N–QUEENS

Concepts of Programming

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Introduction and Overview

1. Project Idea:

The N-Queens project aims to design and implement a program capable of solving the N-Queen problem for different board sizes.

The value of N is selected by user, allowing the program to work with small and large boards alike.

To deal with this challenge, the project explores 2 different programming paradigms:

- Pure Functional
- Imperative

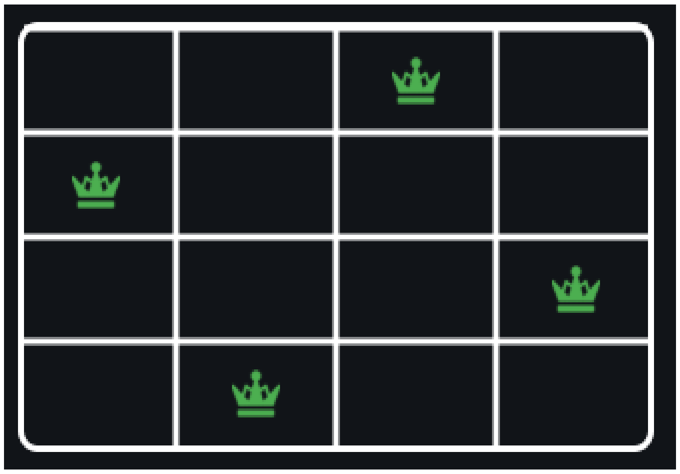
Using multiple approaches allow comparison of performance, effectiveness, and search behavior.

2. Problem Description:

In the N-Queen problem, the task is to arrange N queens on a NxN board so that no queen is attacking any other queen.

So to satisfy that no 2 queens must share the same row, column, or diagonal

As N increases, the number of possible board states grows exponentially



Valid solution for 4-Queens

Applied Paradigm

1. Pure Functional:

Pure Functional programming emphasizes immutability, recursion, and no side effects

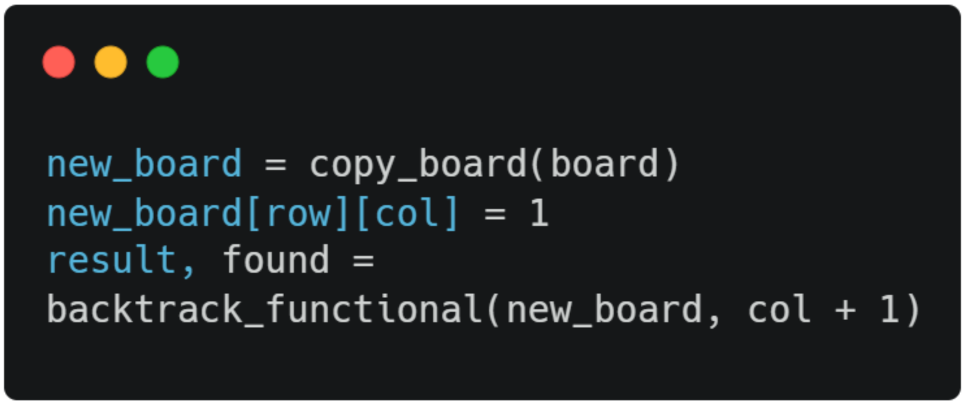
Functions don’t modify external state, instead, they return new values

Loops are avoided, and recursion or higher-order functions are used to process data

In the N-Queens code:

- Functions like *is_safe_row*, *is_safe_upper* are recursive and don’t modify the board, they only check conditions
- *copy_board* creates a new board each time a queen is placed instead of modifying the original board

- *try_rows* and *backtrack_functional* recursively explore rows and columns without altering the original board
- Each function returns a new board state or Boolean avoiding the side effects



```
new_board = copy_board(board)
new_board[row][col] = 1
result, found =
backtrack_functional(new_board, col + 1)
```

Here the *new_board* is a new copy of the board with the queen placed, the original board remains unchanged

Advantages:

- Predictable behavior
- More suitable for concurrency
- Easier testing

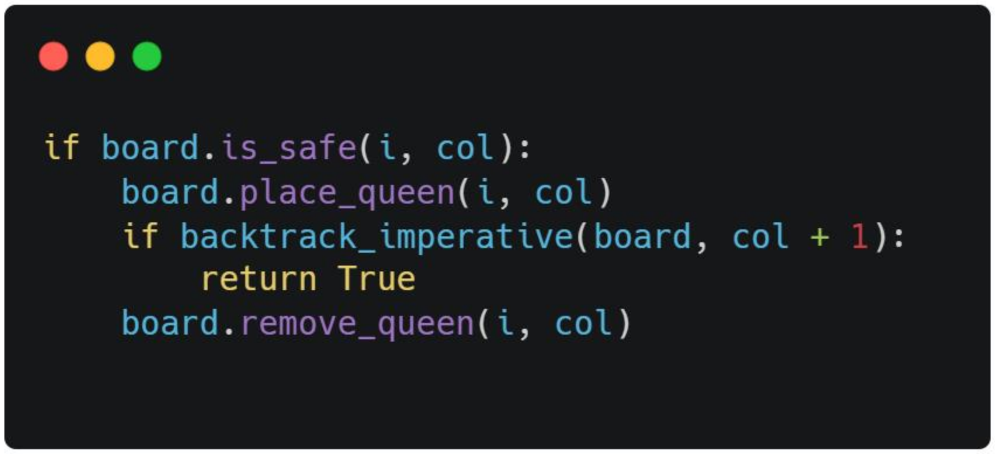
2. Imperative:

Imperative programming focuses on changing program state through statements, loops, and explicit instructions

The program describes how to achieve a goal by updating variables step by step

In the N-Queens code:

- *backtrack_imperative* uses loops to iterate through rows *for i in range(board.N)*
- It directly *modifies the board via board.place_queen(i,col) and board.remove_queen(i,col) which has side effects*
- The board is a mutable object, recursion is still used but the state is constantly updated in place rather than creating copies



```python
if board.is_safe(i, col):
    board.place_queen(i, col)
    if backtrack_imperative(board, col + 1):
        return True
    board.remove_queen(i, col)
```

Here the *same board object is modified and restored at each step, instead of creating new copies*

Advantages:

- More efficient in memory and time
- Easier to implement step by step

Paradigm	Functional	Imperative
Mutability	Immutable	Mutable
Iteration	Recursion	Loop

Results and Analysis

1. Results and Comparison

- To keep comparison fair, we used the same start state and same board size
- We ran each paradigm several times to get average
- For N=5

Paradigm	Avg Time
Functional	0.000100
Imperative	0.000041

- For N=15

Paradigm	Avg Time
Functional	0.158944
Imperative	0.040047

2. Analysis and Discussion

1)Functional:

- Uses less memory
- Executes faster

2)Imperative:

- Introduces significant overhead which slows down algorithm

Paradigm	Advantage	Disadvantage
Functional	Fast, memory-efficient and straightforward	Side effects can make it harder to understand
Imperative	Predictable, avoid side effects	Slower and higher memory usage

So in the N-Queens problem, using imperative paradigm is more efficient