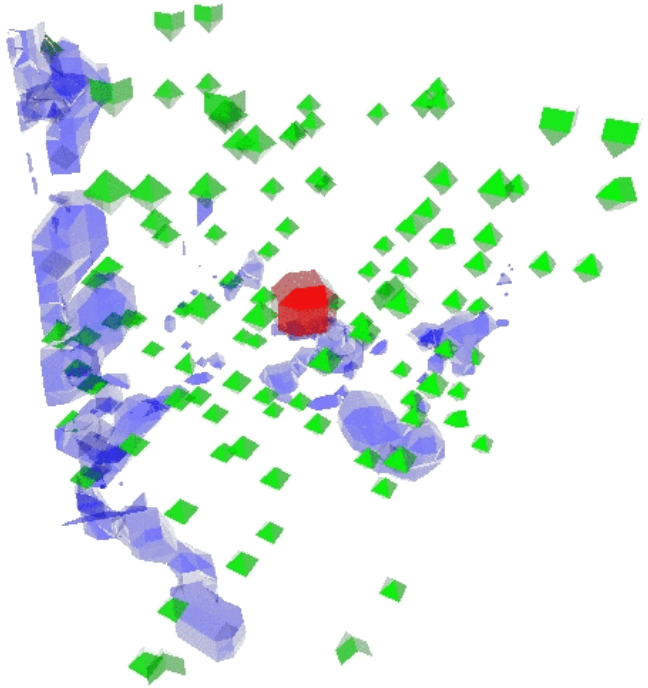
GPU-Accelerated 3D Ant Colony Simulation and Visualization



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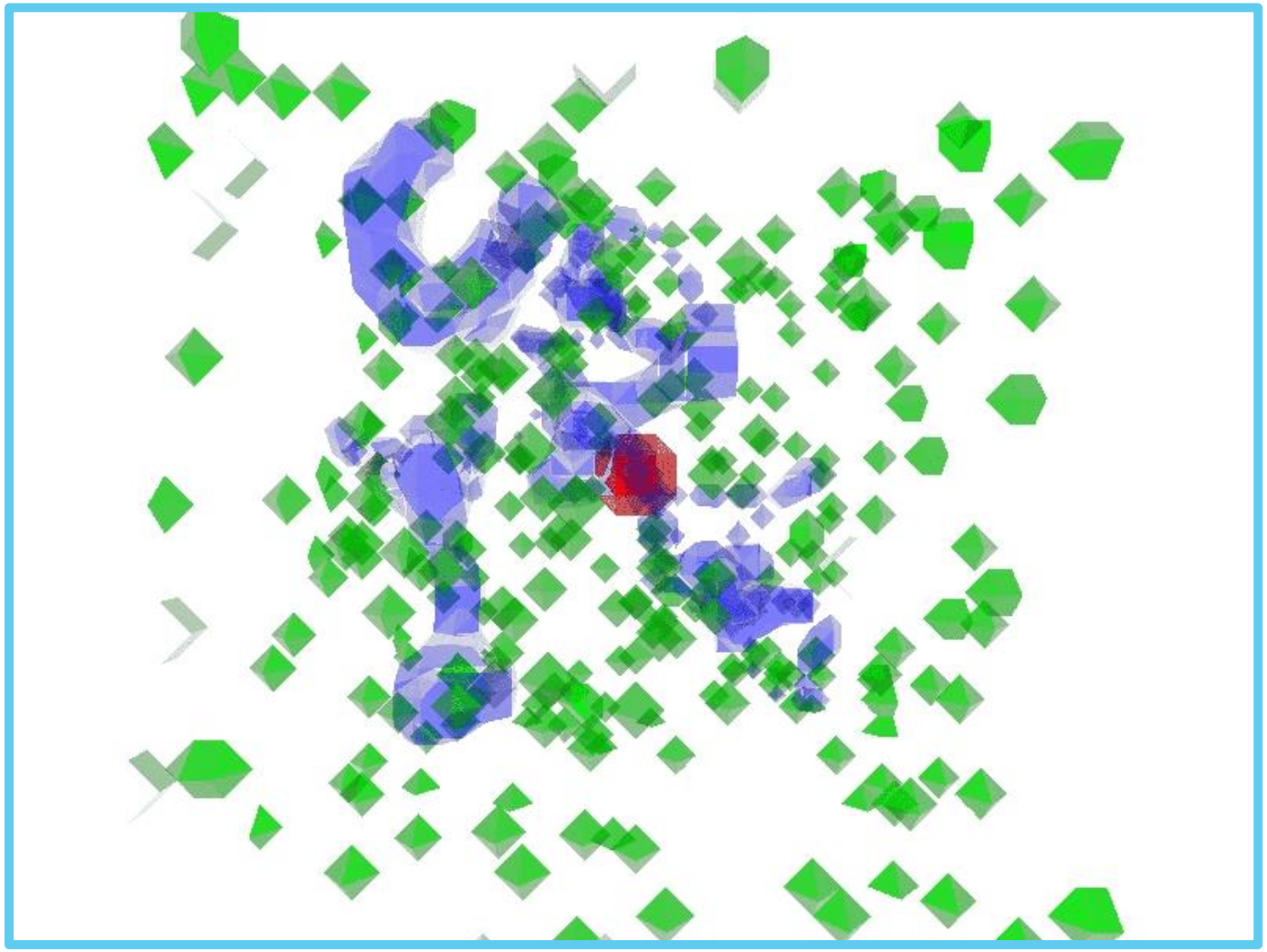
Motivation / Background

- Ant colony optimization algorithms are useful for pathfinding
  - Robotics, distributed networks
- Each ant only needs knowledge of its immediate surroundings
  - This makes it great for parallelization / GPGPU

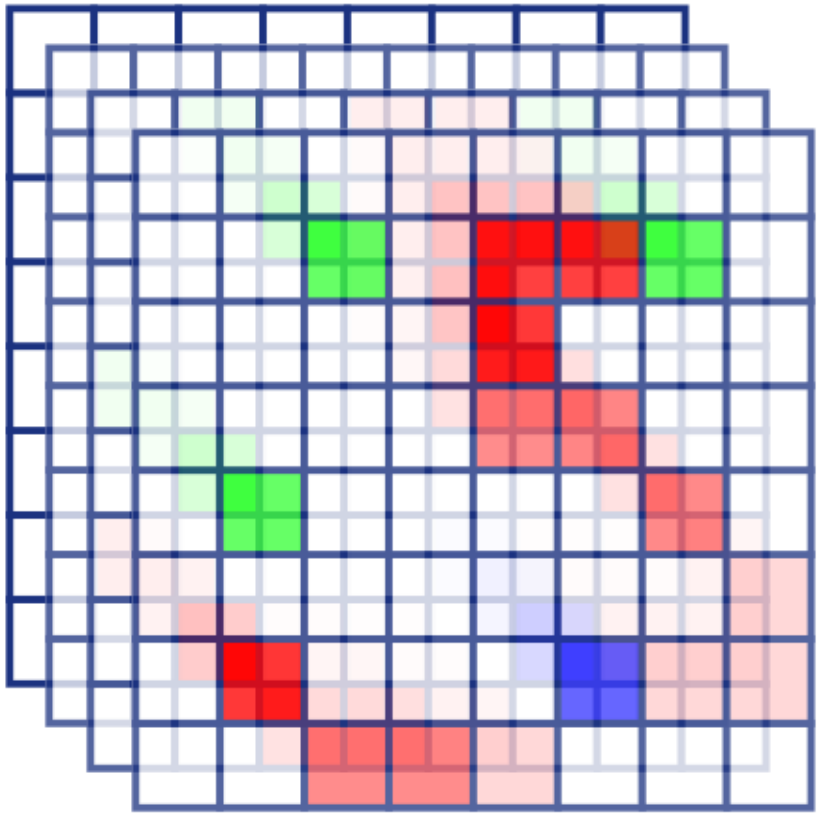
- Basic setup:
  - Ants wander randomly from nest, laying pheromone trails
  - They pick up food and bring it back to the nest
  - Other ants follow the trail to the food

Demo



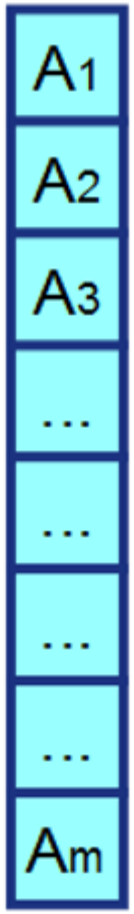
Approach – Simulation - World

- 3D texture (N x N x N)
  - Red: Nest
  - Green: Food Amount
  - Blue: Trail Strength
  - Alpha: Ant
- Shader sets trail to max value if ant is in cell
  - Otherwise, fades the trail



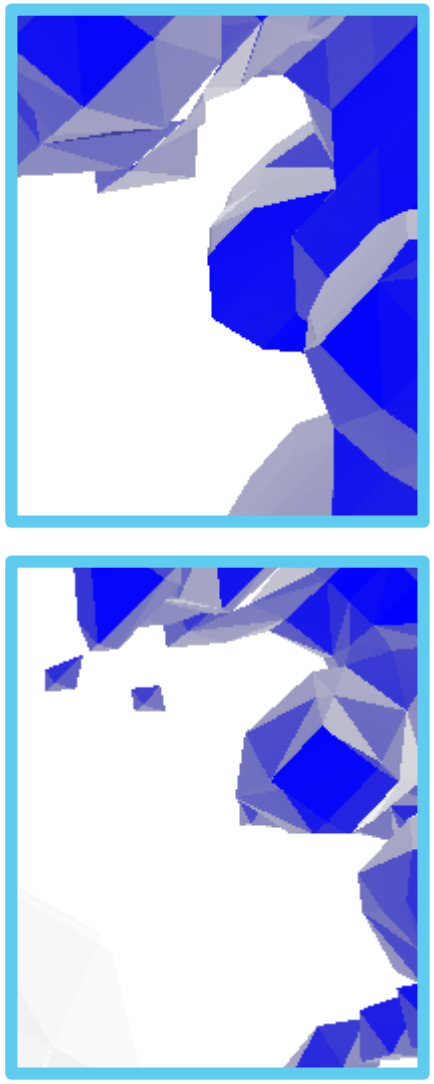
Approach – Simulation - Ant

- 2D texture (M x 1)
  - RGB: XYZ position in world
  - Alpha: ant state (direction, carrying food)
- For each ant, the fragment shader:
  - Picks up / drops off food
  - Determines where the ant is allowed to move
  - Calculates score for each possible choice
  - Moves to best choice (sometimes moves randomly)

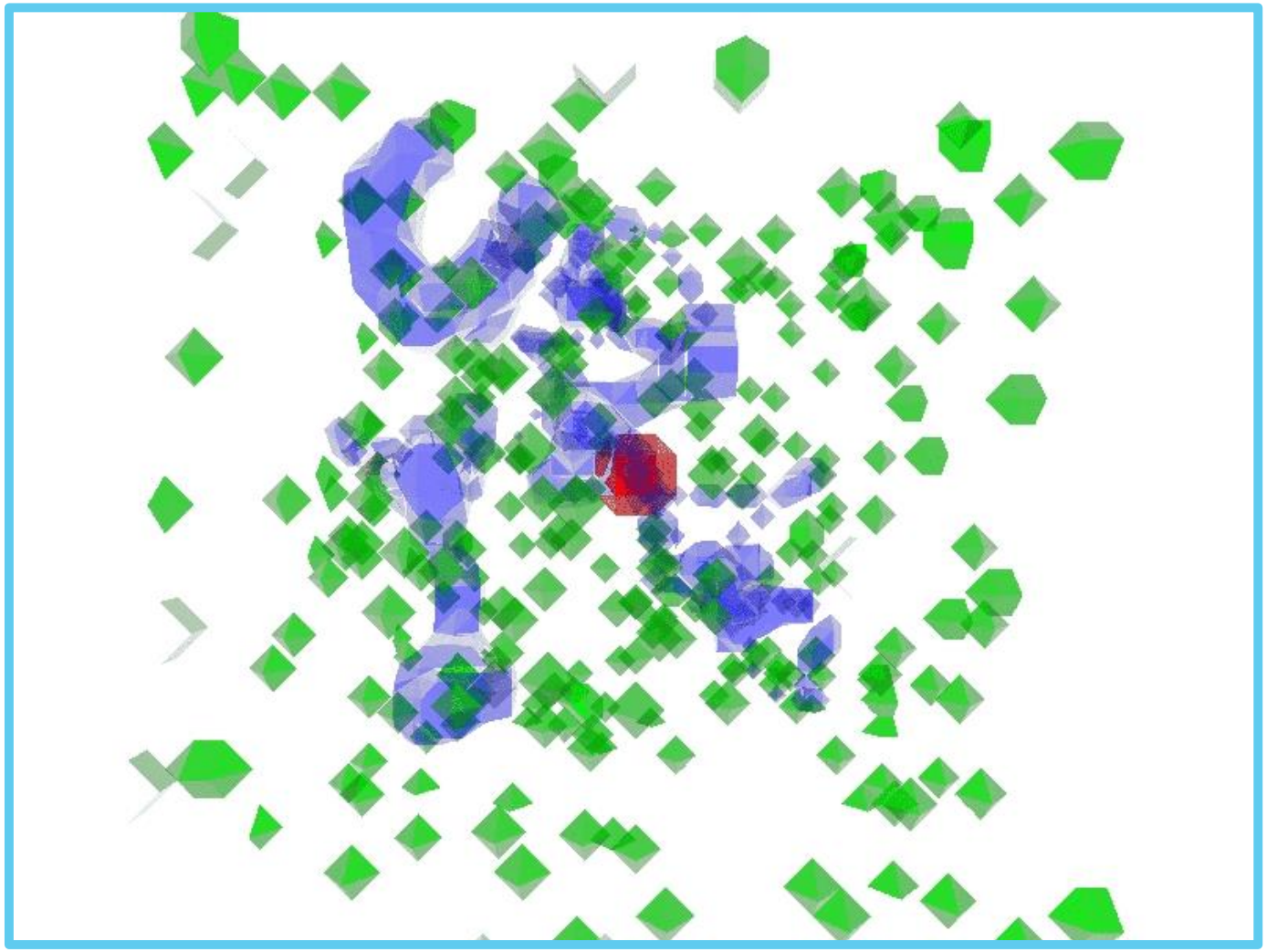


Approach - Visualization

- Geometry shader
  - Input: a single vertex at each grid point
  - Output: A set of triangles for the mesh near that point
- Using marching cubes algorithm (Lorensen 1987)
  - Evaluate value at point and 8 surrounding points
  - Look up in array of 256 possible configurations
  - Use linear interpolation to determine vertex locations

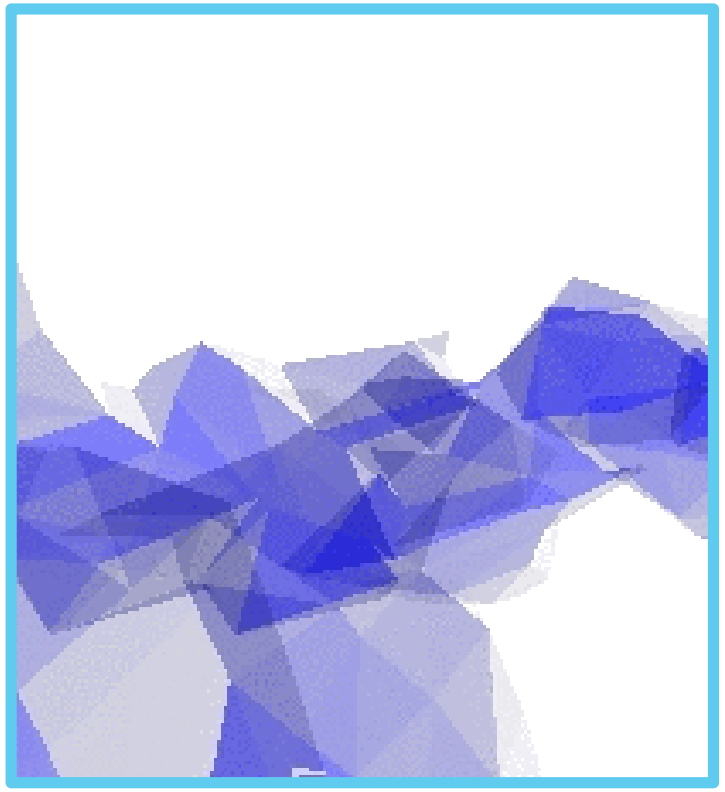


Demo



Results

- Swarm behavior of ants is sensitive to variation in ant path-finding algorithm
  - Ants can get stuck in their own trail
  - This happens in the real world too (ant mills)
- Runs at real-time rates up to world size of 128x128x128



Summary

- Simulated ant-like motion using fragment shaders
- Visualized simulation using marching cube algorithm in geometry shaders
- UI includes customizable parameters

Future Work

- Use of VBOs can improve visualization performance
- Different trails (toward food and toward nest) can improve swarm behavior
- Storing history of ant movement can prevent self-loops
- Weighted random selection of possible destinations, rather than always choosing highest score

Questions?