

# Project 2: N-Queens

Adapted from the [Course Scheduling of Stanford CS221](#)

## Introduction

In this project, you are going to construct a CSP for N-Queens problem. You will be given several python files.

### Files you'll edit:

[submission.py](#)

Where you need to fill in codes in three places.

### Files you need to look at:

[test.py](#)

You can use this file to grade your program.

[run.py](#)

You can use this file to run your program to see results.

[csp.py](#)

The important class CSP is provided in this file.

**Files to Edit and Submit:** You will fill in portions of [submission.py](#) during the assignment. You should submit this file with your code and comments. Please do **NOT** change the other files in this distribution or submit any of our original files other than these files.

**Evaluation:** Your code will be auto-graded for technical correctness. Please do **NOT** change the names of any provided functions or classes within the code, or you will wreak havoc on the auto-grader. However, the correctness of your implementation -- not the auto-grader's judgements -- will be the final judge of your score. We will review and grade assignments individually to ensure that you receive correct credit for your work.

**Academic Dishonesty:** We will be checking your code against other submissions in the class for logical redundancy. If you copy someone else's code and submit it with minor changes, we will know. We trust you all to submit your own work only; *please* don't let us down. If you do, we will pursue the strongest consequences available to us.

## CSP for N-Queens

a) [5 points] Implement [backtrack\(\)](#) (part a) according to the pseudocode.

```
def BacktrackingSearch(assignment):
    if all variables assigned:
        add current assignment to assignments
    else:
        var <- choose an unassigned variable
        for value in ordered domain of var:
            if value consistent with assignment
                add {var = value} to assignment
                BacktrackingSearch(assignment)
                delete var from assignment
```

Note that the solver collects some basic statistics on the performance of the algorithm. You should take advantage of these statistics for debugging and analysis. You should get 40 (optimal) assignments with exactly 552 operations (number of calls to `backtrack()`).

- b) [5 points] Let's create a CSP to solve the N-Queens problem: Given an  $n \times n$  board, we'd like to place  $n$  queens on this board such that no 2 queens are on the same *row*, *column*, or *diagonal*. Implement `create_n_queens_csp()` by adding  $n$  variables and some number of binary factors. You should get 92 (optimal) assignments for  $n = 8$  with exactly 2057 operations.

*Hint: If you get a larger number of operations, make sure your CSP is minimal. Try to define the variables such that the size of domain is  $O(n)$ .*

- c) [5 points] You might notice that our search algorithm explores quite a large number of states even for the  $8 \times 8$  board. Let's see if we can do better. One heuristic we discussed in class is using most constrained variable (MCV): To choose an unassigned variable, pick the  $X_j$  that has the fewest number of values  $a$  which are consistent with the current partial assignment (  $a$  for which `check_factor()` on  $X_j = a$  returns True). Implement this heuristic in `get_unassigned_variable()` under the condition `self.mcv = True`. It should take you exactly 1361 operations to find all optimal assignments for 8 queens CSP — that's 30% fewer!

Some useful fields:

- Ø `csp.unary_factors[var][val]` gives the unary factor value.
- Ø `csp.binary_factors[var1][var2][val1][val2]` gives the binary factor value.
  - ✧ Here, `var1` and `var2` are variables and `val1` and `val2` are their corresponding values.
- Ø In `BacktrackingSearch`, if `var` has been assigned a value, you can retrieve it using `assignment[var]`. Otherwise `var` is not in `assignment`.

- d) [10 points] The previous heuristics looked only at the local effects of a variable or value. Let's now implement arc consistency (AC-3) that we discussed in lecture. After we set variable  $X_j$  to value  $a$ , we remove the values  $b$  of all neighboring variables  $X_k$  that could cause arc-inconsistencies. If  $X_k$ 's domain has changed, we use  $X_k$ 's domain to remove values from the domains of its neighboring variables. This is repeated until no domains have changed. **After applying AC-3, either every arc is arc-consistent (then `arc_consistency_check()` should return True), or some variable has an empty domain, indicating that the CSP cannot be solved (then `arc_consistency_check()` should return False).** Note that this may significantly reduce your branching factor, although at some cost. Your job is to fill in `arc_consistency_check()` and then the `backtrack()` (part d) compatible with AC-3. (Implement the `BacktrackingSearch` strictly under the pseudocode!)

```

def BacktrackingSearch(assignment):
    if all variables assigned:
        add current assignment to assignments
    else:
        var <- choose an unassigned variable
        for value in ordered domain of var:
            if value consistent with assignment
                add {var = value} to assignment
                localCopy <- store a deep copy for domains
                domain[variable] <- [value]
                succeed = arc_consistency_check(variable)
                if succeed:
                    BacktrackingSearch(assignment)
                use pre-stored localCopy to undo modify on domain
                delete var from assignment

```

**With AC-3 enabled, it should take you 583 operations only to find all optimal assignments to 8 queens CSP.**

**Take a deep breath! This part requires time and effort to implement — be patient.**

*Hint 1: documentation for `CSP.add_unary_factor()` and `CSP.add_binary_factor()` can be helpful.*

*Hint 2: although AC-3 works recursively, you may implement it iteratively. Using a queue might be a good idea. `li.pop(0)` removes and returns the first element for a python list `li`.*

### **Submission (IMPORTANT THINGS! READ THREE TIMES)**

- Submit your code, **only one file: submission.py**, through e-learning in **one** zip file with name “<student\_id>\_your\_name\_PJ2.zip”. E.g. “19307100112\_ZhangSan\_PJ2.zip”
- **Project 2 is due on October 31st, Sun, 11:59pm, 2021.**
- If you have any questions about this project, please contact [18307130328@fudan.edu.cn](mailto:18307130328@fudan.edu.cn).