COS 126 – Atomic Theory of Matter
Goal of the Assignment

- Calculate Avogadro’s number
  - Using Einstein’s equations
  - Using fluorescent imaging

- Input data
  - Sequence of images
  - Each image is a rectangle of pixels
  - Each pixel is either light or dark

- Output
  - Estimate of Avogadro’s number
Assignment: Four Programs

- **Blob data type**
  - Maximal set of connected light pixels

- **BlobFinder**
  - Find *all* blobs in a JPEG image
  - List all the *big* blobs (aka beads)

- **BeadTracker**
  - Track beads from one image to the next

- **Avogadro**
  - Data analysis to estimate Avogadro’s number from the motion of beads
Atomic Theory Overview

- Brownian Motion
  - Random collision of molecules
  - Displacement over time fits a Gaussian distribution
Atomic Theory Overview

- Avogadro’s Number
  - Number of atoms needed to equal substance’s atomic mass in grams
    - $N_A$ atoms of Carbon-12 = 12 grams
  - Can calculate from Brownian Motion
    - Variance of Gaussian distribution is a function of resistance in water, number of molecules
Blob.java

- API for representing particles (blobs) in water
  - public Blob()
  - public void add(int i, int j)
  - public int mass() // number of pixels
  - public double distanceTo(Blob b) // from center (average)
  - public String toString()

- Only need *three* values to efficiently store
  - Do *not* store the positions of every pixel in the blob

Center of mass, and # of pixels
Blob Challenges

- Format numbers in a nice way
  - `String.format("%2d (%8.4f, %8.4f)", mass, cx, cy);`
  - (Use same format in `System.out.printf()`)
  - E.g., "%6.3f" -> _2.354
  - E.g., "%10.4e" -> 1.2535e-23

- Thoroughly test
  - Create a simple main()
BlobFinder.java

- Locate all blobs in a given image
  - And identify large blobs (called beads)

- API
  - public BlobFinder(Picture picture, double tau)
    - Calculate luminance (see Luminance.java, 3.1)
      - Include pixels with a luminance >= tau (threshold)
    - Find blobs with DFS (see Percolation.java, 2.4)
      - The hard part, next slide...
  - public int countBeads(int P)
    - Counts the beads with at least P pixels
  - public Blob[] getBeads(int P)
    - Returns all beads with at least P pixels
    - Array must be of size equal to number of beads
BlobFinder - Depth First Search

- Use boolean[][][] array to mark visited
- Traverse image pixel by pixel
  - Ignore already-visited pixels
  - Dark pixel
    - Mark as visited, continue
  - Light pixel
    - Create new blob, call DFS
- DFS algorithm
  - Base case: simply return if
    - Pixel out-of-bounds
    - Pixel has been visited
    - Pixel is dark (and mark as visited)
  - Add pixel to current blob, mark as visited
  - Recursively visit up, down, left, and right neighbors
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BlobFinder Challenges

- Data structure for the collection of blobs
  - Store them any way you like
  - But, be aware of memory use
BlobFinder Challenges

- Data structure for the collection of blobs
  - Store them any way you like
  - But, be aware of memory use
- Array of blobs?
  - But, how big should the array be?
- Linked list of blobs?
  - Memory efficient, but harder to implement
- Anything else?
  - Submit your (extra) object classes
BeadTracker.java

- Track beads between successive images
- Single main function
  - Take in a series of images
  - Output distance traversed by all beads for each time-step
    - For each bead found at time t+1, find closest bead at time t and calculate distance
      - Not the other way around!
      - Don’t include if distance > delta pixels (new bead)
BeadTracker Challenges

- Reading multiple input files
  - java BeadTracker 25 180.0 25.0 run_1/*.jpg
  - Expands files in alphabetical order
  - End up as args[3], args[4], ...

- \( P \) (size of Bead)
- \( \tau \) (Luminance threshold)
- \( \delta \) (max distance)
BeadTracker Challenges

- Reading multiple input files
  - `java BeadTracker 25 180.0 25.0 run_1*.jpg`
  - Expands files in alphabetical order
  - End up as args[3], args[4], ...

- Avoiding running out of memory
  - Do *not* open all picture files at same time
  - Only two need to be open at a time

- Recompiling
  - Recompile if Blob or BlobFinder change
Avogadro.java

- Analyze Brownian motion of all calculated displacements
  - Lots of crazy formulas, all given, pretty straightforward
  - Be careful about units in the math, convert pixels to meters, etc.
- Can test without the other parts working
  - We provide sample input files
  - Can work on it while waiting for help
Conclusion: Final Tips

- Avoiding subtle bugs in BlobFinder
  - Don’t pass Blobs between private methods
  - ... it makes bugs hard to track down

- Common errors in BlobFinder
  - NullPointerException
  - StackOverflowError (e.g., if no base case)
  - No output (need to add prints)

- Look at checklist Q&A
Conclusion: Final Tips

- Testing with a main()
  - BlobFinder, BeadTracker, and Avogadro
  - Must have a main() that can handle I/O described in Testing section of checklist

- Timing analysis
  - Look at feedback from earlier assignments
  - BeadTracker is time sink, so analyze that

- How can you run 100 frames?