Smart Grid

De Heuristische Helden

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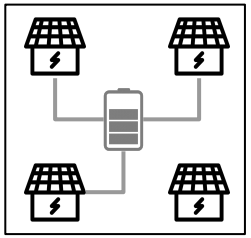
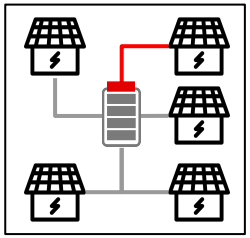
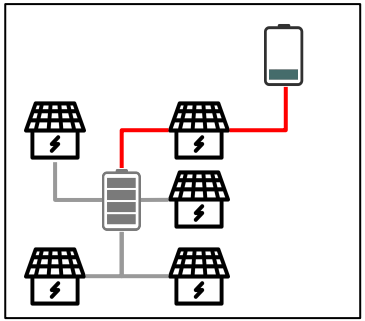
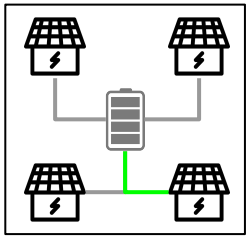
Part A - Connecting houses and batteries

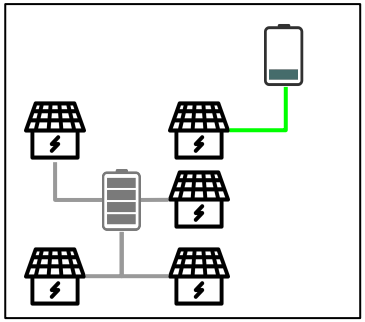
Constraints





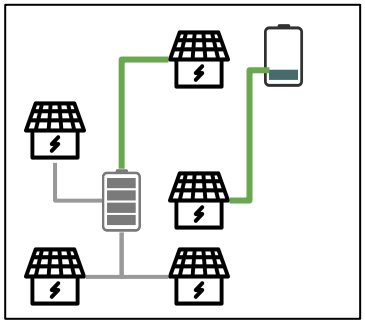


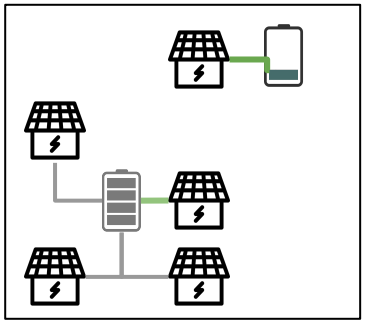




Part A - Connecting houses and batteries

Optimization:
sum(Manhattan distance) of all the connections





Part A - State Space & Complexity

Complexity: $\#\mathbf{Batteries}^{\#\mathbf{Houses}}$ (assuming no max. capacity of the batteries)

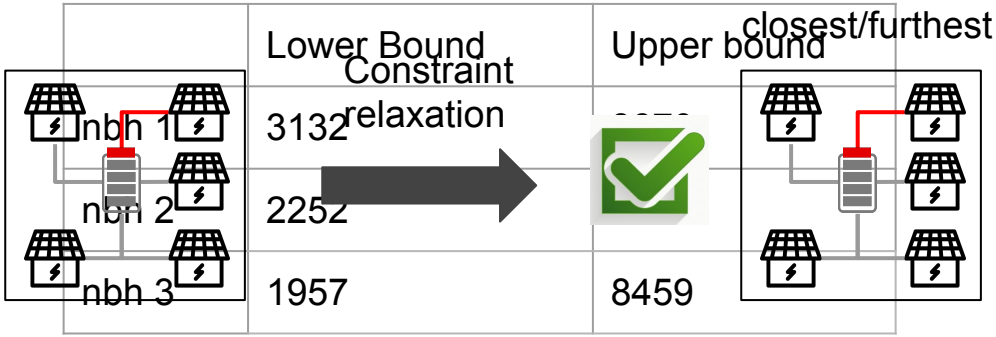
Neighbourhood	Number of houses	Number of Batteries	State space: B^H
1	150	5	$7 * 10^{104}$
2	150	5	$7 * 10^{104}$
3	149	5	$1.4 * 10^{104}$

Part A - State Space & Complexity

Complexity: $\#\mathbf{Batteries}^{\#\mathbf{Houses}}$ (assuming no max. capacity of the batteries)

Neighbourhood	**When checking 10^6 states per second, time needed to exhaust state space**
1	$1{,}6 * 10^{81}$ * age of the universe
2	$1{,}6 * 10^{81}$ * age of the universe
3	$3{,}2 * 10^{80}$ * age of the universe

Part A - Bounds of the solution space



Methods - Part A

- **Connecting houses and batteries**
  - Random Battery Cycler
  - Steepest Ascent Hillclimber

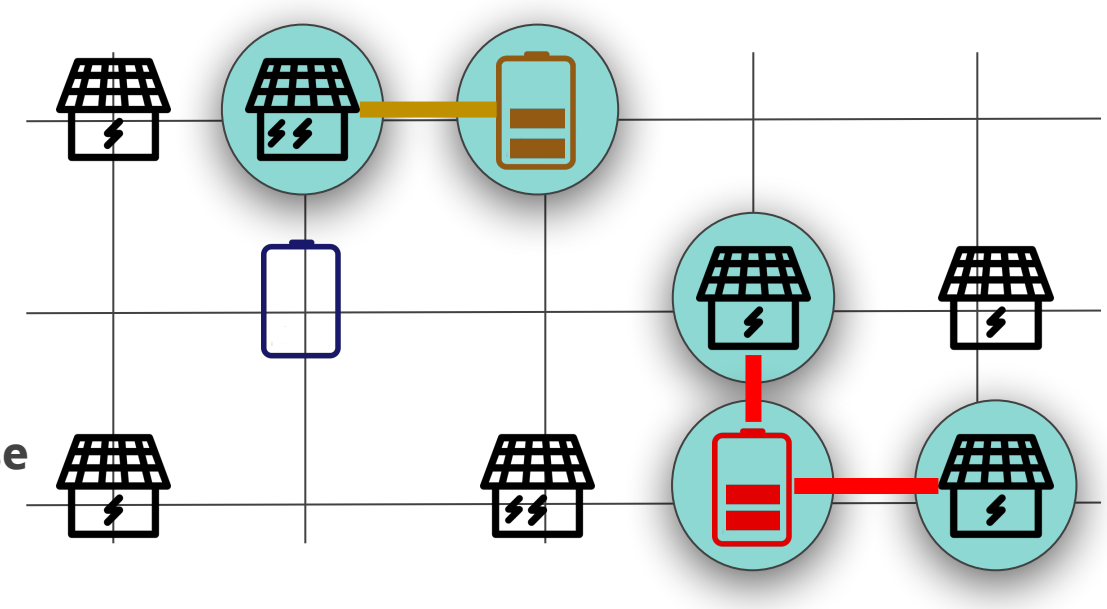
Methods - Random Battery Cycler

output = 1

output = 2

capacity = 3

1. Pick random battery
2. Connect to closest <u>available</u>, fitting house
3. Repeat



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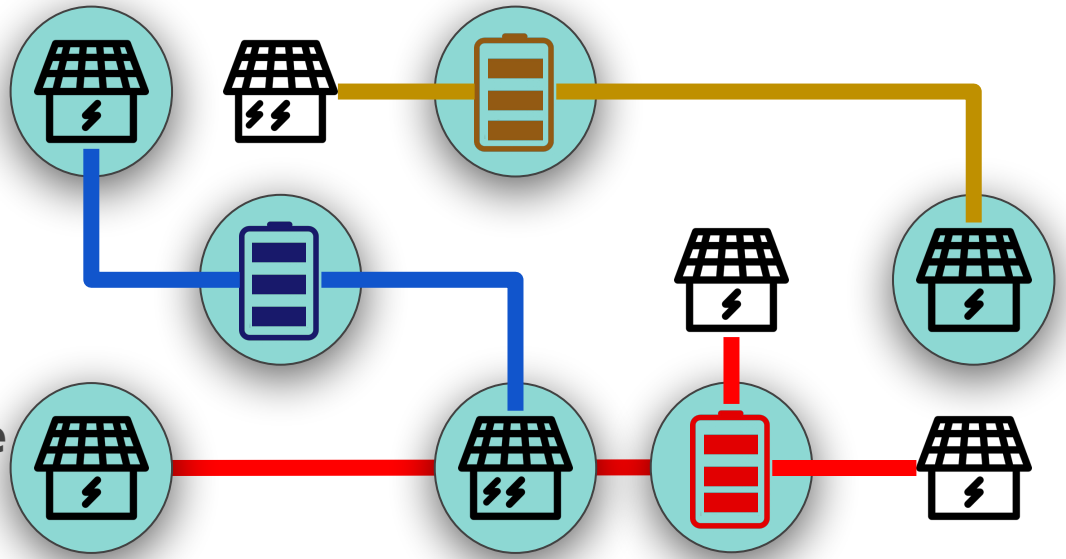
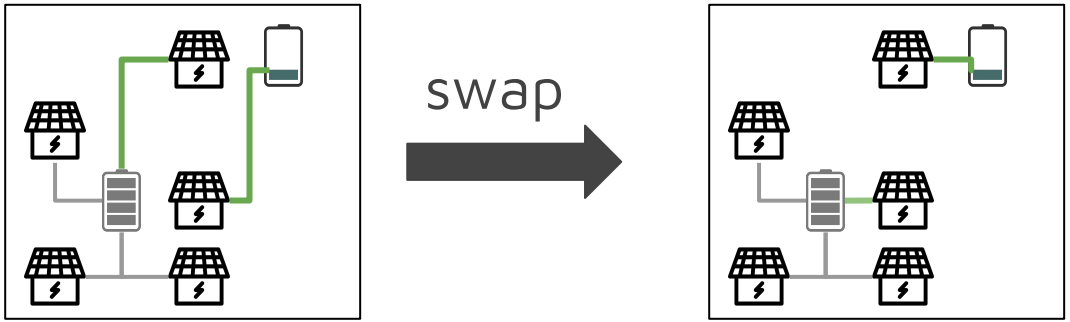
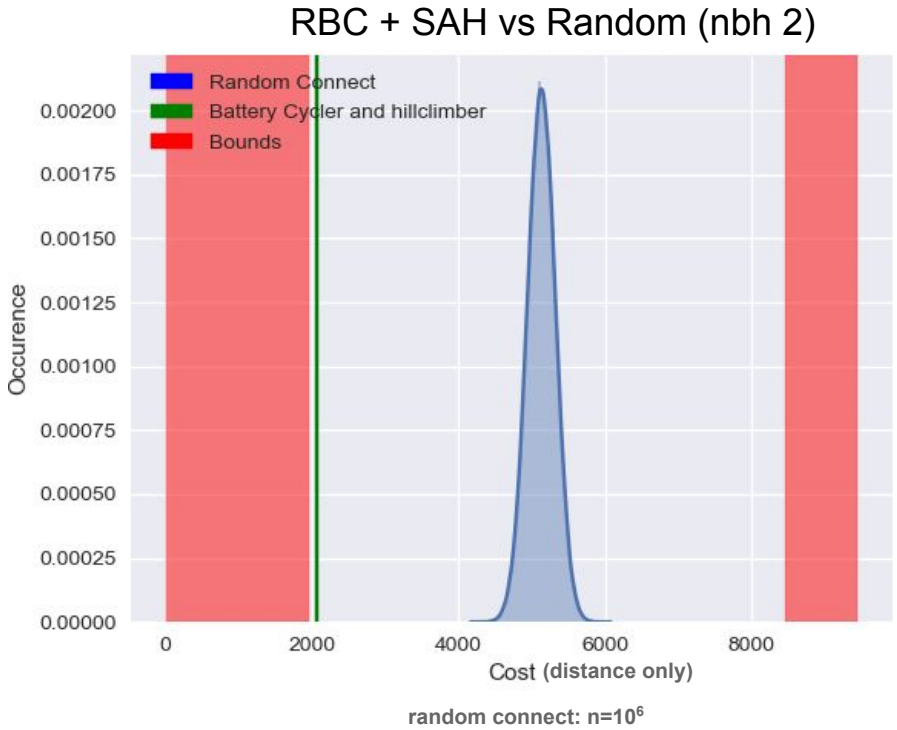


Methods - Steepest Ascend Hillclimber

Makes the most profitable swap until a (local) optimum is reached



Part A - Results



random connect: $n=10^6$

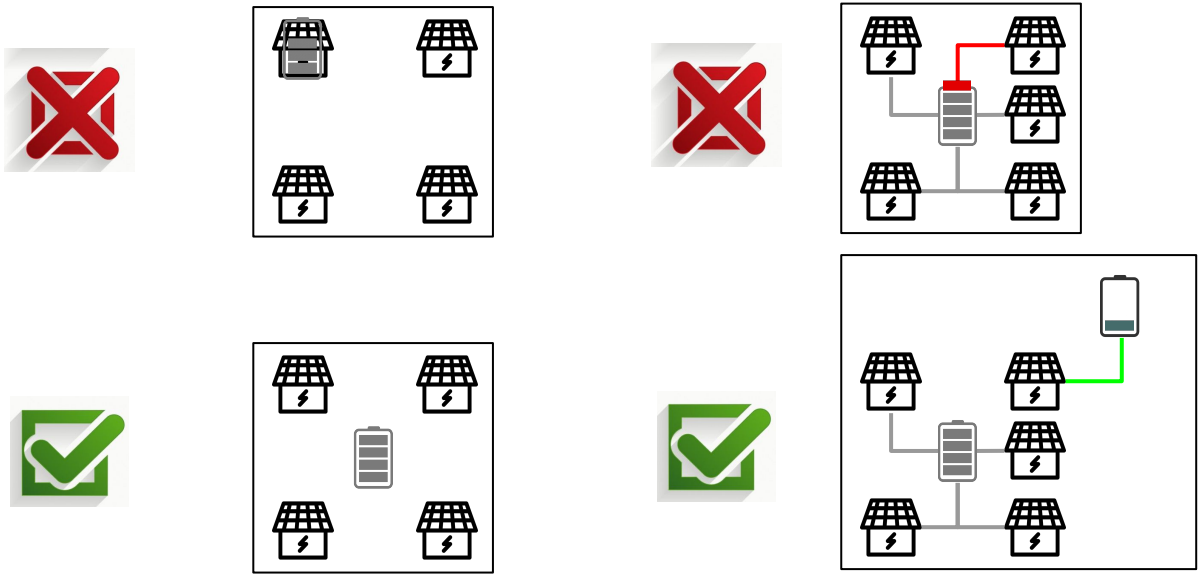
	Random Battery Cycler	‘Absolute’ Lower Bound
nbh 1	3486	3132
nbh 2	2292	2252
nbh 3	2069	1957

Part A - Results

	Random Battery Cycler + Greedy Hillclimber	**Z-score**	**‘Absolute’ Lower Bound**	**Z-score**
nbh 1	3486	-12.5	3132	-14.6
nbh 2	2292	-16.5	2252	-16.7
nbh 3	2069	-16.1	1957	-16.7

Part B - Placing Batteries

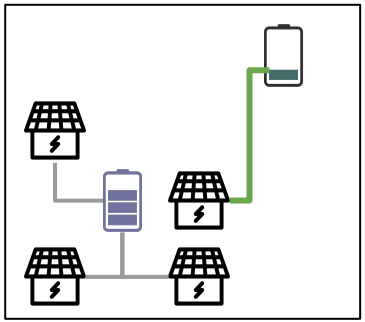
Constraints

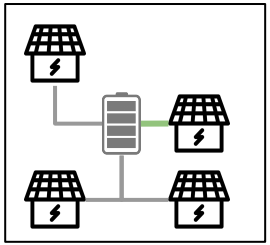


Part B - Placing Batteries

Optimization:

Cost function: B_{costs} + total connection length * 9





Part B - Placing batteries

State Space complexity:

$$\sum_{i=0}^{u} c \cdot \frac{r!}{(r-n)!}$$

u=max nr. of batteries
n=nr. of batteries
r=nr. of free positions at start
c=nr. of combinations of length i

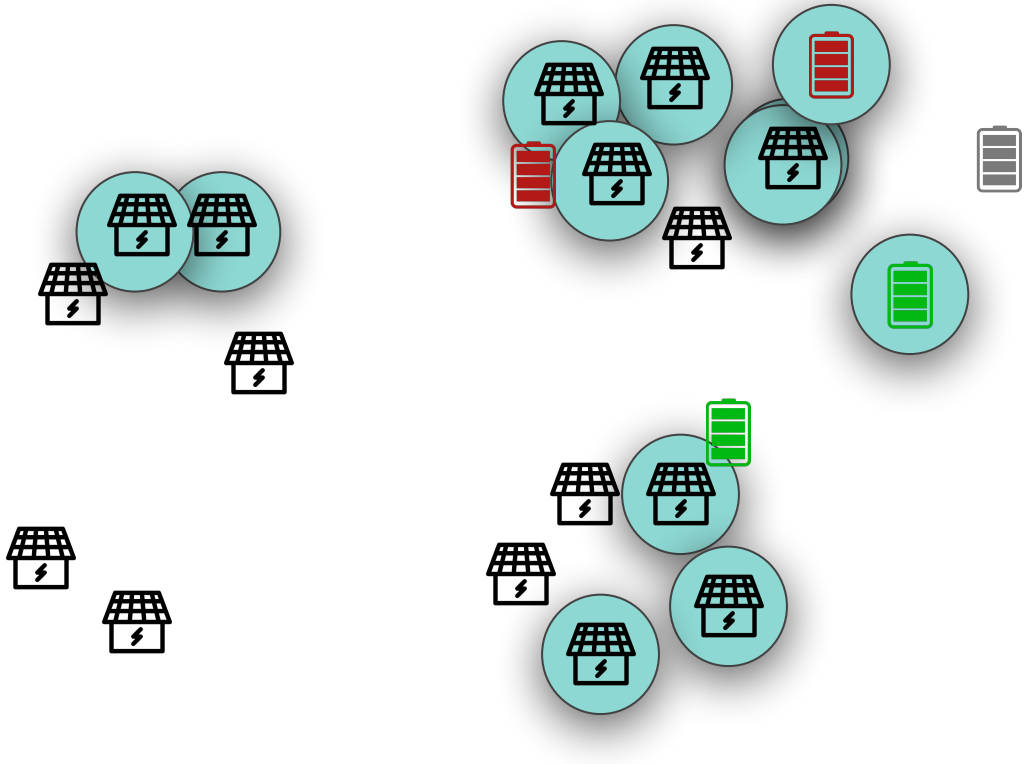
Neighbourhood	State Space
1	$5.76 * 10^{57}$
2	$5.76 * 10^{57}$
3	$5.80 * 10^{57}$

Methods - Part B

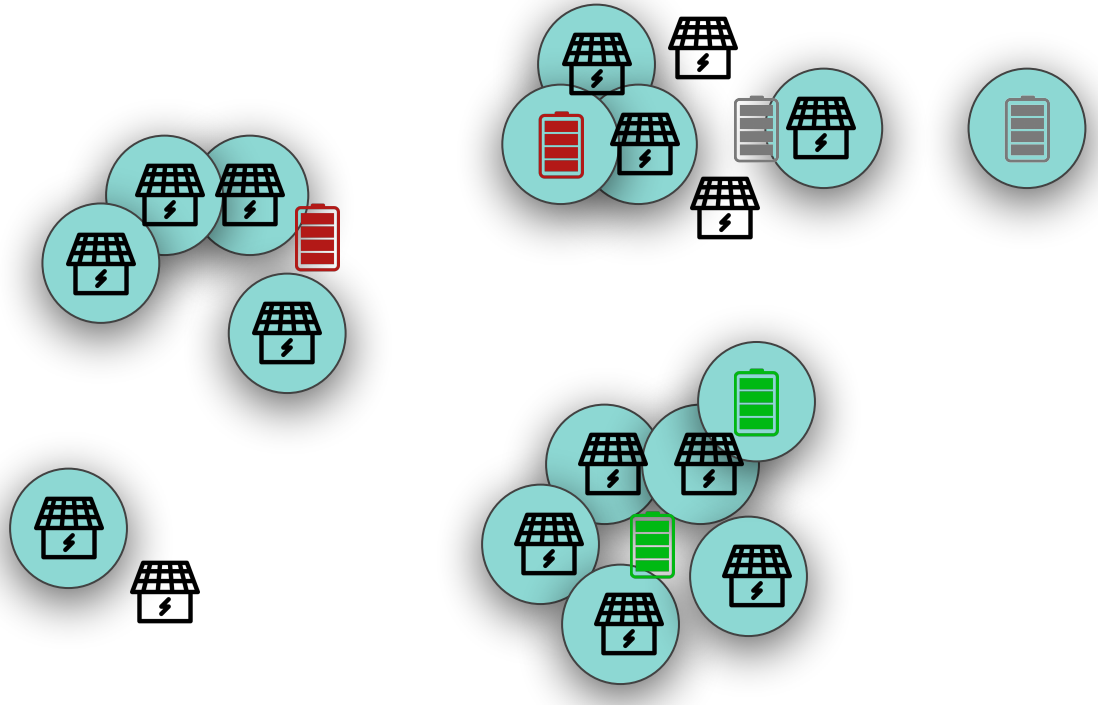
Moving/Placing batteries

- K-Bats
- Bat Propagation
- Bat Migration

Methods - K-bats (k-means clustering)



Methods - K-bats (k-means clustering)



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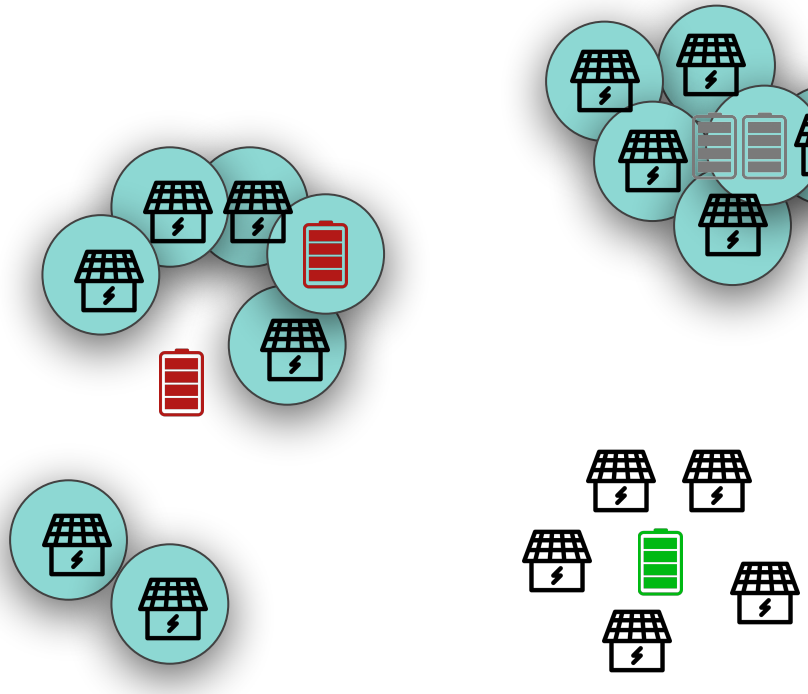
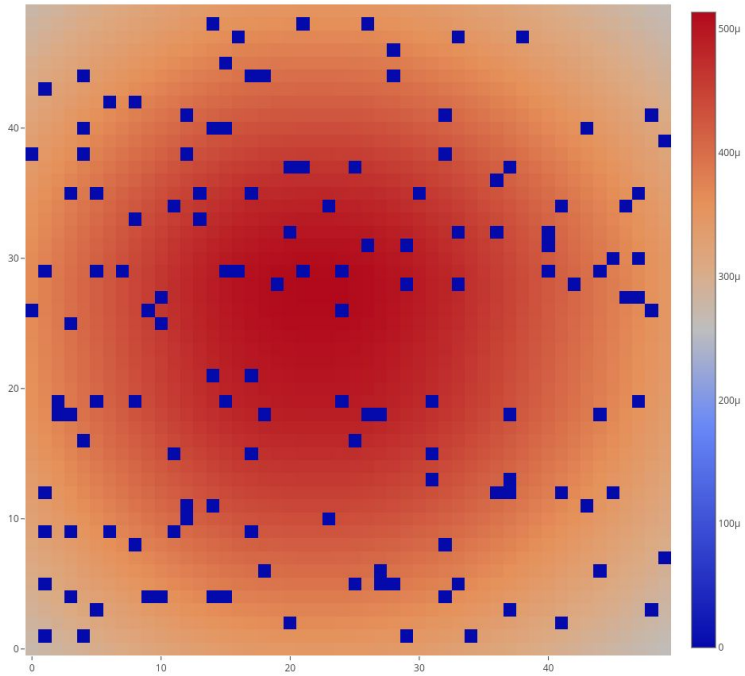


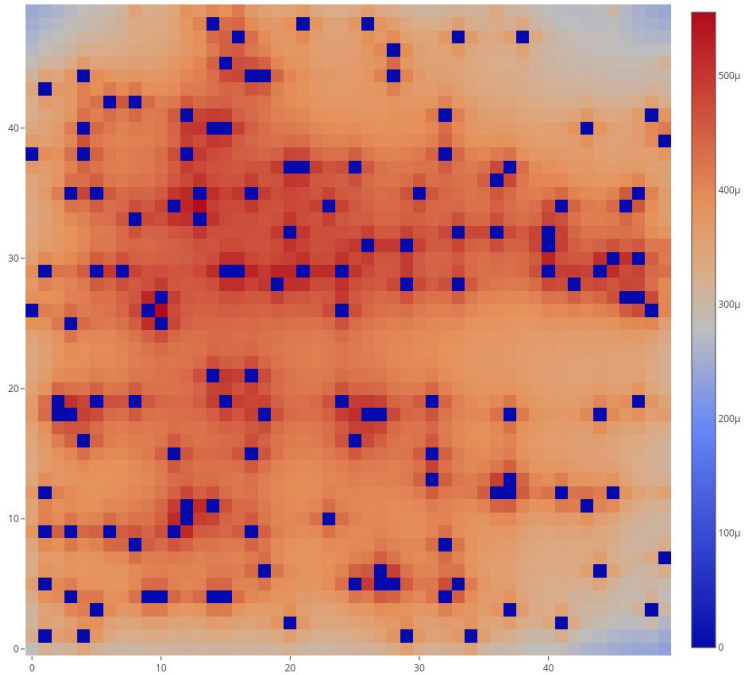
Methods - Global Heatmap



All distances count equally:

$$\sum_{n}^{N} \frac{1}{d}$$

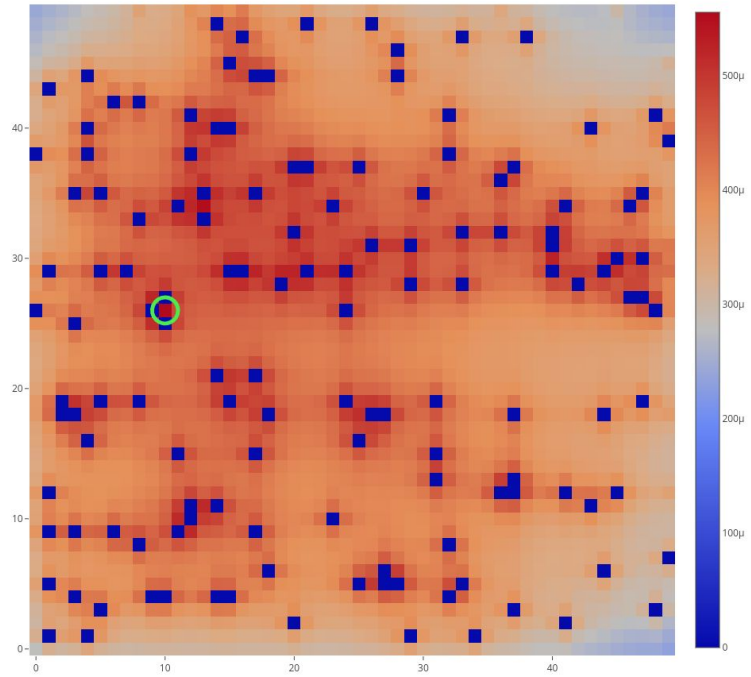
Methods - Local Heatmap

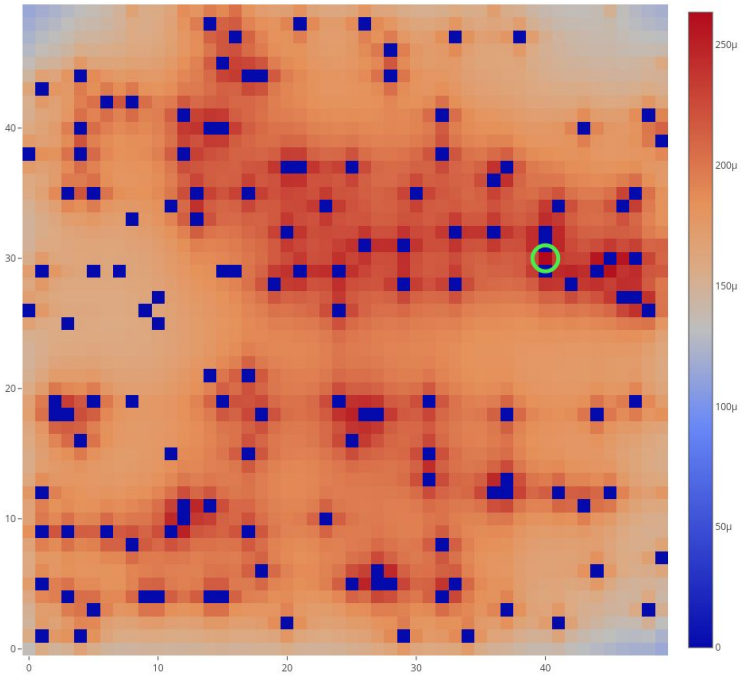


Low distances weigh more heavily:

$$\frac{1}{\sum_{n=0}^{n=N} d(house, battery)}$$

Methods - Bat Migration



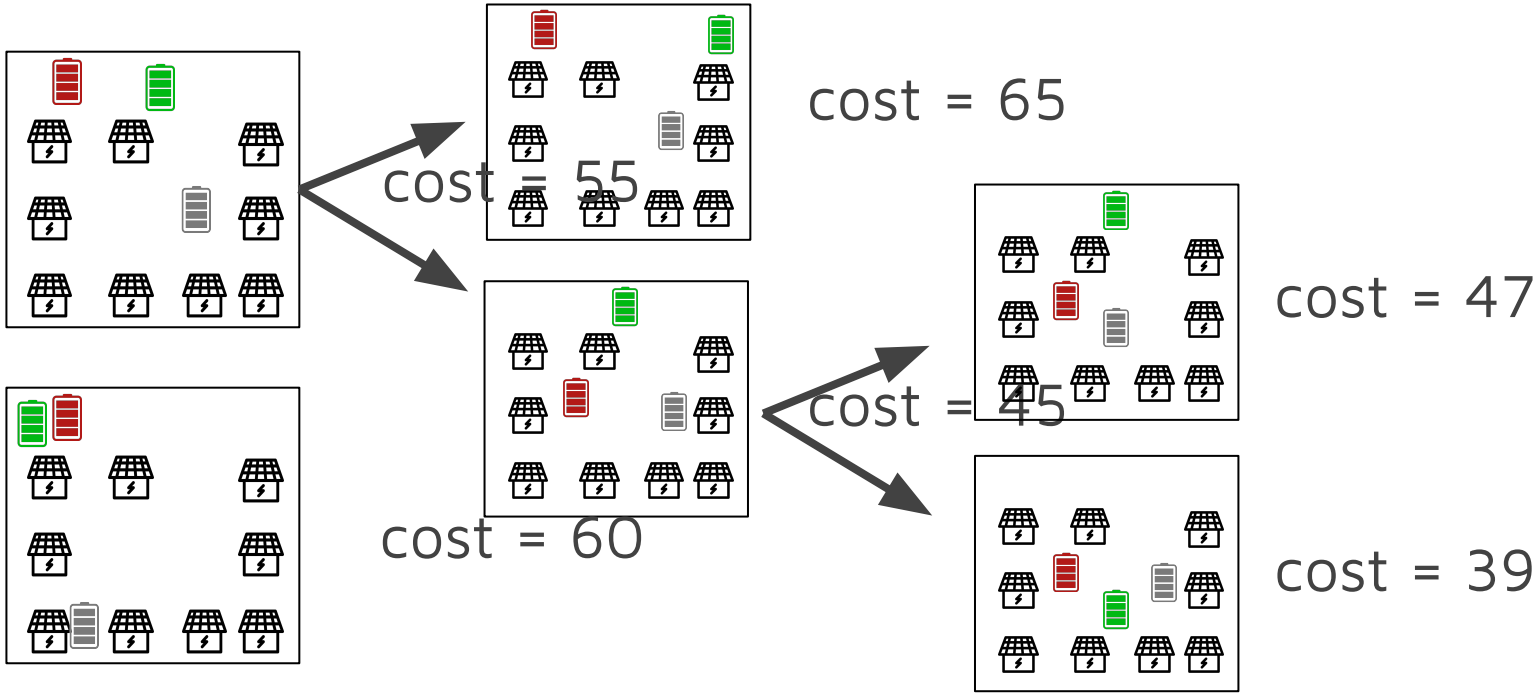


Methods - Bat Propagation

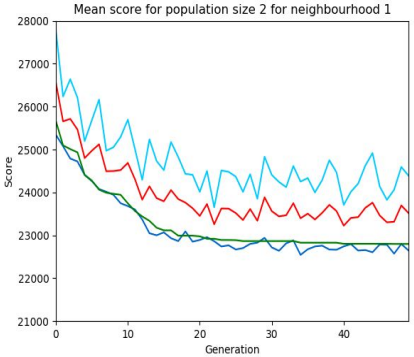
1st generation:

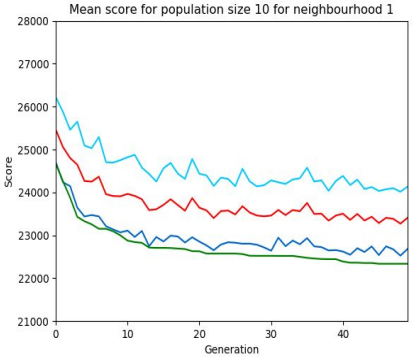
2nd generation:

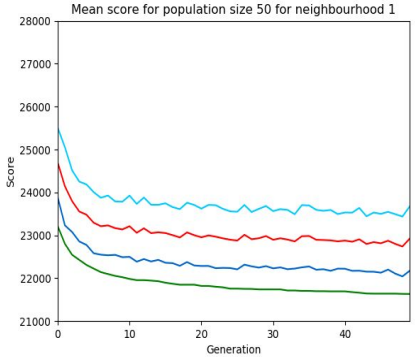
3rd generation: → ... → **Xth** generation

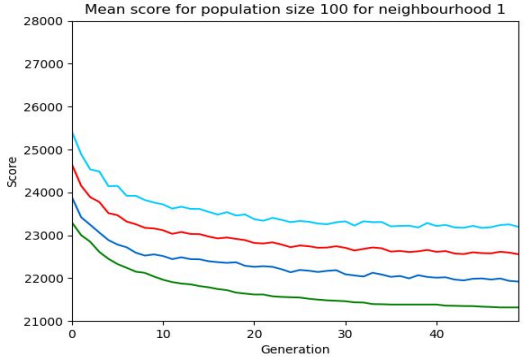


Part B - Results - Bat Propagation

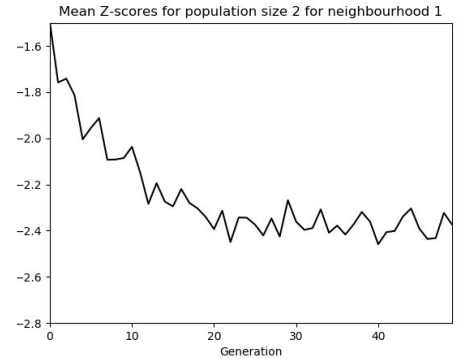


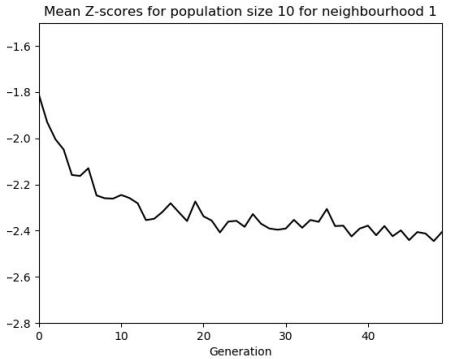


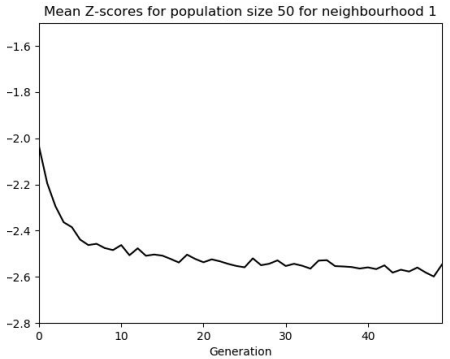


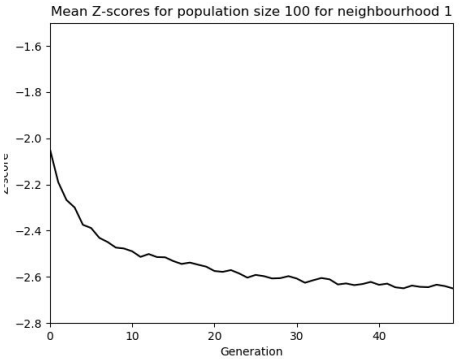


Part B - Results - Bat Propagation

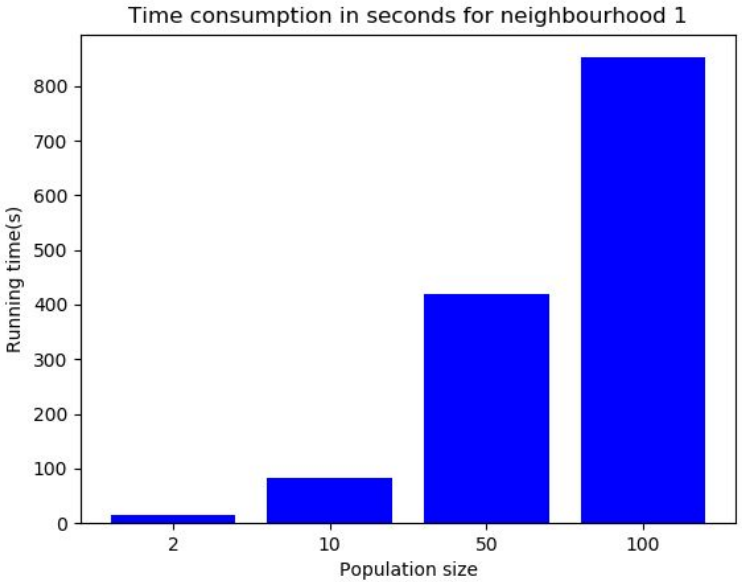


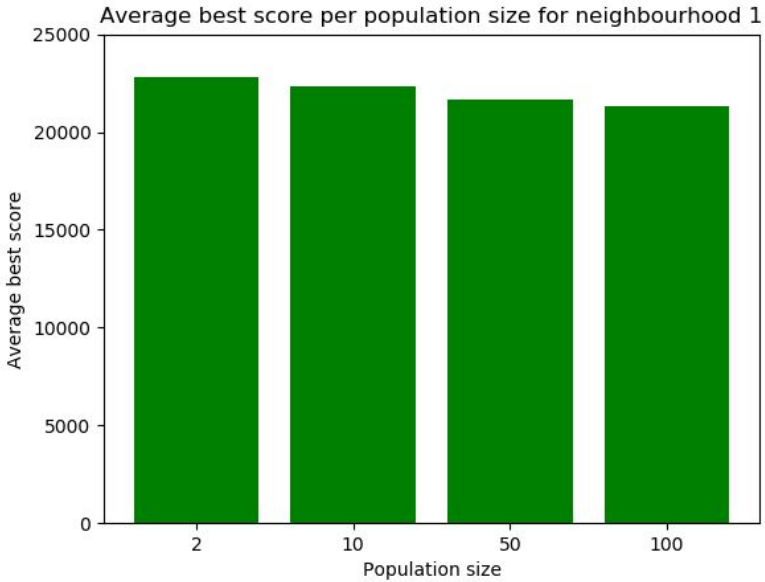




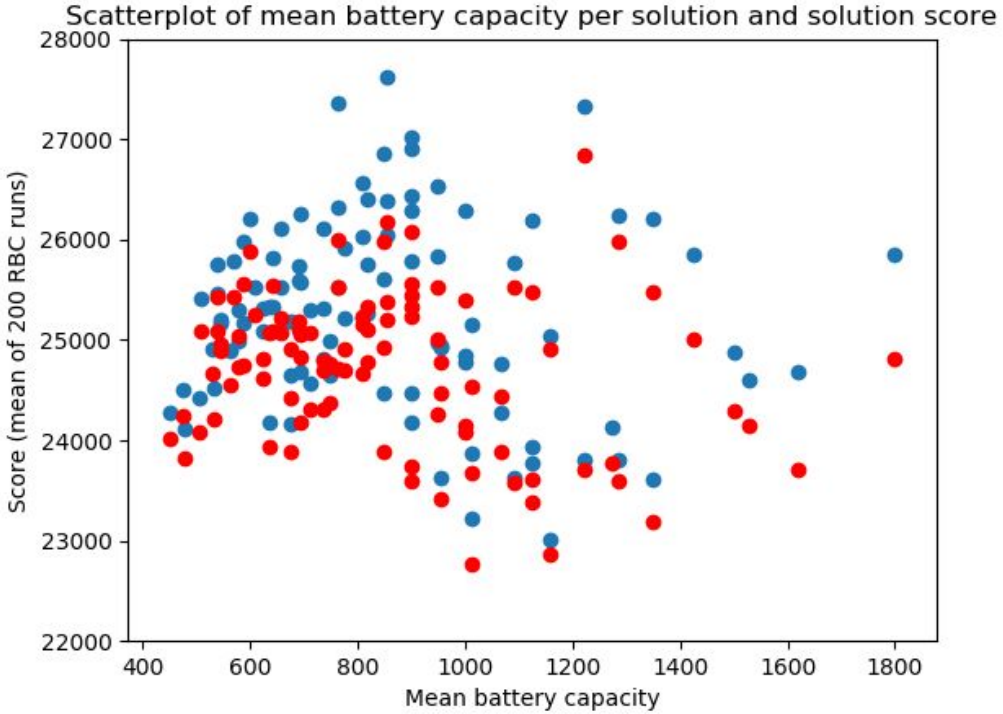


Part B - Results - Bat Propagation

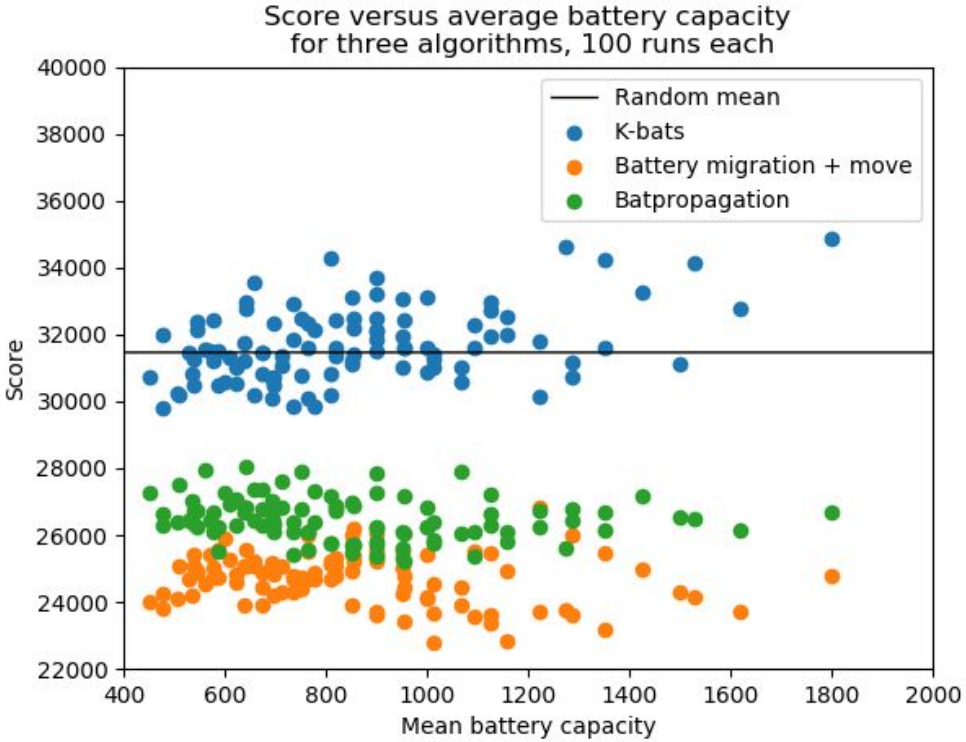




Part B - Results - Bat migration



Part B - Results



Conclusion

- **Case A**
  - Significantly better than random solutions
- **Case B**
  - Less significance, still better than random
    - except K-means
  - Major challenge: identifying, evading local optima
    - solution: population size, repeats

Discussion

- No guaranties for best solution
- Case A: chances of better solution small
- Case B:
  - In this case, … best solutions

Discussion

- Runtime may improve solutions
- Hypothesis: strong bias to fewer batteries not proved
- Bat-Migration significantly (10x) faster than propagation

Future research & Ideas

- K-bats while accounting for capacity
- Battery schemes which have tighter fits are probably harder to solve because Bin-packing will become a more relevant problem
- K-bats does not seem to influence random-connect, why so?

Dummy neighbourhoods, difficulty?

Neighbour hood	**Stdev of the output values**	Random Battery Cycler
1	14.4	3486
2	9.2	2292
3	2.9	2069

“Een wijs man programmeert niet tegen de wind in”

- *De Heuristische Helden*

References

- wijk pictures: http://heuristieken.nl/wiki/index.php?title=SmartGrid
- Lego batman picture: https://www.google.nl/search?q=lego+batman&source=lnms&tbm=isch&sa=X&ved=0ahUKEwj3vb3F2IDbAhVPL1AKHUrhCqEQ_AUICigB&biw=1536&bih=759#imgrc=BmEt2hS6L-YR5M:
- Pindakaas picture: https://www.google.nl/search?biw=1536&bih=710&tbm=isch&sa=1&ei=syP3Wo_9Lo7YwALWpYVY&q=ah+pindakaas&oq=ah+pindakaas&gs_l=img.3...5262.5545.0.5700.0.0.0.0.0.0.0.0..0.0....0...1c.1.64.img..0.0.0....0.hjylh3O5BD8#imgrc=fNqbC3aB35zPzM:
- Migrating birds: https://www.thespruce.com/how-birds-migrate-386445
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- Houses: https://www.flaticon.com/icon-packs/smart-home
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