Smart Grid

Programmeer theorie

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18 Juni, 2020

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How are we going to present?

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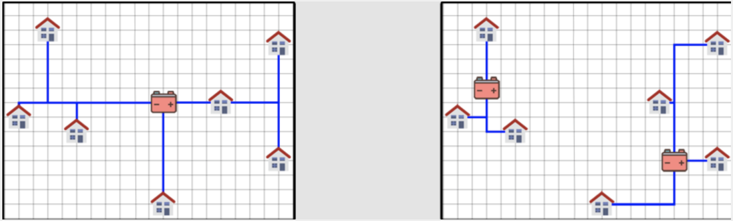
Goal Project

Introduction of the problem



- Houses produce energy (e.g green energy)
  - More energy than they use!
  - We want to store this extra energy.
- This energy is stored in batteries.

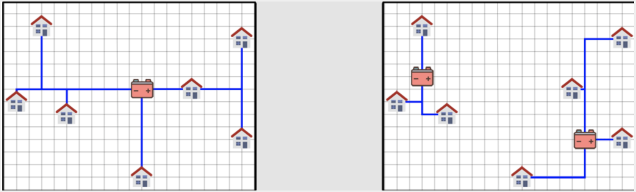
Questions:

- Given the locations of: the houses and the batteries
  - What is the cheapest way to connect them? (Because cables cost money!)
- Follow-up question 1: Where to put the batteries?
- Follow-up question 2: How many batteries can we use?

Constraints

Take into consideration:

- Houses have a maximum output energy
- Batteries have a maximum capacity
  - Rule for batteries: The maximum output of the houses counted up may not exceed the battery capacity.



- Batteries should not be connected to each other. Also not through a house.
- A house should not be connected to more batteries.
- Each house needs a unique cable to be connected to the battery.
- More cables can be positioned over the same grid segment

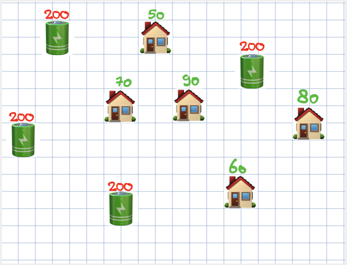
State Space

Upper bound on state space

State Space

The upper bound on the amount of states in the state space is

$$\left(\underbrace{\binom{50+50}{50}}_{\text{Amount of ways to connect house to battery}} \cdot \underbrace{5}_{\text{amount batteries}} \right)^{150} = 2.65 \cdot 10^{4455}$$



Upper bound on total price

Information:

- 5 batteries, each 5000
- cable price $=$ length cable $\cdot 9$

Lower bound price

Lower bound price:

$$\text{price} = 5 \cdot 5000 + 1 \cdot 9 \cdot 150 = \mathbf{26,350}$$

Lower bound price

Upper bound price:

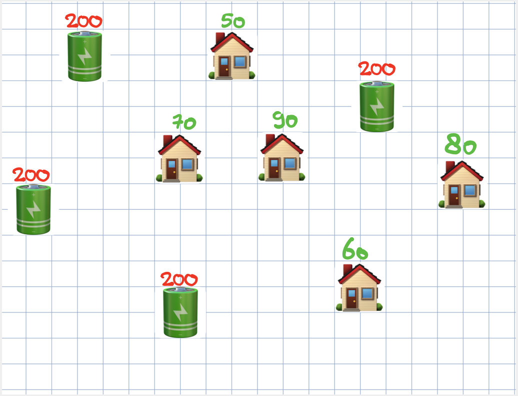
$$\text{price} = 5 \cdot 5000 + 100 \cdot 9 \cdot 150 = \mathbf{160,000}$$

Algorithms

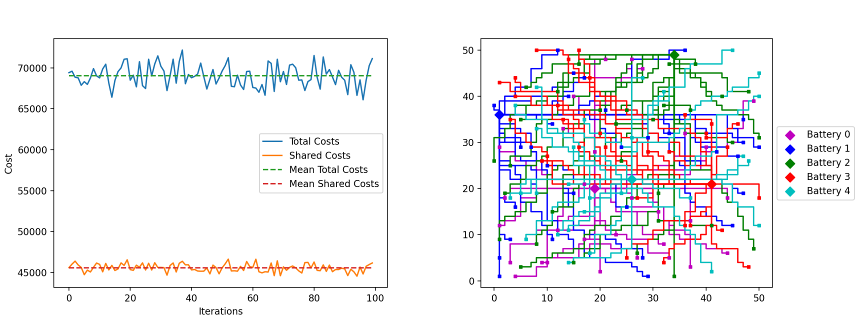
Algorithms - Random

Random Algorithm

- for house in list of houses:
  - find a random battery (that satisfies the constraints)
  - generate random cable



Algorithms - Random Results

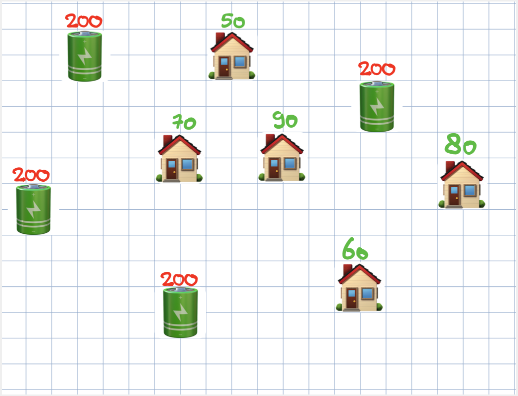


Algorithms

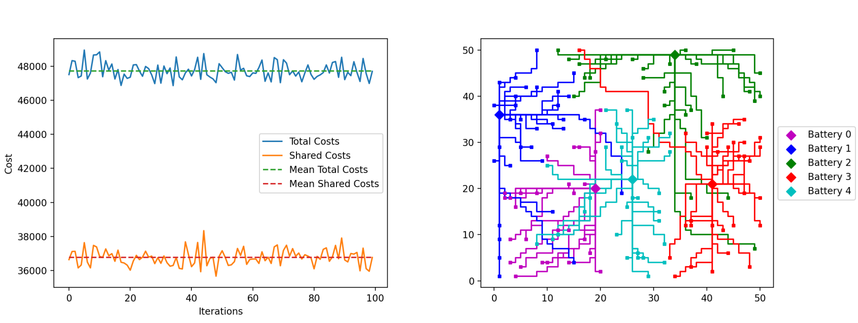
- Greedy + Swap:
  - Greedy House
  - Greedy Battery
- Greedy optimization + Swap:
  - Greedy House
  - Greedy Battery

Greedy House

- for house in houses:
  - look for closest available battery
  - connect



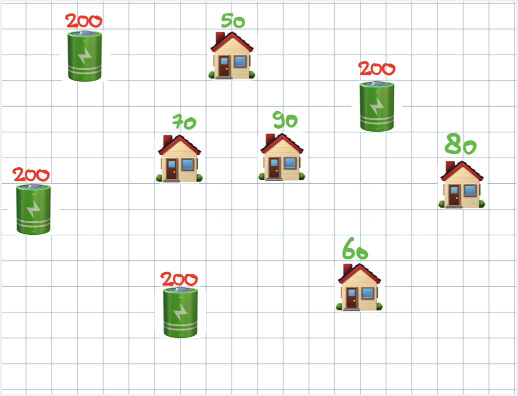
Algorithms - Greedy House Results



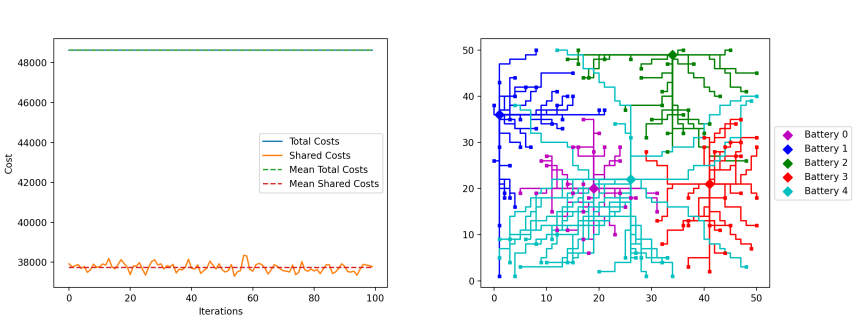
Algorithms - Greedy Battery

Greedy Battery

- for battery in batteries:
  - Make list of houses that are closest
  - Connect all possible starting from close houses



Algorithms - Greedy Battery Results



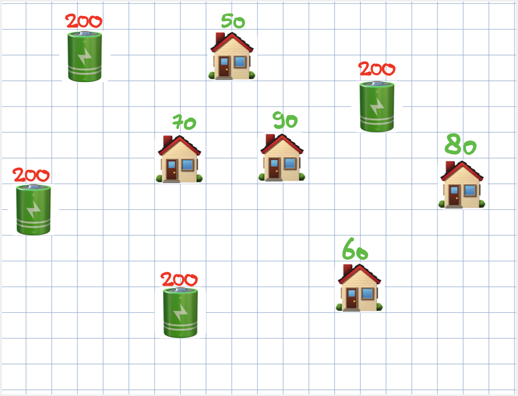
Greedy Algorithm Problem

- No guarantee that all houses will be connected!
- Solution: Swap houses at the end $+$ other optimizations to the algorithm itself!

Algorithm - Greedy

Greedy House Optimization

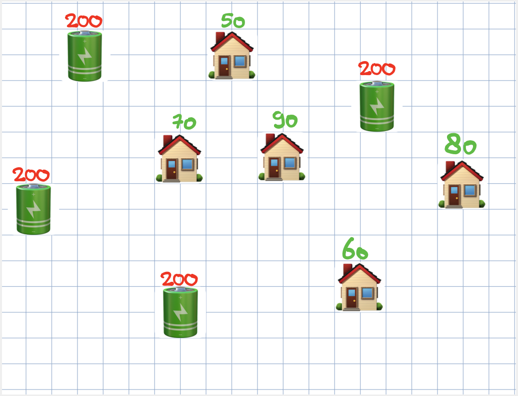
- **for house in houses:** ← order matters!, 150! possibilities
  - look for closest available battery
  - connect



Algorithms - Greedy

Greedy Battery

- **for battery in batteries:** ← 5! = 120 combinations
  - Make list of houses that are closest
  - Connect all possible starting from close houses

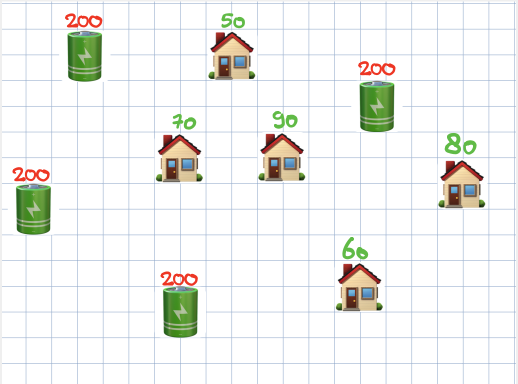


Algorithms - Simulated Annealing

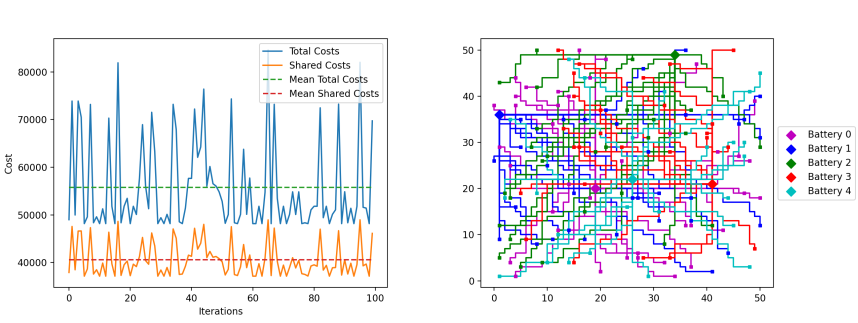
- Greedy with respect to what....
- Make a new score function!
- New heuristic

$$\text{score} = w_1 \cdot \text{manhattan} + w_2 \cdot \text{house-output}$$

- Want to find score(w_1, w_2) function such that total cost is lowest



Algorithms - Simulated Annealing Results

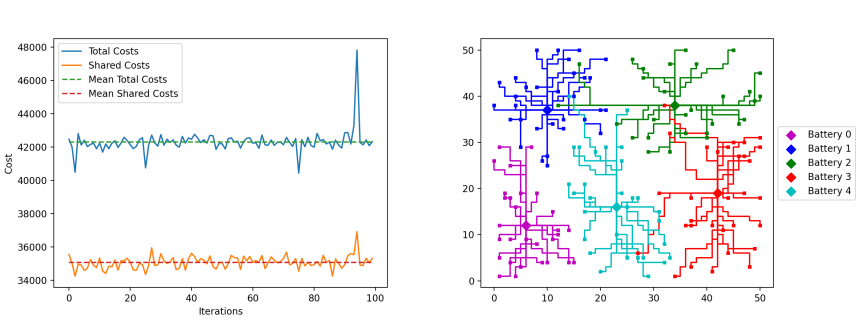


Algorithms - Clustering Algorithm

Clustering Pseudo Code

- Create initial solution with **greedy house** algorithm
- Reposition the batteries to the means of their collection of connected houses
- If new location = house, change location slightly
- Find new config with **greedy house** and if new price is worse, repeat
- Repeat until difference is small

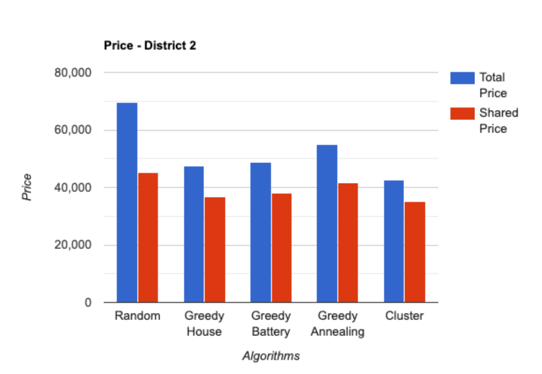
Algorithms - Clustering Algorithm Results



Results

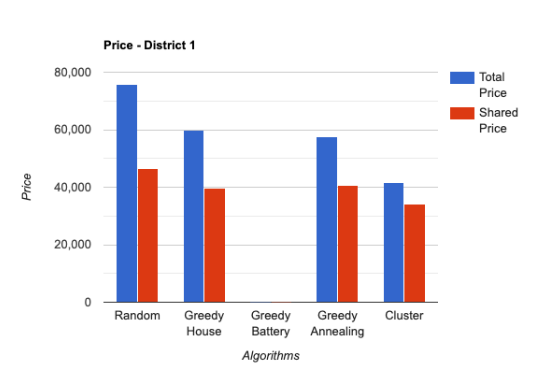
Comparison of Results

District 2



Comparison of Results

District 1



Conclusion

Conclusion

- Goal: Understand and explore smart grid problem
- Method: Optimize and build on algorithms to optimize price
- General approach
- Unconventional Heuristics: Combine them!
- No “one size fits all” solution

Thank you for attending!