CSE306 - Fluid Simulation - Project 2

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1 Project structure

1.1 Main Function

The main function initializes a fluid system with 50 particles and runs the fluid solver. It then creates 32 points in the fluid system, assigns uniform weights (lambdas) to these points, and applies the optimal transport (OT) solver to these points and weights. The OT solution is then saved to an SVG file named "voronoi.svg".

1.2 Fluid Class

This class describes the behavior of a fluid system consisting of an array of particles each with their respective velocities evolving over time.

- **Attributes:**
  - `particles`: Array of particles each with their positions and velocities.
- **Methods:**
  - `stepFluid`: Advances the fluid system by one time step.
  - `runFluid`: Runs the solver for a specified number of steps, which updates the positions and velocities of all particles in the fluid system.

1.3 OT Class

This class implements the Optimal Transport (OT) solver. The solver takes a set of points and weights in the fluid system and solves the optimal transport problem using the LBFGS optimization algorithm.

- **Attributes:**
  - `points`: Array of points in the fluid system.
  - `weights`: Lambdas - array of weights associated to the points
  - `solution`: An instance of the PowerDiagram class, storing the solution of the optimal transport problem.
- **Methods:**
  - `solve`: Solves the optimal transport problem.
  - `evaluate`: Evaluates the objective function of the optimization problem.

1.4 Polygon Class

This class represents a polygon within the fluid system, described by an array of vertices. These polygons form part of the Power Diagram.

- **Attributes:**
  - `vertices`: Array of vertices defining the polygon.
- **Methods:**
  - `area`: Computes the area of the polygon.
  - `integrateSquareDistance`: Computes the integral of the square distance of the polygon's vertices from a point.
  - `centroid`: Computes the centroid of the polygon.

1.5 PowerDiagram Class

This class encapsulates the Power Diagram of the set of points and their weights in the fluid system. The Power Diagram is represented as an array of polygons, and the polygons are used in the fluid solver and the OT solver.

- **Attributes:**
  - `polygons`: Array of Polygon instances representing the Power Diagram.
- **Methods:**
  - `clipPolygonByEdge`: Clips a polygon by an edge.
  - `clipPolygonByBisector`: Clips a polygon by a bisector.
  - `intersect_with_disk`: Intersects a polygon with a disk.
  - `compute`: Computes the Power Diagram given the set of points and weights.

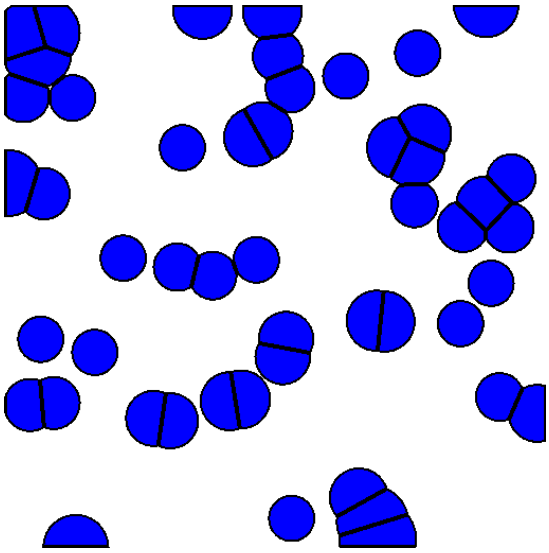
2 Execution Flow

The main function starts the fluid simulation by creating a Fluid instance and invoking the runFluid method which simulates the motion of particles based on Euler's equations. Next, an Optimal Transport (OT) instance is generated. The solve method is called with the positions and weights of the fluid system's points, utilizing the LBFGS algorithm to determine the optimal transport plan. The solution of the optimal transport problem informs the creation of a PowerDiagram instance.The simulation concludes with the generation of an SVG file, "voronoi.svg", visualizing the final state of the power diagram and the corresponding fluid system.

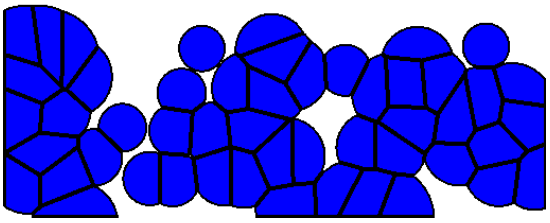
3 Results

The simulation depicted below uses 50 particles, and was executed on a machine equipped with a 2.6 GHz 6-Core Intel Core i7 processor, resulting in a termination time of 13 seconds. Parameters and their respective values used in the simulation include:

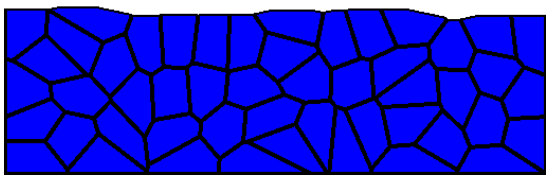
- `dt`: Set to 0.002
- `mass_particle`: Set to 50
- `epsilon2`: Set to 0.004^2



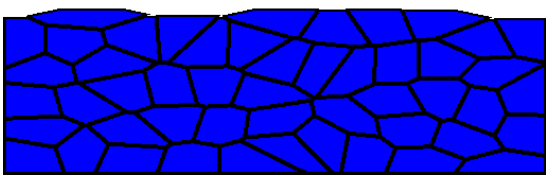
(a) Frame 0



(b) Frame 12



(a) Frame 18



(b) Frame 33