Light Up Puzzle Evolutionary Algorithm Sampler

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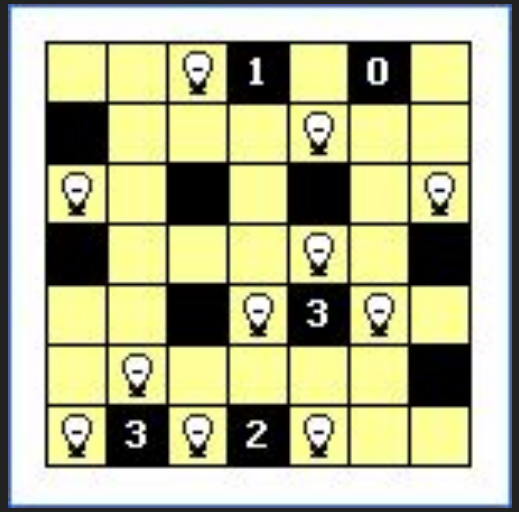
Light Up Puzzles?



https://www.puzzle-light-up.com/

Problem Complexity

- NP-Complete (hard to solve, easy to verify) - perfect for EAs
- Brute forcible in 2^n time

Definitions

- Genotype Representation
  - List of bulbs
- Phenotype Representation
  - 2D grid of cells
- Fitness Function
  - Real valued representation
  - Lit cell ratio
- Crossover
  - N-Point crossover on bulb list

Definitions

- Mutation
  - Bulb shuffling
- Local Optimum vs. Global Optimum
- “Website/Provided Puzzle” and “Random Puzzles”
  - For random puzzles: a new puzzle was generated for every experiment run
- Convergence criterion
  - After ‘n’ evaluations with little change in fitness, end the experiment

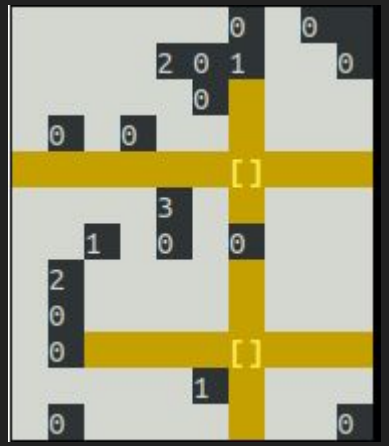
Experimentation

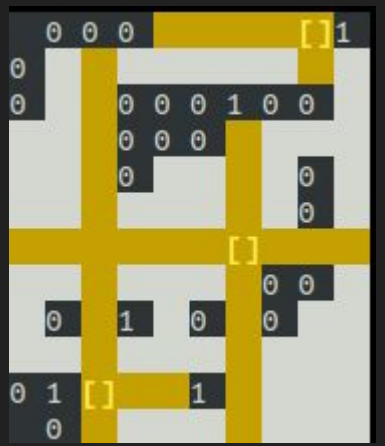
- Random Search
- Standard EA
- Constraint Satisfaction EA
- Multi-Objective EA

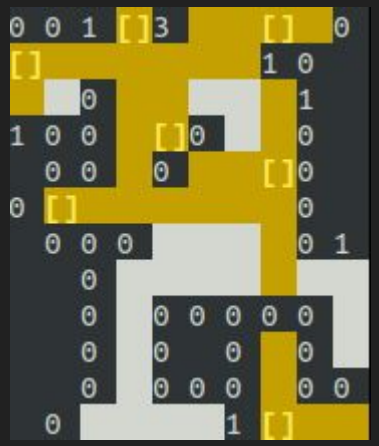
Random Search

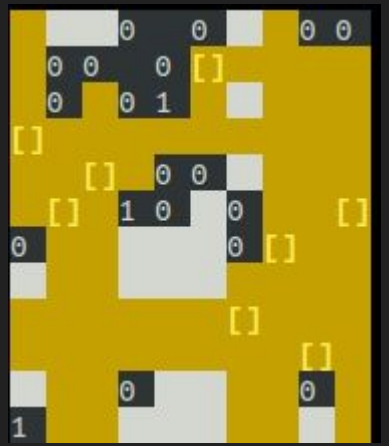
- Worst out of all of the algorithms
- Randomly places bulbs on the map
- Evaluates fitness of random solutions
- Used as baseline for comparison & reasoning behind using an EA
- Random search does not perform well - warrants an EA

Random Search

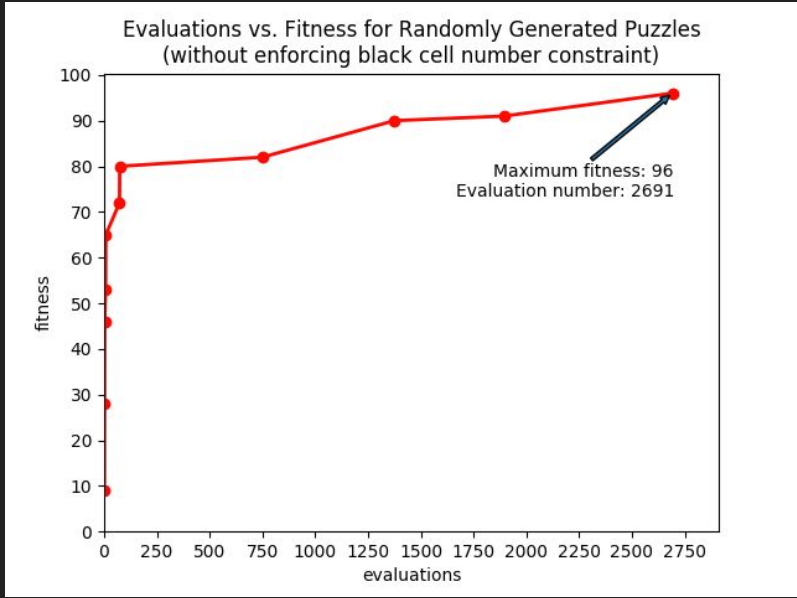


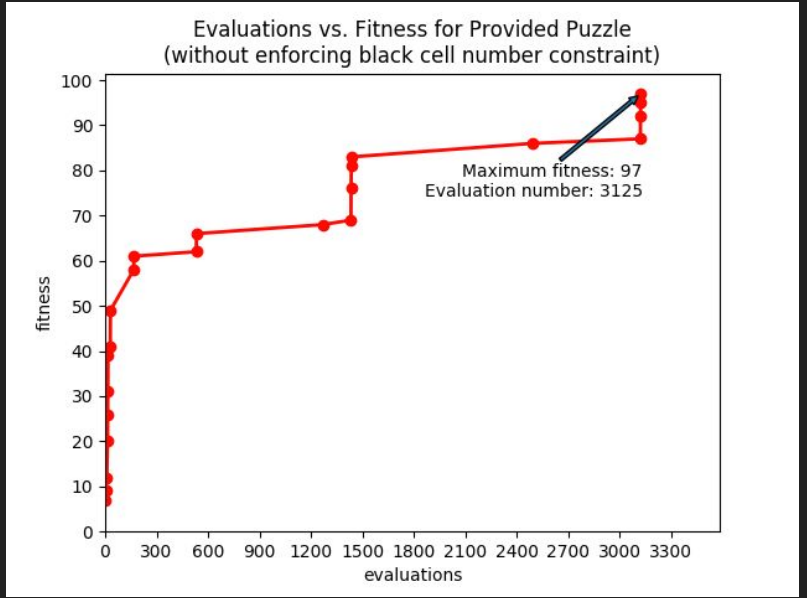






Random Search





Note: experiments were run for 10,000 fitness evaluations

Standard EA

- Initial Population - harsh, needle in a haystack
- Fitness Evaluation
- Parent Selection

Selection Methods

FPS(Fitness proportional selection)

Selection Methods

K-Tournament

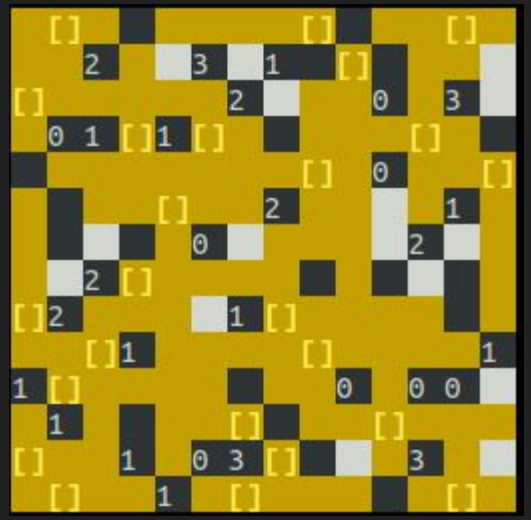
- With replacement
- Without replacement

Truncation

Random

- Recombination
- Mutation
- Survival Selection

Standard EA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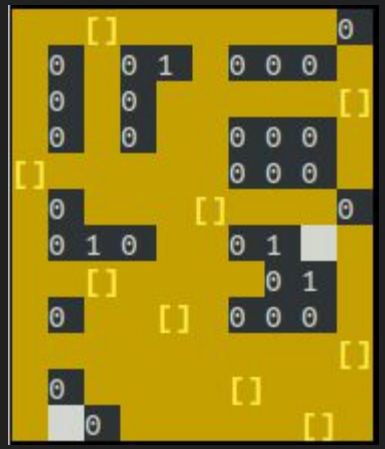
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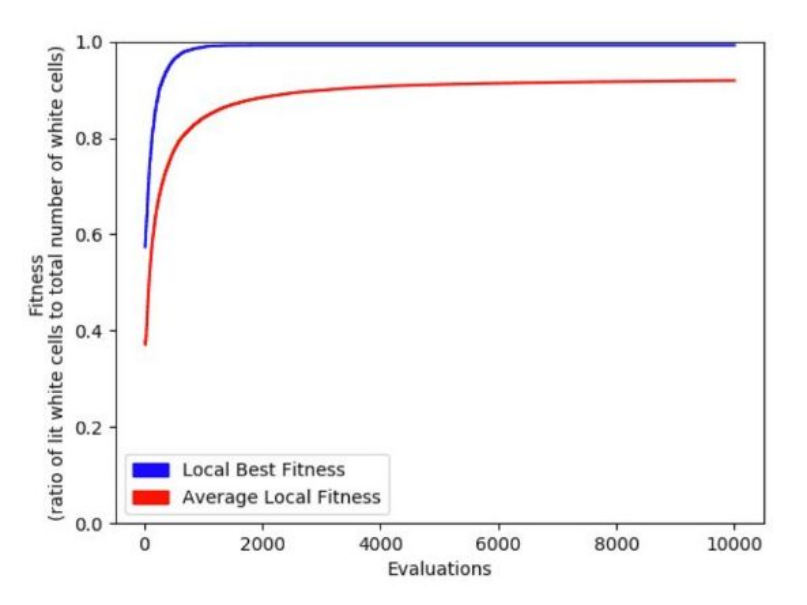
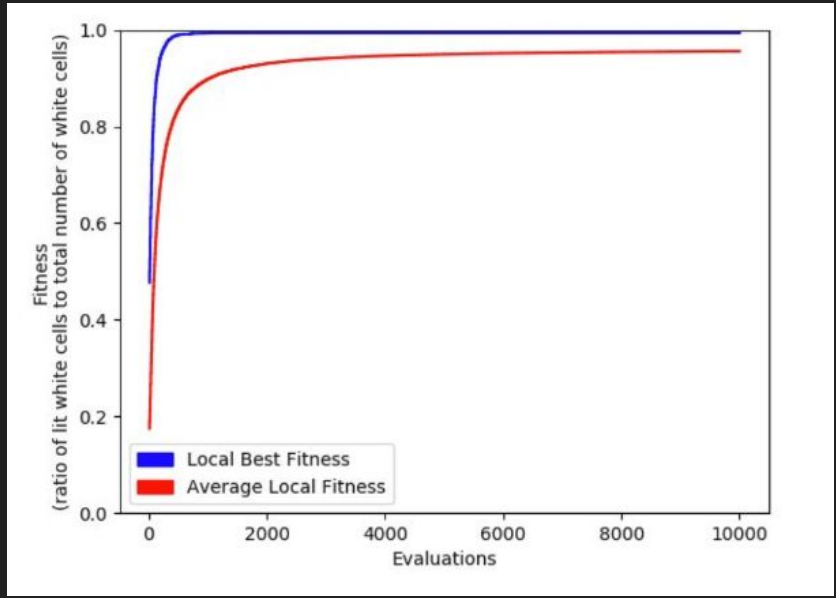
Standard EA

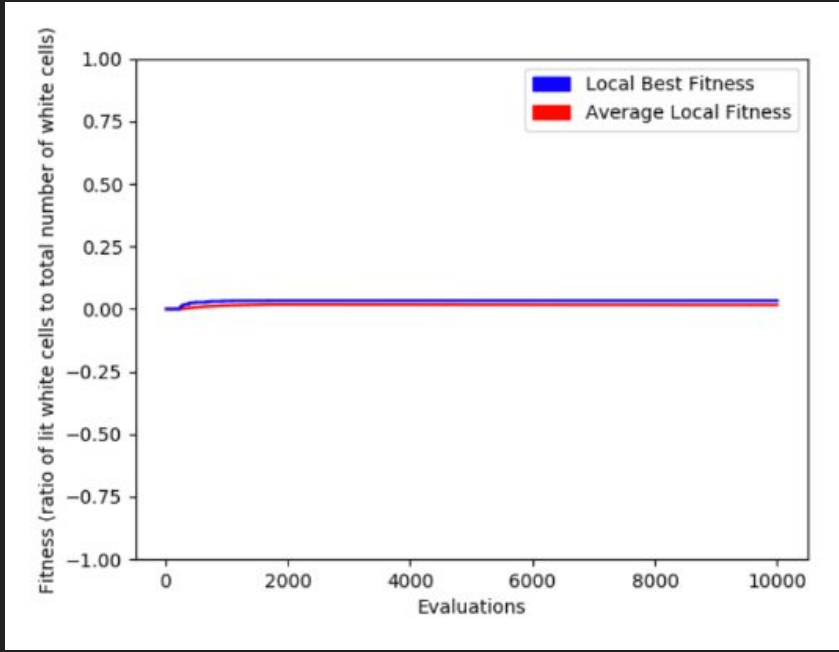


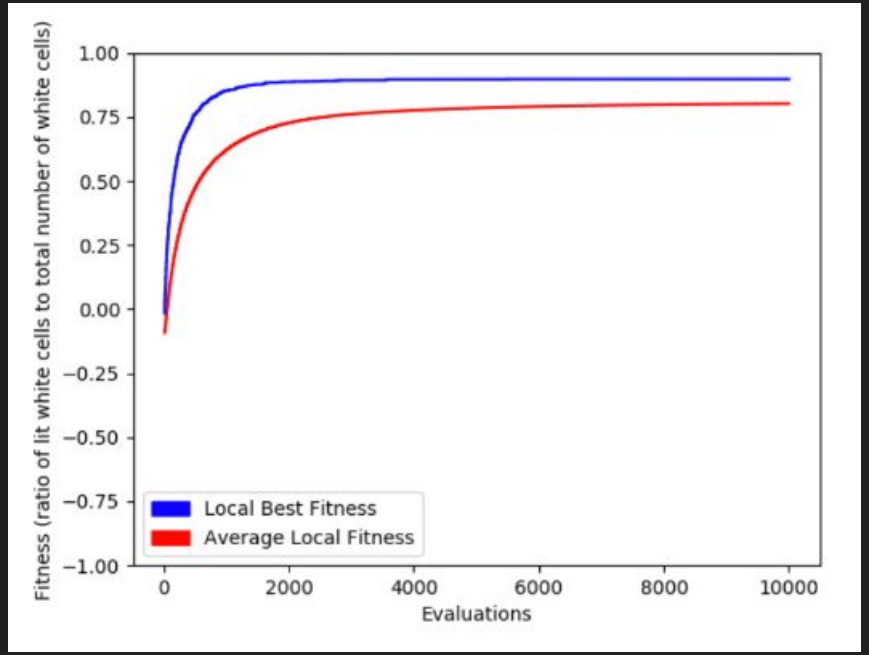
Provided Puzzle



Randomly Generated Puzzles

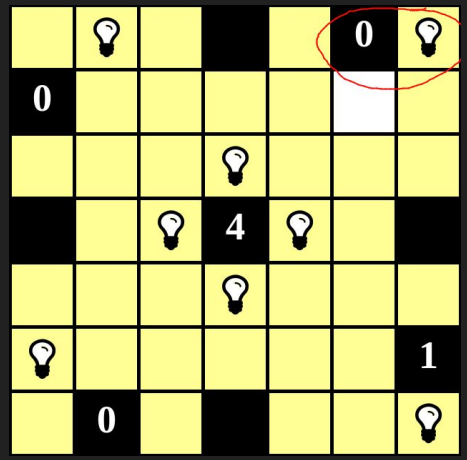
Constraint Satisfaction EA

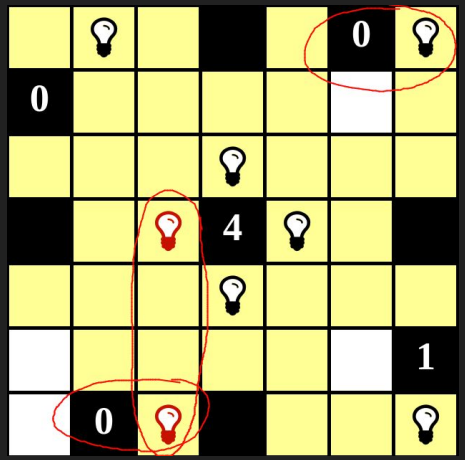




Constraint Satisfaction EA

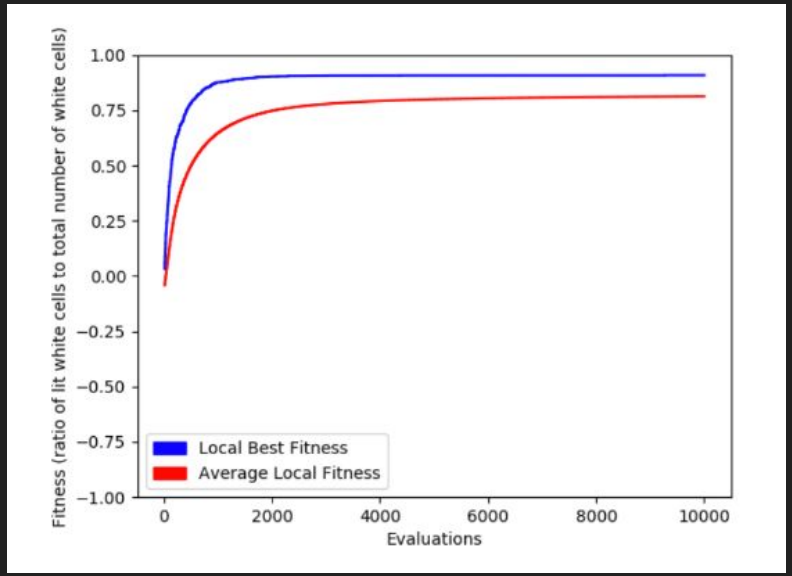
- Penalty function
  - (configurable constant) * (# bulbs shining on eachother + # invalid black cell constraints)
  - Scale as the algorithm progresses



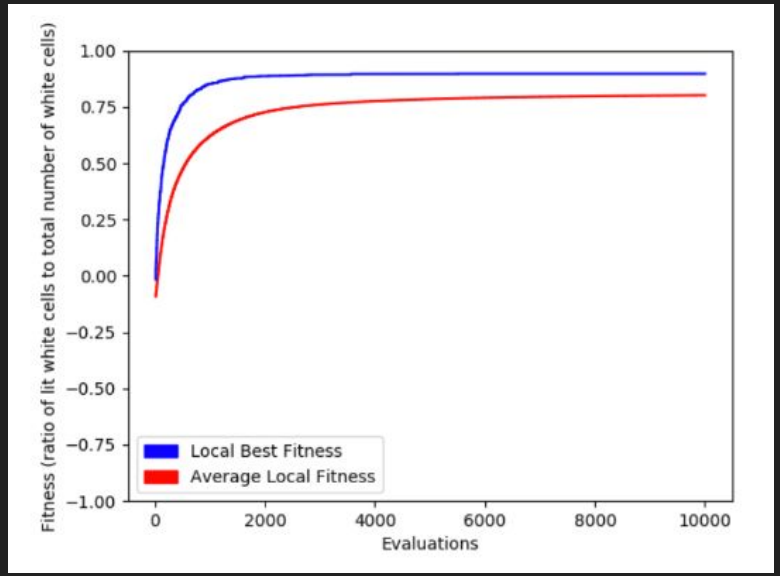


Constraint Satisfaction EA

- Initialization comparisons (for penalty function EA)



Validity Enforced plus Uniform Random



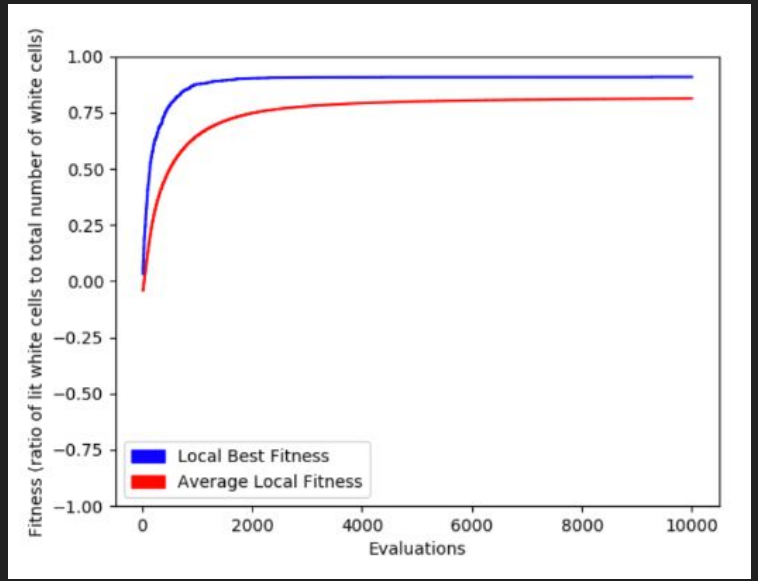
Uniform Random

Constraint Satisfaction EA

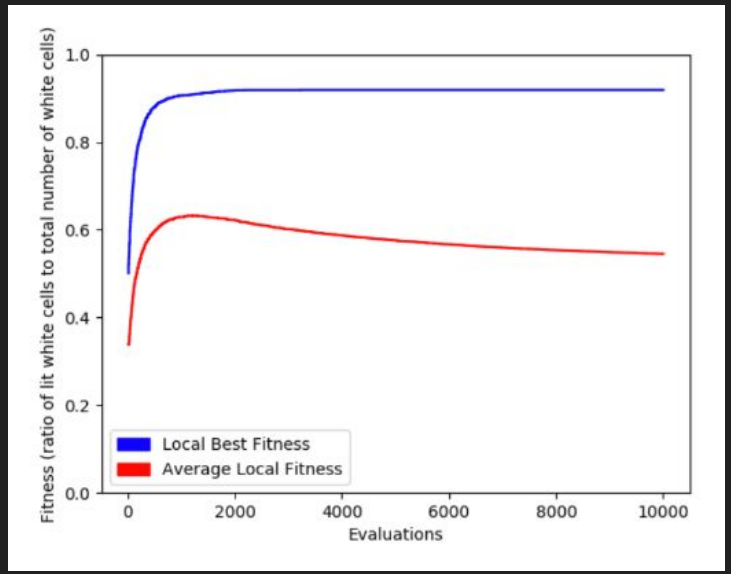
- Repair function
  - Ensures valid offspring
  - Many genotypes may map to the same phenotype
  - Not great for exploring invalid solutions
  - Strategy:
    1. Remove bulbs that shine on eachother
    2. “Brute force” bulbs around black cells

Constraint Satisfaction EA

- Penalty Coefficient vs Repair Function EA (for validity enforced plus uniform random)

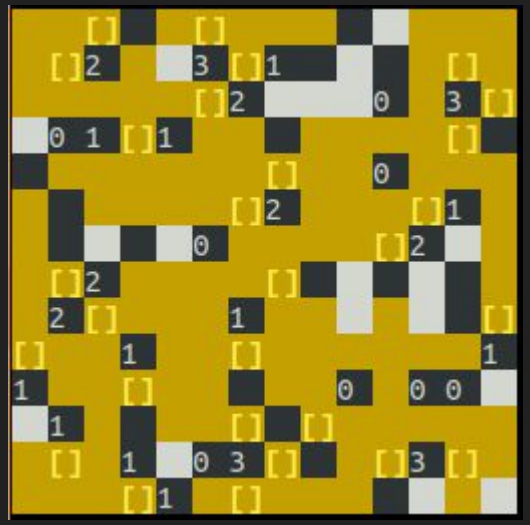


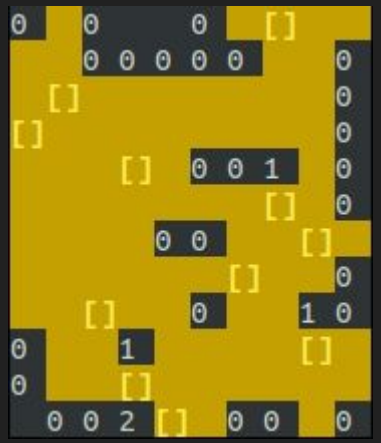
Penalty Function EA

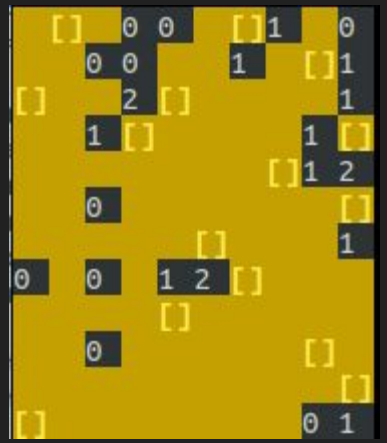


Repair Function EA

Constraint Satisfaction EA



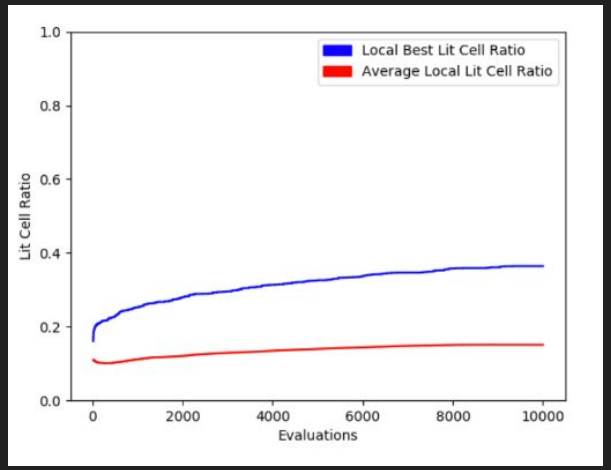




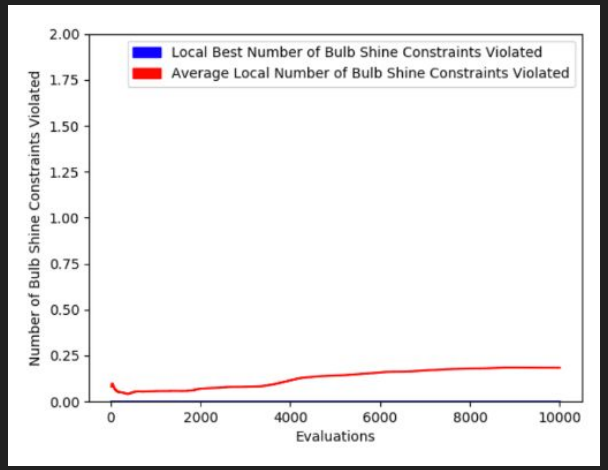
Multi-Objective EA

- Objectives, Sub - Fitnesses
- Domination
- Parent Selection
- Survival Selection
- Results and problem compared to penalty function

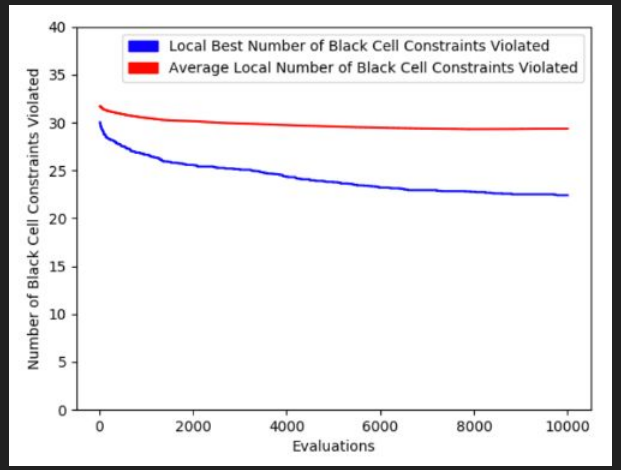
Multi-Objective EA



Lit Cell Ratio Subfitness (maximize)

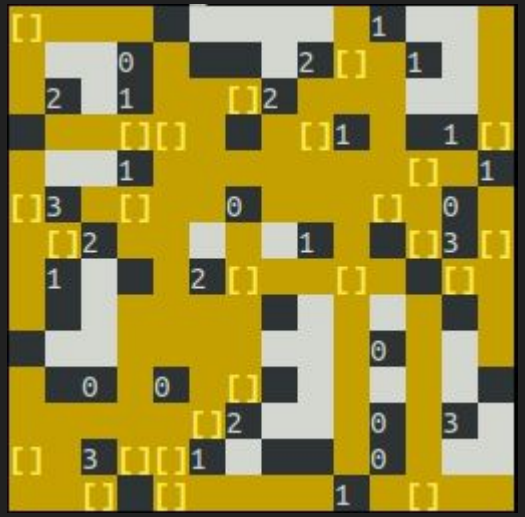


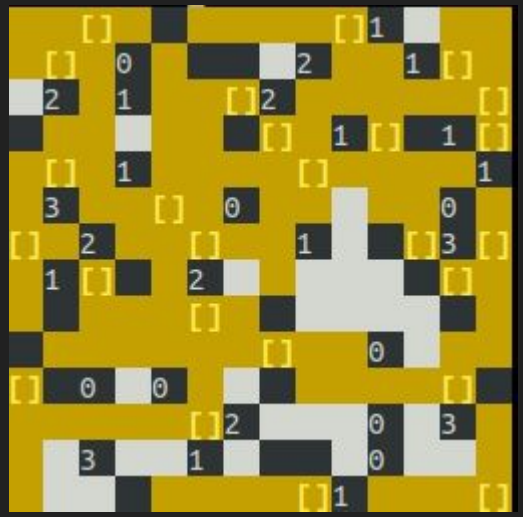
Bulb Shine Constraint Subfitness (minimize)

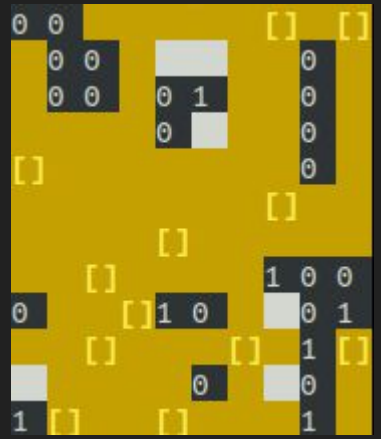


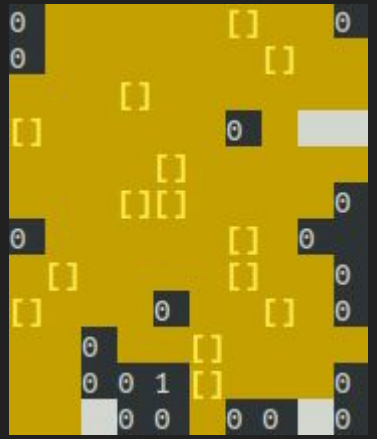
Black Cell Constraint Subfitness (minimize)

Multi-Objective EA









Worse with 4 objectives

Demo

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