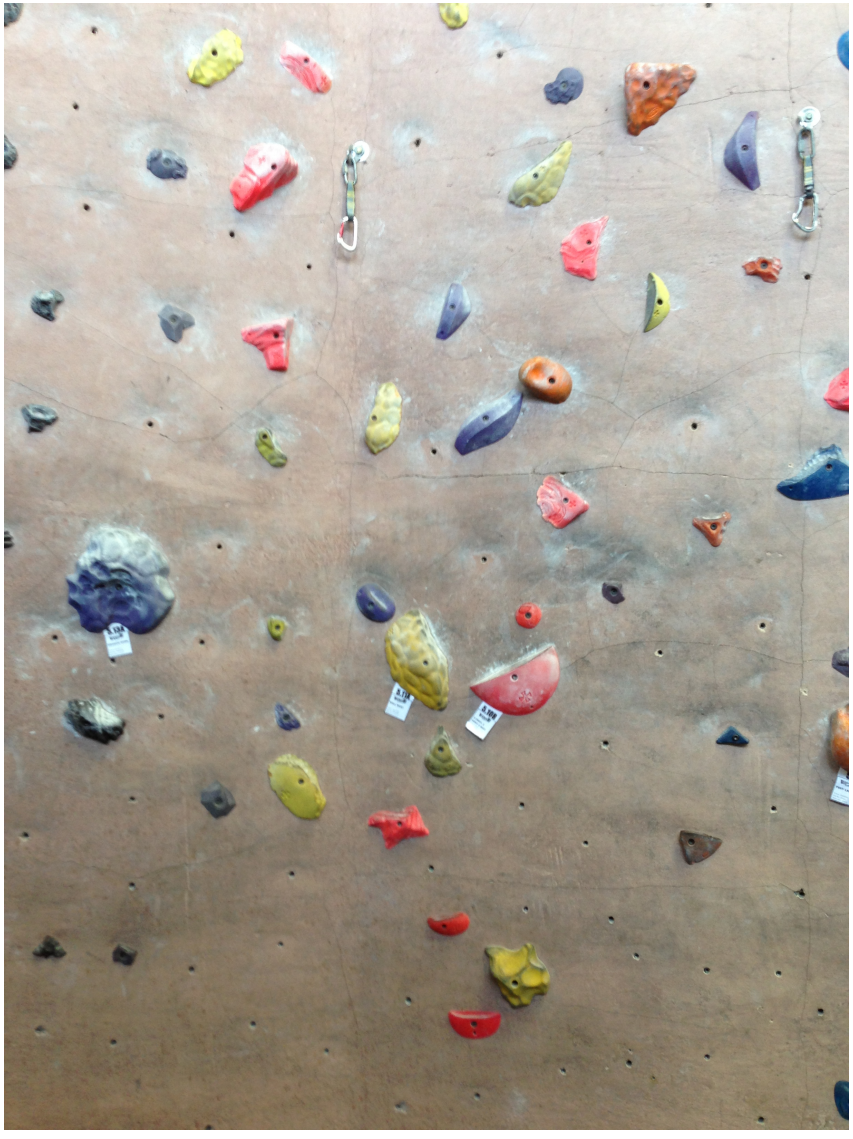
Rock Climbing



Challenges

- Physically-viable arrangements
- Balance forces
- Minimize muscle strain
- Path efficiency

Rock Climbing



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Scope Constraints

- Motion in 2D plane – no overhang
- Depth correlated to grip size

Solution Specifications

Input:

- A low-resolution color photo of a rock wall
- Single pixel selection by user that maps to one of the grips in the desired route

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- Rendering of climber positions along the solution path
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Tools:

- OpenCV Library
- Qt C++ Framework

Pipeline

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Image Processing

- Route Detection
- Grip Analysis

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Heuristic Analysis

- Modeling Grip Support

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Physics Engine

- Modeling a Human
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- Starting a Route
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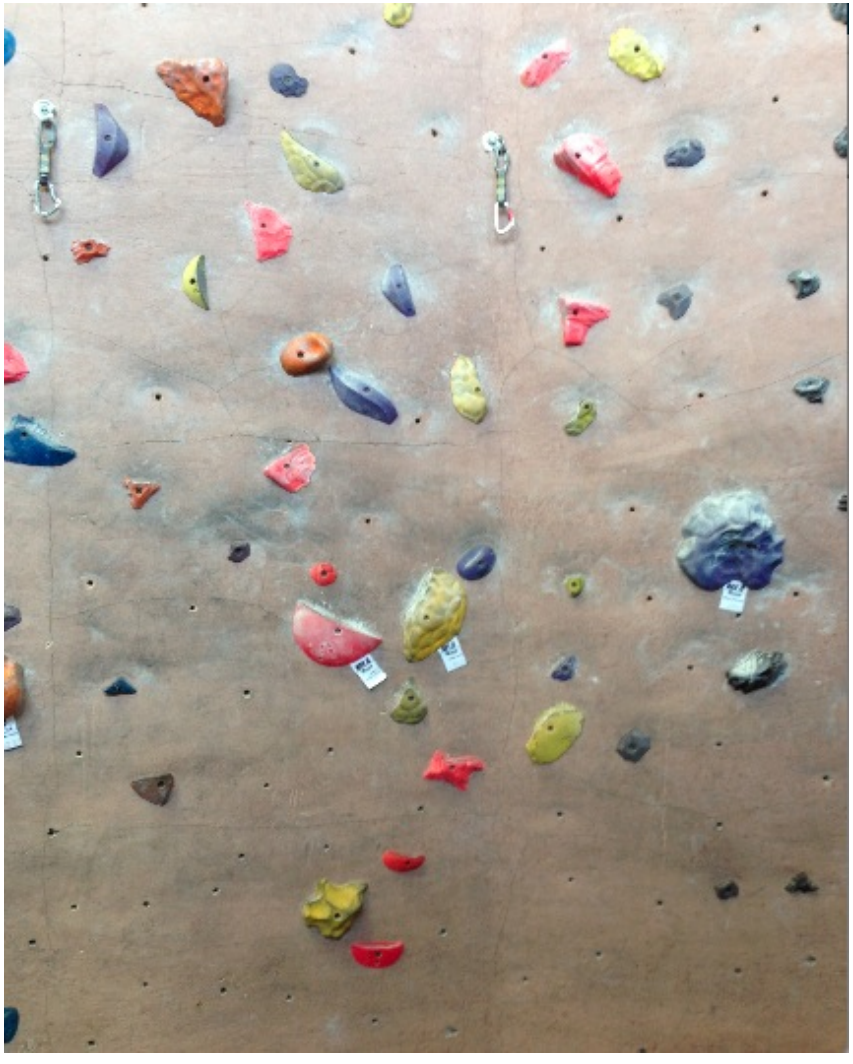
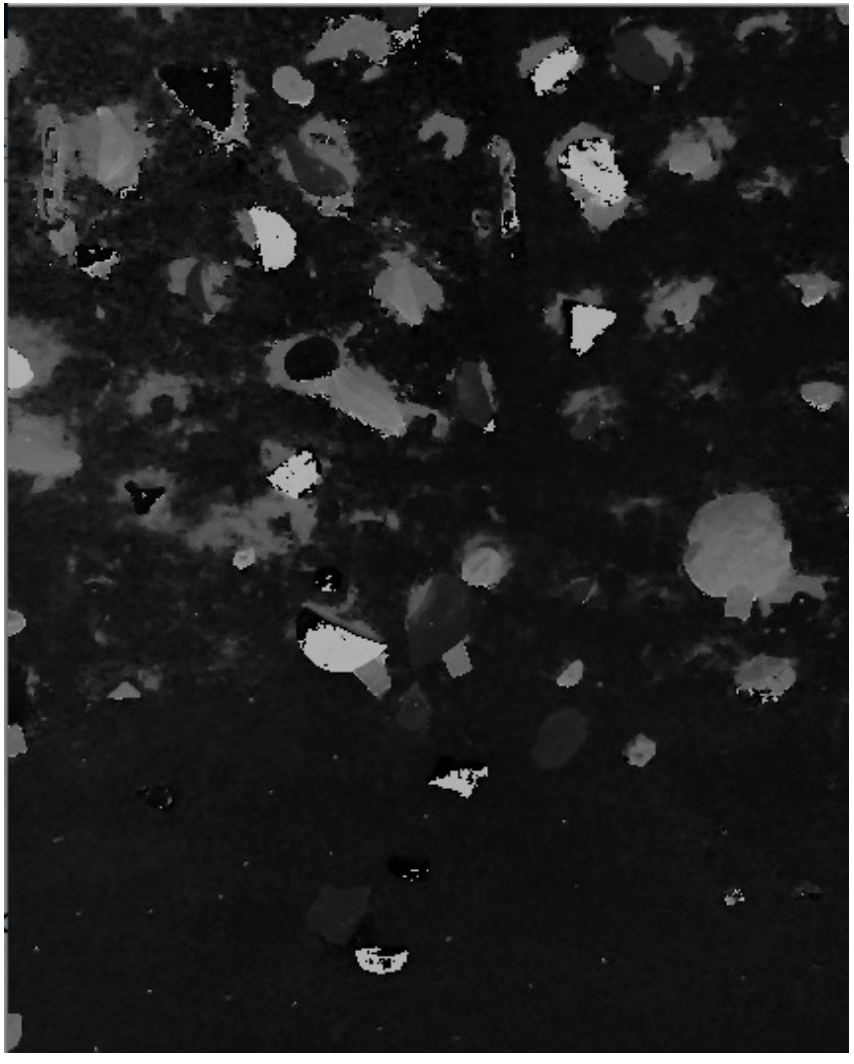


Steps:

Image Processing



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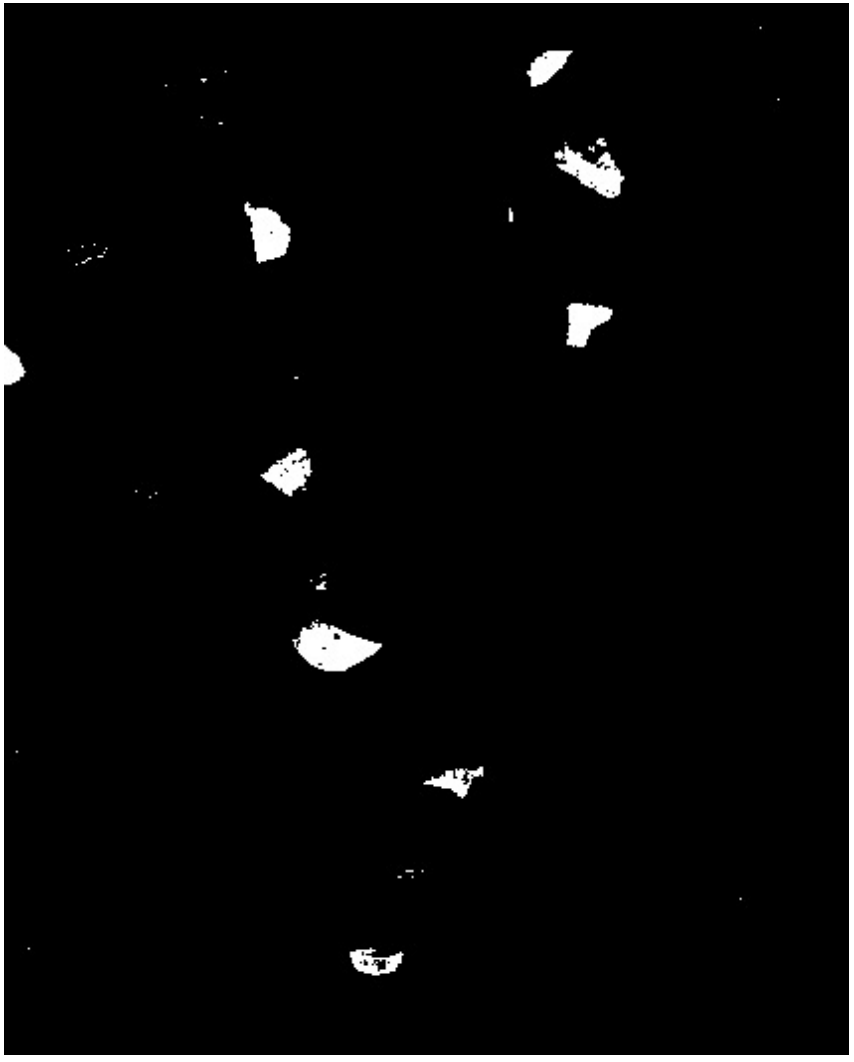

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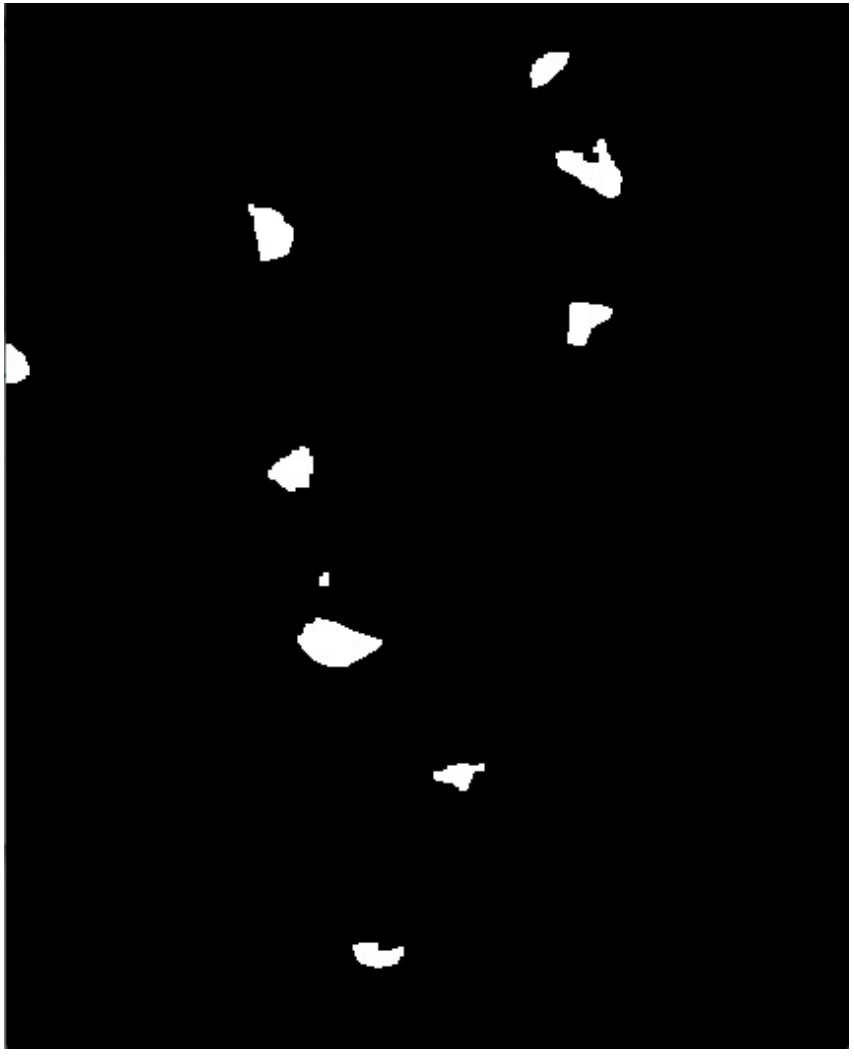

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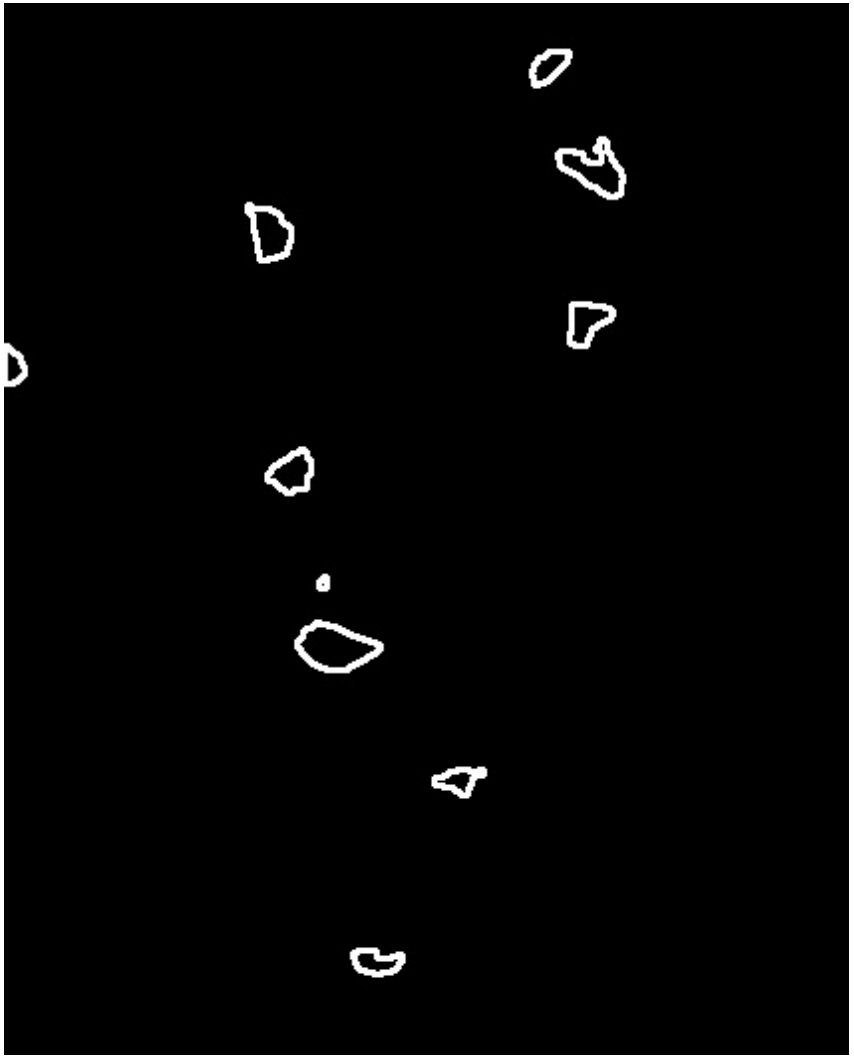


Steps:

- Convert to HSV color space
- Threshold image by hue of user selection
- Denoise image using dilation & erosion
- Represent grips as contour

Grip Analysis

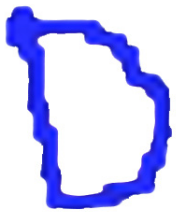
Grip Analysis

Physical Properties:

- Area
- Perimeter
- Center of Mass
- Convexity Defects

Grip Analysis

Orientation Estimation



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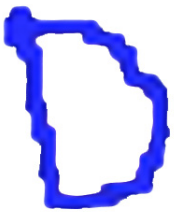

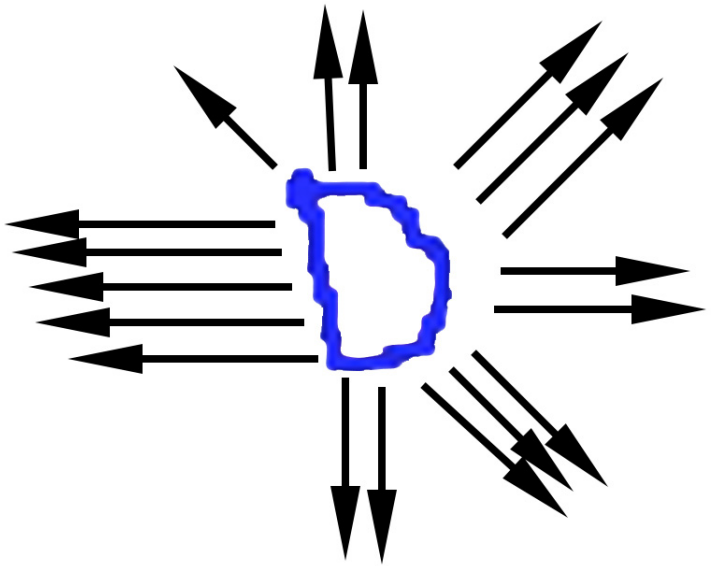

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- Can it support a hand or just a foot?
- Can it support two limbs?

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$$F = f(a, p, d, N, \theta)$$

where a is area, p is perimeter, d are the convexity defects, N is the normal field, and θ is the angle at which the grip is grabbed.

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As an approximation,

$$F = a \cdot N[\theta] + \text{hardlim}(d) \cdot |d|.$$

Physics Engine

Modeling a Human

- 4 point mass limbs
- A center of mass, which is not necessarily the geometric center of limbs
- Limbs have minimum and maximum distances from center

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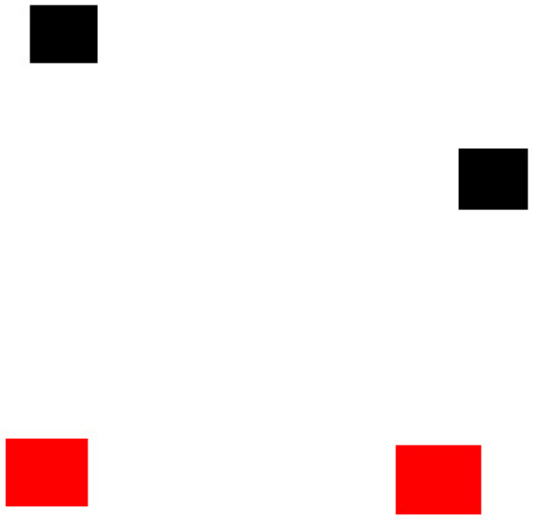
Challenge is exploring possibilities for the center of mass.

Center of Mass



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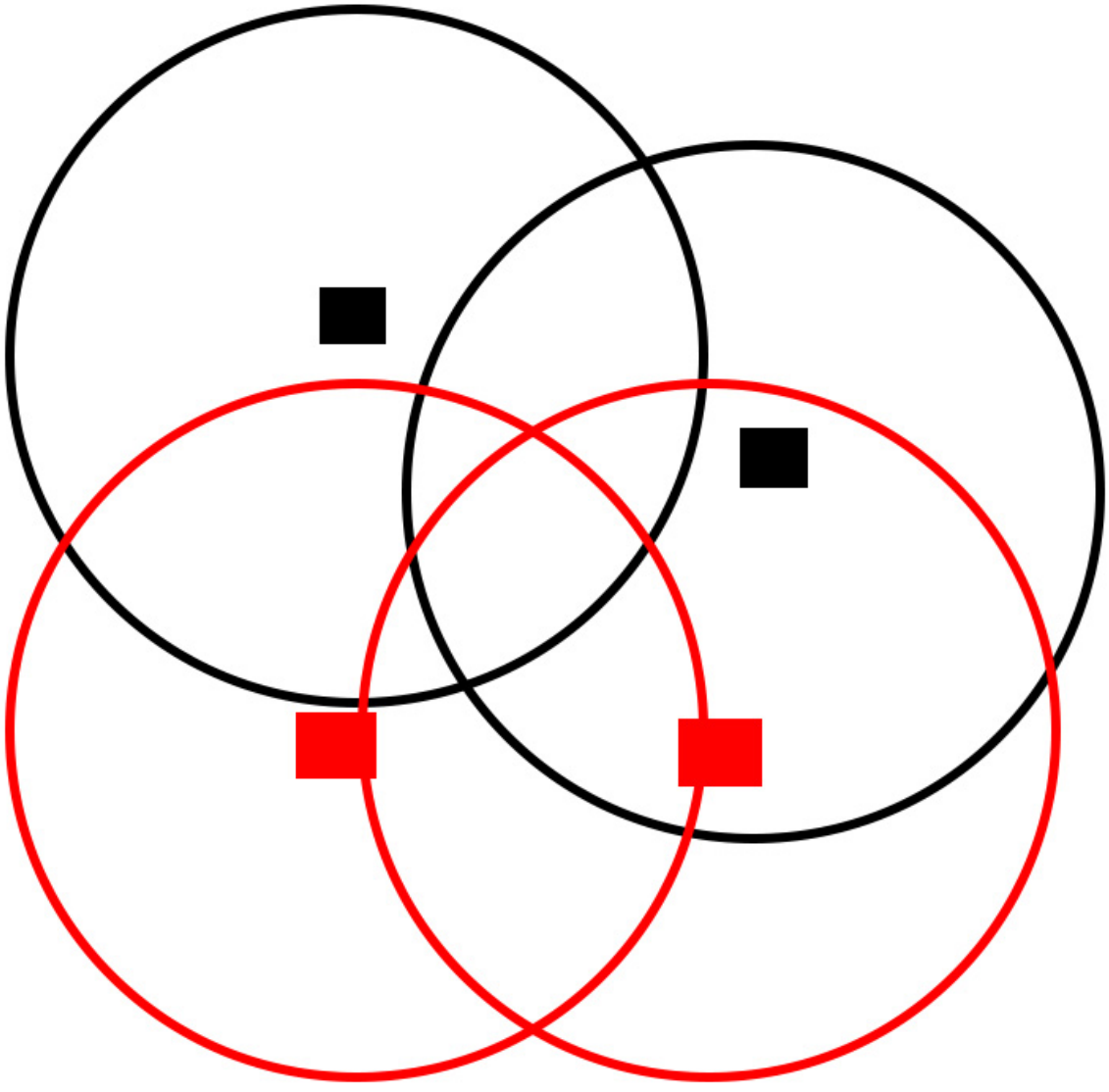

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- Move one limb at a time
- Configuration should be reasonable
- Analyze forces and ensure the grips can support the climber

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Exploration

- Allow limbs to be on no grips or to share
- Assign strain for each move and for distance of the move
- Cost function to minimize strain and maximize height

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Starting

- Search permutations of 4 lowest grips for viable position
- Search higher if necessary, provided it can be reached from the ground

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