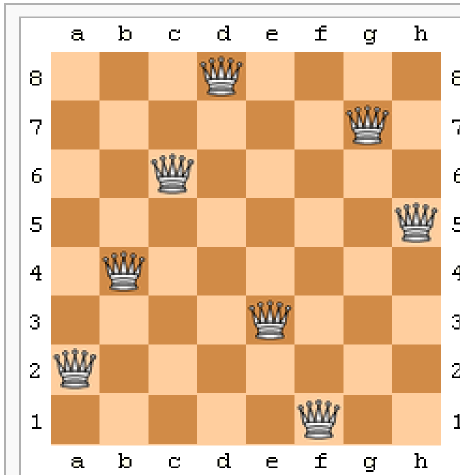
nqueens

(CP: “hello world”)

Eight queens puzzle

From Wikipedia, the free encyclopedia

The **eight queens puzzle** is the problem of putting eight chess queens on an 8×8 chessboard such that none of them is able to capture any other using the standard chess queen's moves. The queens must be placed in such a way that no two queens would be able to attack each other. Thus, a solution requires that no two queens share the same row, column, or diagonal. The eight queens puzzle is an example of the more general ***n* queens puzzle** of placing *n* queens on an *n*×*n* chessboard, where solutions exist only for *n* = 1 or *n* ≥ 4.



One solution.

Contents [hide]

History

[edit]

The puzzle was originally proposed in 1848 by the chess player Max Bezzel, and over the years, many mathematicians, including Gauss and Georg Cantor, have worked on this puzzle and its generalized n-queens problem. The first solutions were provided by Franz Nauck in 1850. Nauck also extended the puzzle to n-queens problem (on an n×n board—a chessboard of arbitrary size). In 1874, S. Gunther proposed a method of finding solutions by using determinants, and J.W.L. Glaisher refined this approach.

Eight queens puzzle - Wikipedia, the free encyclopedia - Windows Internet Explorer

http://en.wikipedia.org/wiki/Eight_queens_puzzle

nqueens

Page Tools

History

[edit]

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Edsger Dijkstra used this problem in 1972 to illustrate the power of what he called structured programming. He published a highly detailed description of the development of a depth-first backtracking algorithm.[2]

This puzzle appeared in the popular early 1990s computer game *The 7th Guest*.

Constructing a solution

[edit]

The problem can be quite computationally expensive as there are 4,426,165,368 (or 64!/(56!8!)) possible arrangements of eight queens on the board, but only 92 solutions. It is possible to use shortcuts that reduce computational requirements or rules of thumb that avoids brute force computational techniques. For example, just by applying a simple rule that constrains each queen to a single column (or row), though still considered brute force, it is possible to reduce the number of possibilities to just 16,777,216 (8^8) possible combinations, which is computationally manageable for n=8, but would be intractable for problems of n=1,000,000. Extremely interesting advancements for this and other toy problems is the development and application of heuristics (rules of thumb) that yield solutions to the *n* queens puzzle at an astounding fraction of the computational requirements. This heuristic solves *n* queens for any n $n \geq 4$ or $n = 1$:

1. Divide *n* by 12. Remember the remainder (*n* is 8 for the eight queens puzzle).
2. Write a list of the even numbers from 2 to *n* in order.
3. If the remainder is 3 or 9, move 2 to the end of the list.
4. Append the odd numbers from 1 to *n* in order, but, if the remainder is 8, switch pairs (i.e. 3, 1, 7, 5, 11, 9, …).
5. If the remainder is 2, switch the places of 1 and 3, then move 5 to the end of the list.
6. If the remainder is 3 or 9, move 1 and 3 to the end of the list.
7. Place the first-column queen in the row with the first number in the list, place the second-column queen in the row with the second number in the list, etc.

For *n* = 8 this results in the solution shown above. A few more examples follow.

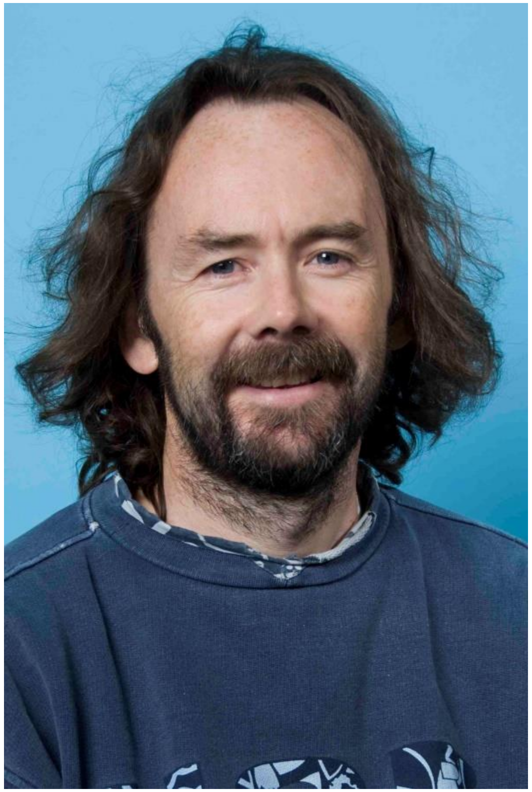
- 14 queens (remainder 2): 2, 4, 6, 8, 10, 12, 14, 3, 1, 7, 9, 11, 13, 5.

start Eight qu… nqueens emacs@… Comma… Microsof… 10:46

Homework hw00

```
                              m-queens
                              --------
The famous n-queens problem is actually a simplifcation of the much more
important m-queens problem, which is originally attributed to Adardhir I the
founder of the Sassanid Empire. His mother Rodhagh challenged him to cover
his empire with the minimum number of castles so that no place was not pro-
tected by cavalry within 1 week riding. Adardhir simplifed this problem into
the m-queens problem, based on the game of chess, which was becoming popular
at the time, under the name shatranj. His son Shapur I is attributed with the
first optimal solution on a standard 8x8 chessboard. The m-queens problem,
generalizing Adardhir's problem, is to cover an n x n chess board with as few
queens as possible so that no queen can take another and no more queens can
be placed on the board without being taken.

For example given n = 5 a solution might be
q = [2, 0, 5, 3, 1]; representing the solution

     . Q . . .
     . . . . .
     . . . . Q
     . . Q . .
     Q . . . .

where 0 means no queen on that row. Note that above a 5th queen cannot be
placed on the board witjout being under attack.

and a minimal solution might be
q = [5,2,0,3,0]; representing the solution

     . . . . Q
     . Q . . .
     . . . . .
     . . Q . .
     . . . . .

That is, above we see that by placing 3 queens on the 5x5
board the queens do not attack each other and all other vacant
positions are under attack. The above solution is minimal
```

Peter Stuckey myth?



Edsger W. Dijkstra

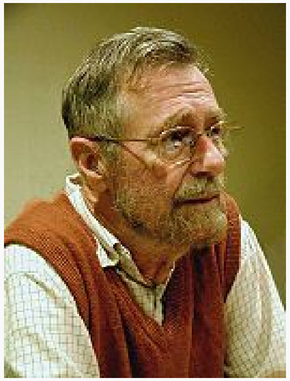
From Wikipedia, the free encyclopedia

(Redirected from Edsger Dijkstra)

Edsger Wybe Dijkstra (May 11, 1930 – August 6, 2002; Dutch pronunciation: [ˈɛtsxər ˈwibə ˈdɛikstra]) was a Dutch computer scientist. He received the 1972 Turing Award for fundamental contributions to developing programming languages, and was the Schlumberger Centennial Chair of Computer Sciences at The University of Texas at Austin from 1984 until 2000.

Shortly before his death in 2002, he received the ACM PODC Influential Paper Award in distributed computing for his work in the sub-topic of self-stabilization of program computation. This annual award was renamed the Dijkstra Prize the following year, in his honour.

Edsger Wybe Dijkstra



Born	May 11, 1930 Rotterdam, Netherlands
Died	August 6, 2002 (aged 72) Nuenen, Netherlands
Fields	Computer science
Institutions	Mathematisch Centrum Eindhoven University of Technology The University of Texas at Austin
Doctoral advisor	Adriaan van Wijngaarden
Doctoral students	Nico Habermann Martin Rem David Naumann Cornelis Hemerik Jan Tijmen Udding Johannes van de Snepscheut

Contents [hide]

Life and work [edit]

Born in Rotterdam, Netherlands, Dijkstra studied theoretical physics at Leiden University, but he quickly realized he was more interested in computer science. Originally employed by the Mathematisch Centrum in Amsterdam, he held a professorship at the Eindhoven University of Technology in the Netherlands, worked as a research fellow for Burroughs

Structured programming

From Wikipedia, the free encyclopedia

Structured programming can be seen as a subset or subdiscipline of procedural programming, one of the major programming paradigms. It is most famous for removing or reducing reliance on the GOTO statement.

Historically, several different structuring techniques or methodologies have been developed for writing structured programs. The most common are:

1. Edsger Dijkstra's structured programming, where the logic of a program is a structure composed of similar sub-structures in a limited number of ways. This reduces understanding a program to understanding each structure on its own, and in relation to that containing it, a useful separation of concerns.
2. A view derived from Dijkstra's which also advocates splitting programs into sub-sections with a single point of entry, but is strongly opposed to the concept of a single point of exit.
3. Data Structured Programming or Jackson Structured Programming, which is based on aligning data structures with program structures. This approach applied the fundamental structures proposed by Dijkstra, but as constructs that used the high-level structure of a program to be modeled on the underlying data structures being processed. There are at least 3 major approaches to data structured program design proposed by Jean-Dominique Warnier, Michael A. Jackson, and Ken Orr.

The two latter meanings for the term "structured programming" are more common, and that is what this article will discuss. Years after Dijkstra (1969), object-oriented programming (OOP) was developed to handle very large or complex programs (see below: *Object-oriented comparison*).

Contents [hide]

Programming paradigms

- Agent-oriented
- Component-based
  - Flow-based
  - Pipeline
- Concatenative
- Concurrent computing
- Declarative (contrast: Imperative)
  - Functional
    - Dataflow
      - Cell-oriented (spreadsheets)
      - Reactive
  - Graph-oriented
  - Goal-oriented
    - Constraint
      - Logic
        - Constraint logic
        - Abductive logic
        - Inductive logic
- Event-driven
  - Service-oriented
- Feature-oriented
- Function-level (contrast: Value-level)
- Imperative (contrast: Declarative)
  - Greater separation of concerns
    - Aspect-oriented

A.P.I.C. Studies in Data Processing
No. 8

STRUCTURED PROGRAMMING

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ACADEMIC PRESS
LONDON AND NEW YORK

CONTENTS

This section has not been included because the problem tackled in it is very exciting. On the contrary, I feel tempted to remark that the problem is perhaps too trivial to act as a good testing ground for an orderly approach to the problem of program composition. This section has been included because it contains a true eye-witness account of what happened in the classroom. It should be interpreted as a partial answer to the question that is often posed to me, viz. to what extent I can teach programming style. (I never used the "Notes on Structured Programming"—mainly addressed to myself and perhaps to my colleagues—in teaching. The classroom experiment described in this section took place at the end of a course entitled "Introduction into the Art of Programming", for which separate lecture notes—with exercises and all that—were written. As at the moment of writing the students that followed this course have still to pass their examination, it is for me still an open question how successful I have been. They liked the course, I have heard that they described my programs as "logical poems", so I have the best of hopes.)

17. The Problem Of The Eight Queens

This last section is adapted from my lecture notes "Introduction into the Art of Programming". I owe the example—as many other good ones—to Niklaus Wirth. This last section is added for two reasons.

Firstly, it is a second effort to do more justice to the process of invention. (As a matter of fact I start where the student is not familiar with the concept of backtracking and aim at discovering it as I go along.)

Secondly, and that is more important, it deals with recursion as a programming technique. In preceding sections (particularly in "On a program model") I have reviewed the subroutine concept; there it emerged as an embodiment of what I have also called "operational abstraction". In the relation between main program and subroutine we can distinguish quite clearly two different semantic levels. On the level of the main program the subroutine represents a primitive action; on that level it is used on account of "what it does for us" and on that same level it is irrelevant "how it works". On the level of the subroutine body we are concerned with how it works but can—and should—abstract from how it is used. This clear separation of the two semantic levels "what it does" and "how it works" is denied to the designer of a recursive procedure. As a result of this circumstance the design of a recursive routine requires a different mental skill, justifying the inclusion of the current section in this manuscript. The recursive procedure has to be understood and conceived on a single semantic level: as such it is more like a sequencing device, comparable to the repetitive clauses.


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structured programming
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Microsof...
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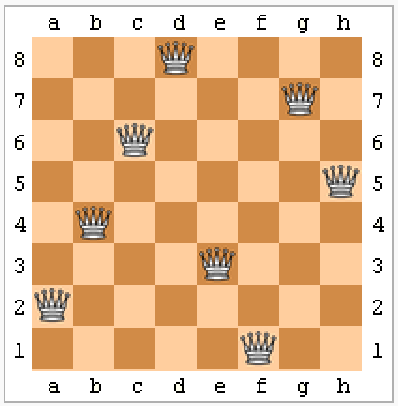
Back to nqueens

- 20 queens (remainder 8): 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 3, 1, 7, 5, 11, 9, 15, 13, 19, 17.

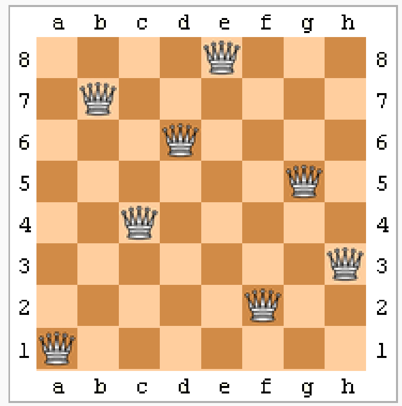
Solutions to the eight queens puzzle

[edit]

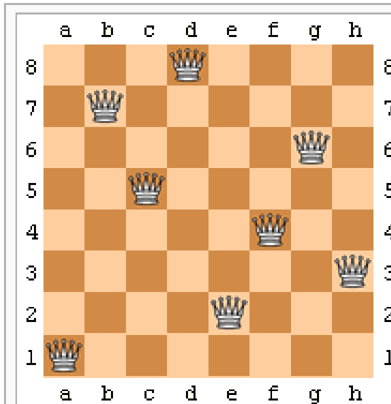
The eight queens puzzle has 92 **distinct** solutions. If solutions that differ only by symmetry operations (rotations and reflections) of the board are counted as one, the puzzle has 12 **unique** (or **fundamental**) solutions, which are presented below:



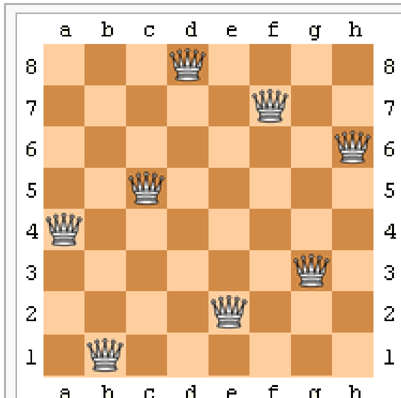
Unique solution 1



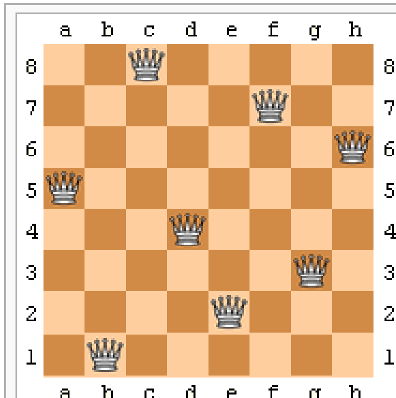
Unique solution 2



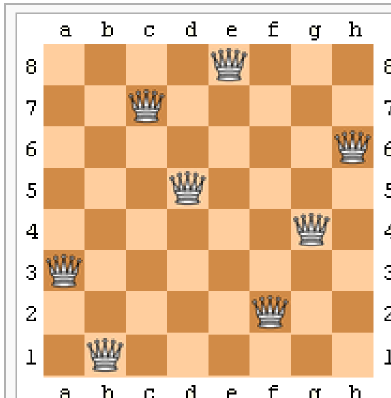
Unique solution 3



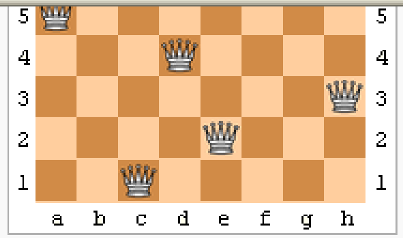
Unique solution 4



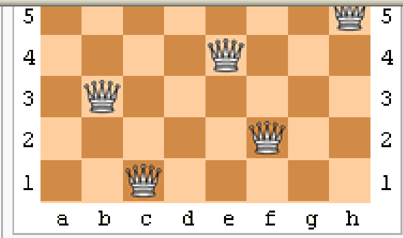
Unique solution 5



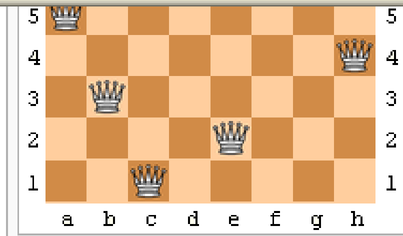
Unique solution 6



Unique solution 10



Unique solution 11



Unique solution 12

Counting solutions

[edit]

The following table gives the number of solutions for placing *n* queens on an *n* × *n* board, both unique (sequence A002562 in OEIS) and distinct (sequence A000170 in OEIS).

n:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	..	24	25	26
unique:	1	0	0	1	2	1	6	12	46	92	341	1,787	9,233	45,752	..	28,439,272,956,934	275,986,683,743,434	2,789,712,466
distinct:	1	0	0	2	10	4	40	92	352	724	2,680	14,200	73,712	365,596	..	227,514,171,973,736	2,207,893,435,808,352	22,317,699,61

Note that the six queens puzzle has fewer solutions than the five queens puzzle.

There is currently no known formula for the exact number of solutions.

Related problems

[edit]

Using pieces other than queens

For example, on an 8×8 board one can place 32 knights, or 14 bishops, 16 kings or 8 rooks, so that no two pieces attack each other. Fairy chess pieces have also been substituted for queens. In the case of knights, an easy solution is to place one on each square of a given color, since they move only to the opposite color.

Nonstandard boards

Pólya studied the *n* queens problem on a toroidal ("donut-shaped") board. In 2009 Pearson and Pearson algorithmically populated three-dimensional boards $(n \times n \times n)$ with n^2 queens, and proposed that multiples of these can yield solutions for a four-dimensional version of the puzzle.

Domination

Given an $n \times n$ board, find the **domination number**, which is the minimum number of queens (or other pieces) needed to attack or occupy

The eight queens puzzle as an exercise in algorithm design

[edit]

Main article: Eight queens puzzle solutions

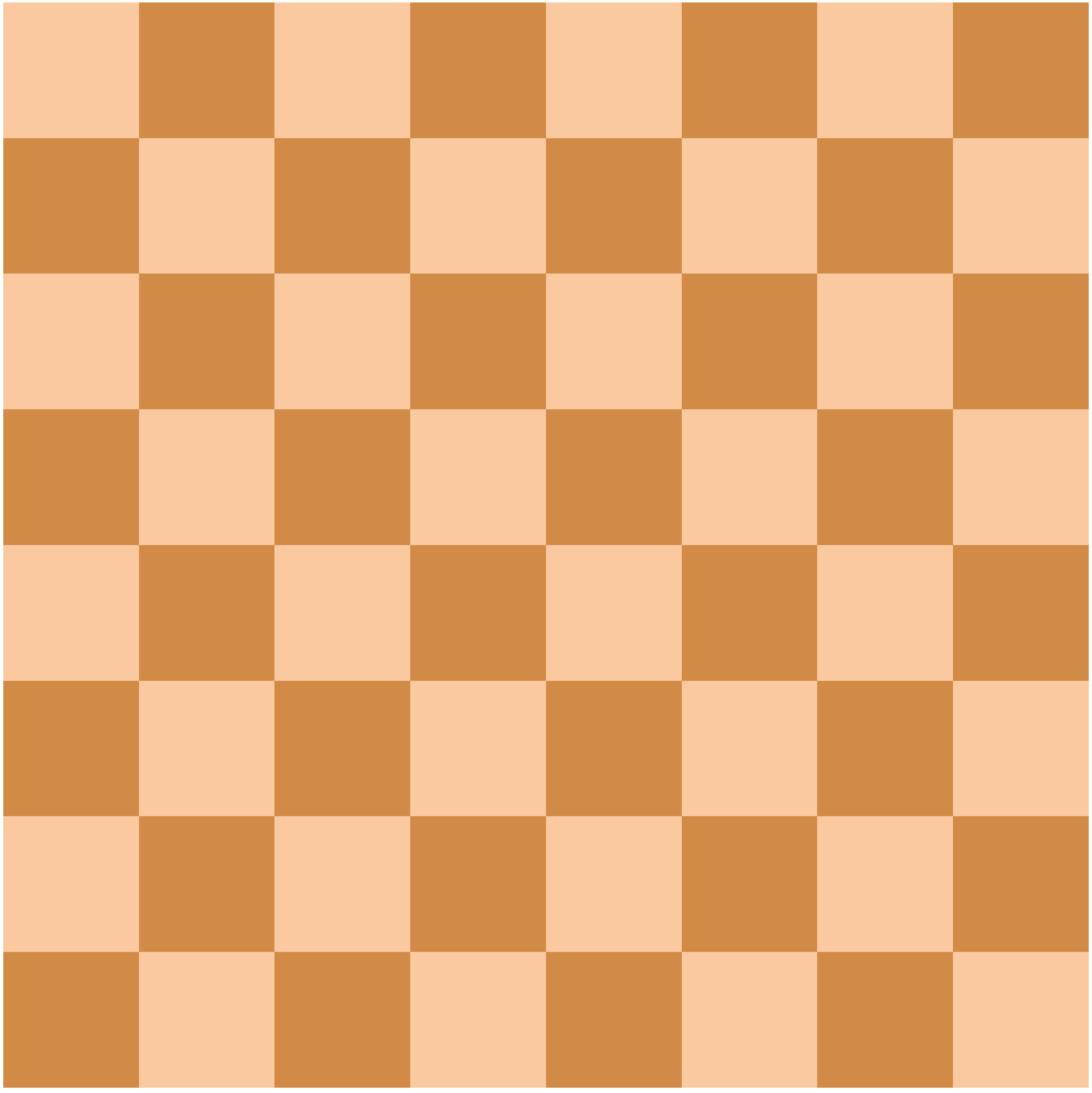
Finding all solutions to the eight queens puzzle is a good example of a simple but nontrivial problem. For this reason, it is often used as an example problem for various programming techniques, including nontraditional approaches such as constraint programming, logic programming or genetic algorithms. Most often, it is used as an example of a problem which can be solved with a recursive algorithm, by phrasing the *n* queens problem inductively in terms of adding a single queen to any solution to the problem of placing $n-1$ queens on an n-by-n chessboard. The induction bottoms out with the solution to the 'problem' of placing 0 queens on an n-by-n chessboard, which is the empty chessboard.

This technique is much more efficient than the naïve brute-force search algorithm, which considers all $64^8 = 2^{48}$ = 281,474,976,710,656 possible blind placements of eight queens, and then filters these to remove all placements that place two queens either on the same square (leaving only 64!/56! = 178,462,987,637,760 possible placements) or in mutually attacking positions. This very poor algorithm will, among other things, produce the same results over and over again in all the different permutations of the assignments of the eight queens, as well as repeating the same computations over and over again for the different sub-sets of each solution. A better brute-force algorithm places a single queen on each row, leading to only $8^8 = 2^{24}$ = 16,777,216 blind placements.

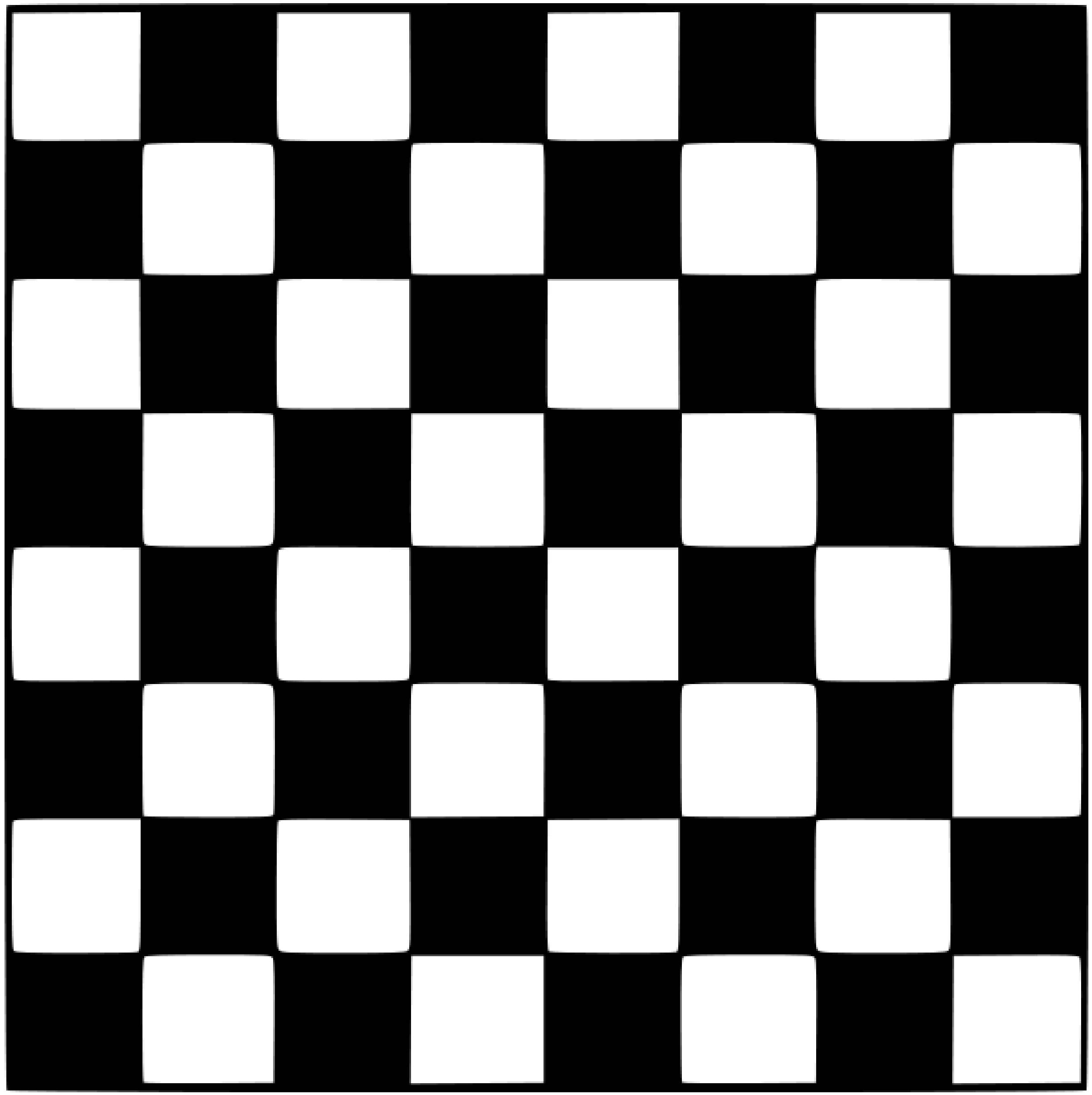
It is possible to do much better than this. One algorithm generates the permutations of the numbers 1 through 8 (of which there are 8! = 40,320), and uses the elements of each permutation as indices to place a queen on each row, guaranteeing no rook attacks. Then it rejects those boards with diagonal attacking positions. The backtracking depth-first search program, a slight improvement on the permutation method, constructs the search tree by considering one row of the board at a time, eliminating most nonsolution board positions at a very early stage in their construction. Because it rejects rook and diagonal attacks even on incomplete boards, it examines only 15,720 possible queen placements. A further improvement which examines only 5,508 possible queen placements is to combine the permutation based method with the early pruning method: the permutations are generated depth-first, and the search space is pruned if the partial permutation produces a diagonal attack. Constraint programming can also be very effective on this problem.

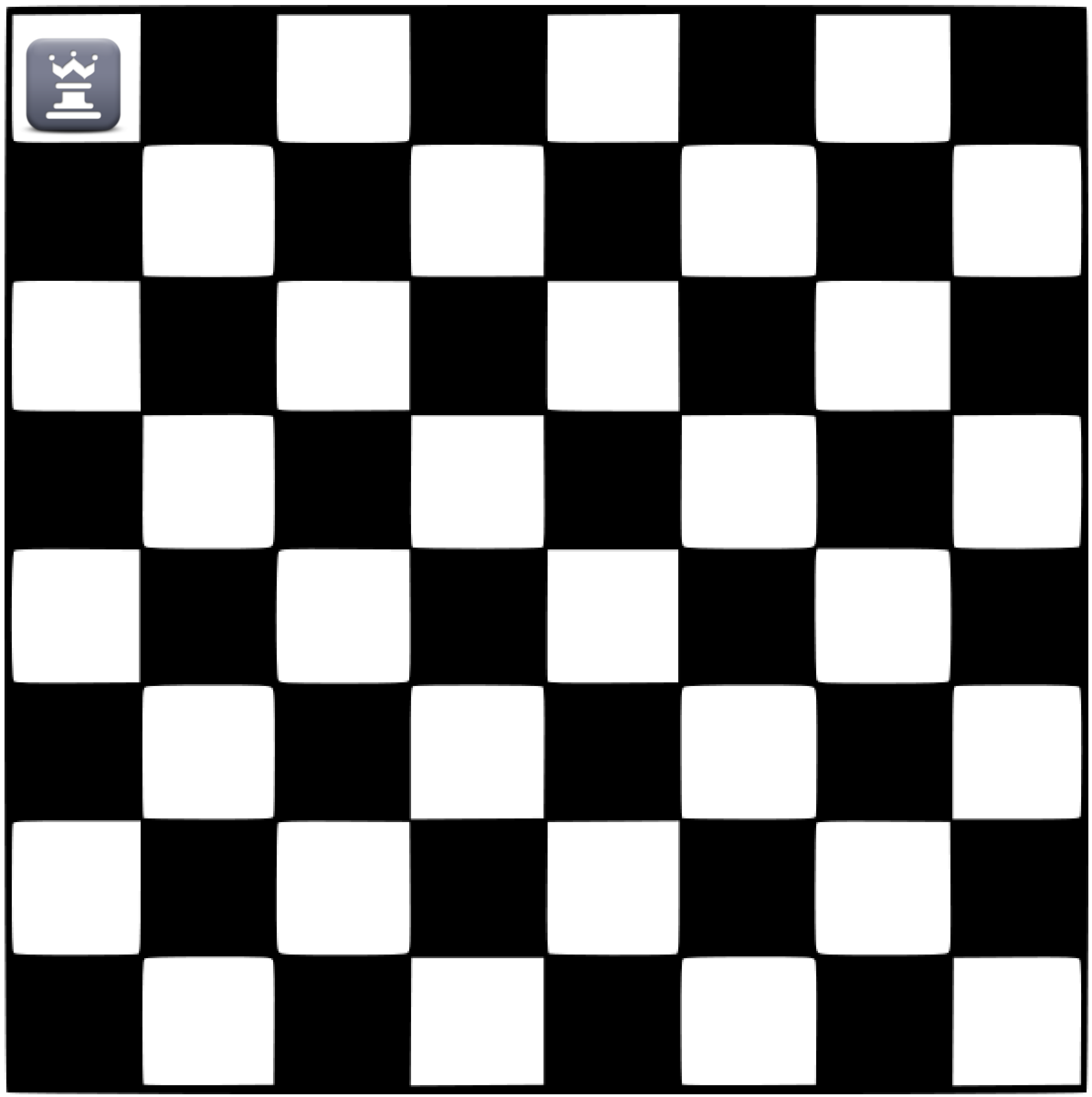
An alternative to exhaustive search is an 'iterative repair' algorithm, which typically starts with all queens on the board, for example with one queen per column. It then counts the number of conflicts (attacks), and uses a heuristic to determine how to improve the placement of the queens. The 'minimum-conflicts' heuristic — moving the piece with the largest number of conflicts to the square in the same column where the number of conflicts is smallest — is particularly effective: it solves the 1,000,000 queen problem in less than 50 steps on average. This assumes that the initial configuration is 'reasonably good' — if a million queens all start in the same row, it will obviously take at least 999,999 steps to fix it. A 'reasonably good' starting point can for instance be found by putting each queen in its own row and column such that it conflicts with the smallest number of queens already on the board.

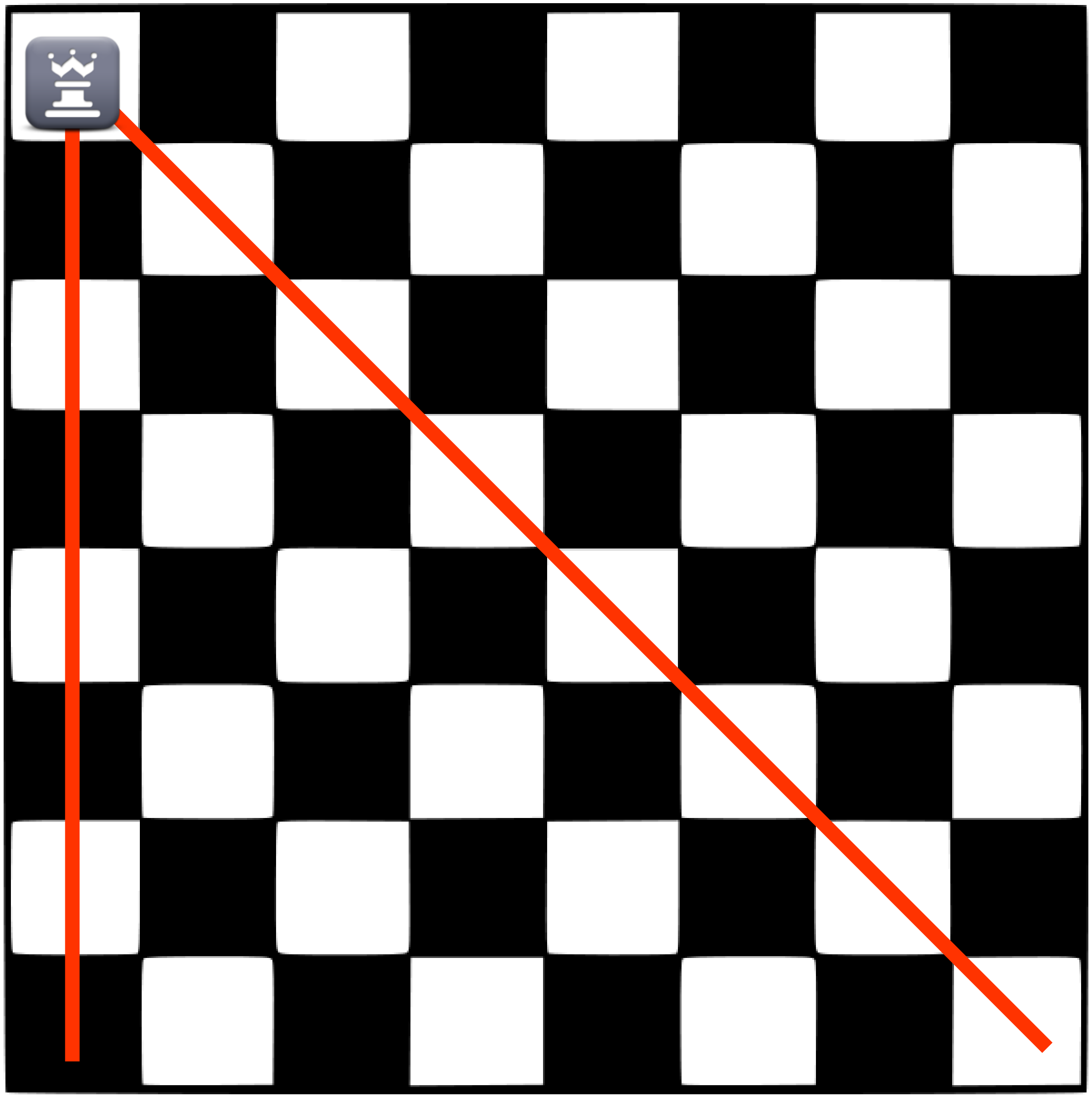
Note that 'iterative repair', unlike the 'backtracking' search outlined above, does not guarantee a solution: like all non-hillclimbing (i.e., greedy)

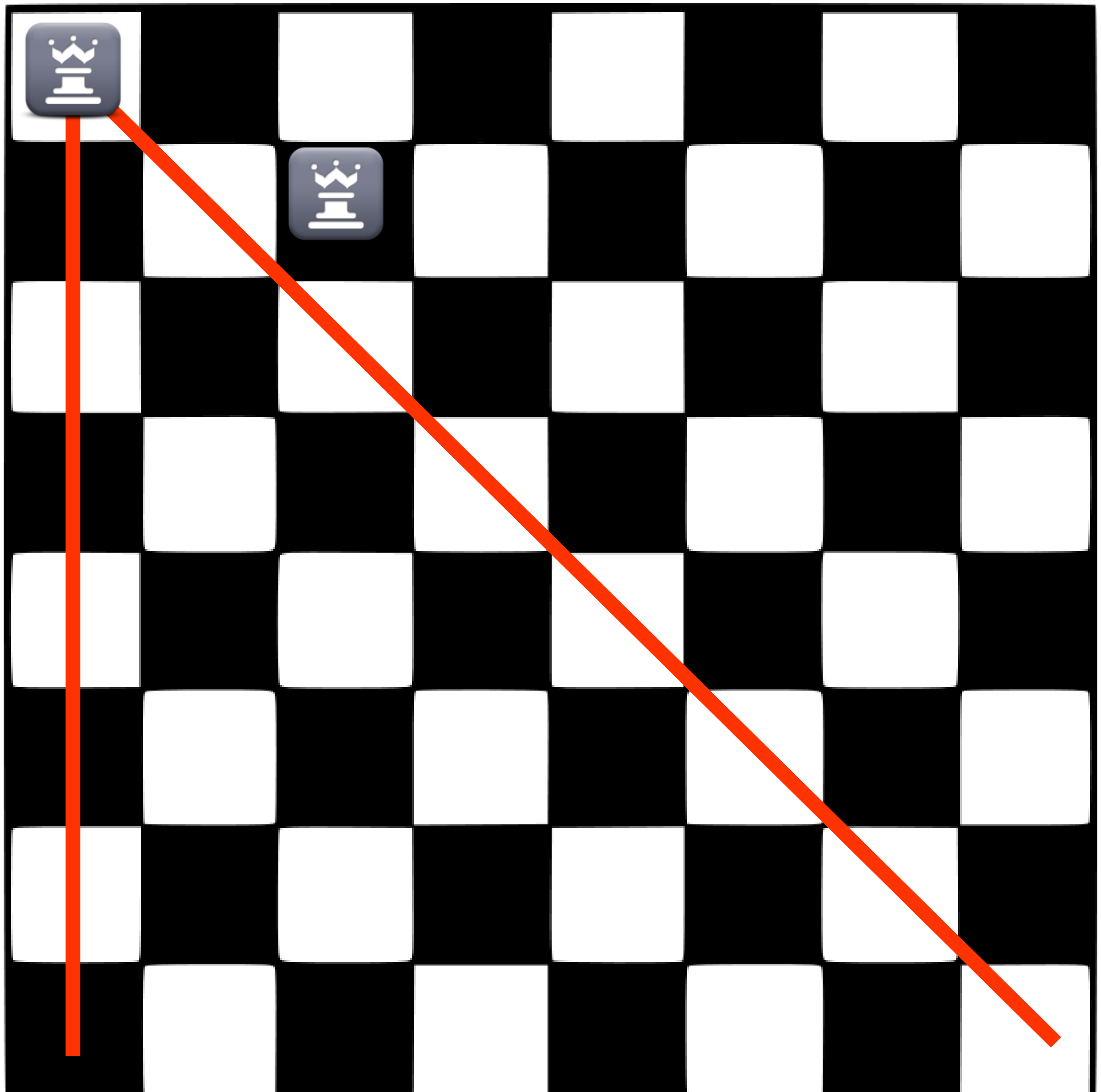


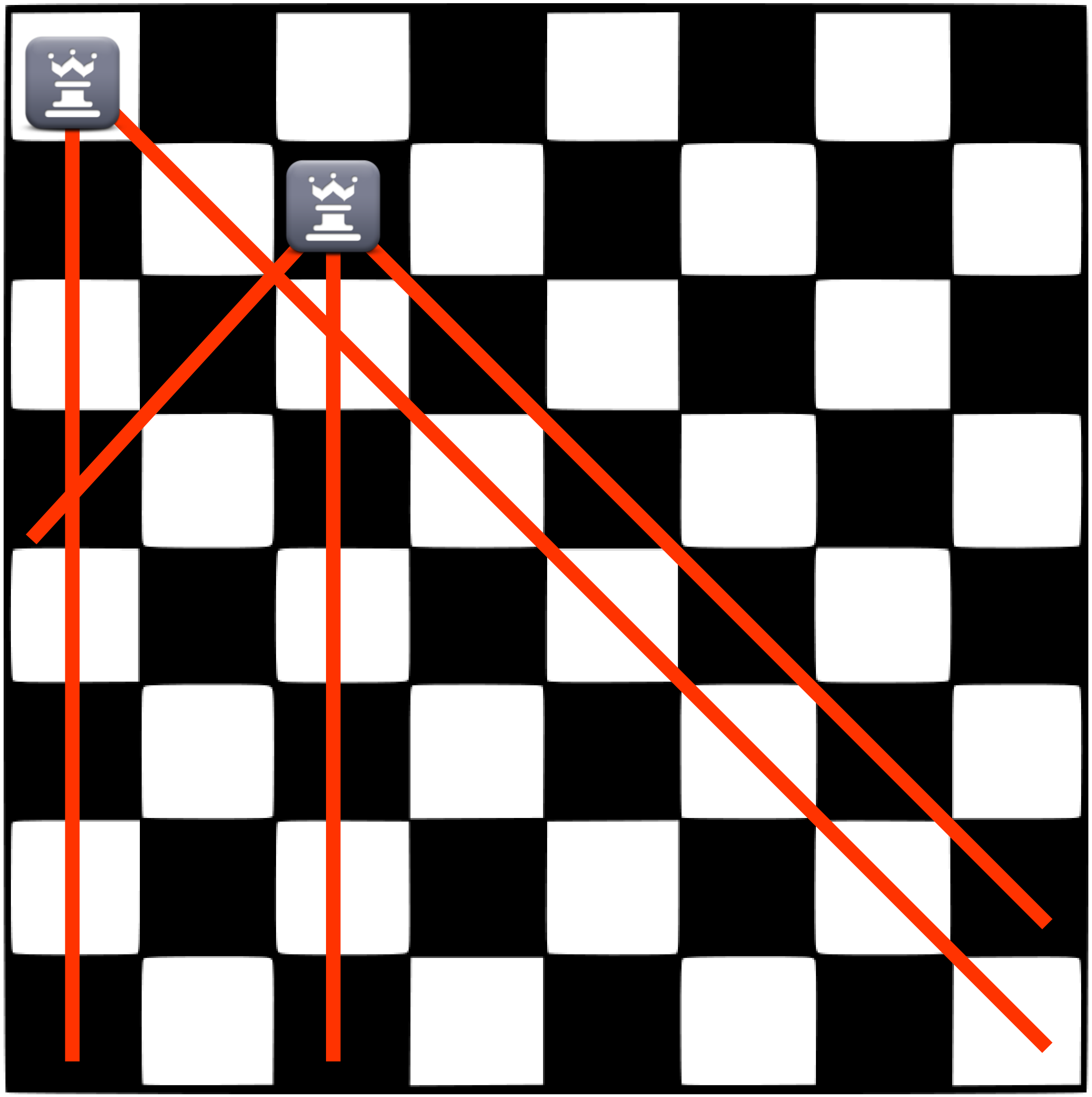
How might it go?

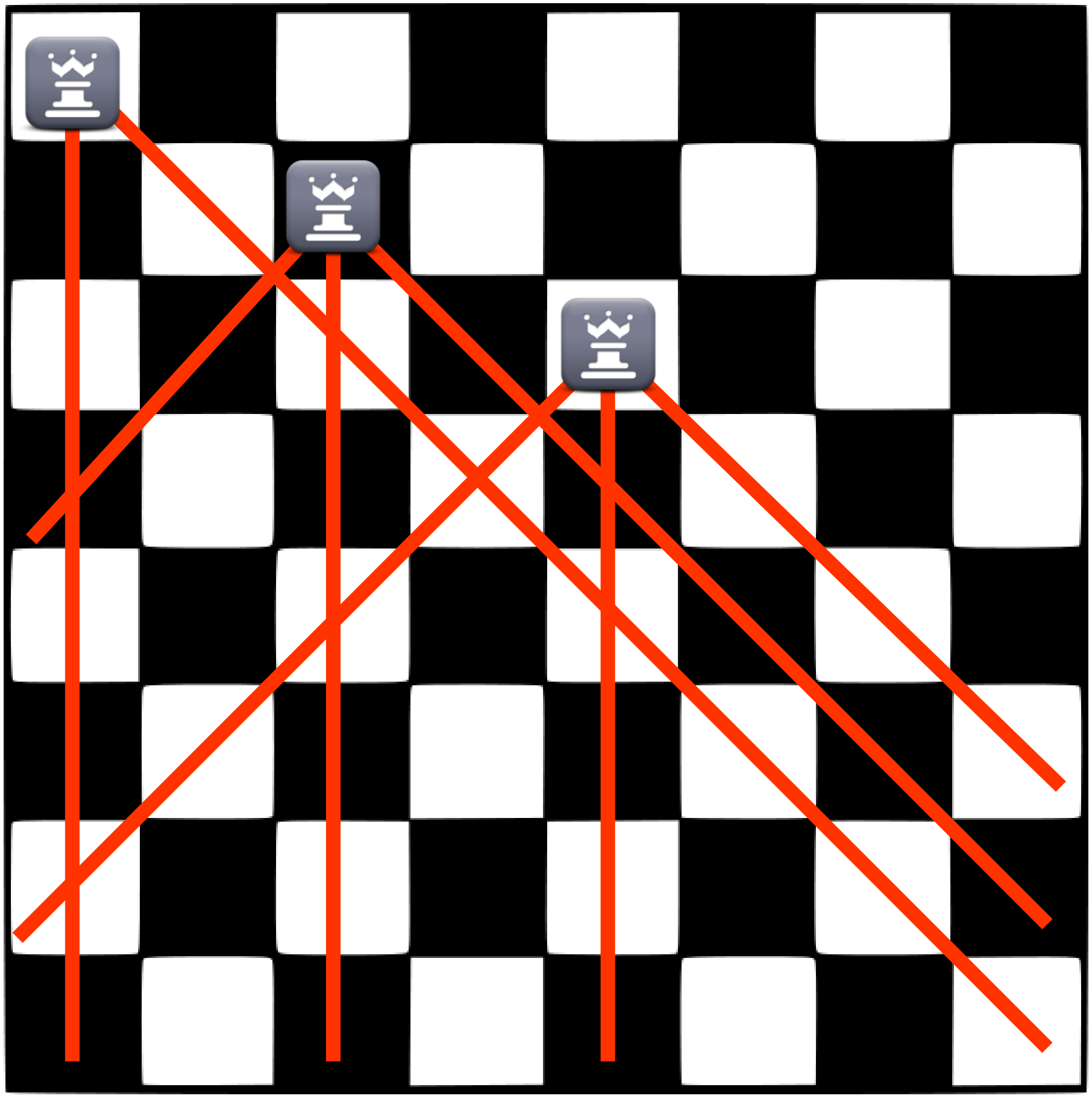


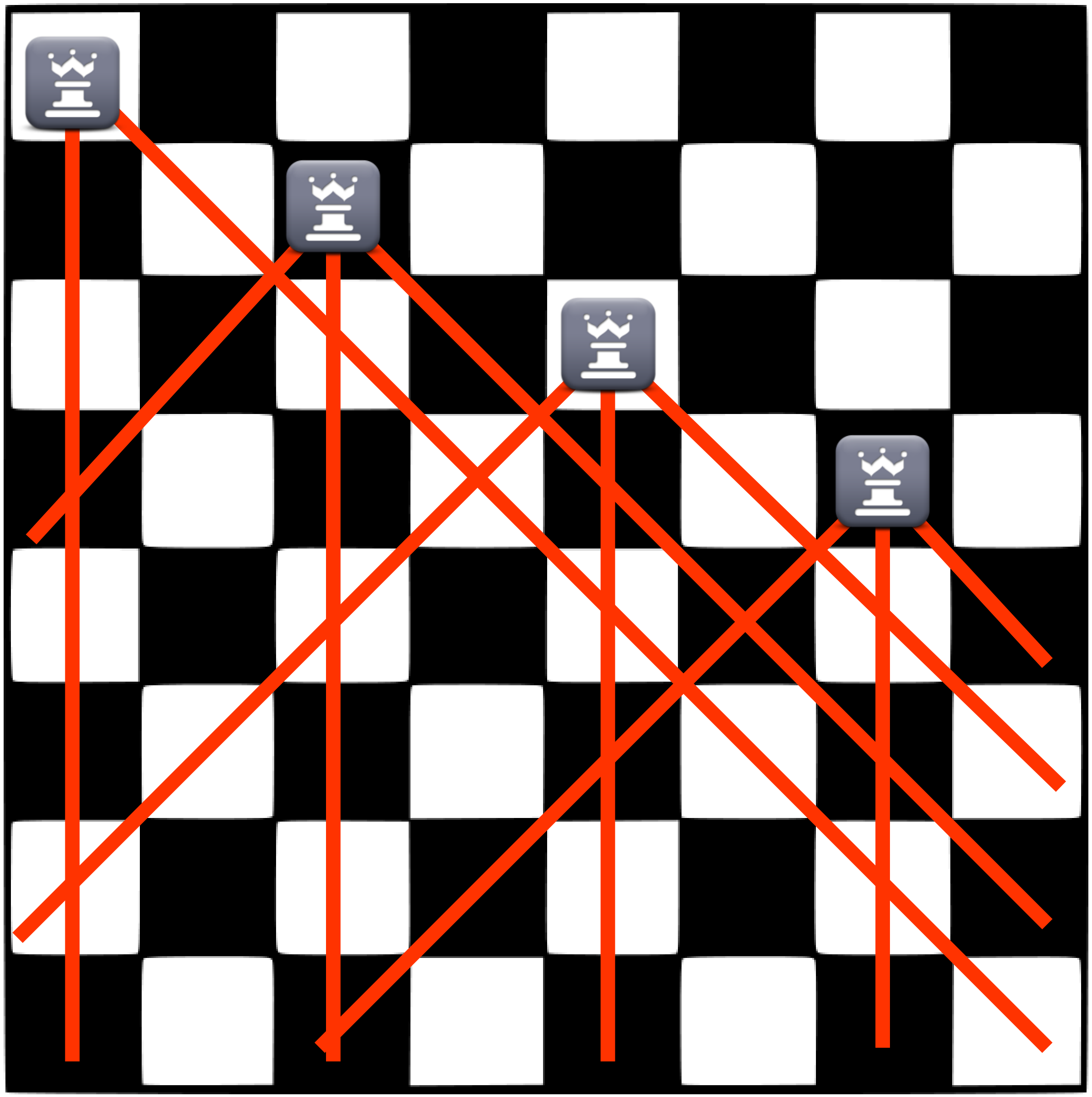


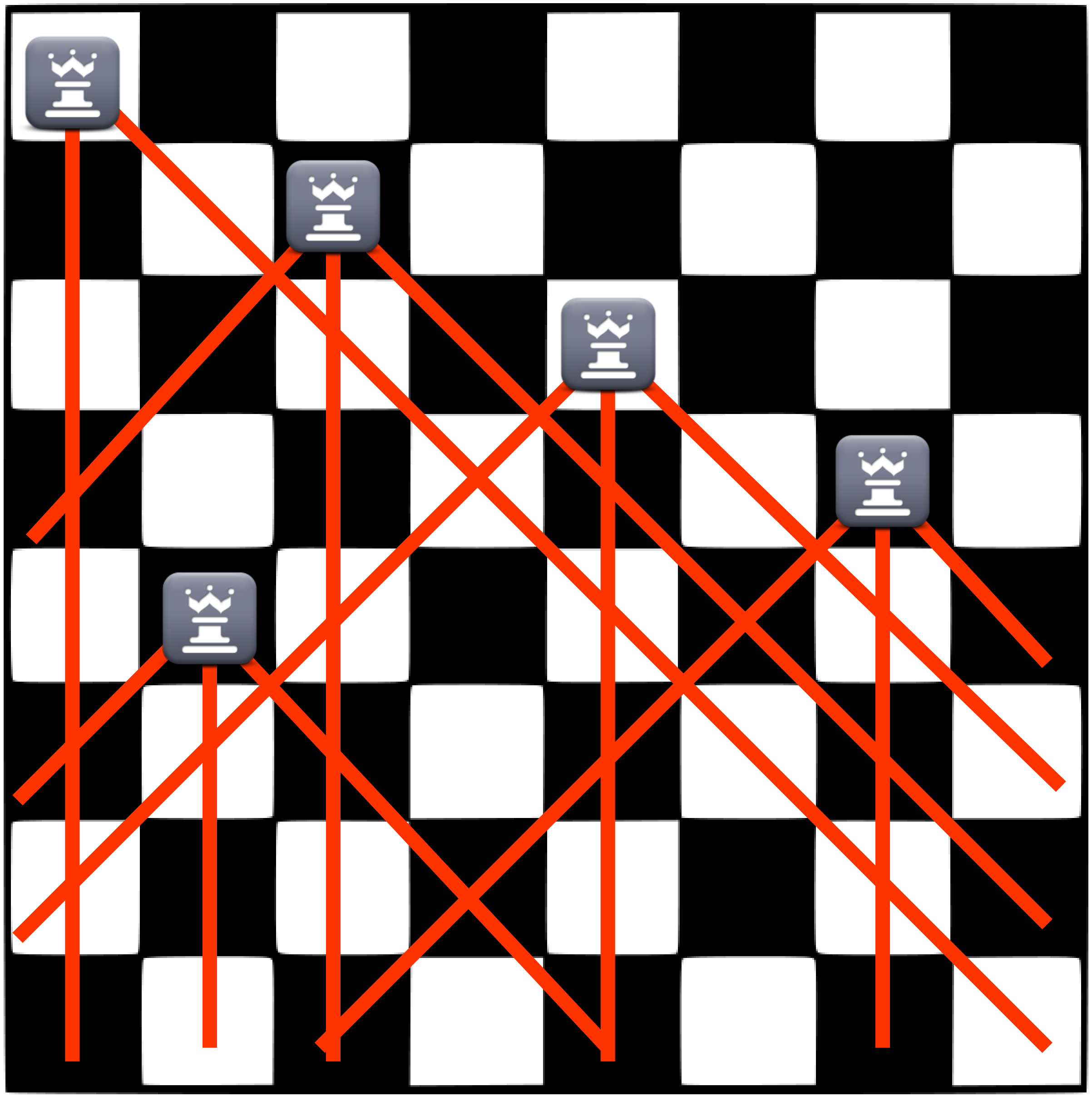


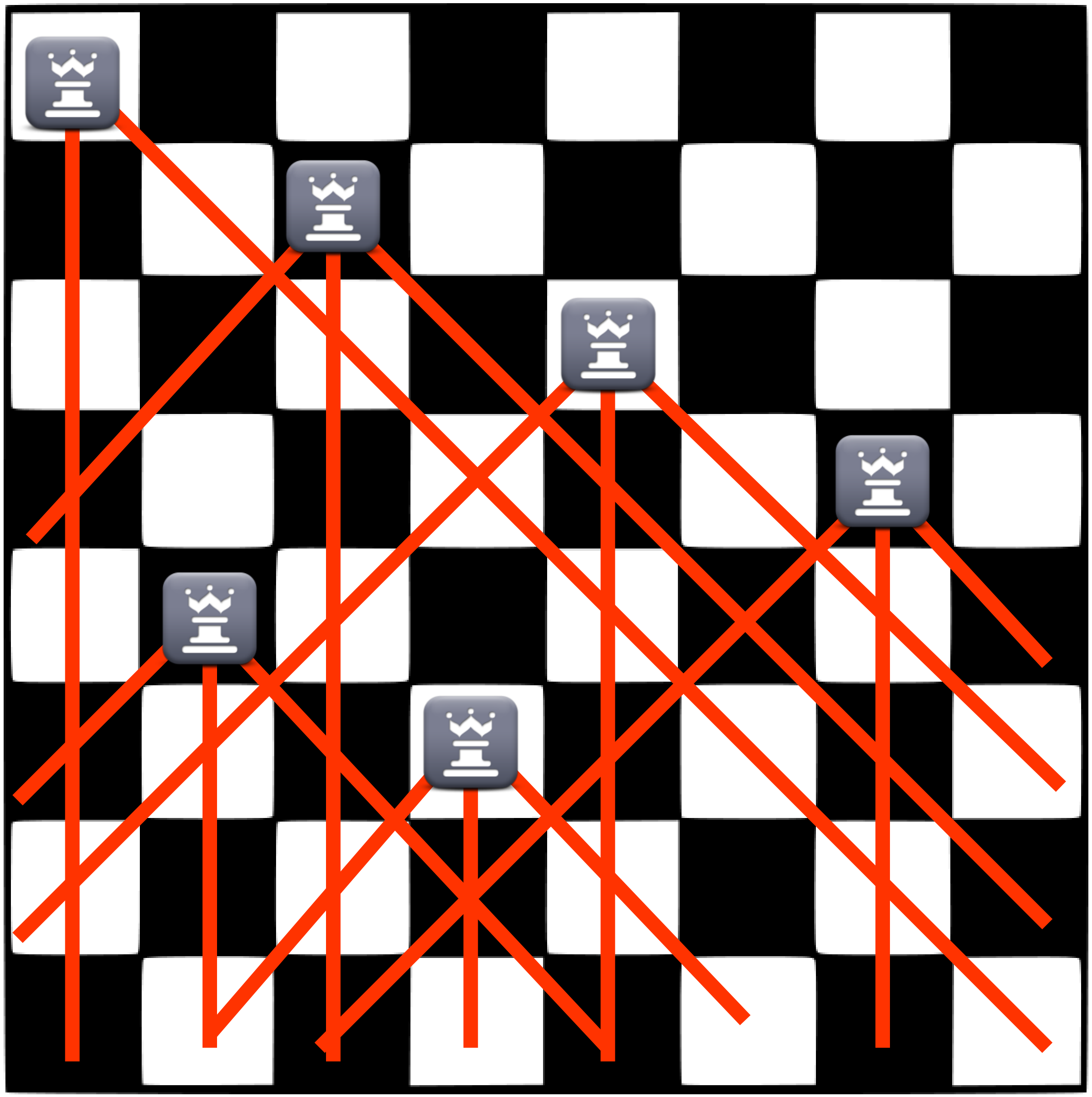


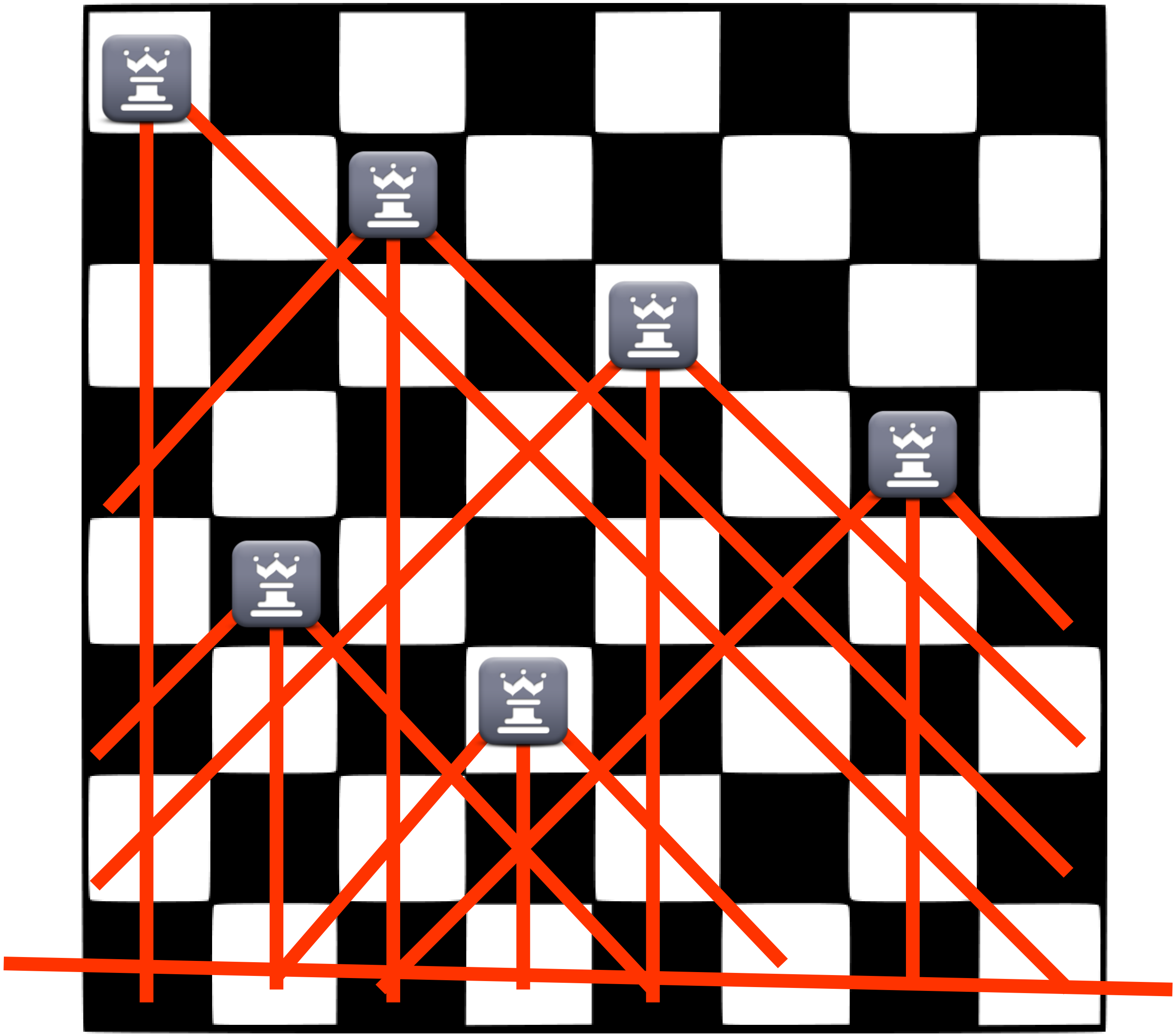












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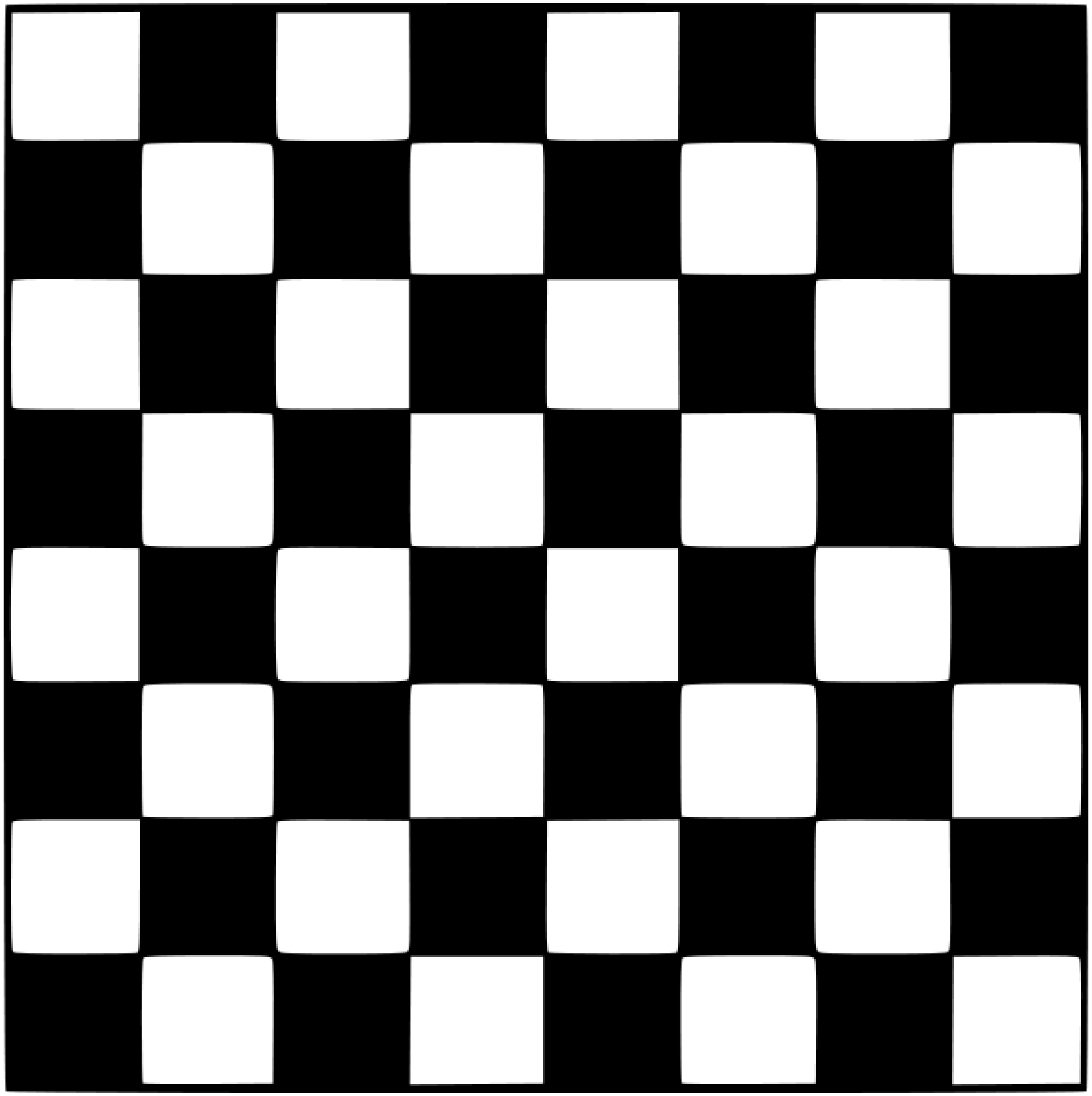
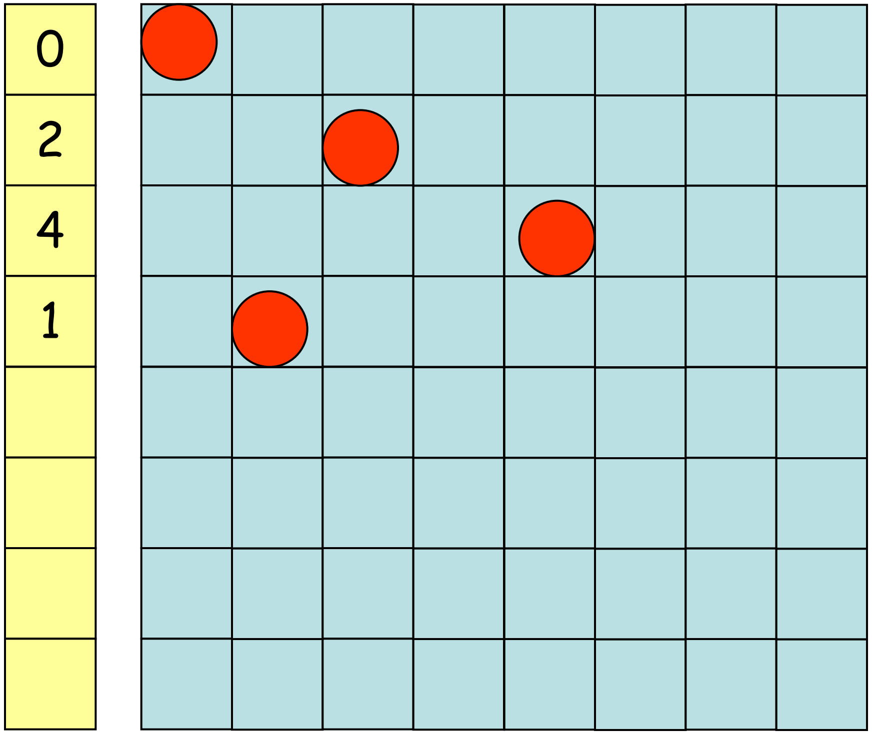
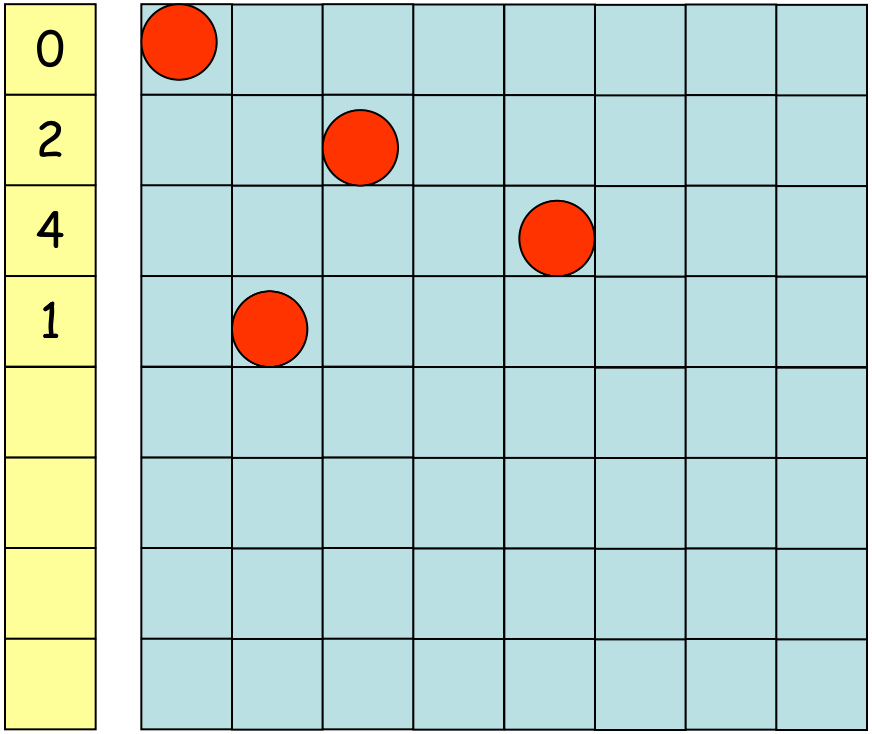




Representation/model
8 constrained integer variables
Domains [0..7]
A variable represents a row
v[i] = j ↔ queen on row i, column j



Representation/model

Constraints

no column attacks

$v[i] \neq v[j]$ for all $i \neq j$

no diagonal attacks

$|v[i] - v[j]| \neq |i - j|$

emacs@BYRON

File Edit Options Buffers Tools Java Help

NQueens0

```java
import java.io.*;
import java.util.*;
import org.chocosolver.solver.Model;
import org.chocosolver.solver.Solver;
import org.chocosolver.solver.variables.IntVar;
import org.chocosolver.solver.constraints.IIntConstraintFactory.*;

public class NQueens0 {

    public static void main(String[] args) {

        int n           = Integer.parseInt(args[0]);
        Model model     = new Model("nqueens");
        Solver solver = model.getSolver();
        IntVar[] q      = model.intVarArray("queen",n,0,n-1);

        //
        // columns constraint
        //
        for (int i=0;i<n-1;i++)
            for (int j=i+1;j<n;j++)
                model.arithm(q[i],"!=",q[j]).post();

        //
        // diagonal constraint
        //
        for (int i=0;i<n-1;i++)
            for (int j=i+1;j<n;j++)
                model.distance(q[i],q[j],"!=",Math.abs(i-j)).post();

        boolean solved = solver.solve();

        if (solved){
```

-\--- NQueens0.java 8% L38 (Java/l Abbrev)

NQueens0

```java
import java.io.*;
import java.util.*;
import org.chocosolver.solver.Model;
import org.chocosolver.solver.Solver;
import org.chocosolver.solver.variables.IntVar;
import org.chocosolver.solver.constraints.IIntConstraintFactory.*;
```

NQueens0

```
int n          = Integer.parseInt(args[0]);
Model model    = new Model("nqueens");
Solver solver  = model.getSolver();
IntVar[] q     = model.intVarArray("queen",n,0,n-1);
```

NQueens0

```
//
// columns constraint
//
for (int i=0;i<n-1;i++)
    for (int j=i+1;j<n;j++)
        model.arithm(q[i],"!=",q[j]).post();
```

NQueens0

```
//
// diagonal constraint
//
for (int i=0;i<n-1;i++)
    for (int j=i+1;j<n;j++)
        model.distance(q[i],q[j],"!=",Math.abs(i-j)).post();
```

NQueens0

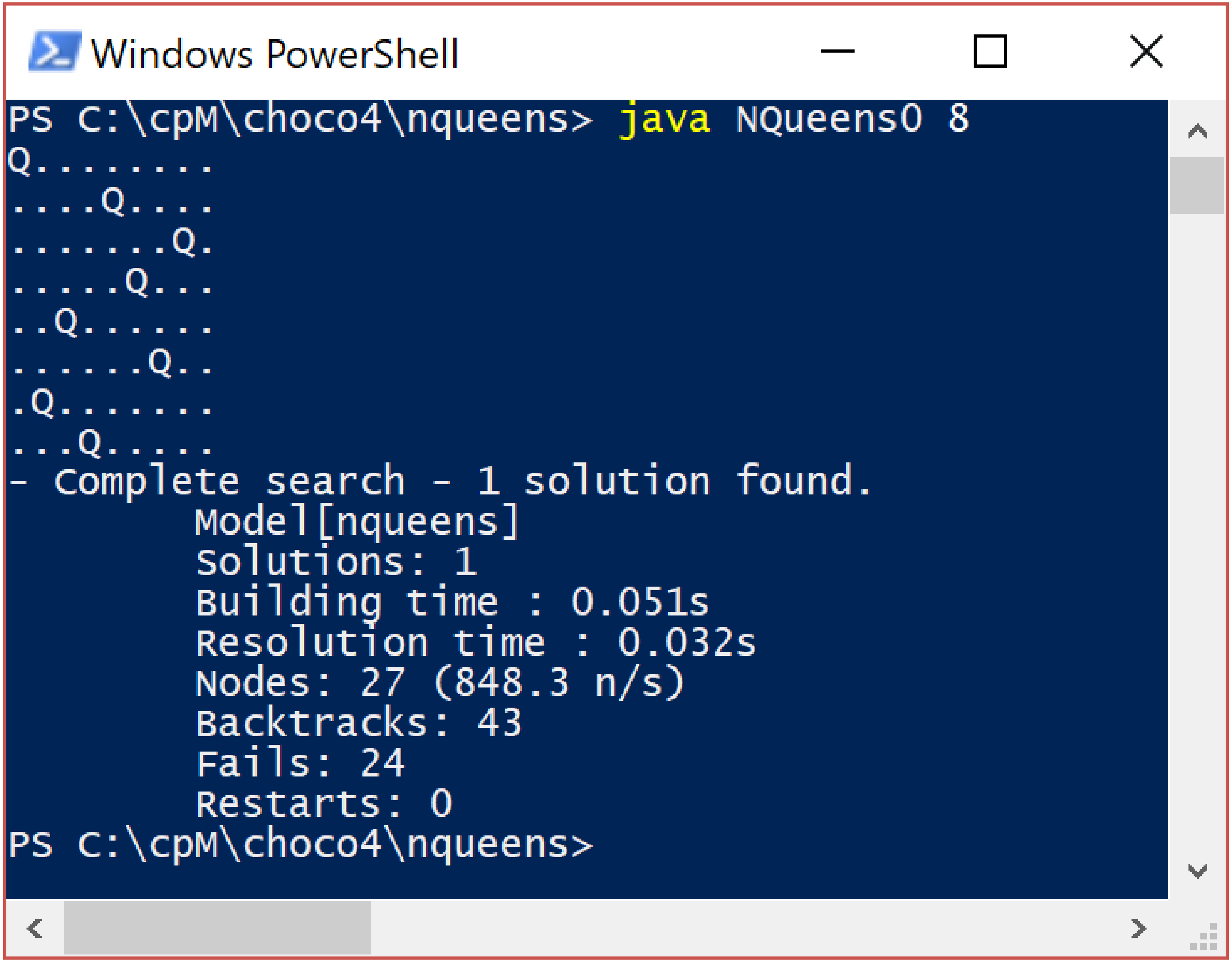
```java
solver.setSearch(Search.inputOrderLBSearch(q)); // simplest
boolean solved = solver.solve();
```

NQueens0

```
if (solved){
     for (int i=0;i<n;i++){
          for (int j=0;j<q[i].getValue();j++) System.out.print(".");
          System.out.print("Q");
          for (int j=q[i].getValue();j<n;j++) System.out.print(".");
          System.out.println();
     }
}
System.out.println(solver.getMeasures());
```

Windows PowerShell

```
PS C:\cpM\choco4\nqueens> java NQueens0 4
.Q..
...Q.
Q....
..Q..
- Complete search - 1 solution found.
        Model[nqueens]
        Solutions: 1
        Building time : 0.050s
        Resolution time : 0.030s
        Nodes: 4 (131.3 n/s)
        Backtracks: 3
        Fails: 2
        Restarts: 0
PS C:\cpM\choco4\nqueens> _
```


Windows PowerShell
PS C:\cpM\choco4\nqueens> java NQueens0 8
Q.......
....Q...
.......Q.
.....Q..
..Q.....
......Q..
.Q......
...Q....
- Complete search - 1 solution found.
Model[nqueens]
Solutions: 1
Building time : 0.051s
Resolution time : 0.032s
Nodes: 27 (848.3 n/s)
Backtracks: 43
Fails: 24
Restarts: 0
PS C:\cpM\choco4\nqueens>

Windows PowerShell

```
PS C:\cpM\choco4\nqueens> java NQueens0 20
Q...................
..Q.................
....Q...............
.Q..................
...Q................
............Q.......
..............Q.....
...........Q........
.................Q..
...................Q
................Q...
........Q...........
...............Q....
..................Q.
.......Q............
.........Q..........
......Q.............
.............Q......
.....Q..............
..........Q.........
- Complete search - 1 solution found.
        Model[nqueens]
        Solutions: 1
        Building time : 0.057s
        Resolution time : 0.881s
        Nodes: 37,331 (42,351.6 n/s)
        Backtracks: 74,624
        Fails: 37,320
        Restarts: 0
PS C:\cpM\choco4\nqueens>
```

NQueens1

```
solver.setSearch(Search.minDomLBSearch(q)); // fail-first
boolean solved = solver.solve();
```

NQueens1

```
PS C:\cpM\choco4\nqueens> java NQueens1 20
Q...................
..Q.................
....Q...............
.............Q......
................Q...
...Q................
...............Q....
......Q.............
...........Q........
.................Q..
..............Q.....
..................Q.
.....Q..............
.........Q..........
...................Q
..........Q.........
.......Q............
.Q..................
............Q.......
........Q...........
- Complete search - 1 solution found.
        Model[nqueens]
        Solutions: 1
        Building time : 0.053s
        Resolution time : 0.075s
        Nodes: 44 (582.8 n/s)
        Backtracks: 60
        Fails: 33
        Restarts: 0
PS C:\cpM\choco4\nqueens> t
```

NQueens3

```
int solutions = 0;
while (solver.solve()) solutions++;

System.out.println("solutions: "+ solutions);
System.out.println(solver.getMeasures());
```

NQueens3

Windows PowerShell

```
PS C:\cpM\choco4\nqueens> java NQueens3 8
solutions: 92
- Complete search - 92 solution(s) found.
        Model[nqueens]
        Solutions: 92
        Building time : 0.057s
        Resolution time : 0.089s
        Nodes: 455 (5,096.8 n/s)
        Backtracks: 727
        Fails: 272
        Restarts: 0
PS C:\cpM\choco4\nqueens> java NQueens3 12
solutions: 14200
- Complete search - 14,200 solution(s) found.
        Model[nqueens]
        Solutions: 14,200
        Building time : 0.058s
        Resolution time : 2.017s
        Nodes: 116,973 (58,003.8 n/s)
        Backtracks: 205,547
        Fails: 88,574
        Restarts: 0
PS C:\cpM\choco4\nqueens> t
```

Version 3.2 (2-core)

N:	Total	Unique	days hh:mm:ss.--
5:	10	2	0.00
6:	4	1	0.00
7:	40	6	0.00
8:	92	12	0.00
9:	352	46	0.00
10:	724	92	0.00
11:	2680	341	0.00
12:	14200	1787	0.00
13:	73712	9233	0.02
14:	365596	45752	0.05
15:	2279184	285053	0.22
16:	14772512	1846955	1.47
17:	95815104	11977939	9.42
18:	666090624	83263591	1:11.21
19:	4968057848	621012754	8:32.54
20:	39029188884	4878666808	1:10:55.48
21:	314666222712	39333324973	9:24:40.50

<------ N-Queens Solutions -----> <---- time ---->

AMD Athlon(tm) Dual Core Processor 5050e 2.60 GHz
Microsoft Visual C++ 2008 Express Edition with SP1
Windows SDK for Windows Server 2008 and .NET

```
//
// columns constraint ... allDiff!
//
model.allDifferent(q).post();
```

```
//
// columns constraint ... allDiff!
//
model.allDifferent(q).post();
```

NQueens 1

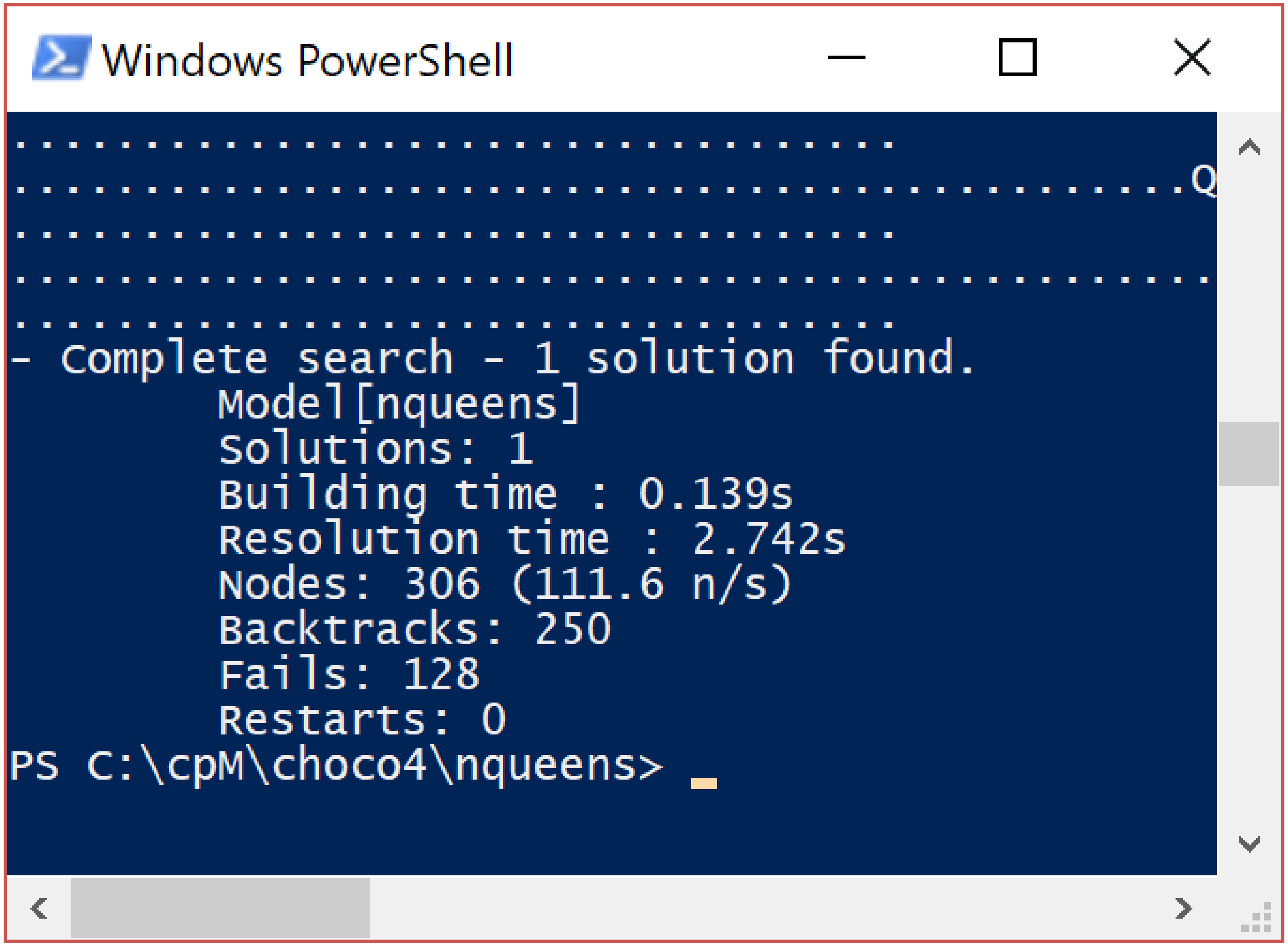
N = 200

Windows PowerShell

```
...................................Q..........
..................................
.............................................Q
..................................
..............................................
..................................
- Complete search - 1 solution found.
        Model[nqueens]
        Solutions: 1
        Building time : 0.174s
        Resolution time : 56.920s
        Nodes: 147,014 (2,582.8 n/s)
        Backtracks: 293,662
        Fails: 146,838
        Restarts: 0
PS C:\cpM\choco4\nqueens>
```

NQueens 2

N = 200



Harder questions

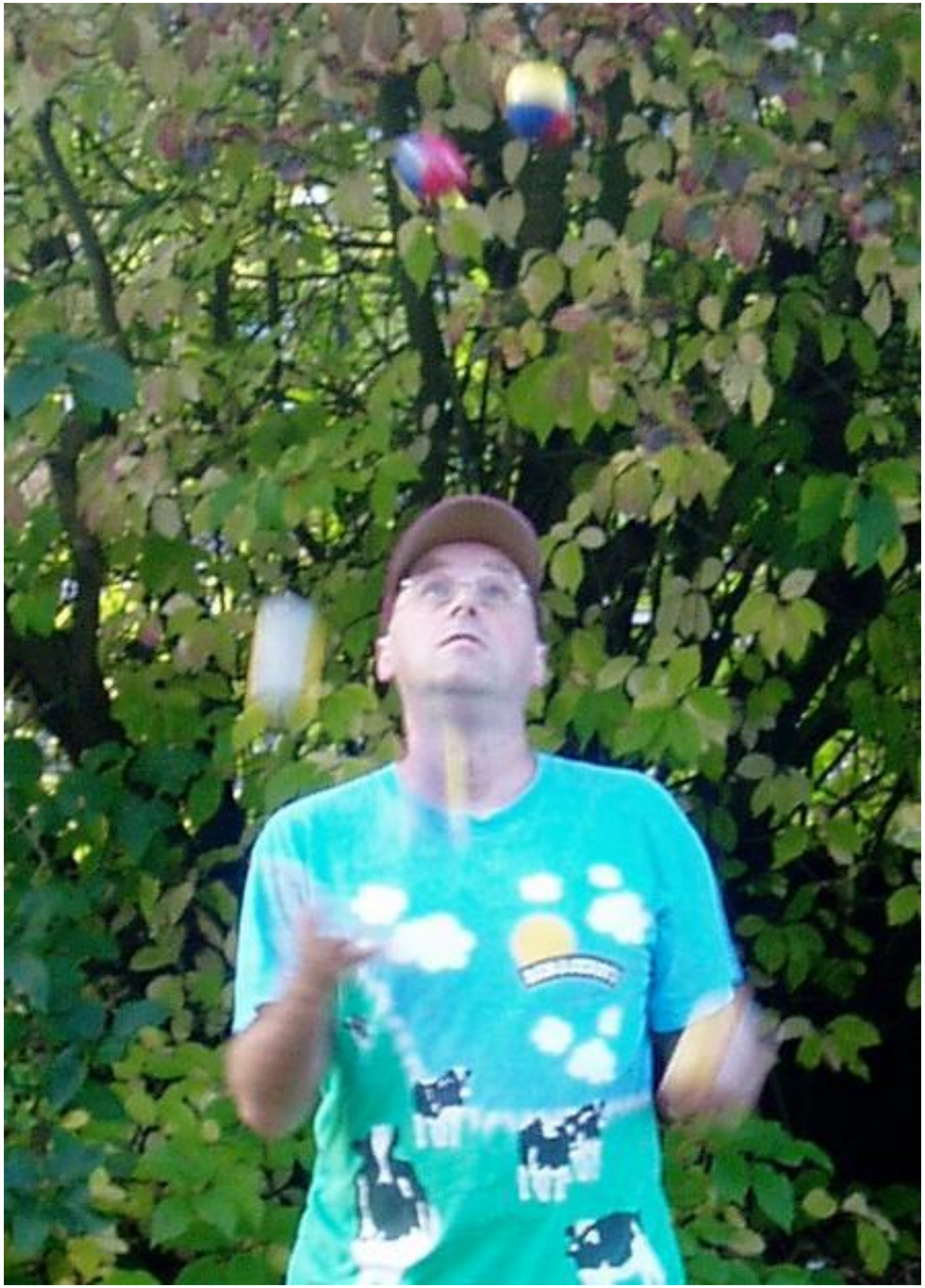
Could we have a different representation?

Could we solve it a different way (other than systematic search) ?

Does the problem get harder or easier as it gets larger?

What happens if we start with some queens already on the board?

Could we view nqueens differently, maybe as a permutation problem?



stop