Sharks and Fish 1

- **The fish are points with masses $fishm_i$ moving according to Newton's laws ($F = ma$) subject to an external force (current). The current depends on position.**
- **Use Euler's method to integrate.**
- **Accumulate the mean-square-velocity of all the fish**

$$\left[\sum_{i=1}^{\#fish} \frac{velocity_i^2}{\#fish} \right]^{1/2}$$

and plot it as a function of time.

- **Choose the time step dt in the integrator (see the matlab code for details) small enough to keep the simulation accurate:**

$$dt = .1 \cdot \frac{\max_{1 \le i \le \#fish} |velocity_i|}{\max_{1 \le i \le \#fish} |acceleration_i|}$$

- **Complete matlab implementation in /usr/castle/share/proj/shortcourse/wator prob1/matlab/fish1.m**
- **50 lines long (13 excluding comments, graphics)**

Sharks and Fish 2

- As in Problem 1, the fish are points with masses $fish_m$ moving according to Newton's laws ($F = ma$) subject to an external force (gravity).
- Integrate using Euler's method as in Problem 1.
- Accumulate and plot the mean-square-velocity of all the fish as in Problem 1.
- Choose the time step dt in the integrator as in Problem 1.
- Complete matlab implementation in /usr/castle/share/proj/shortcourse/wator prob2/matlab/fish2.m
- 63 lines long (24 lines excluding comments, graphics)

Sharks and Fish 3, aka Game of Life

- Fish occupy a d-by-d periodic grid, with at most one fish per grid cell.
- The rules for deciding whether a fish occupies a cell during the next time step are:
  1. A new fish is born at a grid cell if it is currently empty and exactly three of its eight neighboring cells are nonempty.
  2. A fish dies of loneliness if it has 0 or 1 neighbors.
  3. A fish dies of overcrowding if it has 4 or more neighbors.
  4. Other cell configurations are stable.
- Parallel execution of these rules are relatively simple because the next state is purely a function of 9 cells at the previous state and does not depend on other state changes at the same step
- Complete matlab implementation in
  /usr/castle/share/proj/shortcourse/wator
  prob3/matlab/fish3.m
- 11 line inner loop

Sharks and Fish 4

- **Fish occupy a d-by-d periodic grid, with at most one fish per grid cell.**
- **Each fish chooses a random direction to move at each time step, either Up, Down, Left or Right.**
- **To resolve the conflict of fish wanting to move to the same grid point at the same time, we first move those fish Right that want to move right, then Up, then Left, and then Down. Fish cannot move if a cell is occupied. A fish may move at most once during a time step.**
- **Complete matlab implementation in**
  /usr/castle/share/proj/shortcourse/wator
  prob4/matlab/fish4.m
- **120 lines of matlab, 80 minus graphics and comments**

Sharks and Fish 5

- Sharks and Fish occupy a d-by-d grid of 2-D ocean, moving, breeding, eating and dying according to rules.
- Sharks and Fish may only occupy grid points, and may only move at discrete clock ticks.
- The square region is "periodic", meaning the right and left edges are connected, and the top and bottom regions are connected.
- Only one shark or one fish may occupy a grid point at one time.
- Each fish chooses a direction to move at each time step, by computing a vector as the sum of the following components, and then trying to move up (U), down (D), left (L) or right (R) depending on the vector:
  - a random vector (each component independent Normal(0,1))
  - an external force (current) which is a function of position, and
  - a "gravitational repulsion" from all sharks, i.e. a 1/distance law with gravitational constant $FISHREPEL$ (fish do not attract or repel fish).
- If the age of a fish exceeds $FBREED$, and it moves, it leaves a new fish behind.

Sharks and Fish 5 (cont)

- **Each sharks also chooses a direction vector, which is a sum of**
  - **a random vector (each component independent Normal(0,1))**
  - **an external force (same current as for fish) which is a function of position,**
  - **a "gravitational attraction" to all fish, i.e. a 1/distance law with gravitational constant** $SHARKATTRACT$ **(sharks do not attract or repel sharks), and**
  - **a strong, local attraction to nearby fish, equal to** $EATNOW$ **times the sum of random-length vectors pointing to any fish which are immediate U, D, L or R nearest neighbors.**
- **Sharks "breed" at random, the same way fish do, with probability-of-breeding constant** $Prob\_breed_{shark}$**.**
- **If the age of a shark exceeds** $SBREED$**, and it moves, it leaves a new shark behind.**
- **A shark moving into the space occupied by a fish eats the fish.**
- **Sharks which have not eaten for** $STARVE$ **time steps die.**

Sharks and Fish 5 (cont)
Conflict Resolution

- If two fish or two sharks want to move into the same location in a time step, we have a conflict.
- To resolve the conflict, we impose a priority scheme: At each time step we do the following steps sequentially:
  - The sharks who want to move L get to move, ...
  - The sharks who want to move R get to move, ...
  - The sharks who want to move U get to move, ...
  - The sharks who want to move D get to move, ...
  - The fish who want to move L get to move, ...
  - The fish who want to move R get to move, ...
  - The fish who want to move U get to move, ...
  - The fish who want to move D get to move, ...
- It is forbidden to move in to an occupied location, except for sharks moving into locations occupied by fish, and eating them.
- Each shark or fish may move at most once per step.
- Other, less biased priority scheme are possible, such as randomization.
- Complete matlab implementation in
  /usr/castle/share/proj/shortcourse/wator
  prob5/matlab/fish5.m

Sharks and Fish 6

- Sharks and Fish occupy a d-by-d region of 2-D ocean, moving, breeding, eating and dying according to rules.
- The square region is "periodic", meaning the right and left edges are connected, and the top and bottom regions are connected.
- Fish and Sharks are perfect disks of radius one, and must be disjoint.
- Each fish has mass $fishm$ and each shark mass $sharkm$.
- Fish move according to Newton's laws ($F = ma$), under a force F which is the sum of
  - an external force (current) which is a function of position, and
  - a "gravitational repulsion" from all sharks, i.e. a 1/distance law with gravitational constant $FISHREPEL$ (fish do not attract or repel fish).
- Fish colliding with fish bounce perfectly elastically, conserving kinetic energy and momentum.
- Fish "breed" at random, with the probability of a fish splitting into two new identical fish during $[t, t+\tau]$ equal to $Prob\_breed_{fish} \cdot \tau$ for τ small. The new fish move with equal and opposite (relative) random velocities from the place of birth. Mass, momentum and energy are not conserved.

Sharks and Fish 6 (cont)

- Sharks also move according to Newton's laws ($F = ma$), under a force which is the sum of
  - an external force (same current as for fish) which is a function of position,
  - a "gravitational attraction" to all fish, i.e. a 1/distance law with gravitational constant $SHARKATTRACT$ (sharks do not attract or repel sharks), and
  - a strong, local attraction to nearby fish, proportional to 1/distance**12.
- Sharks colliding with Sharks bounce perfectly elastically, conserving kinetic energy and momentum.
- Sharks "breed" at random, the same way fish do, with probability-of-breeding constant $Prob\_breed_{shark}$.
- Sharks colliding with fish eat the fish. Mass, momentum and energy are not conserved.
- Sharks which have not eaten for a time $STARVE$ die.