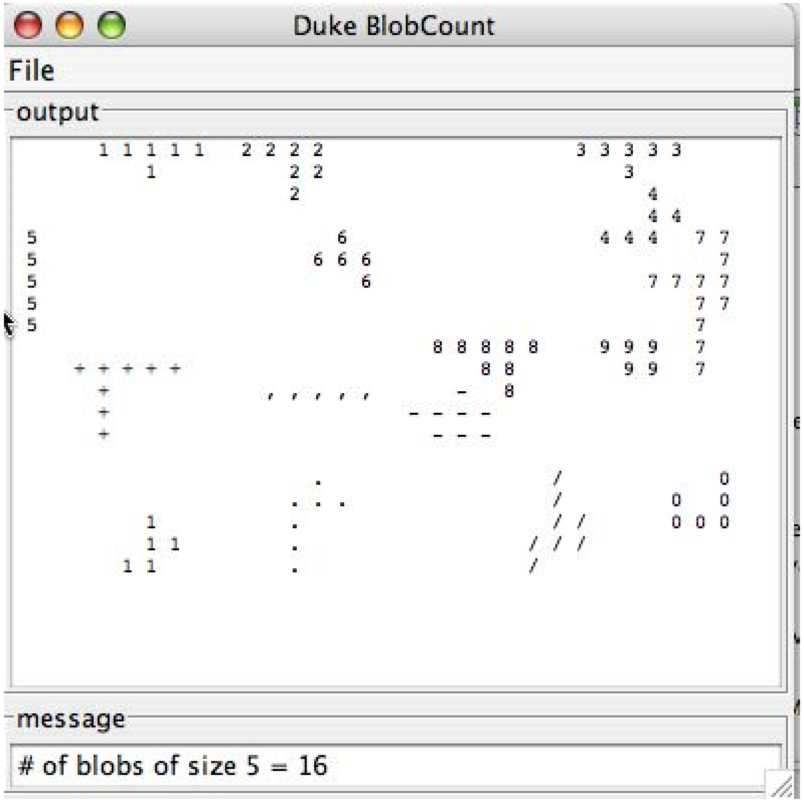
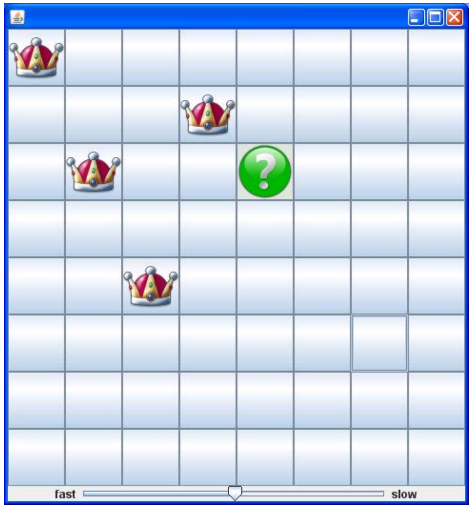
# CompSci 100e
# Program Design and Analysis II



```
      1 1 1 1 1   2 2 2 2                     3 3 3 3 3
          1           2 2                         3
                      2                             4
                                                    4 4
5                         6                     4 4 4   7 7
5                       6 6 6                             7
5                           6                       7 7 7 7
5                                                       7 7
5                                                       7
                                  8 8 8 8 8     9 9 9   7
    + + + + +                         8 8         9 9   7
      +             , , , , ,       -   8
      +                         - - - -
      +                           - - -

                        .                   /             0
                      . . .                 /         0   0
          1           .                     / /       0 0 0
          1 1         .                   / / /
        1 1           .                   /
```

# of blobs of size 5 = 16



March 3, 2011

Prof. Rodger

# Announcements

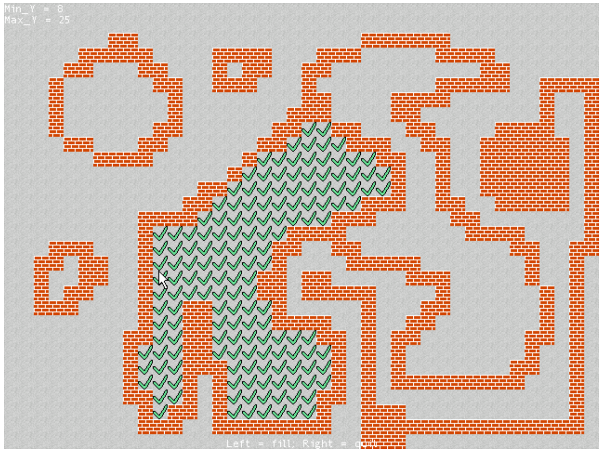
- Written assignment due tonight – put .pdf file in Eclipse and submit it
- APTS due Tuesday after break – use recursion
- No Lab Friday March 4 or Monday March 14
- Today – two examples of recursion
  - Blob counting
  - 8 Queens - backtracking

# Blob Counting, Flood Fill

- Flood a region with color
  - Erase region, make transparent, ..
  - How do find the region?

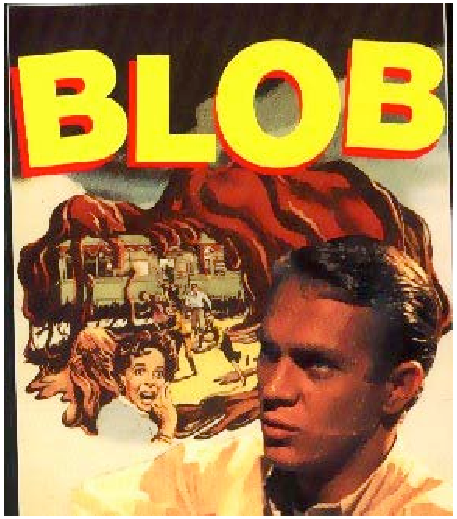
- Finding regions, blobs, edges, ..
  - See blob counting code
  - What is a blob?

- Recursion helps, but necessary?
  - Performance, clarity, …
  - Ease of development



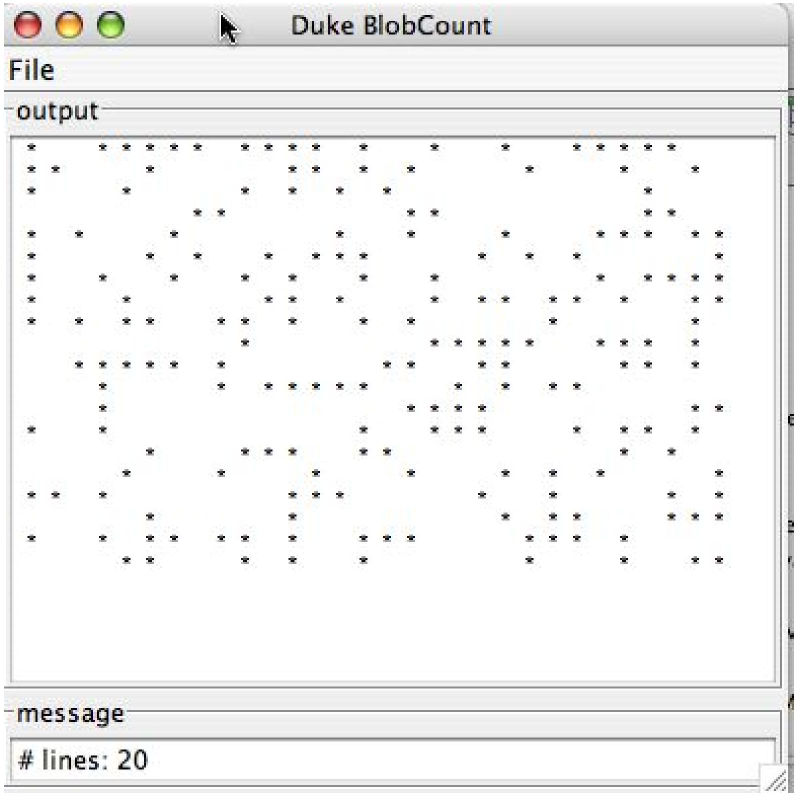
```
Min_Y = 8
Max_Y = 25
```

```
Left = fill; Right = quit
```



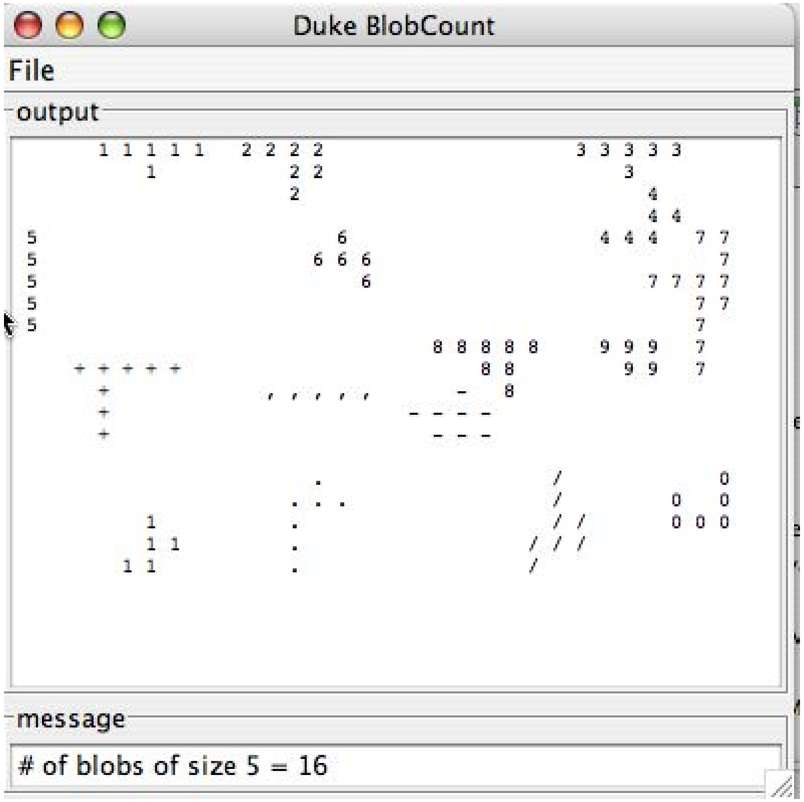
# First Example - BlobCount

- How do we find images? Components? Paths?
  - Create information from data



```
*     * * * * *   * * * *   *     *     *     * * * * *
* *       *           * *   *   *         *       *     *
*       *         *   *   *   *                     *
              * *               * *                 * *
*   *       *             *     *       *       * * *   * *
*         *   *     *   * * *         *   *   *           *
*     *     *     *   *     *     *             *   * * * *
*       *           * *   *       *   * *   * *   *     * *
*   *   * *     * *   *     *   *           *           *
                  *               * * * * *     * * *   *
    * * * * *   *             * *     * *         * *   *
      *         *   * * * * *       *   *   * *
      *                         * * * *                 * *
*     *                     *     * * *       *   * *   *
          *       * * *     * *                   *   *
        *       *       *       *       *   *   *         *
* *   *               * * *           *     *         *   *
          *           *                 *   * *       * * *
*     *   * *   * *   *     * * *         * * *   *
        * *       *   *     *             *       *     * *
```

# lines: 20



```
      1 1 1 1 1   2 2 2 2                     3 3 3 3 3
          1           2 2                         3
                      2                             4
                                                    4 4
5                         6                     4 4 4   7 7
5                       6 6 6                             7
5                           6                       7 7 7 7
5                                                       7 7
5                                                       7
                                  8 8 8 8 8     9 9 9   7
    + + + + +                         8 8         9 9   7
      +             , , , , ,       -   8
      +                         - - - -
      +                           - - -

                        .                   /             0
                      . . .                 /         0   0
          1           .                     / /       0 0 0
          1 1         .                   / / /
        1 1           .                   /
```

# of blobs of size 5 = 16

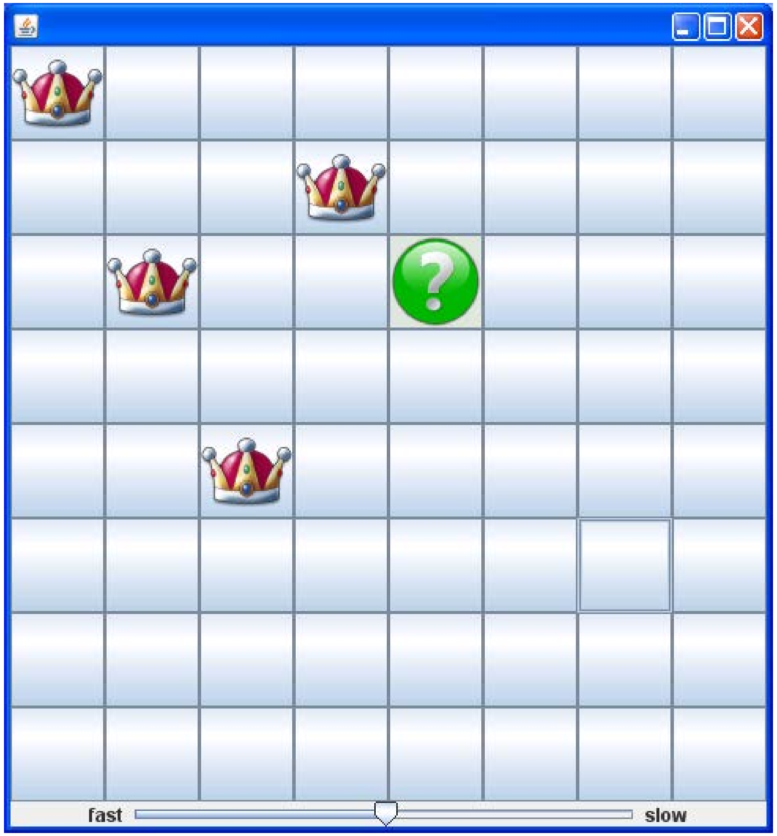
# Details and Idioms in blob code

- Method `blobFill` has four parameters
  - (row,column) of where search starts
  - Character being searched for (initially * or blob)
  - Character to fill with on success (e.g., count '2' or '4')
    - Mark for visualization
    - Mark to ensure we don't search again!
- If (row,column) is part of blob, count it and ask neighbors for their counts
  - They're part of blob (if never visited before)
- Return total of yourself and neighbors
  - Key to recursion: do one thing and ask for help

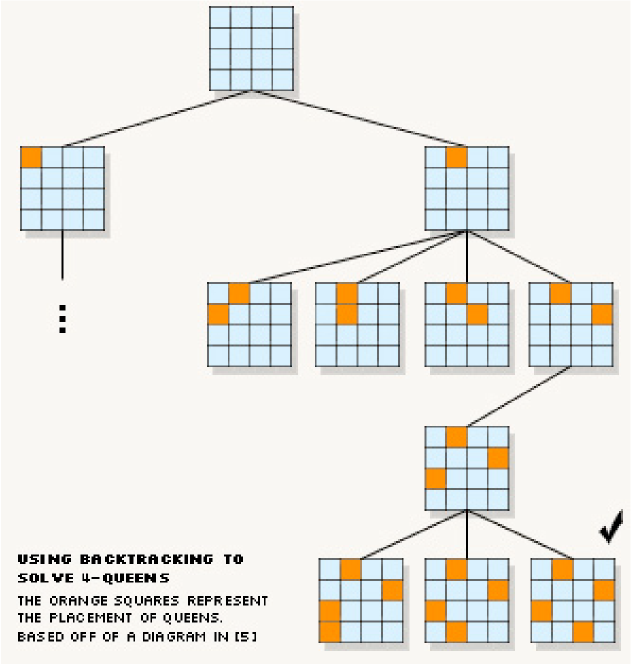
# Blob questions

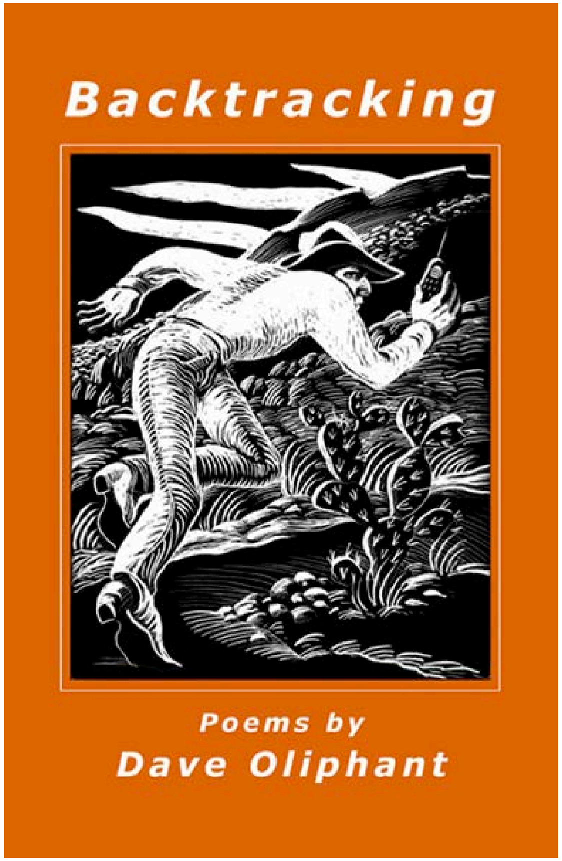
- What changes if diagonal cells are adjacent?
  - Conceptually and in code
- How do we find blob sizes in a range?
  - Not bigger than X, but between X and Y
- How would we number blobs by size rather than by when they're found?
  - Do we have the tools to do this in existing code?
- Can we avoid recursion and do this iteratively?

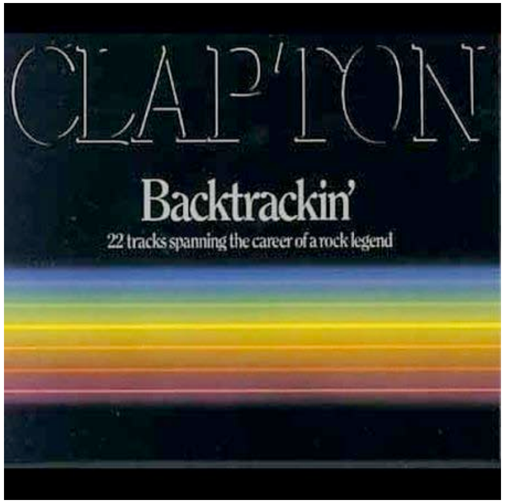
# Second Example – 8 Queens

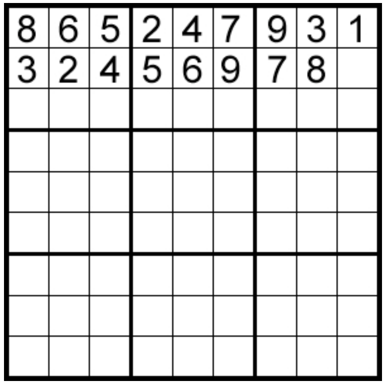


# Backtracking by image search


USING BACKTRACKING TO SOLVE 4-QUEENS
THE ORANGE SQUARES REPRESENT THE PLACEMENT OF QUEENS.
BASED OFF OF A DIAGRAM IN [5]







| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 8 | 6 | 5 | 2 | 4 | 7 | 9 | 3 | 1 |
| 3 | 2 | 4 | 5 | 6 | 9 | 7 | 8 | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

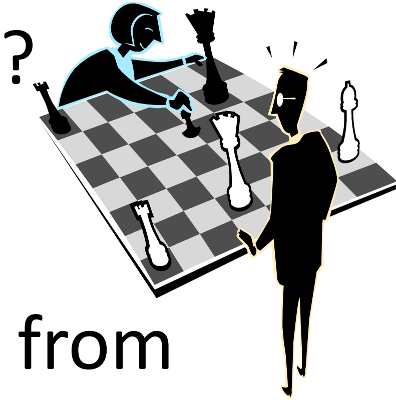
# Searching with no guarantees

- Search for best move in automated game play
  - Can we explore every move?
  - Are there candidate moves ranked by “goodness”?
  - Can we explore entire tree of possible moves?

- Search with partial information
  - Predictive texting with T9 or iTap or …
  - Finding words on a Boggle board
  - What numbers fit in Sudoku square

- Try something, if at first you don’t succeed ….

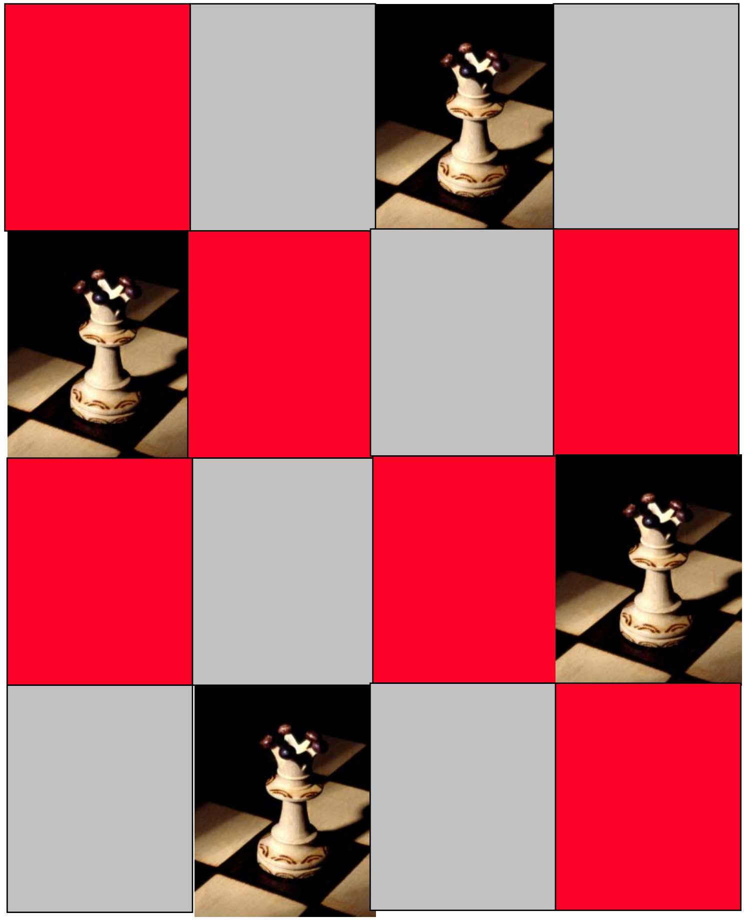
# Search, Backtracking,Heuristics



- How do you find a needle in a haystack?
  - How does a computer play chess?
  - Why would you write that program?
  - 
- How does Bing/Googlemap find routes from one place to another?
  - Shortest path algorithms
  - Longest path algorithms
- Optimal algorithms and heuristic algorithms
  - When is close good enough? How do measure “closeness”?
  - When is optimality important, how much does it cost?

# Classic problem: N queens

- Can queens be placed on a chess board so that no queens attack each other?
  - Easily place two queens
  - What about 8 queens?
- Make the board NxN, this is the N queens problem
  - Place one queen/column
  - Horiz/Vert/Diag attacks
- Backtracking
  - Tentative placement
  - Recurse, if ok done!
  - If fail, undo tentative, retry
- wikipedia-n-queens



# Backtracking idea with N queens

- For each column *C*, tentatively place a queen
  - Try first row in column *C*, if ok, move onto next column
    - Typically “move on” is recursive
  - If solved, done, otherwise try next row in column *C*
    - Must unplace queen when failing/unwind recursion

- Each column C “knows” what row R it’s on
  - If first time, that’s row zero, but might be an attack
  - Unwind recursion/backtrack, try “next” location

- Backtracking: record an attempt go forward
  - Move must be “undoable” on backtracking/unwinding

# N queens backtracking: `Queens.java`

```
public boolean solve(int col){
  if (col == mySize) return true;

        // try each row until all are tried

  for(int r=0; r < mySize; r++){
      if (myBoard.safeToPlace(r,col)){
          myBoard.setQueen(r,col,true);
          if (solve(col+1)){
              return true;
          }
          myBoard.setQueen(r,col,false);
      }
  }
  return false;
}
```

# Basic ideas in backtracking search

- Enumerate all possible choices/moves
  - We try these choices in order, committing to a choice
  - If the choice doesn't pan out we must undo the choice
    - Backtracking step, choices must be undoable
- Inherently recursive, when to stop searching?
  - When all columns tried in N queens
  - When we have found the exit in a maze
  - When every possible moved tried in Tic-tac-toe or chess?
    - Is there a difference between these games?
- Summary: enumerate choices, try a choice, undo a choice, this is *brute force* search: try everything

# Pruning vs. Exhaustive Search

- If we consider every possible placement of 4 queens on a 4x4 board, how many are there? (N queens)
  - `4x4x4x4` if we don't pay attention to any attacks
  - `4x3x2x1` if we avoid attacks in same row

- What about if we avoid diagonal attacks?
  - Pruning search space makes more search possible, still could be lots of searching to do!

- Estimate how long to calculate # solutions to the N-queens problem with our Java code….

# Queens Details

- How do we know when it’s safe to place a queen?
  - No queen in same row, or diagonal
  - For each column, store the row that a queen is in
  - See QBoard.java for details

- For GUI version, we use a *decorator*
  - The QBoardGUI is an IQueenState class and it has an IQueenState object in it
  - Appears as an IQueenState to client, but uses an existing one to help do its work
  - One of many object oriented design patterns, seen in Huff in the BitInputStream class