Hidato Puzzles

A Genetic Algorithm for Solving Beehive Hidato Puzzles

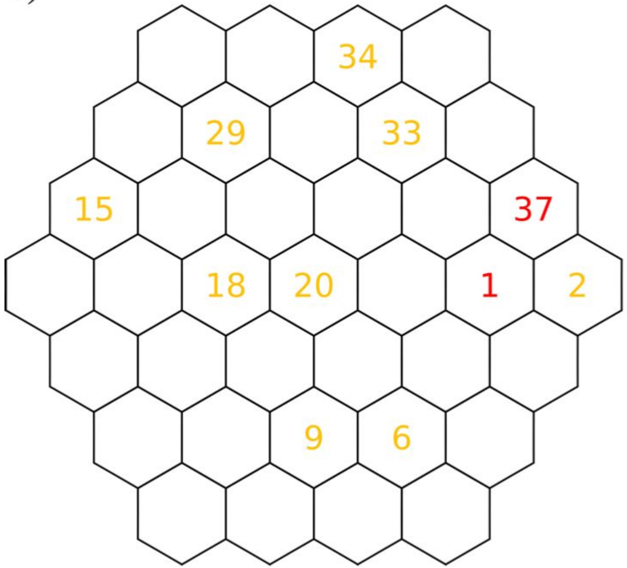
Presented by:
Iman Parhizkari
Aref Moqadam Mehr

Fall 2019
Shahid Beheshti University

Introduction

- Hidato Puzzle
- Proposed GA
  - Diversity Preservation
  - Convergence Based Gene Insertion (CBGI) Strategy
- Results

a)



Hidato Gameplay

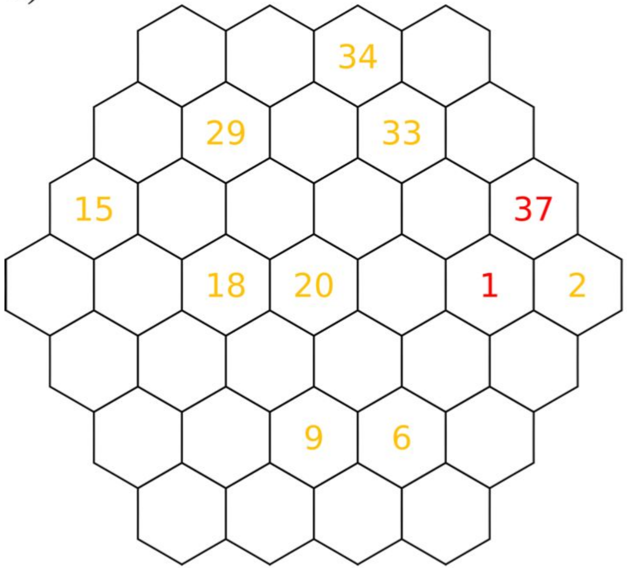
- Initially there is a grid of hexagons with some prefilled fixed numbers.
- The aim is to fill the empty hexagons with consecutive numbers from 1 to the largest number in the grid
- In other words, 1 must be adjacent to 2, 2 must be adjacent to 3 and so on, generating a continuous path.

Every Hidato puzzle has a unique solution!

Beehive Hidato Rules

- Rule 1: Each hexagonal cell of the grid must be filled with a natural number ranging from 1 to n;
- Rule 2: Each number, ranging from 1 to n, is only in one hexagonal cell (i.e., number repetition is not allowed on grid)
- Rule 3: Prefilled numbers are not allowed to change.

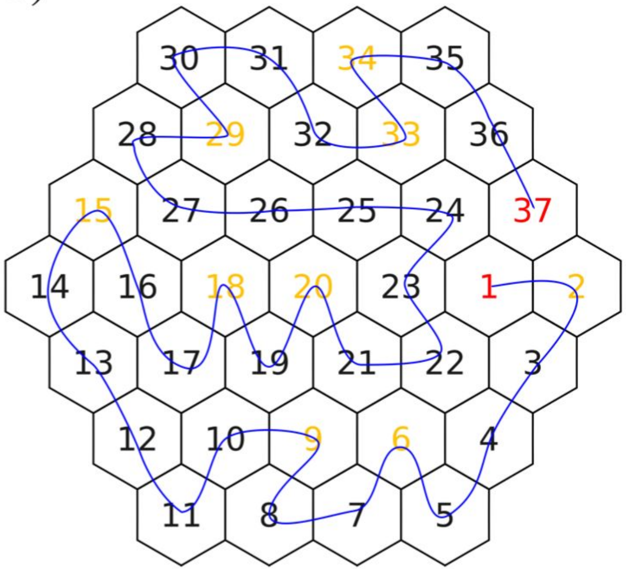
a)



Beehive Hidato Rules

- Rule 1: Each hexagonal cell of the grid must be filled with a natural number ranging from 1 to n;
- Rule 2: Each number, ranging from 1 to n, is only in one hexagonal cell (i.e., number repetition is not allowed on grid)
- Rule 3: Prefilled numbers are not allowed to change.

b)



The Proposed Genetic Algorithm

- Initiates generating a random initial population of candidate Beehive Hidato solutions.
- Uses common genetic operators and the RTS niching technique to preserve population diversity.
- A new strategy based on gene convergence rate.
- The population evolves until the maximum number of fitness function evaluations (FEs) allowed or until the global optimum is found.

Representation

- Solution is represented by a permutation of integers of 1 to n, where n is the total number of genes on a given chromosome (e.g.: {1, 5, 3, 2, 4}).
- Always starting from the top left to the bottom right hexagonal cell of the grid.
- Fixed prefilled numbers of Hidato are not included in the chromosome.
- Arranging only the non fixed numbers of the problem.
- Are considered only in order to complete the solution in the fitness evaluations.

Fitness Function

- For each hexagonal cell of the Beehive Hidato, we sum one point to each following number (successor or predecessor) that is connected to it in an adjacent hexagonal cell.
- For a Beehive Hidato of size N, the fitness of the optimum solution is equals:

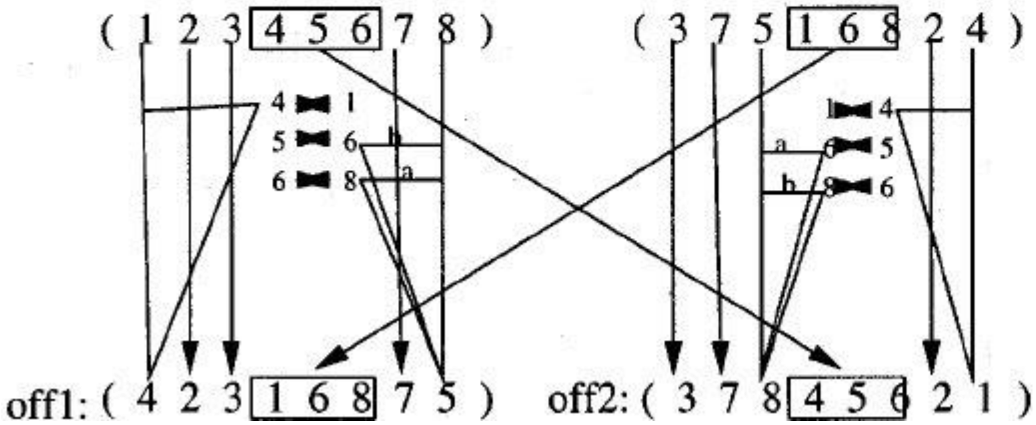
$$FOpt = (N*2) - 2$$

Diversity Preservation and Restricted Tournament Selection

- To avoid premature convergence to local optimum.
- In this scheme, parents are randomly selected and a newly generated individual is inserted in the population replacing the most similar among w randomly selected individuals if it is better than the most similar one.
- The distance between two solutions for the Beehive Hidato problem was defined here as the number of hexagonal cells with distinct values.
- the w parameter was dynamically set to linearly decay from 100% of the population to 10%.

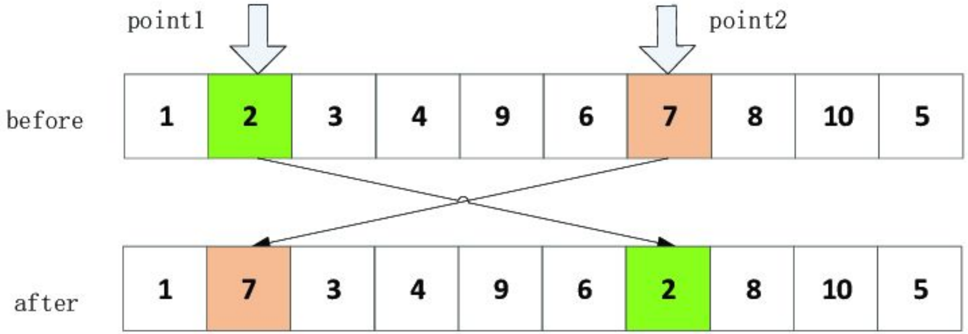
Genetic Operators

Partially Mapped Crossover (PMX):



Genetic Operators

Swap Mutation:



Crossover probability was set to 90%, and mutation probability was set to 10%.

Convergence Based Gene Insertion - (CBGI)

- after a elapsed evolution time S (a percentage of the total evolution time, calculated on the maximum number of tness function evaluations), for each gene of the current best individual, the algorithm evaluates the number of occurrences of its gene value, in the same position, for all individuals in the population.
- Then, this quantity is divided by the population size, to get its rate. The gene with the highest convergence rate (above of a parameter c) is then selected to be inserted in the Beehive Hidato problem as a fixed number, in its corresponding position.

Results

- Problems 1 to 10   have 19 hexagons (class 1 problems)
- Problems 11 to 21 have 37 hexagons (class 2 problems)
- All experiments have:
  - Population size of 250 individuals
  - A maximum of 2.0E + 05 fitness function evaluations.

Results

Table 1. Beehive Hidato class 1 problems without the CBGI strategy

problem	best fit.	avg. best fit.	st. dev.	avg. FEs	st. dev.	SR
1	36	36.00	0.00	6728.07	1600.58	1.00
2	36	36.00	0.00	4626.67	1012.95	1.00
3	36	36.00	0.00	8990.13	2583.16	1.00
4	36	36.00	0.00	19549.20	13161.44	1.00
5	36	36.00	0.00	4898.13	1300.68	1.00
6	36	36.00	0.00	8771.80	2126.81	1.00
7	36	36.00	0.00	6284.13	1842.03	1.00
8	36	36.00	0.00	8004.20	1927.22	1.00
9	36	36.00	0.00	7841.07	2492.01	1.00
10	36	36.00	0.00	4458.73	1679.17	1.00
average:	36	36.0	0.0	8015.21	2972.61	1.00

Table 3. Beehive Hidato class 1 problems with the CBGI strategy

problem	best fit.	avg. best fit.	st. dev.	avg. FEs	st. dev.	SR
1	36	36.00	0.00	6914.60	1637.27	1.00
2	36	36.00	0.00	4368.67	1202.92	1.00
3	36	36.00	0.00	8176.93	2898.01	1.00
4	36	36.00	0.00	16811.07	10453.98	1.00
5	36	36.00	0.00	4754.73	1461.79	1.00
6	36	36.00	0.00	9156.93	2757.87	1.00
7	36	36.00	0.00	6343.33	1550.25	1.00
8	36	36.00	0.00	7018.67	2281.46	1.00
9	36	36.00	0.00	7864.73	2388.08	1.00
10	36	36.00	0.00	4396.40	1355.34	1.00
average	36	36.0	0.0	7580.6	2798.7	1.00

Results

Table 2. Beehive Hidato class 2 problems without the CBGI strategy

problem	best fit.	avg. best fit.	st. dev.	avg. FEs	st. dev.	SR
11	72	71.60	0.81	78498.20	23461.47	0.80
12	72	70.60	1.83	94339.00	39673.09	0.60
13	72	72.00	0.00	48389.20	6871.02	1.00
14	72	69.80	1.32	93993.13	31468.55	0.17
15	72	68.53	1.66	134916.33	28188.26	0.03
16	72	68.67	1.69	140021.33	28992.19	0.03
17	72	70.80	1.24	102235.80	30075.19	0.47
18	72	70.13	0.51	84031.67	18814.75	0.07
19	72	67.33	2.06	150680.13	28936.90	0.03
20	72	71.93	0.37	46169.40	9177.76	0.97
21	72	71.47	1.04	78580.47	15773.78	0.77
average:	72	70.26	1.14	95623.15	23766.63	0.45

Table 4. Beehive Hidato class 2 problems with the CBGI strategy

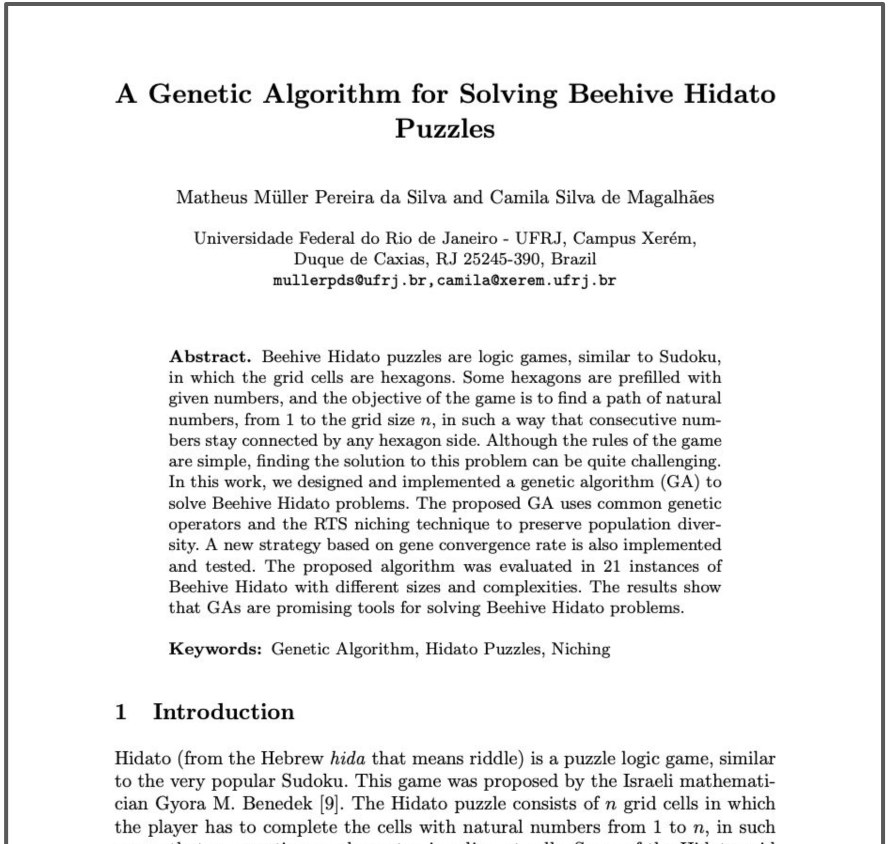
problem	best fit.	avg. best fit.	st. dev.	avg. FEs	st. dev.	SR
11	72	71.93	0.37	78173.47	23525.59	0.97
12	72	70.13	2.03	84586.60	21264.76	0.53
13	72	71.93	0.37	47842.33	5929.11	0.97
14	72	70.00	1.49	96046.20	32206.56	0.27
15	72	69.07	1.55	145073.33	33799.58	0.07
16	72	69.27	1.23	124719.00	19956.63	0.03
17	72	70.80	1.13	87628.47	13251.76	0.43
18	72	70.27	0.69	80048.73	15193.18	0.13
19	72	68.53	2.16	138049.33	24089.08	0.13
20	72	71.47	0.90	44107.53	9508.78	0.73
21	72	71.60	0.97	74137.13	13698.76	0.83
average:	72	70.45	1.17	90946.56	19311.25	0.46

Conclusion

- This is the first work to address this problem.
- The proposed algorithm uses GA and the RTS niching technique.
- A new strategy based on gene rate convergence (CBGI) is also proposed and tested in an attempt to improve the GA search.
  - a higher success rate for more challenging cases
  - a higher convergence speed

Reference

- Da Silva, Matheus MP, and Camila S. De Magalhes. "A genetic algorithm for solving beehive hidato puzzles." *XIII Brazilian Congress on Computational Intelligence*. 2017.



A Genetic Algorithm for Solving Beehive Hidato Puzzles

Matheus Müller Pereira da Silva and Camila Silva de Magalhães

Universidade Federal do Rio de Janeiro - UFRJ, Campus Xerém,
Duque de Caxias, RJ 25245-390, Brazil
mullerpds@ufrj.br,camila@xerem.ufrj.br

Abstract. Beehive Hidato puzzles are logic games, similar to Sudoku, in which the grid cells are hexagons. Some hexagons are prefilled with given numbers, and the objective of the game is to find a path of natural numbers, from 1 to the grid size n, in such a way that consecutive numbers stay connected by any hexagon side. Although the rules of the game are simple, finding the solution to this problem can be quite challenging. In this work, we designed and implemented a genetic algorithm (GA) to solve Beehive Hidato problems. The proposed GA uses common genetic operators and the RTS niching technique to preserve population diversity. A new strategy based on gene convergence rate is also implemented and tested. The proposed algorithm was evaluated in 21 instances of Beehive Hidato with different sizes and complexities. The results show that GAs are promising tools for solving Beehive Hidato problems.

Keywords: Genetic Algorithm, Hidato Puzzles, Niching

1 Introduction

Hidato (from the Hebrew *hida* that means riddle) is a puzzle logic game, similar to the very popular Sudoku. This game was proposed by the Israeli mathematician Gyora M. Benedek [9]. The Hidato puzzle consists of n grid cells in which the player has to complete the cells with natural numbers from 1 to n, in such

Thanks!