04-03-2023

CS051A

INTRO TO COMPUTER SCIENCE WITH TOPICS IN AI

18: Problem solving via search and matrices

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Lectures

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Labs

Lecture 18: Problem solving via search and matrices

- Problem solving via search
- Matrices
- Assignment 9

Search algorithm

Keep track of a list of states that we *could* visit; we'll call it to_visit.

General idea:

- take a state off the to_visit list
- if it's the goal state
  - we're done!
- if it's not the goal state
  - Add all of the next possible states to the to_visit list
- repeat

Search algorithms

- add the start state to to_visit
- Repeat
  - take a state off the to_visit list
  - if it's the goal state
    - we're done!
  - if it's not the goal state
    - Add all of the next possible states to the to_visit list
- Depth first search (DFS): to_visit is a stack
- Breadth first search (BFS): to_visit is a queue

Implementing the state space

- What the "world" looks like.
  - We'll define the world as a collection of discrete states.
  - States are connected if we can get from one state to another by taking a particular action.
  - The set of all possible states is called the state space.

Implementing the state space

- What the "world" looks like.
  - We'll define the world as a collection of discrete states.
  - States are connected if we can get from one state to another by taking a particular action.
  - The set of all possible states is called the state space.
- State:
  - Is this the goal state? (is_goal function)
  - What states are connected to this state? (next_states function)

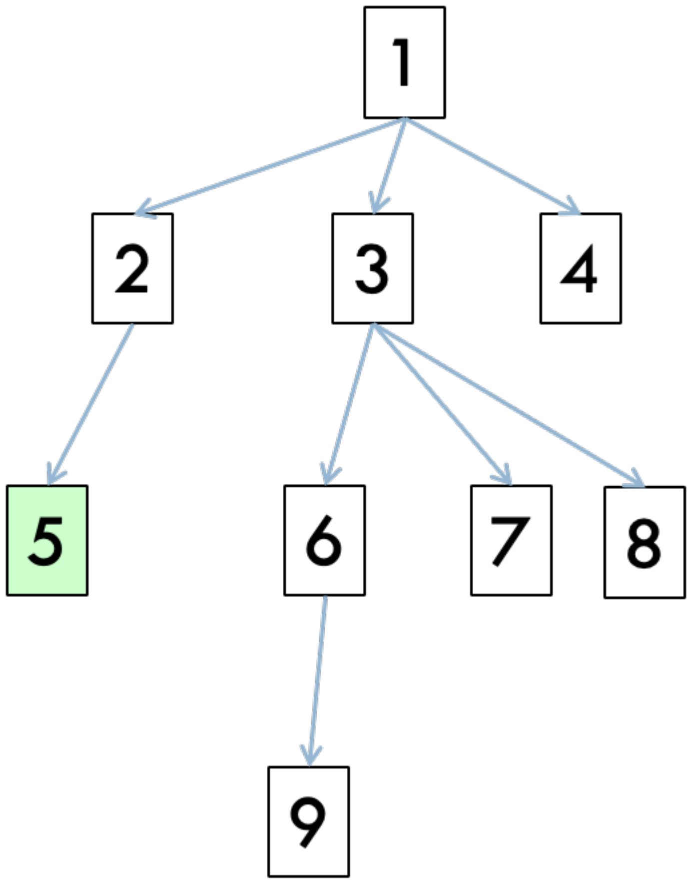
Search variants implemented

- add the start state to to_visit
- Repeat
  - take a state off the to_visit list
  - if it's the goal state
    - we're done!
  - if it's not the goal state
    - Add all of the next possible states to the to_visit list

```
def dfs(start_state):
    s = Stack()
    return search(start_state, s)


def bfs(start_state):
    q = Queue()
    return search(start_state, q)


def search(start_state, to_visit):
    to_visit.add(start_state)

    while not to_visit.is_empty():
        current = to_visit.remove()

        if current.is_goal():
            return current
        else:
            for s in current.next_states():
                to_visit.add(s)
    return None
```

In what order would this variant visit the states?

```
def search(state):
    if state.is_goal():
        return state
    else:
        for s in state.next_states():
            result = search(s)
            if result != None:
                return result
        return None
```



- Order: 1, 2, 5

In what order would this variant visit the states?

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def search(state):
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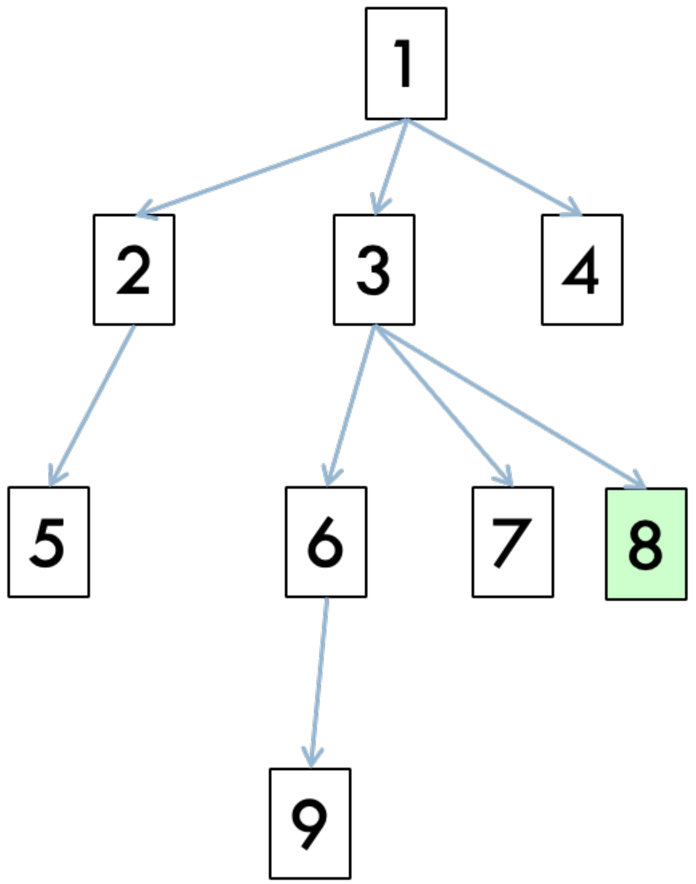

- Order: 1, 2, 5, 3, 6, 9, 7, 8

In what order would this variant visit the states?

```
def search(state):
    if state.is_goal():
        return state
    else:
        for s in state.next_states():
            result = search(s)
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```

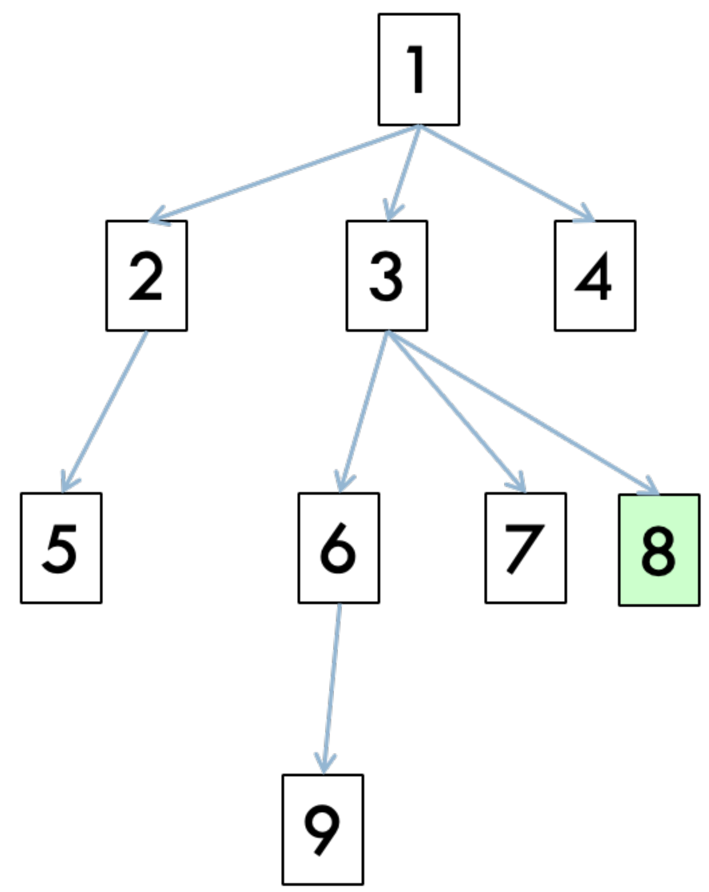

- Order: 1, 2, 5, 3, 6, 9, 7, 8
- What search algorithm is this?

In what order would this variant visit the states?

```
def search(state):
    if state.is_goal():
        return state
    else:
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            result = search(s)
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        return None
```
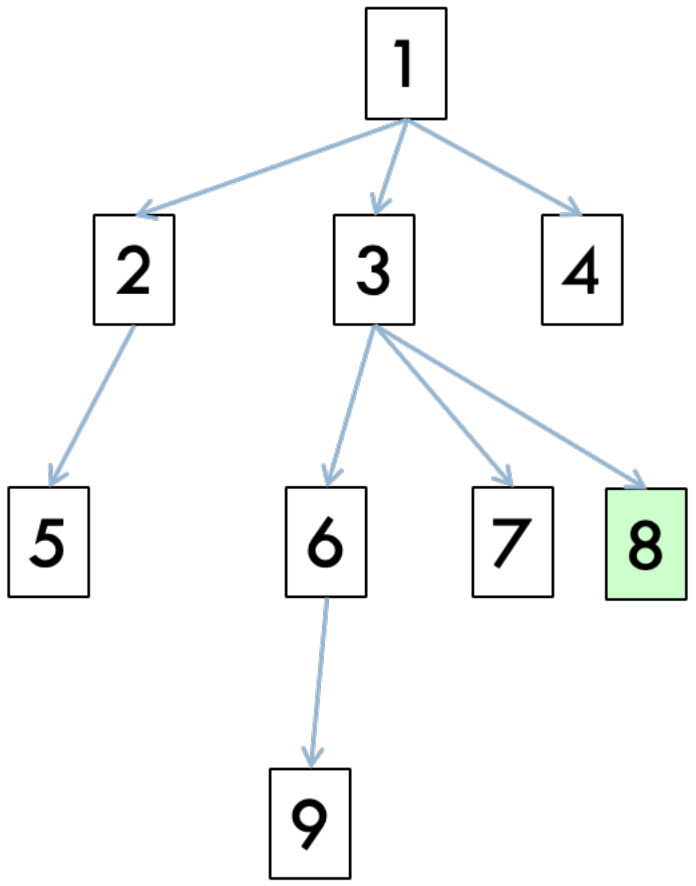
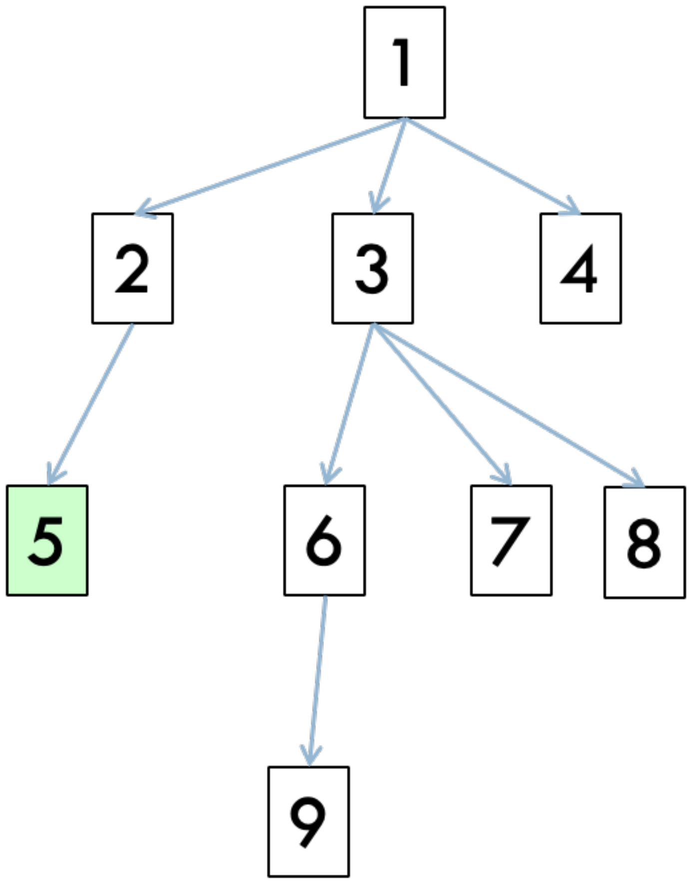



- Order: 1, 2, 5, 3, 6, 9, 7, 8
- DFS!

DFS with a stack

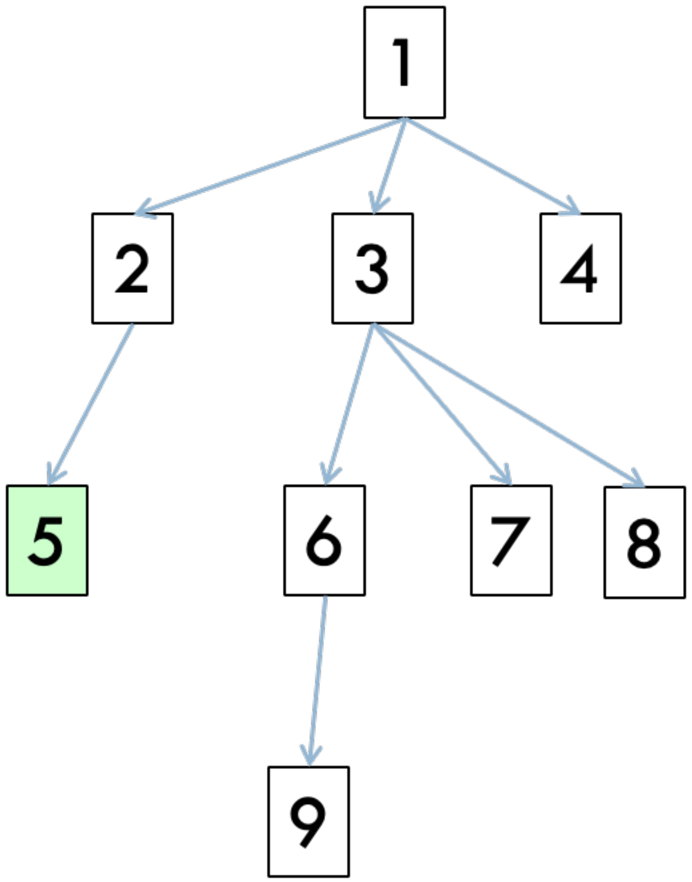
```
def dfs(start_state):
    s = Stack()
    return search(start_state, s)

def search(start_state, to_visit):
    to_visit.add(start_state)

    while not to_visit.is_empty():
        current = to_visit.remove()

        if current.is_goal():
            return current
        else:
            for s in current.next_states():
                to_visit.add(s)
    return None
```



- Order: 1, 4, 3, 8, 7, 6, 9, 2, 5

One last DFS variant

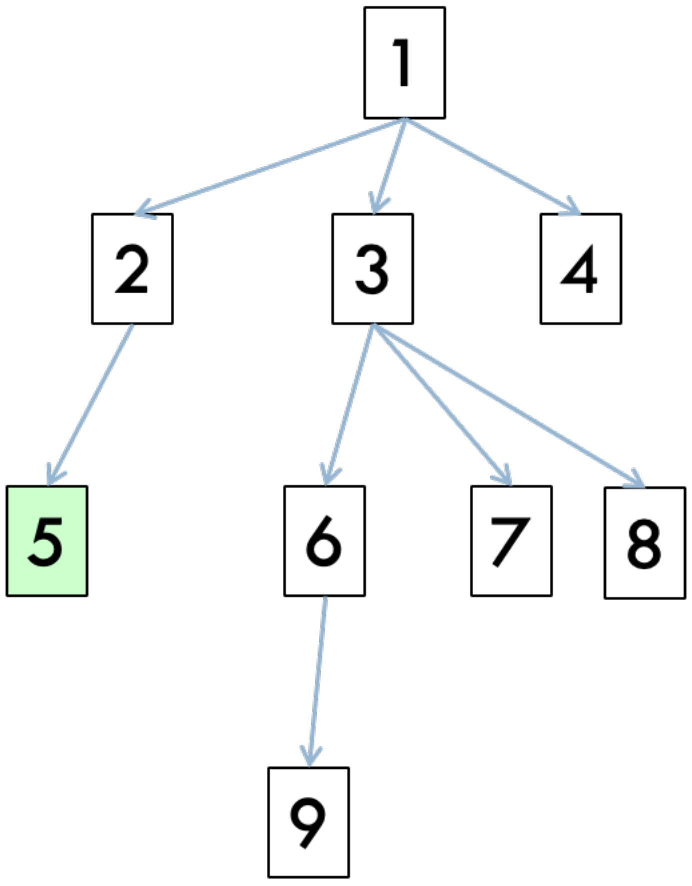
```python
def search(state):
    if state.is_goal():
        return state
    else:
        for s in state.next_states():
            result = search(s)
            if result != None:
                return result
        return None


def dfs(state):
    if state.is_goal():
        return [state]
    else:
        result = []

        for s in state.next_states():
            result += dfs(s)
        return result
```



- How is this different?

One last DFS variant

```
def search(state):
    if state.is_goal():
        return state
    else:
        for s in state.next_states():
            result = search(s)
            if result != None:
                return result
        return None


def dfs(state):
    if state.is_goal():
        return [state]
    else:
        result = []

        for s in state.next_states():
            result += dfs(s)
        return result
```



- Return ALL solutions found, not just one.

Lecture 18: Problem solving via search and matrices

- Problem solving via search
- Matrices
- Assignment 9

What is a matrix?

- A matrix is a two-dimensional structure, e.g.,
  0 1 0
  1 8 2
  5 0 3
  - It has rows and columns.
  - The second row is: 1 8 2
  - The second column is:
    1
    8
    0
- Since we are computer scientists, we'll start indexing at 0. That means that the first row is row 0 and the first column is column 0.

Indexing into matrices

- Individual entries in a matrix can be references by specifying a row and a column.
- 0 1 0
  1 8 2
  5 0 3
- Let's say that the matrix above is called m, what entry does m[1][2] represent?
  - In math, we might write this as m(1, 2).
  - 1 = second row, 2 = third column, that is m[1][2] is 2.
- How would we get at the 3 in the above matrix?
  - m[2][2]

Implementing matrices in Python

- We can use lists of lists!

```
>>> m = [[0, 1, 0], [1, 8, 2], [5, 0, 3]]
>>> m
[[0, 1, 0], [1, 8, 2], [5, 0, 3]]
>>> m[1][2]
2
>>> m[2][2]
3
```

- Could also have constructed this as:

```
>>> m = []
>>> m.append([0,1,0])
>>> m.append([1, 8, 2])
>>> m.append([5, 0, 3])
>>> m
[[0, 1, 0], [1, 8, 2], [5, 0, 3]]
>>> m[1][2]
2
>>> m[2][2]
3
```

Implementing matrices in Python

- what does m[1] represent?
  - the second row!

```
>>> m[1]
[1, 8, 2]
```

- matrices are just lists of lists.

matrix.py

- what do `zero_matrix` and `zero_matrix2` do?
  - They both create a `size x size` matrix with all entries zero.
  - `zero_matrix` does this an entry at a time.
  - `zero_matrix2` does this a row at a time.

```
>>> zero_matrix(3)
[[0, 0, 0], [0, 0, 0], [0, 0, 0]]
>>> zero_matrix2(2)
[[0, 0], [0, 0]]
>>> zero_matrix(1)
[[0]]
>>> m = zero_matrix(2)
>>> m
[[0, 0], [0, 0]]
>>> m[1][1] = 100
>>> m
[[0, 0], [0, 100]]
```

matrix.py

- what does `random_matrix` do?
    - It creates a `size x size` matrix with random ints between 0 and `size x size`

```
>>> random_matrix(3)
[[6, 2, 1], [2, 6, 1], [0, 3, 9]]
>>> random_matrix(3)
[[5, 3, 9], [7, 4, 1], [8, 2, 3]]
>>> random_matrix(3)
[[6, 9, 7], [8, 4, 7], [1, 6, 5]]
```

`matrix.py`

- How would we print out a matrix in a more normal form (one row at a time)?
  - iterate through the rows and print each out.
  - Look at the `print_matrix` and `print_matrix2` function.
- What does the `identity` function do?
  - It creates an identity size by size matrix with all zeros except for ones along the diagonal
- How would we sum up all the numbers in a matrix?
  - Iterate over each entry and add them up
  - Look at the `matrix_sum` function.
  - What does `len(m)` give us?
    - the number of rows (remember, list of lists)
  - what does `len(m[row])` give us?
    - the number of columns (in that row, technically)
  - Look at the `matrix_sum2` and `matrix_sum3` functions.
    - They use the `sum` function to sum up each row and then add that to the total.

copying matrices

- Be careful when you want to create a deep copy of a matrix. See the code below. What's the problem?

```
>>> m = [[1, 2], [3, 4]]
>>> n = m[:]
>>> n[0][0] = 0
>>> n
[[0, 2], [3, 4]]
>>> m
[[0, 2], [3, 4]]
```

copying matrices

- If you want to copy a matrix and avoid aliasing issues, you should either:
  - use the copy module
    ```
    import copy
    copy.deepcopy(m)
    ```
  - or by creating a deep copy of each row and appending it to a new list.

```
>>> m = [[1, 2], [3, 4]]
>>> n = []
>>> for row in m:
...     n.append(row[:])
...
>>> n
[[1, 2], [3, 4]]
>>> n[0][0] = 0
>>> n
[[0, 2], [3, 4]]
>>> m
[[1, 2], [3, 4]]
```

tic_tac_toe.py

- How would you represent a tic tac toe board?
  - As a 3 by 3 matrix.
  - Each entry has one of three values:
    - empty
    - X
    - O

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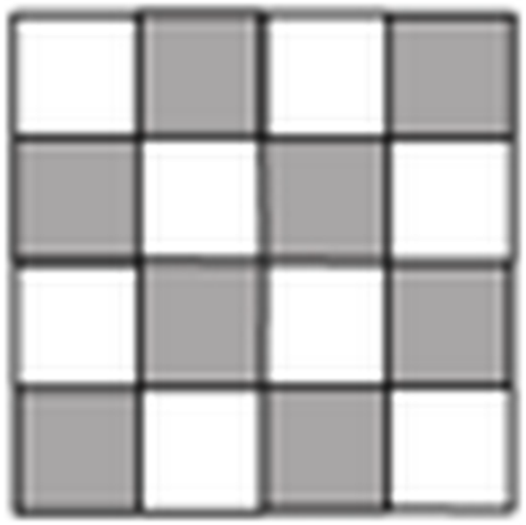
N-queens problem

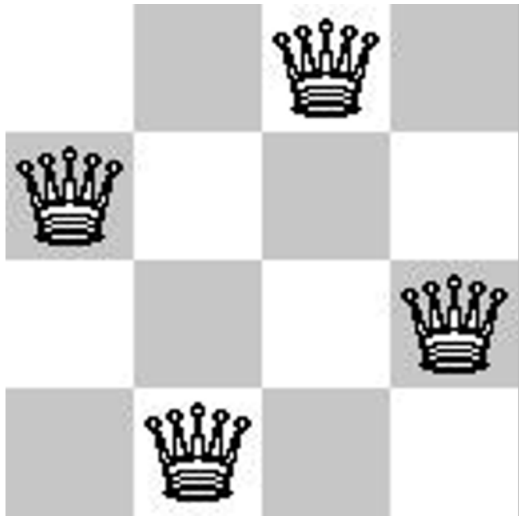
- Place N queens on an N by N chess board such that none of the N queens are attacking any other queen.

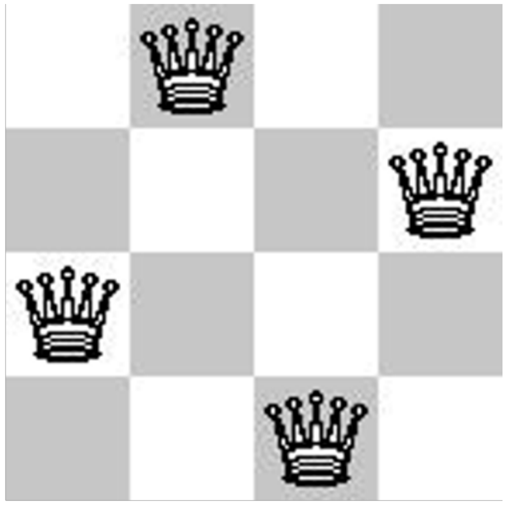


Solution(s)?

N-queens problem

- Place N queens on an N by N chess board such that none of the N queens are attacking any other queen.





N-queens problem

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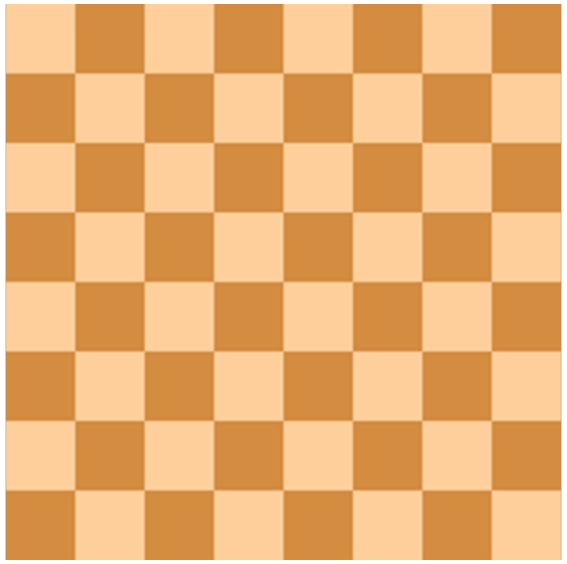

Solution(s)?

N-queens problem

- Place N queens on an N by N chess board such that none of the N queens are attacking any other queen.
- How do we solve this with search:
  - What is a state?
  - What is the start state?
  - What is the goal?
  - How do we transition from one state to the next?

Search algorithm

- add the start state to to_visit
- Repeat
  - take a state off the to_visit list
  - if it's the goal state — Is this a goal state?
    - we're done!
  - if it's not the goal state — What states can I get to from the current state?
    - Add all of the next possible states to the to_visit list
- *Any problem that we can define these three things can be plugged into the search algorithm!*

Resources

- search_variants.py
- matrix.py
- tic_tac_toe.py
- https://en.wikipedia.org/wiki/Eight_queens_puzzle

Homework

- Assignment 9