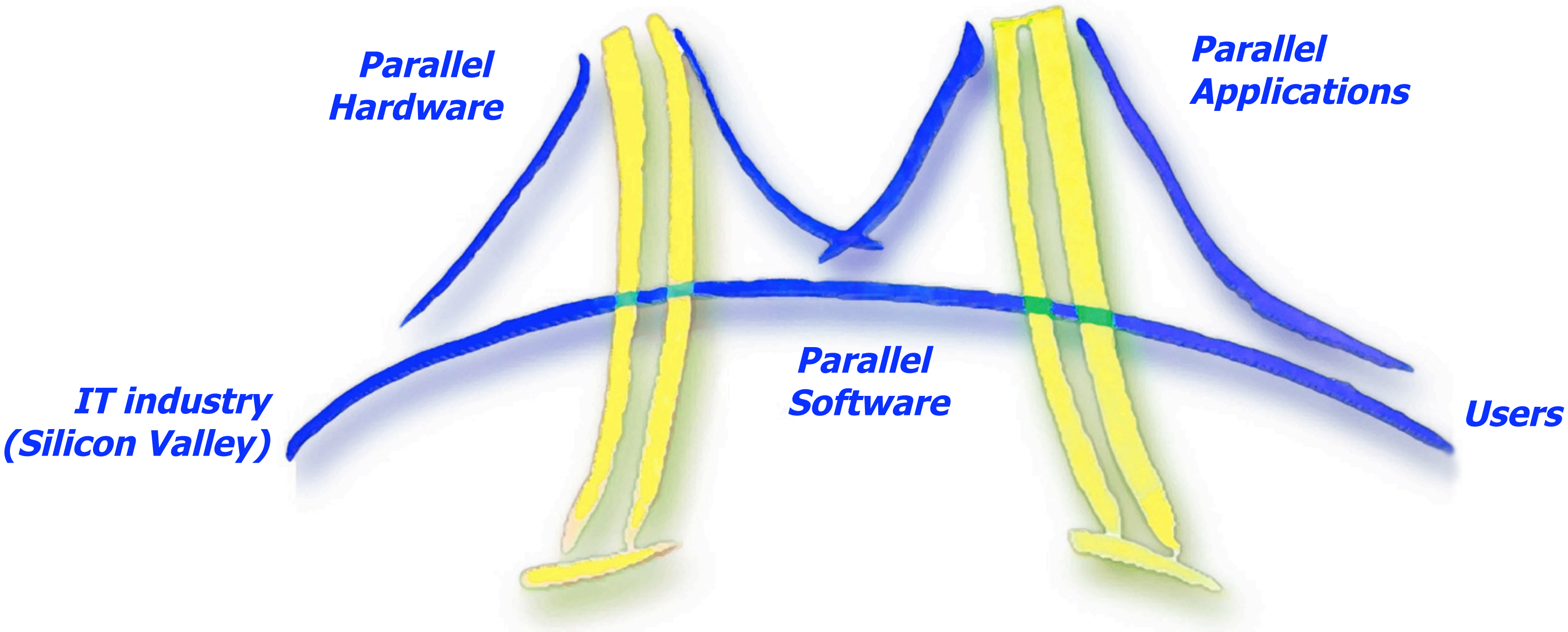


# YADA

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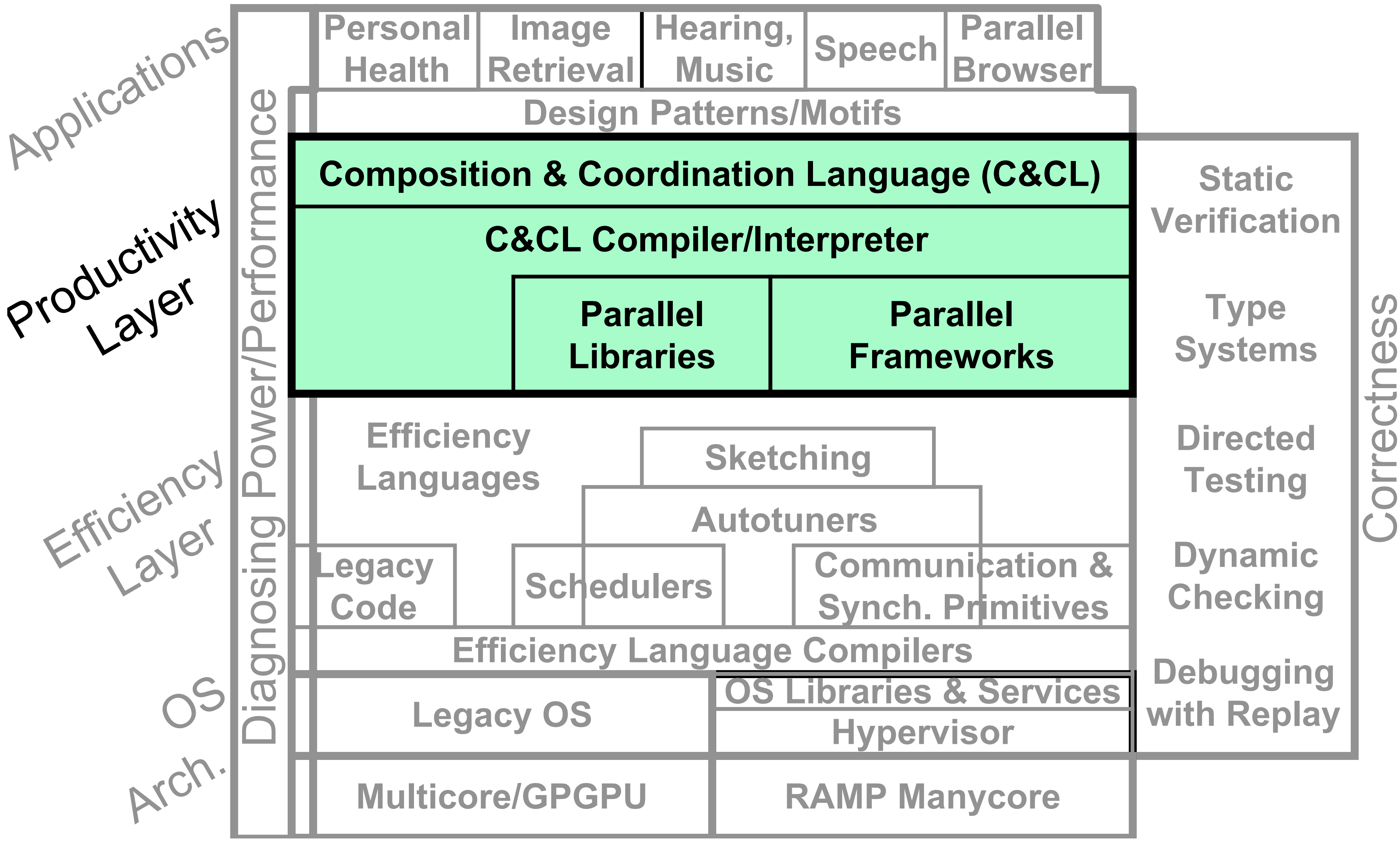
# Par Lab Research Overview

*Easy to write correct programs that run efficiently on manycore*

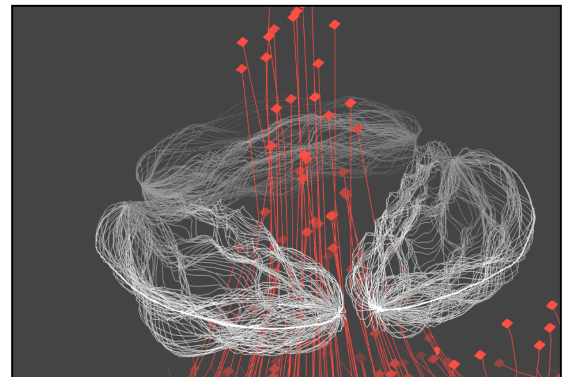


# **Y**et **A**nother **Da**ta Parallel Language

- Main goals
  - Focus on programmers productivity, not just efficiency
    - Provide reasonable per-core performance but good scalability
  - Balance performance, productivity, and compiler complexity
  - Irregular computation is a primary concern
  - Target multicore hardware rather than large-scale parallel machines

# Motivating Applications

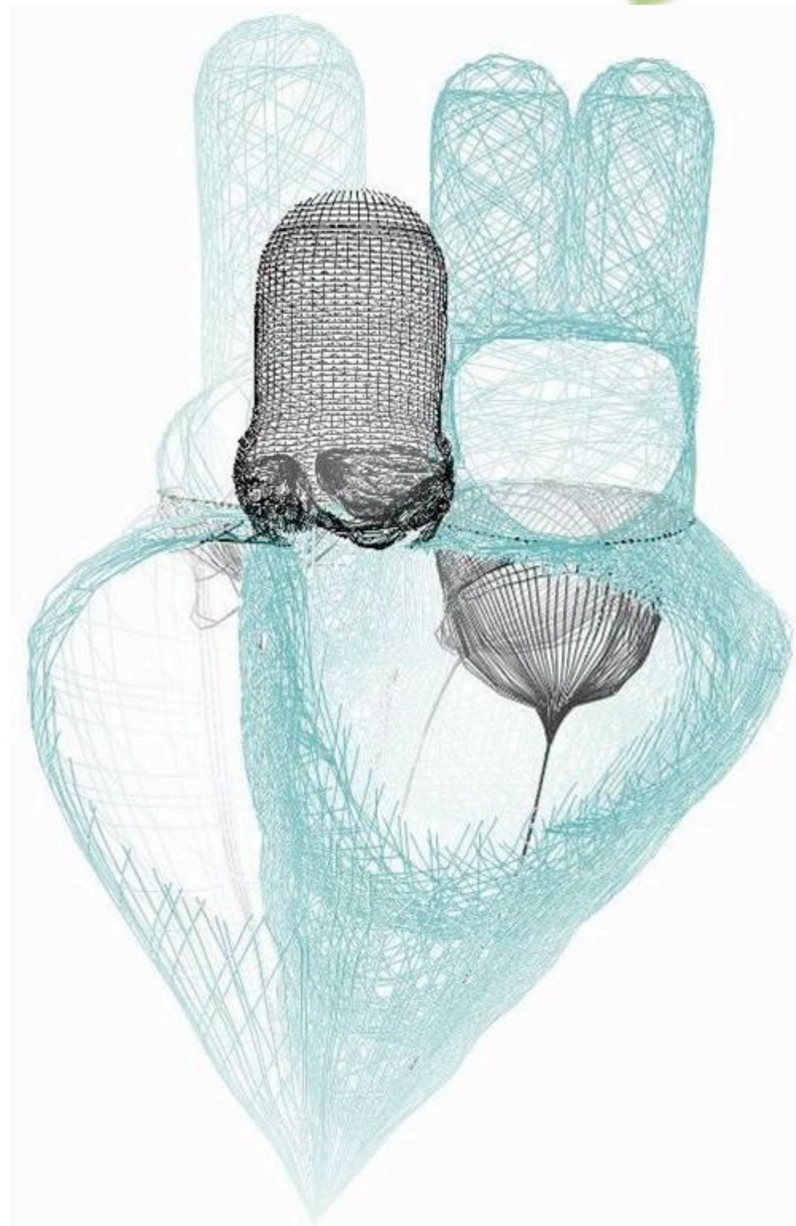
- Heart blood-flow simulation
  - Developed by Peskin and McQueen at NYU
  - Applications
    - Understanding structural abnormalities
    - Evaluating artificial heart valves
    - Eventually, artificial hearts
- Par Lab health code (Tony Keaveny)
- Multimedia



Source: www.psc.org

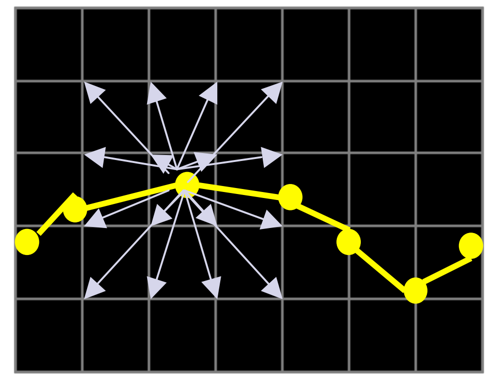
# Heart Model

- Composed of fibers in a fluid grid
- Includes atria, ventricles, valves, and some arteries
- The rest of the circulatory system is modeled by
  - sources: inflow
  - sinks: outflow



# Heart Simulation Structure

2D Dirac Delta Function

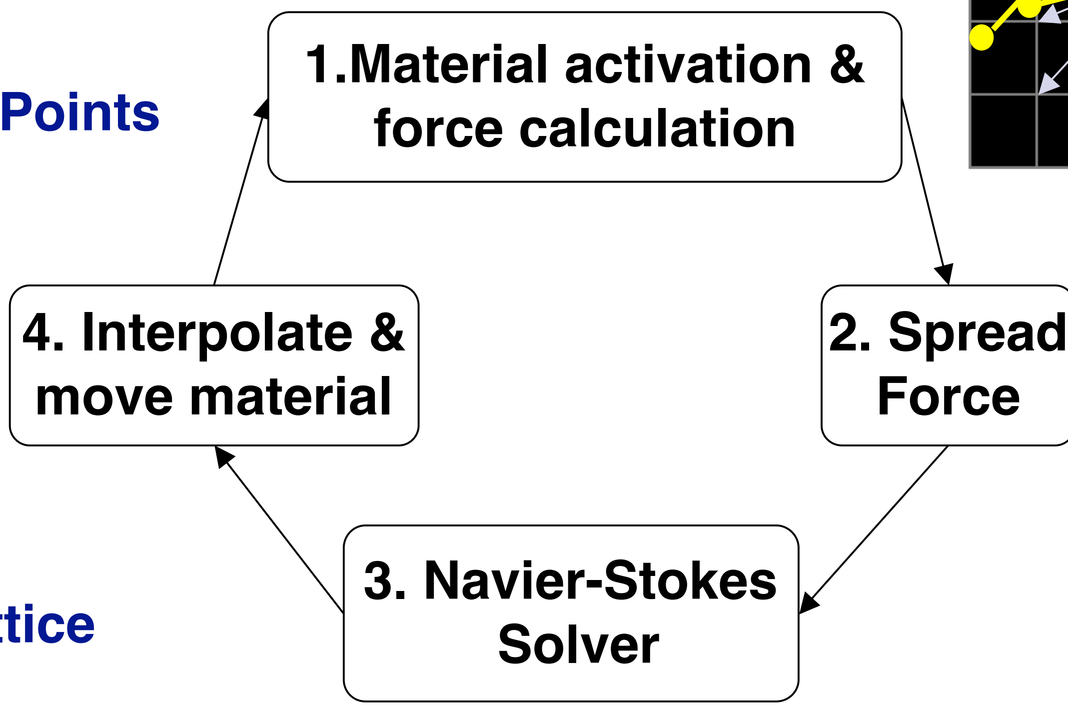


4 phases in each timestep

Material Points

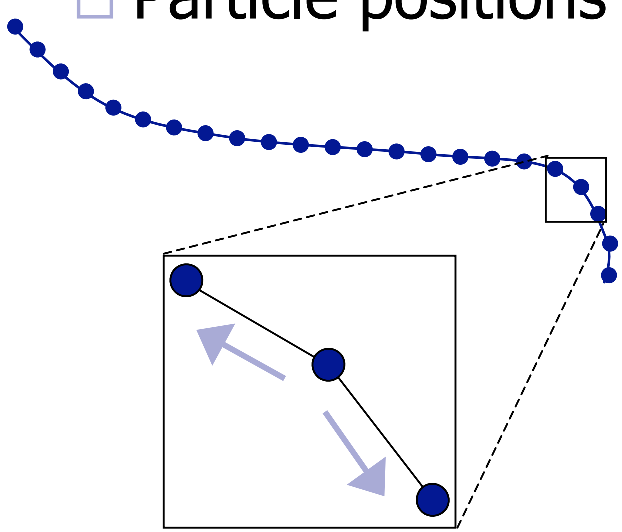
Interaction

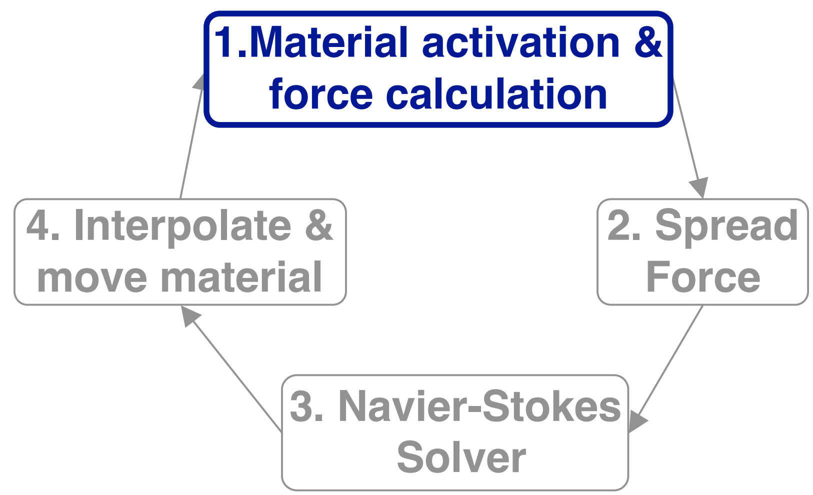
Fluid Lattice



# Force Calculation Phase

- Calculates force on each fiber-particle
  - Force determined by positions of adjacent particles in the fiber according to Hooke’s law
- Fibers independent from each other
- Forces on different particles can be computed in parallel
  - Particle positions not updated, so no races





# Loop-Based Parallelism

- Explicitly parallel loops

```
Fiber fr = ..., fl = ...;
forall (x in f.particles.domain) {
   f[x].force = computeForce(fr[x].pos,
                             fl[x].pos);
}
```

  - Deterministic semantics: no races between iterations
    - Statically checked; warning and runtime checks when static verification fails
  - Iterate on arrays, ranges, trees, graphs, user-defined types, and parallel iterators

# Parallel Aggregate Operations

- Implicit aggregate operations

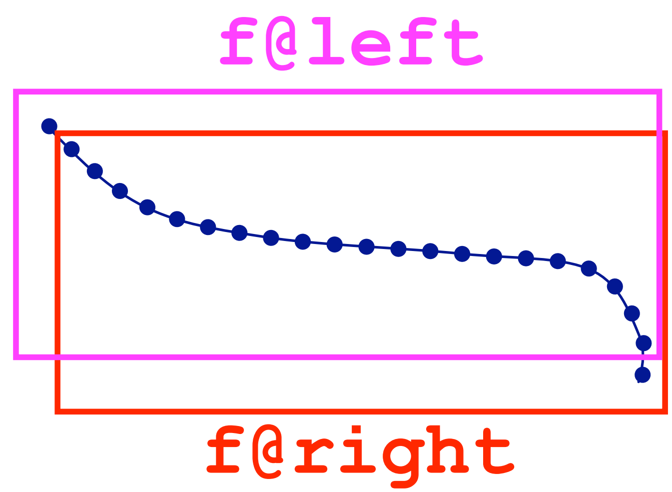
```
A = B + C
```

  - Equivalent to explicitly parallel loop

```
forall (x in A.domain)
  A[x] = B[x] + C[x];
```

- ZPL-style shifts and range restriction operators

```
Fiber fr = f@right;
Fiber fl = f@left;
```



# Nested Parallelism

- Support nested parallelism

```
forall (f in allFibers)
  ...
  forall (x in f.particles.domain)
    ...
```

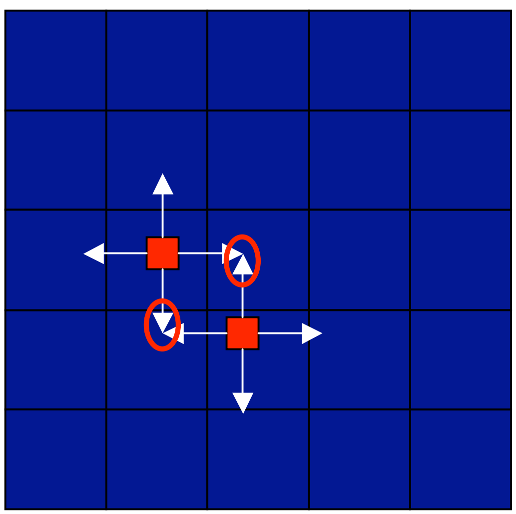
- Two previous implementation strategies for nested parallelism
  - Flatten nesting: has only been applied to functional languages
  - Work stealing: has not been proven on data parallel languages

# Force Calculation in YADA

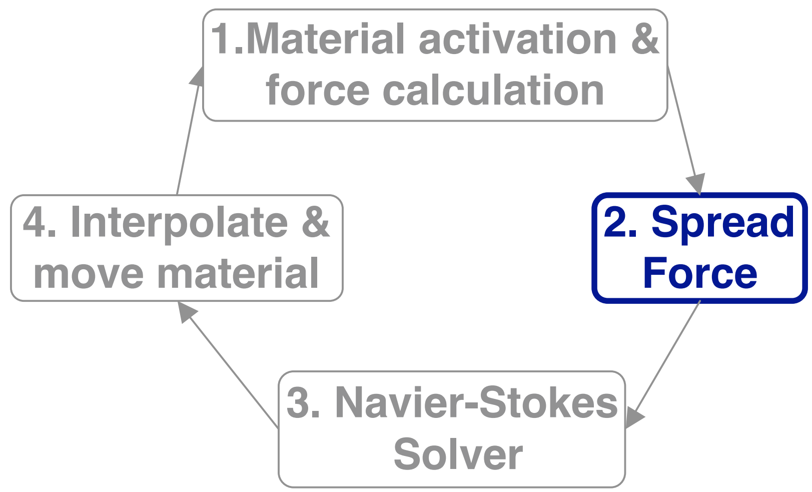
```
forall (f in allFibers) {
  Fiber fr = f@right;
  Fiber fl = f@left;
  forall (x in f.particles.domain) {
    f[x].force = computeForce(fr[x].pos,
                              fl[x].pos);
  }
}
```

# Spread Force Phase

- Each particle spreads its force to its neighboring fluid cells
- A fluid cell may have multiple neighboring particles
- Updates to a fluid cell must be synchronized



2D Example



# Accumulations and Reductions

- Programmer specifies accumulate/reduce operator by qualifying type of reduction target
  - Asserts indifference to order of application of operator
  - Research problem: prove order independence of user-defined functions
- Example: sum of elements of array **`A`**

```
int accumulate(+) sum = 0;
forall (x in A) sum = sum + x;
```

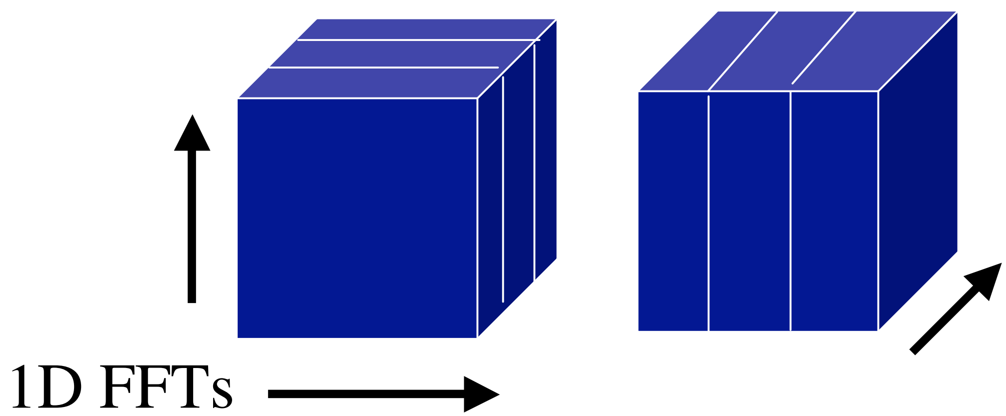
- Multiple implementation strategies
  - Parallel tree reduction
  - Lock and operate
  - Transfer to owner and operate

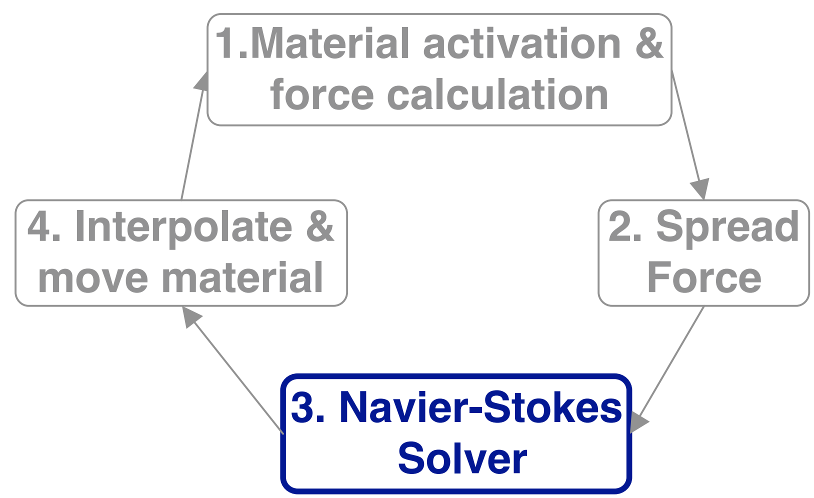
# Spread Force in YADA

```
double accumulate(+) [] force =
    new double[low:high];
forall (p in allParticles) {
  Point pos = [p.x, p.y, p.z];
  force[pos+north] += p.force;
  force[pos+east] += p.force;
  force[pos+south] += p.force;
  force[pos+west] += p.force;
}
```

# Navier-Stokes Phase

- Incompressible fluid needs an elliptic solver
  - High communication demand
  - Information propagates across domain
- Uses FFT-based solver
  - Calls FFTW library to perform actual FFTs
- Need ability to call libraries written in other languages



# Open Issues

- Base language
  - Previous data-parallel languages
  - Fortress/X10/Chapel
  - C family/Java/other sequential languages
- Precise feature set
  - Nested parallelism
  - ZPL-style shift operators

# Moving Forward

- Implementation strategy
  - Initial prototype by Fall 2008 (serial? subset?)
  - Attempt to use existing serial and parallel libraries
- Performance goals
  - Good performance on simple data parallel code
  - Scalable performance on nested parallel code and other new features
- Early evaluation
  - Port heart code
  - Determine suitability for multimedia applications