## CSSE 230 Day 16

Exhaustive search, backtracking, object-oriented Queens

## Check out from SVN: Queens

## Questions



## Announcements and Agenda

- Doublets Partner evaluation due Thursday at 5:00 PM
- Teams for EditorTrees project
- There will be a few updates to the assignment document in the next couple of days.
- Exhaustive search, backtracking, and object-oriented queens

Exam 21 week from today:
7:00-9:00 PM

## EditorTrees project <br> 1) Brief description <br> Meet your team

## EditorTrees project

- In general, implementation of a Data Structure is separate from application.
- Most CSSE 230 projects have used existing data structures to create an application
- In this project you will create an efficient data structure that could be used in a text editor.
- But you will not create an application that uses it.
- EditTree: A height-balanced (but not AVL) binary tree with rank. Insertion and deletion are by position, not by natural ordering of the inserted elements.
- Log N Operations include
- Insert, delete, find, concatenate, split, height, size
- Node fields include balance code and rank.


## EditorTrees Teams

- See schedule page

Meet your partners to plan when you will meet to begin work.
Suggestion: Meet before tomorrow to discuss the project requirements. Formulate a list questions to ask during next class.

Whether or not you meet before next class, read the EditorTrees requirements and come with questions.

# Exhaustive Search and Backtracking 

1) A taste of artificial intelligence

## Exhaustive search

- Given: a (large) set of possible solutions to a problem


## The "search space"

- Goal: Find all solutions (or an optimal solution) from that set
- Questions we ask:
- How do we represent the possible solutions?
- How do we organize the search?
- Can we avoid checking some obvious nonsolutions?

In backtracking, we always try to extend a partial solution

- Examples: Doublets, solving a maze, the " 15 " puzzle.
- Taken from:
- http://www.cis.upenn.edu/~matuszek/cit594-2004/Lectures/38-backtracking.ppt

| 1 | 10 | 2 | -1 |
| :---: | :---: | :---: | :---: |
| 3 |  | 3 | 6 |
| 1 | 11 | 3 | 7 |
| 13 | $1-1$ | 13 | 12 |

In backtracking, we picture the search as a tree and explore it using a pre-order traversal


## The non-attacking chess queens problem is a famous example

- In how many ways can N chess queens be placed on an NxN grid, so that none of the queens can attack any other queen?
- I.e. there are not two queens on the same row, same column, or same diagonal.
- There is no "formula" for generating a solution.
- The famous computer scientist Niklaus Wirth described his approach to the problem in 1971: Program Development by Stepwise Refinement http://sunnyday.mit.edu/16.355/wirthrefinement.htm\#3


Possible moves of the queen are shown

With a partner, discuss "possible solution" search strategies

- In how many ways can N chess queens be placed on an $N \times N$ grid, so that none of the queens can attack any other queen?
- I.e. no two queens on the same row, same column, or same diagonal.


## Search Space Possibilities 1/5

- Very naive approach. Perhaps stupid is a better word!
There are N queens, $\mathrm{N}^{2}$ squares.
- For each queen, try every possible square, allowing the possibility of multiple queens in the same square.
- Represent each potential solution as an N -item array of pairs of integers (a row and a column for each queen).
- Generate all such arrays (you should be able to write code that would do this) and check to see which ones are solutions.
- Number of possibilities to try in the NxN case:
- Specific number for $\mathrm{N}=8$ :
$281,474,976,710,656$

Search Space Possibilities 2 /5

Slight improvement. There are N queens, $\mathrm{N}^{2}$ squares. For each queen, try every possible square, notice that we can't have multiple queens on the same square.

- Represent each potential solution as an N -item array of pairs of integers (a row and a column for each queen).
- Generate all such arrays and check to see which ones are solutions.
- Number of possibilities to try in NxN case:
- Specific number for $\mathrm{N}=8$ :

$$
\begin{array}{r}
178,462,987,637,760 \\
\text { (vs. } 281,474,976,710,656 \text { ) }
\end{array}
$$

## Search Space Possibilities 3/5

- Slightly better approach. There are N queens, N columns. If two queens are in the same column, they will attack each other. Thus there must be exactly one queen per column.
- Represent a potential solution as an N -item array of integers.
- Each array position represents the queen in one column.
- The number stored in an array position represents the row of that column's queen.
- Show array for $4 \times 4$ solution.
- Generate all such arrays and check to see which ones are solutions.
- Number of possibilities to try in NxN case:
- Specific number for $\mathrm{N}=8$ :

16,777,216

## Search Space Possibilities 4 / 5

- Still better approach There must also be exactly one queen per row.
- Represent the data just as before, but notice that the data in the array is a set!
- Generate each of these and check to see which ones are solutions.
- How to generate? A good thing to think about.
- Number of possibilities to try in NxN case:
- Specific number for $\mathrm{N}=8$ :

40,320

Search Space Possibilities 5/5

- Backtracking solution
- Instead of generating all permutations of N queens and checking to see if each is a solution, we generate "partial placements" by placing one queen at a time on the board
- Once we have successfully placed $\mathrm{k}<\mathrm{N}$ queens, we try to extend the partial solution by placing a queen in the next column.
- When we extend to N queens, we have a solution.


## Experimenting with $8 \times 8$ Case

- Play the game:
- http://homepage.tinet.ie/~pdpals/8queens.htm
- See the solutions:
- http://www.dcs.ed.ac.uk/home/mlj/demos/queens


## Program output:

>java Rea1Queen 5
SOLUTION: 13524
SOLUTION: 14253
SOLUTION: 24135
SOLUTION: 25314
SOLUTION: 31425
SOLUTION: 35241
SOLUTION: 41352
SOLUTION: 42531
SOLUTION: 52413
SOLUTION: 53142

## The Linked List of Queen Objects

- Board configuration represented by a linked list of Queen objects


Fields of RealQueen:


Designed by Timothy Budd

## Outline of the algorithm

- Each queen sends messages directly to its immediate neighbor to the left (and recursively to all of its left neighbors)
- Return value provides information concerning all of the left neighbors:
- Example: neighbor.canAttack(currentRow, co7)
- Message goes to the immediate neighbor, but the real question to be answered by this call is
- "Hey, neighbors, can any of you attack me if I place myself on this square of the board?"


## Queen Methods

- findFirst()
- findNext()
, canAttack(int row, int col)

Your job (part of WA6):
Understand the job of each of these methods
Javadoc from the Queen interface can help
Fill in the (recursive) details in the RealQueen class
Debug
More details on next slide

## More algorithm outline

1. Queen asks its neighbors to find the first position in which none of them attack each other

- Found? Then queen tries to position itself so that it cannot be attacked.

2. If the rightmost queen is successful, then a solution has been found! The queens cooperate in recording it.
3. Otherwise, the queen asks its neighbors to find the next position in which they do not attack each other
4. When the queens get to the point where there is no next non-attacking position, all solutions have been found and the algorithm terminates
