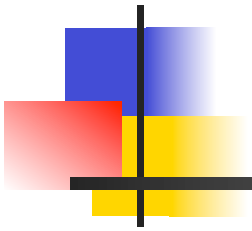
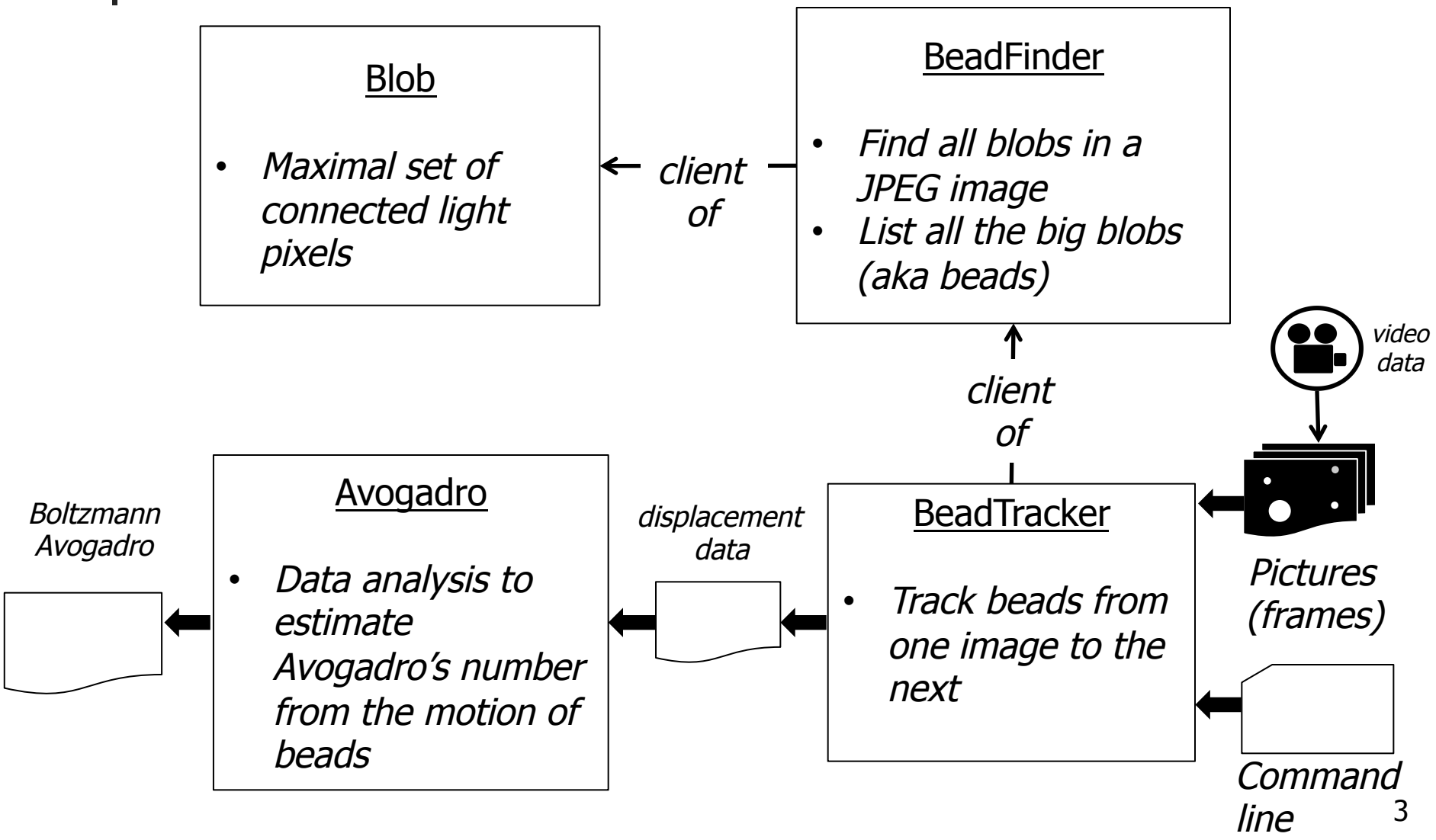


COS 126 – Atomic Theory of Matter

Goal of the Assignment

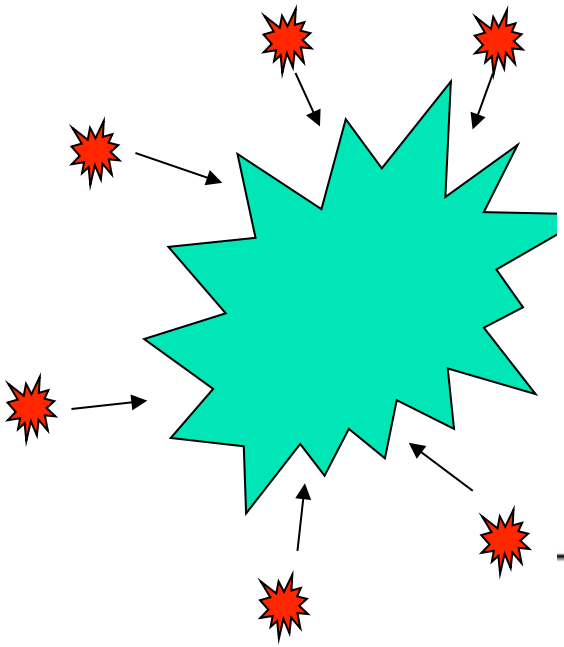
- Calculate Avogadro's number
  - Using Einstein's equations
  - Using fluorescent imaging
- Input data
  - Sequence of images
  - Each image is a rectangle of pixels
  - Each pixel is either light or dark
- Output
  - Estimate of Avogadro's number

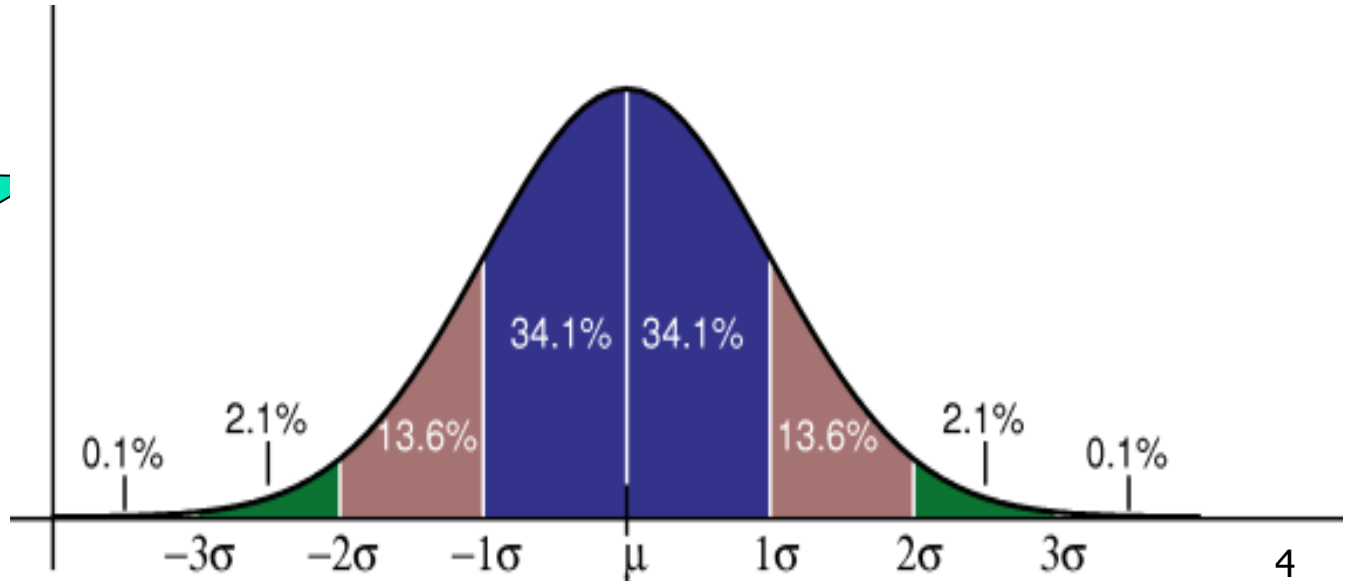
Overview – Four Classes



Atomic Theory Overview

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



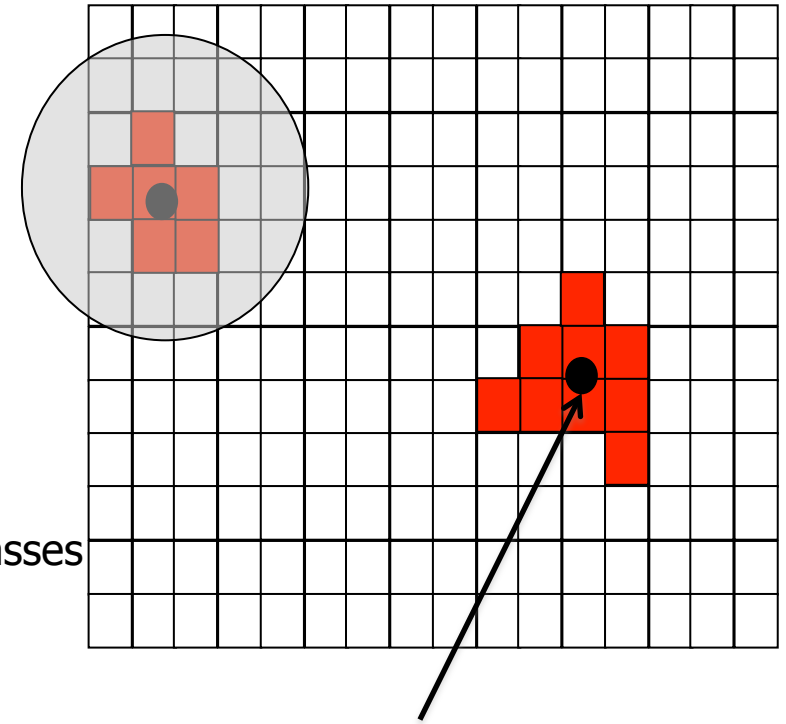


Atomic Theory Overview

- Avogadro's Number
  - Number of atoms needed to equal substance's atomic mass in grams
    - N_A atoms of Carbon-12 = 12 grams
    - N_A == $6.0221367 \times 10^{+23}$
  - Can calculate from Brownian Motion
    - Variance of Gaussian distribution is a function of resistance in water, number of molecules

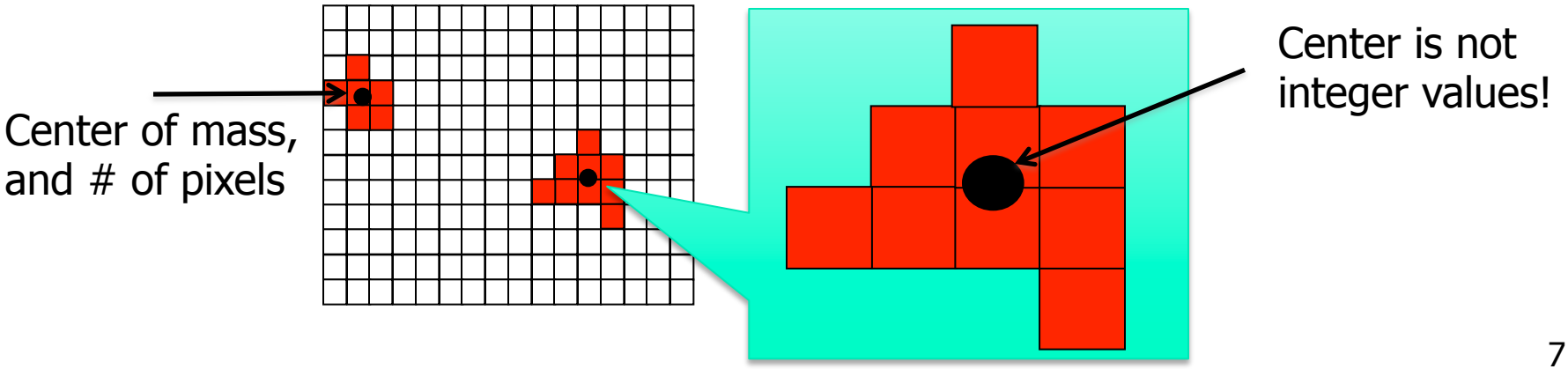
Blob.java

- API for representing particles (blobs) in water
  - public Blob()
    - constructor
  - public void add(int i, int j)
    - add pixel at i,j to Blob
  - public int mass()
    - number of pixels in Blob
  - public double distanceTo(Blob b)
    - Euclidean distance between the center of masses between Blobs
  - public String toString()
    - a string representation of this Blob
  - public static void main(String[] args)
    - unit tests all methods in the Blob data type



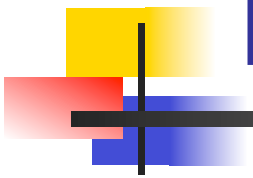
Blob.java

- Center of mass
- Only need three *instance variables*
  - Do *not* store the positions of every pixel in the blob
- Two alternatives:
  - number of points, x-coordinate center of mass, and y-coordinate center of mass) or
  - number of points, sum of x-coordinates, and sum of y-coordinates) needed to compute the center-of-mass



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()
  - Test ALL methods

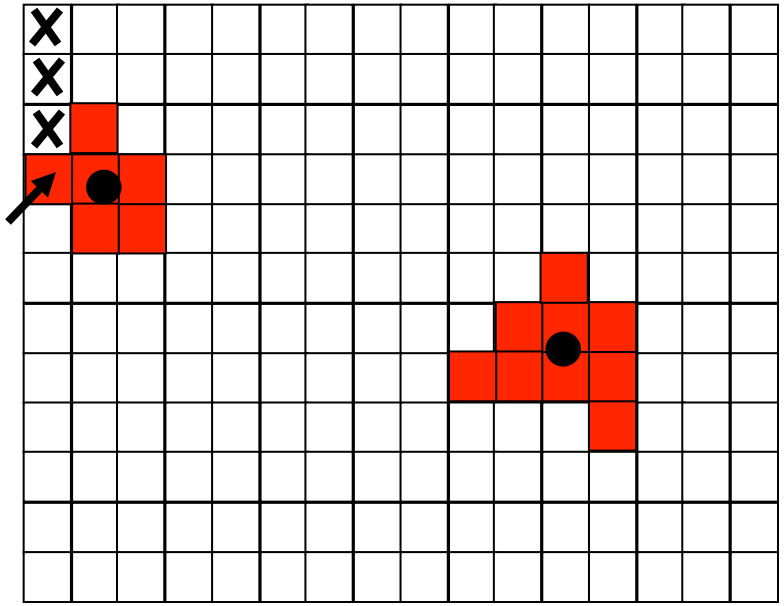


BeadFinder.java

- Locate all blobs in a given image
  - And identify large blobs (called beads)
- API
  - public BeadFinder(Picture picture, double threshold)
    - Calculate luminance (see Luminance.java, 3.1)
      - Include pixels with a luminance >= threshold
    - Find blobs with DFS (see Percolation.java, 2.4)
      - The hard part, next slide…
  - public Blob[] getBeads(int minSize)
    - Returns all beads with at least minSize pixels
    - Array must be of size equal to number of beads

BeadFinder - Depth First Search

- Use boolean[][] array to mark visited
- Traverse image pixel by pixel
  - 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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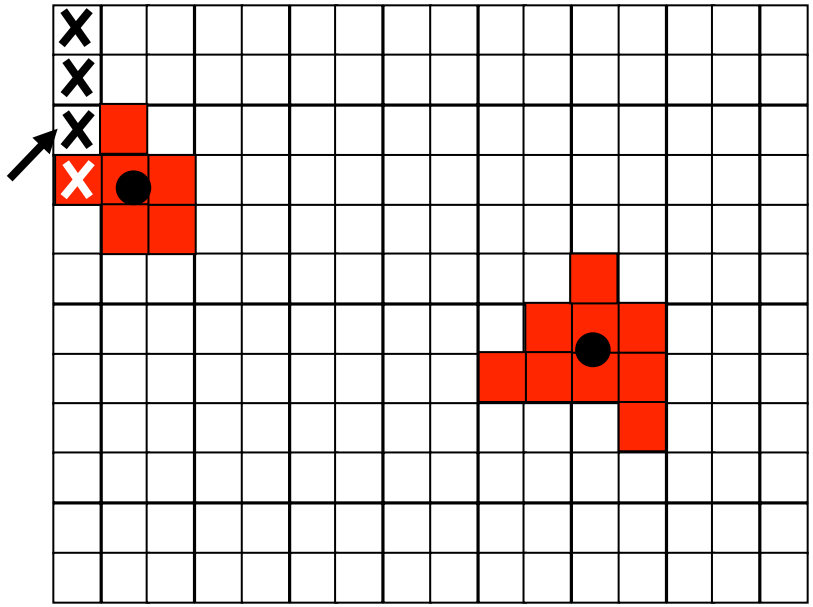

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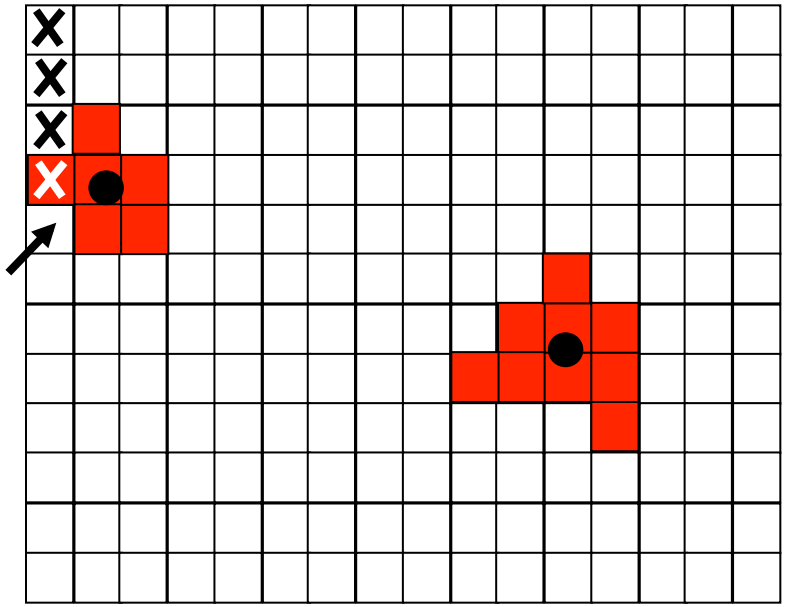

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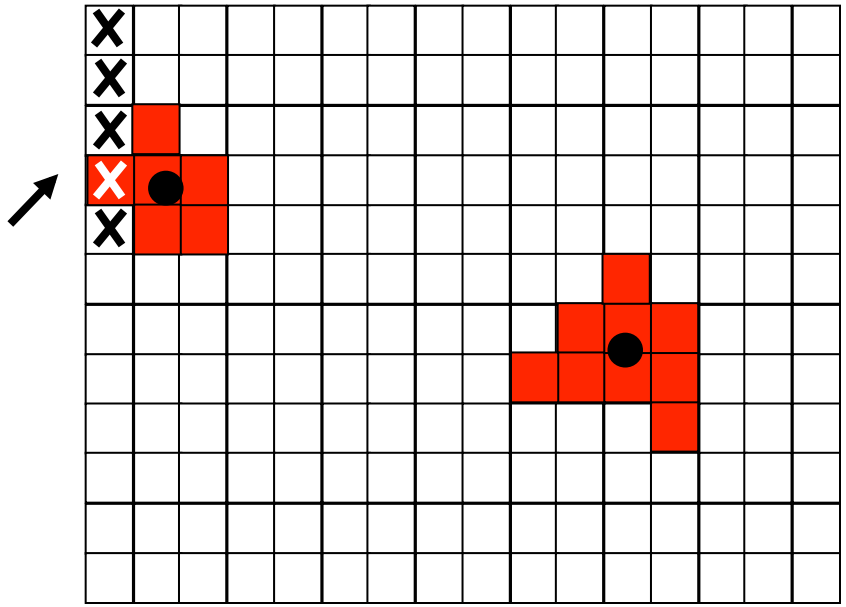

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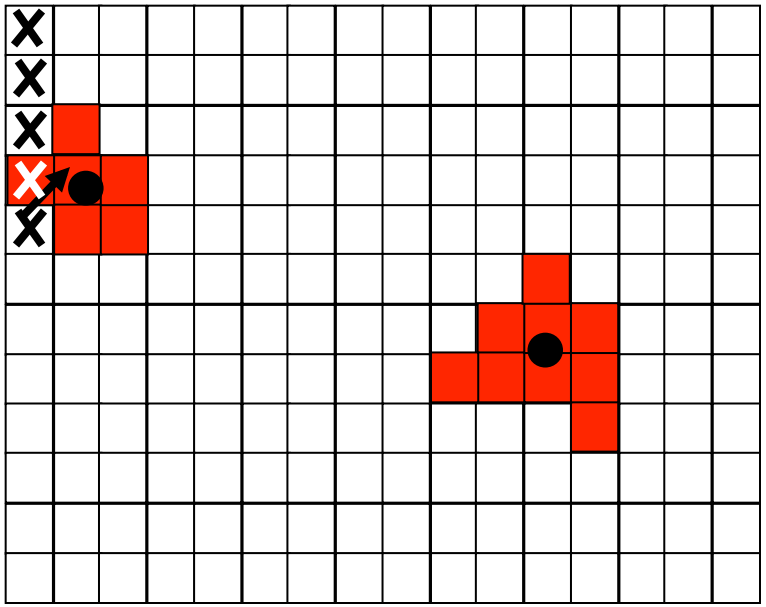

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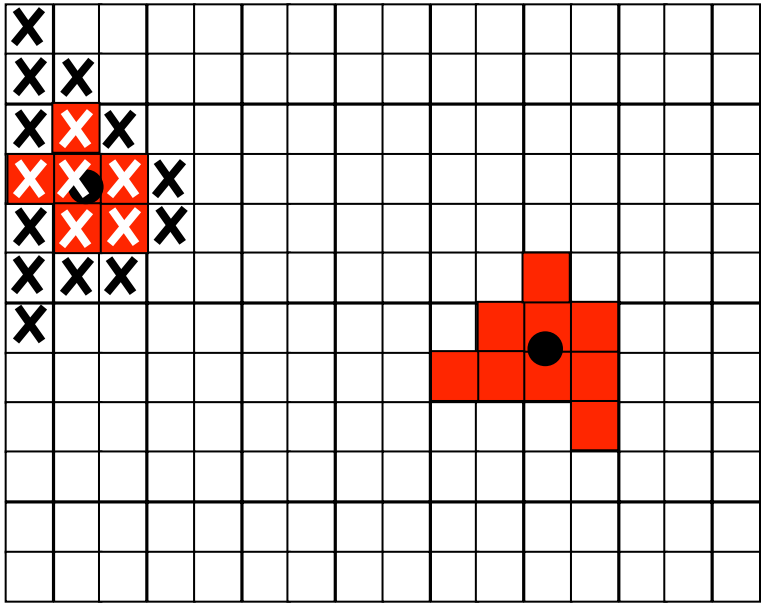
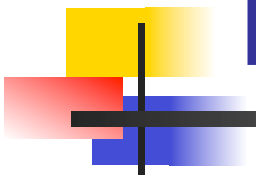


BeadFinder Challenges

- Data structure for the collection of blobs
  - Store them any way you like
  - But be aware of memory use and timing

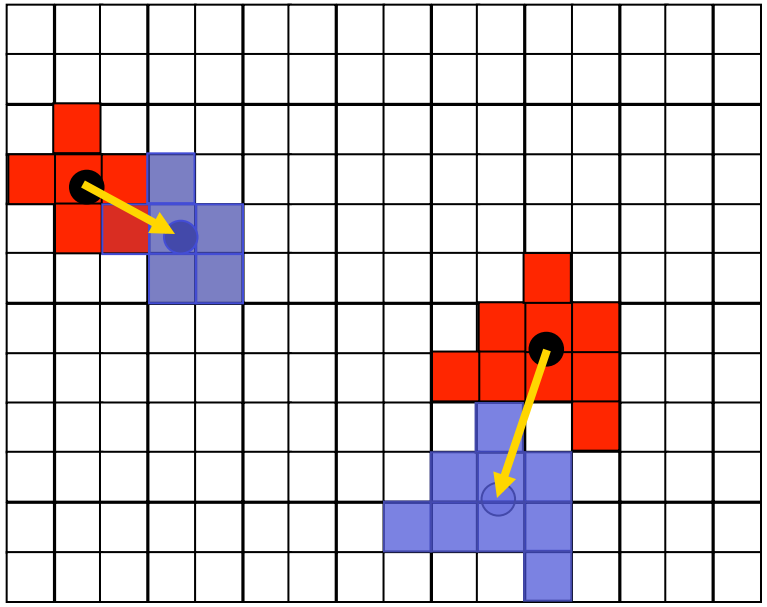
BeadFinder Challenges



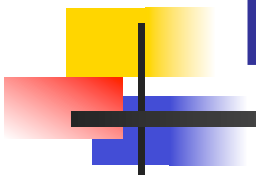
- Data structure for the collection of blobs
  - Store them any way you like
  - But be aware of memory use and timing
- Array of blobs?
  - But how big should the array be?
- Linked list of blobs?
  - Memory efficient, but harder to implement
  - Avoid traversing whole list to add a blob!
- Anything else?
  - Submit your (extra) object classes if not in 4.3

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 > 25 pixels (new bead)

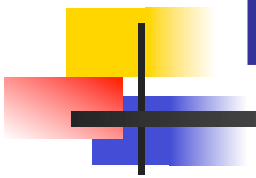


BeadTracker Challenges



- Reading multiple input files
  - java BeadTracker run_1/*.jpg
  - Expands files in alphabetical order
  - End up as args[0], args[1], …
- Avoiding running out of memory
  - How?
- Recompiling
  - Recompile if Blob or BeadFinder change

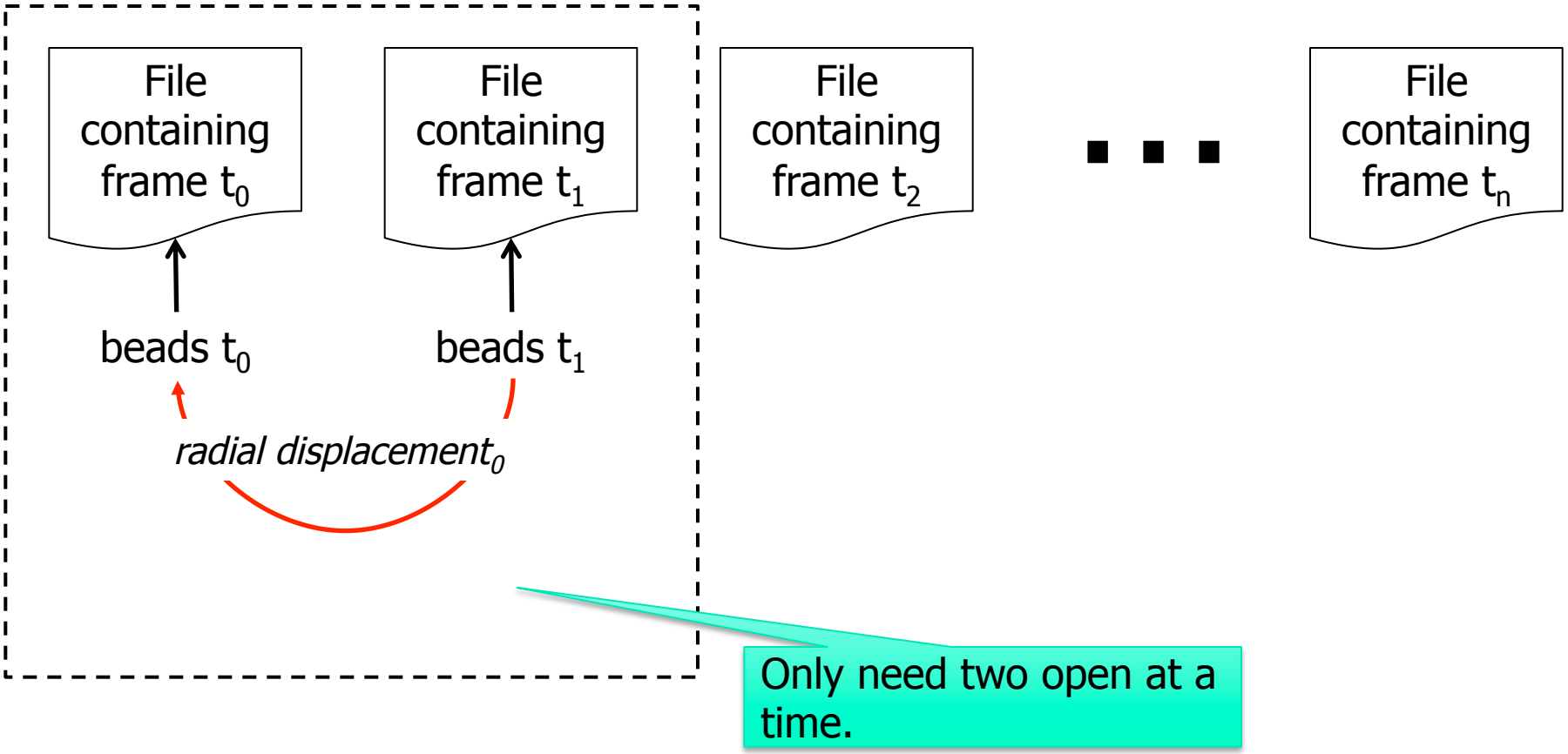
BeadTracker Challenges



- Reading multiple input files
  - java BeadTracker run_1/*.jpg
  - Expands files in alphabetical order
  - End up as args[0], args[1], …
- Avoiding running out of memory
  - Do *not* open all picture files at same time
  - Various ways to do this
- Recompiling
  - Recompile if Blob or BeadFinder change

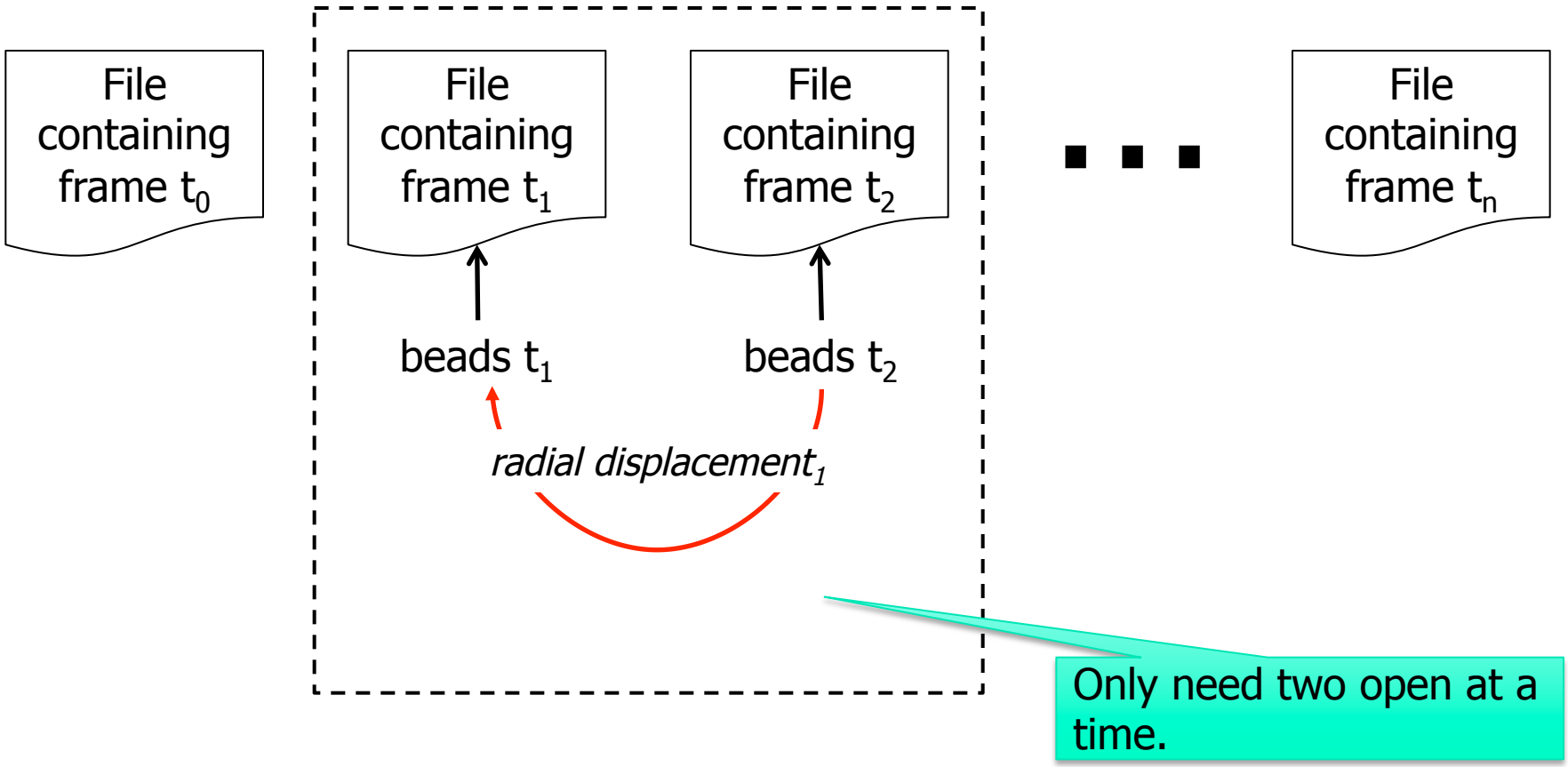
BeadTracker Challenges

- Avoid running out of memory (1)



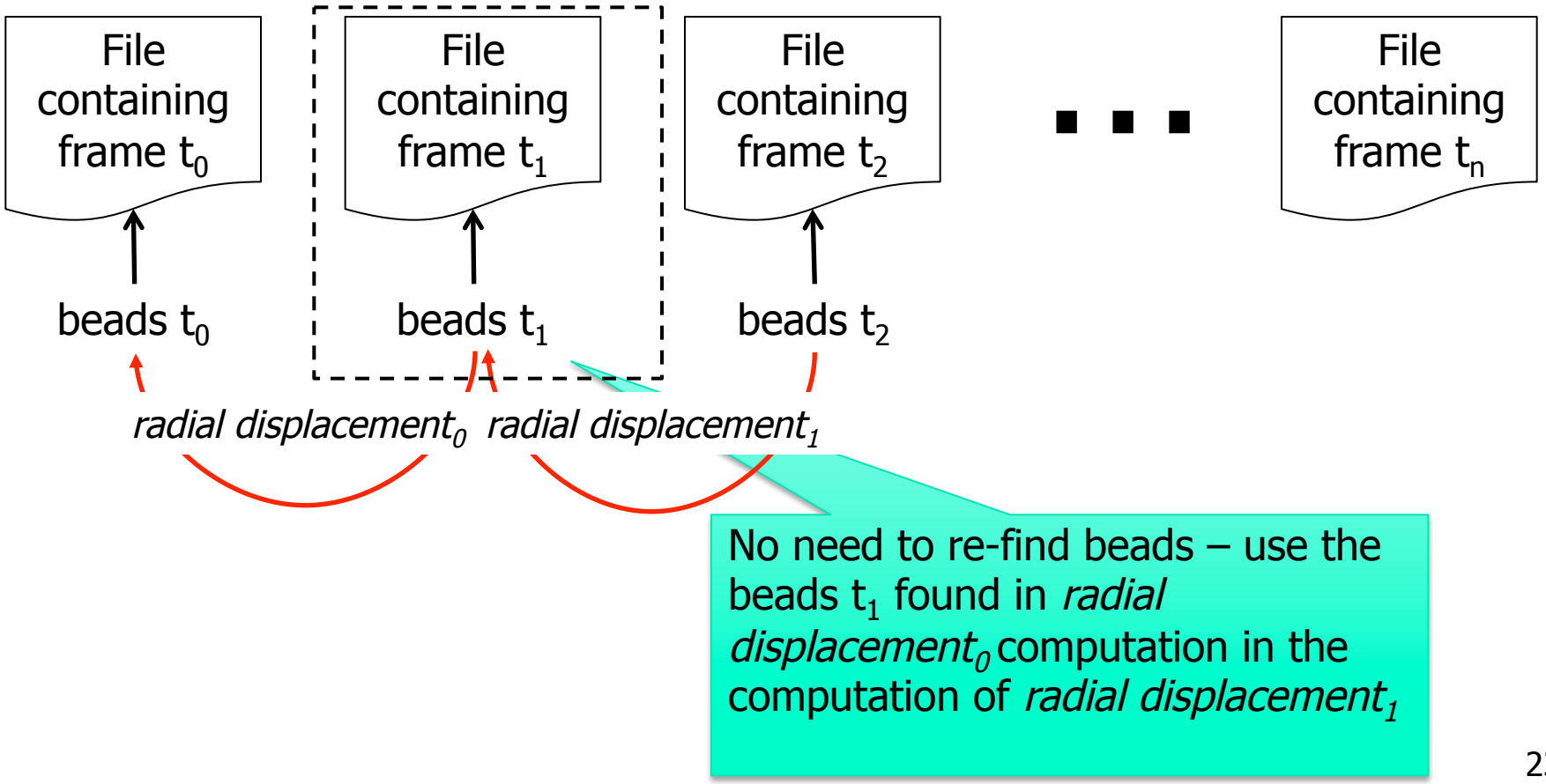
BeadTracker Challenges

- Avoid running out of memory (1)



BeadTracker Challenges

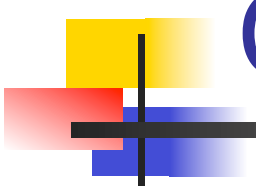
- Avoid running out of memory (2)



Avogadro.java

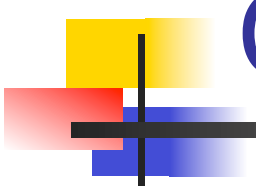
- Analyze Brownian motion of all calculated displacements
  - Lots of crazy formulas, all given, pretty straightforward
  - Be careful about units in the math, convert pixels to meters, etc.
- Can test without the other parts working
  - We provide sample input files
  - Can work on it while waiting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

Conclusion: Final Tips



- Avoiding subtle bugs in BeadFinder
  - Double check what happens at corner cases (e.g., at boundary pixels, or when luminance == tau, or mass == cutoff)
- Common errors in BeadFinder
  - 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()
  - Blob
    - Test all methods
  - BeadFinder, 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?