

Abstract. This is the abstract. TBD.

Keywords: A* · Genetic algorithms · N-queens problem · Heuristic Search.

1 Introduction

In this paper a research will be conducted in order to solve the N-queens search problem using two different approaches. This strategies consist of the use of the A* algorithm and the genetic algorithms.

First, the N-queens problem will be defined. After that, the A* algorithm and its application to this concrete problem will be explained. The same structure will be later applied to the genetic algorithms. Finally, an experimental study will be carried out in order to check the efectiveness of both approaches and the conclusions of the paper will be layed out.

2 N-queens Problem

Introduced in 1848 by chess composer Max Bezzel as the *eight queens puzzle*, it was later solved and extended by Franz Nauck to the *n queens problem*. It is a very well known constraint satisfaction problem, and consists in setting N chess queens in a gameboard of NxN dimensions such as no pair of queens are attacking themselves. In chess, queens can attack other pieces if they are in the same row, column or diagonal as them.

3 A* algorithm

The A* algorithm is an informed search algorithm. Its also an specialization of the BF (Best First) algorithm with a different evaluation function. Before expressing this evaluation function, some concepts must be introduced: $f^*(n) = g^*(n) + h^*(n)$

- $g^*(n)$ is the lowest path cost between the initial node and n .
- $h^*(n)$ is the lowest path cost between n to the nearest target node.
- $f^*(n)$ is the lowest path cost between the initial node to the target node passing through node n .
- $C^* = f^*(initial) = h^*(initial)$ is the cost of the optimal solution.

Once those concepts have been introduced, the A* evaluation function can be defined by: $f(n) = g(n) + h(n)$

- $g(n)$ is the best lowest path cost between the initial node and n obtained during the search until that moment.
- $h(n)$ is a positive estimation of $h^*(n)$, such as $h(n) = 0$ if n is a target node.
- $f(n)$ is an estimation of $f^*(n)$

A* has the following formal properties:

- **Admissibility:** a search algorithm is said to be admissible if it always finds the optimal solution. This means that the heuristic function h must be a positive estimation of the value of $h^*(n)$ for all nodes, that is, $h(n) \leq h^*(n) \forall n$.
- **Dominance:** if $h2$ is better informed than $h1$, then every node expanded by $A^*(h2)$ is expanded by $A^*(h1)$. This means that $A^*(h2)$ dominates $A^*(h1)$. For an heuristic function $h1$ to be better informed than another one $h2$ the following must be true: $h1(n) < h2(n) \leq h^*(n)$ for every n non final.
- **Monotony:** an heuristic function $h1$ is monotonous if for every pair of nodes $n1$ and $n2$ it is true that $h(n1) \leq h(n2) + c(n1, n2)$ being c the cost of going from $n1$ to $n2$.

4 Genetic algorithms

Genetic algorithms are metaheuristic search and optimization algorithms and a class of evolutionary algorithms based on the model of natural biological evolution depicted by Charles Darwin in his book *On the Origin of Species*. They perform the evolution of a population, selecting the fittest individuals to become the parents of the next generation. The next generation will be reproduced using crossover and mutation operators.

A genetic algorithm has the following components:

- A **codification scheme**. The genetic algorithm needs some kind of codification in order to represent potential solutions. It can be a chain of binary digits, permutations, vectors, etc.
- A **fitness function**. This function is used to evaluate each individual and assign to them a value used for their selection as potential parents for the next generation. The fitness value is the non-negative value representing the performance of a given individual.
- A way of **generating the initial population**. This method of creating initial populations can be done by the use of an heuristic function or, in the simplest case, making a random population disregarding their level of quality.
- A set of **genetic operators**.
 - **Selection:** operator that chooses a set of individuals from the current generation to be the parents for the next generation.
 - **Crossover:** operator that combines two or more parents to obtain offsprings that most likely will inherit characteristics from their parents.
 - **Mutation:** operator that makes minor random changes in the genetic structure of a chromosome in order to obtain a new range of genetic material.
- Some **parameters**. Like the population size, number of generations, crossover probability, mutation probability, etc.

5 Application of A* algorithm to the N-queens problem

Two ways of modeling the search space have been defined for this problem:

- **Incremental:** in this version, the initial state is the empty gameboard and in each iteration a new queen is placed in a position such as it is not attacking or being attacked by any other queen in the board. This keeps going until the N queens are placed or until there are no locations in the board where the queen can be placed without breaking the constraints.
- **Complete:** in this version, the initial state is a board where the N queens are already placed. However, the queens can be in locations where they are attacking one another. In each iteration a queen is moved to a different position until a state where no pair of queens are attacking themselves is reached. There are two variants:
 - **Queens in first row:** in this variant the n queens are placed in the first row of the board.
 - **Queens in every column:** in this variant the n queens are placed in random positions of the board, so different executions can lead to different results.

Three heuristic functions were implemented for solving the problem:

- **Null heuristic:** heuristic function that always return zero. It is an admissible heuristic.
- **Number of attacking pairs:** heuristic function that estimates de number of necessary movements in order to achieve a solution by means of analysing the number of attacking pairs in a board where there are already N queens placed. It is an admissible and a monotonous heuristic.
- **Probabilistic estimation of solution:** heuristic function that estimates the probability of finding a solution from any given state. It is an admissible heuristic.

6 Applications of genetic algorithms to the N-queens problem

The genetic algorithm implemented for solving the N-queens problem has the following characteristics:

- **Codification scheme:** a chain of permutations that contains the rows in which the queens are located.
- **Fitness function:** implements fitness scaling, that is, to further differentiate the good chromosomes from the bad ones. The way it is done is by subtracting from the fitness value of all individuals the fitness value of the worst in that generation.
- **Generating the initial population:** a chromosome is a random permutation of the numbers ranged from one to the size of the board such as no number is repeated.
- A set of **genetic operators**.
 - **Selection:** introduces elitism, that is, the best individual of that generation is carried over the next generation.

- **Crossover:** implements the OX (Order crossover) operator. This method of crossover implies that the offspring will inherit the order and position of some of the genes of a parent and the relative order of the remaining genes of the other parent.
- **Mutation:** swaps the content of two random positions of the permutation.
- **Parameters:** *Population size* = 50, *mutation probability* = 0.15, *number of generations* = 100.

7 Experimental Research

Experimental Research.

7.1 Dataset

Dataset

7.2 A* Results

A* Results.

7.3 GA Results

Genetic Algorithm Results.

7.4 Comparison of A* and GA results

Comparison of A* and GA results.

8 Conclusions

Conclusions.

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