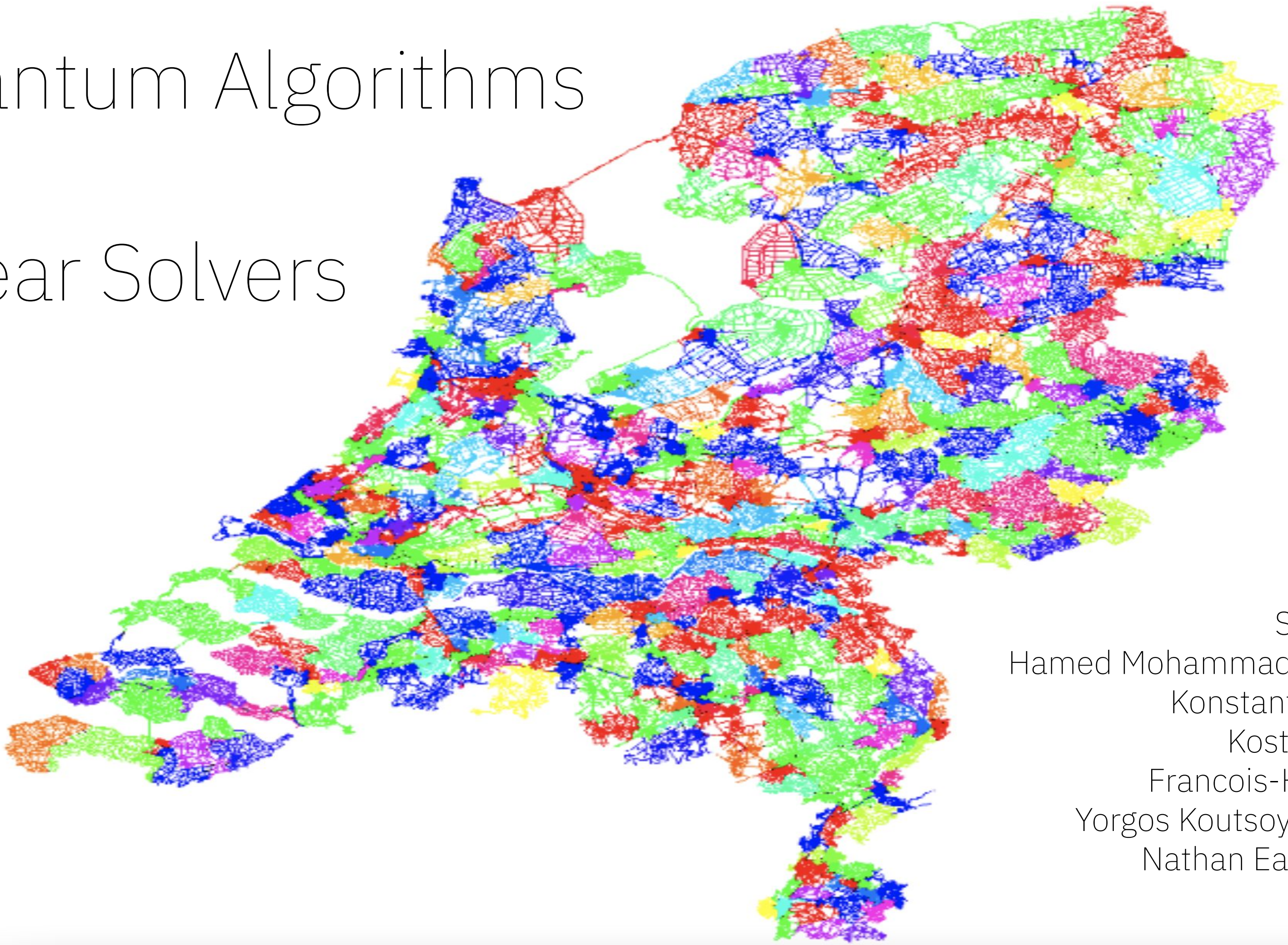
Quantum Algorithms for Linear Solvers



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Kostas Kafousas
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Yorgos Koutsoyannopoulos
Nathan Earnest-Noble
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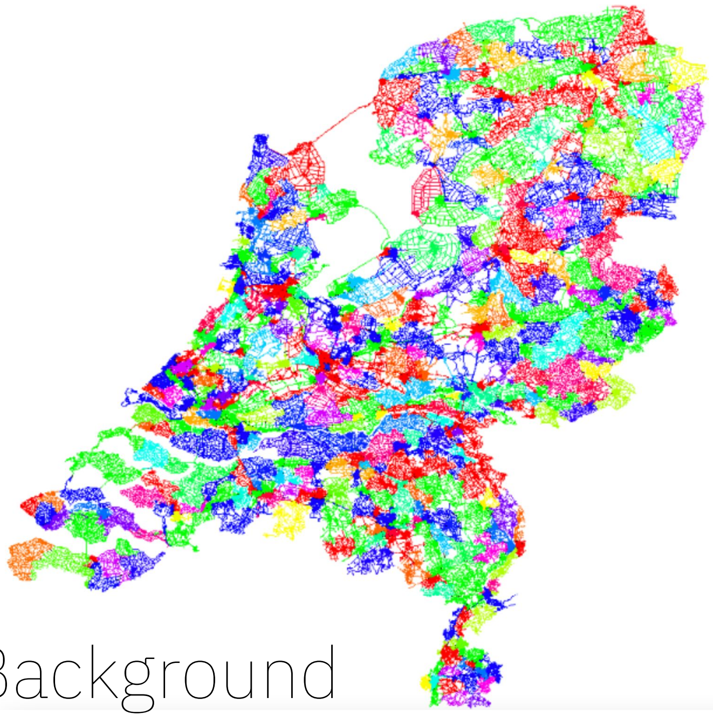
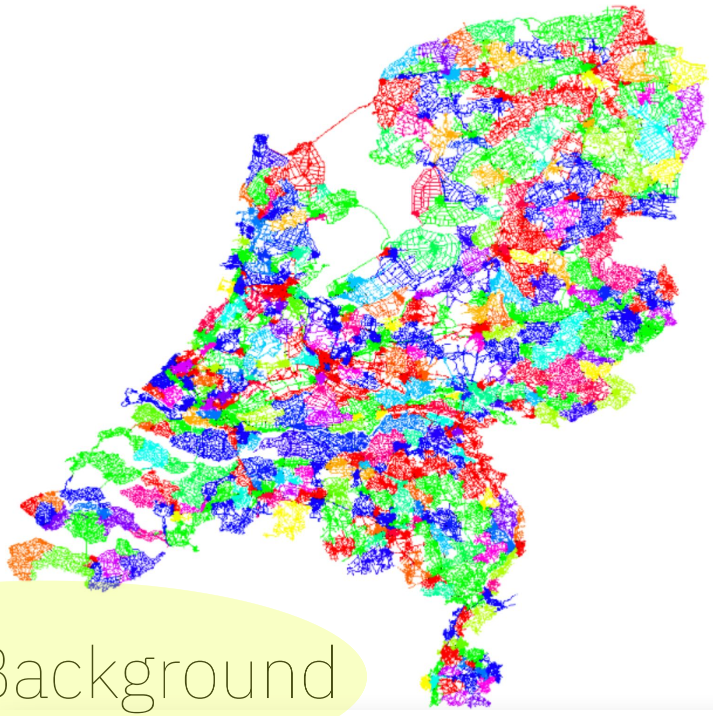
Guide



Part 1: Background

Part 2: Technical

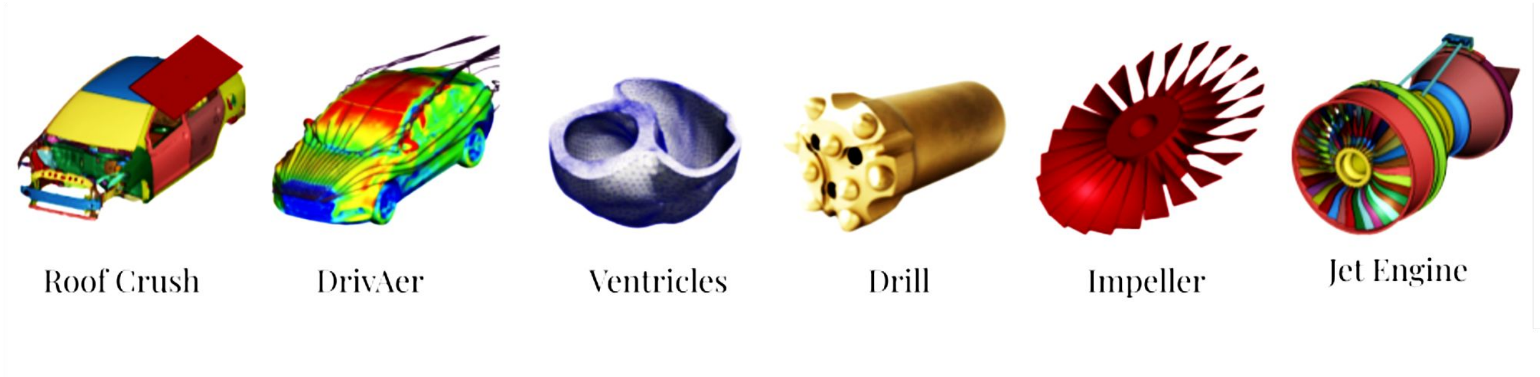
Guide

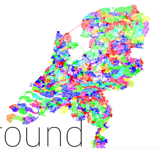


Part 1: Background

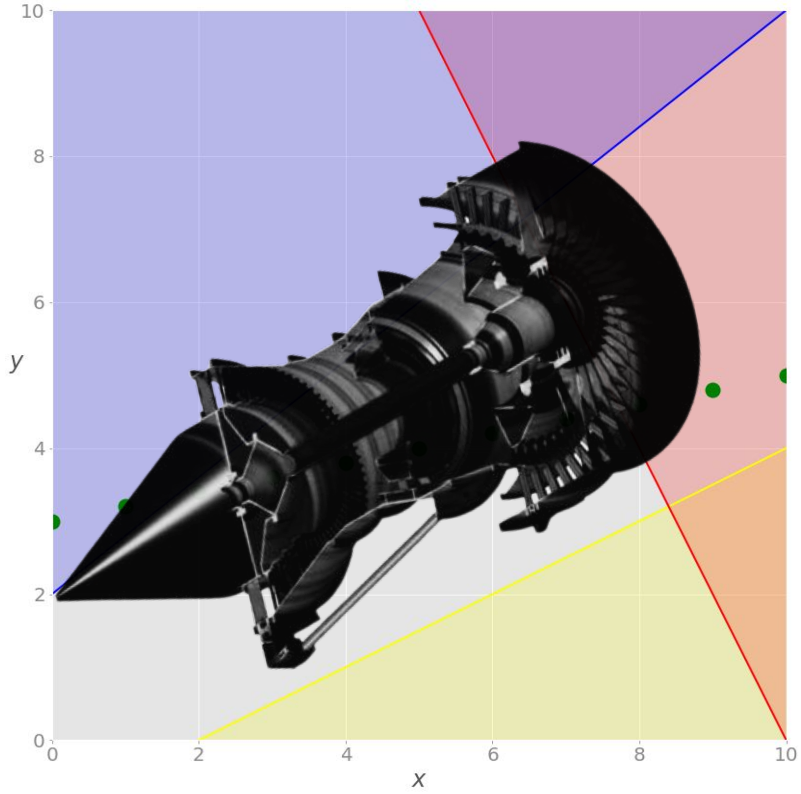
Part 2: Technical

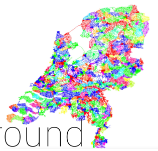
Ansys Simulates Objects





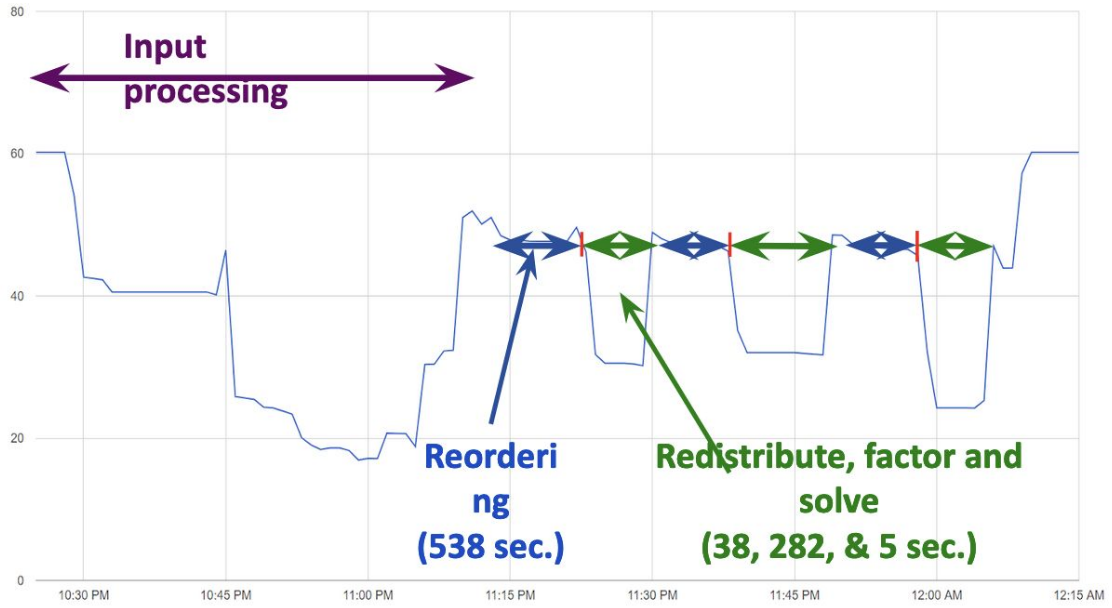
Simulating Objects Requires Solving Linear Equations



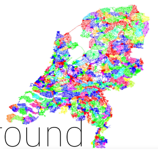


Background

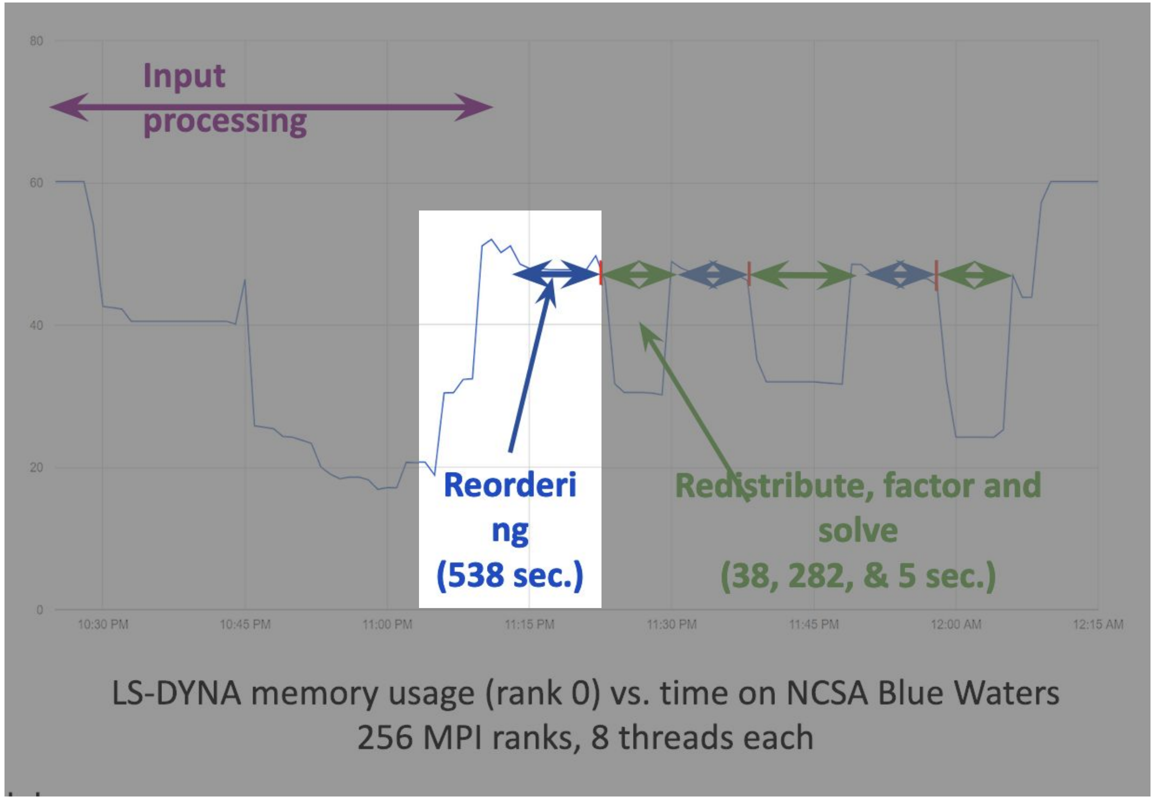
Linear Equation solving is Slow



LS-DYNA memory usage (rank 0) vs. time on NCSA Blue Waters
256 MPI ranks, 8 threads each



Reordering (**Graph Partitioning**) Dominates Runtime



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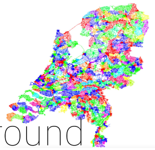
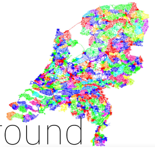
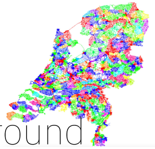


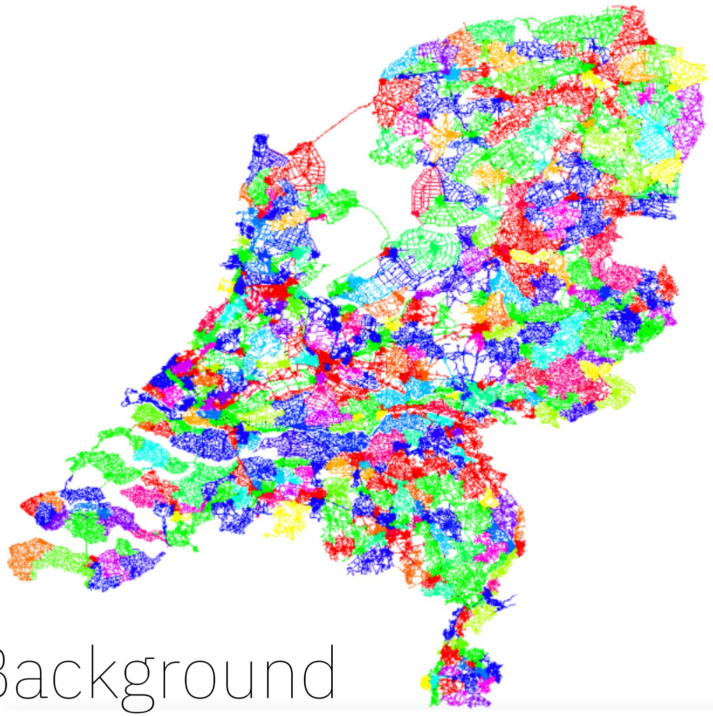
Graph Partitioning: the Bottleneck within the Bottleneck



We want to speed it up.



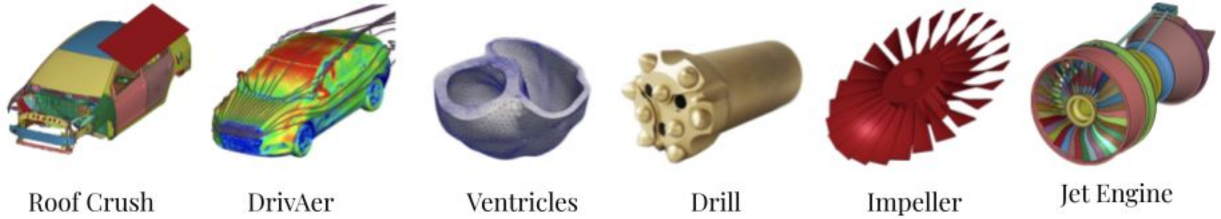
Guide

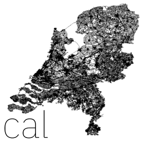


Part 1: Background

Part 2: Technical

Coarsened Graphs





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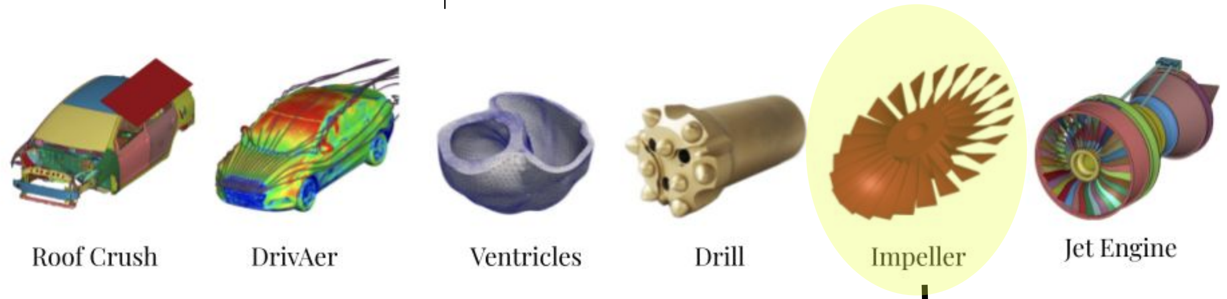
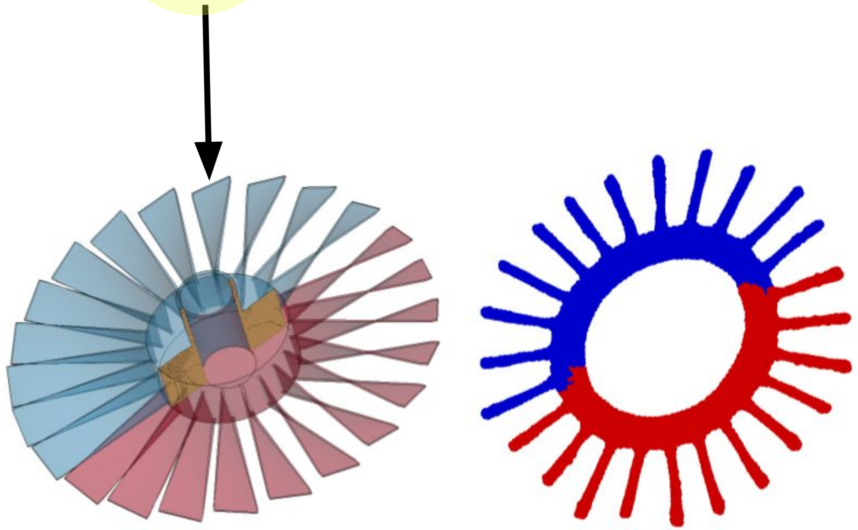
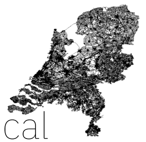
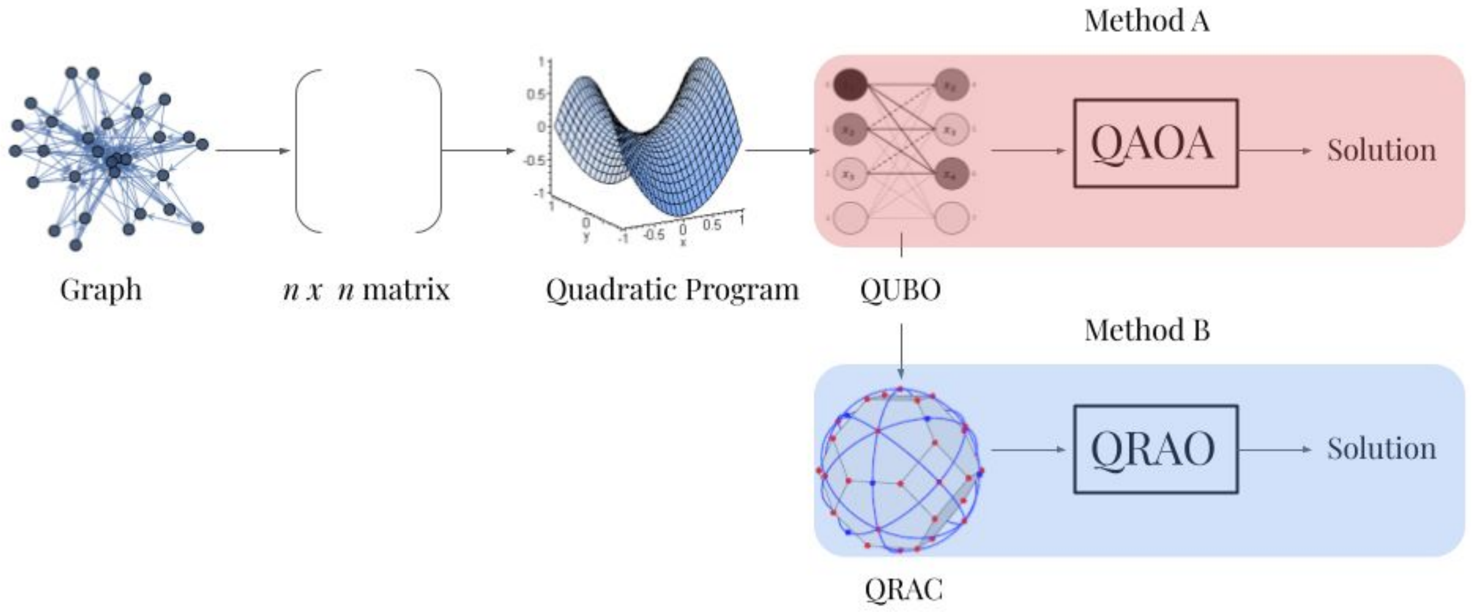
Coarsened Graphs

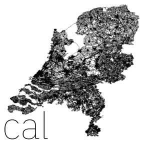





Technical

Two Methods for Quantum Graph Partitioning:





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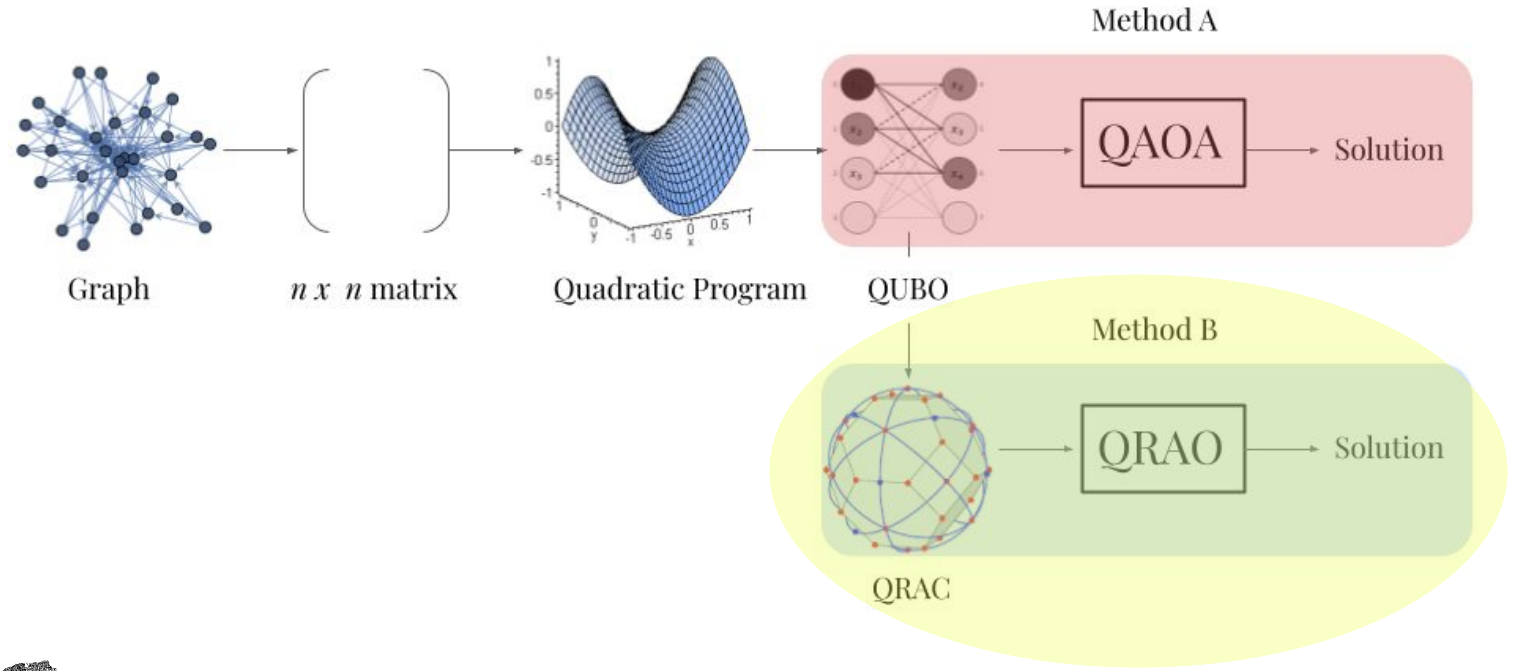

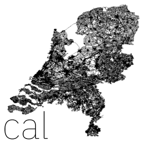

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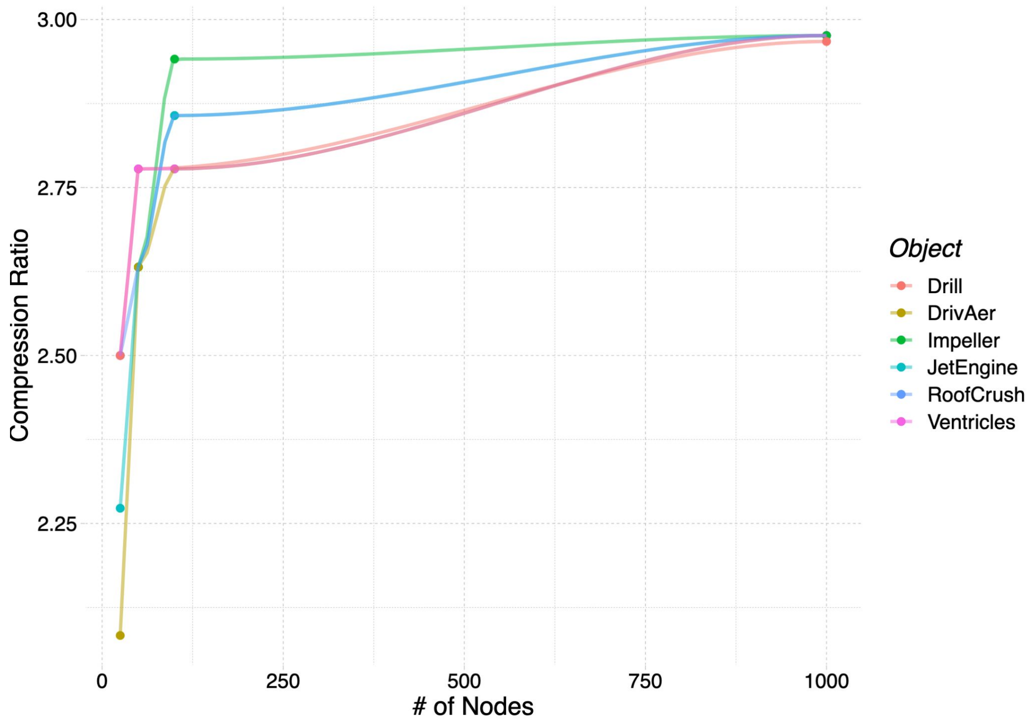
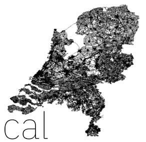
Compression Ratio Improved With Size





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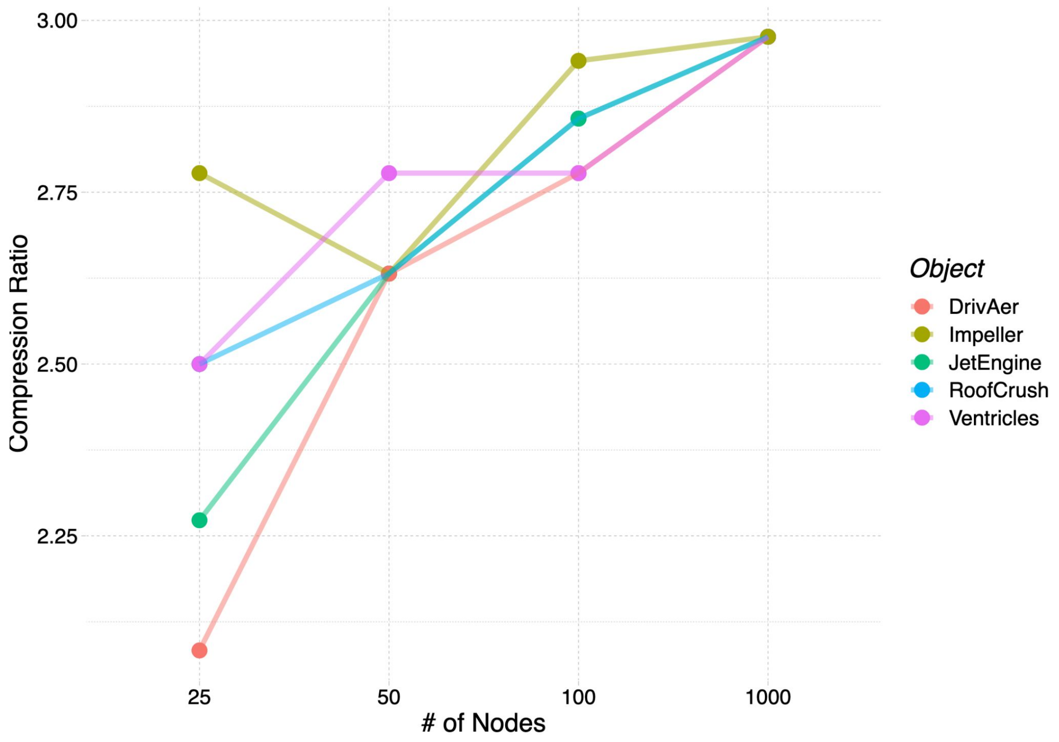
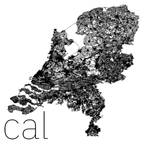
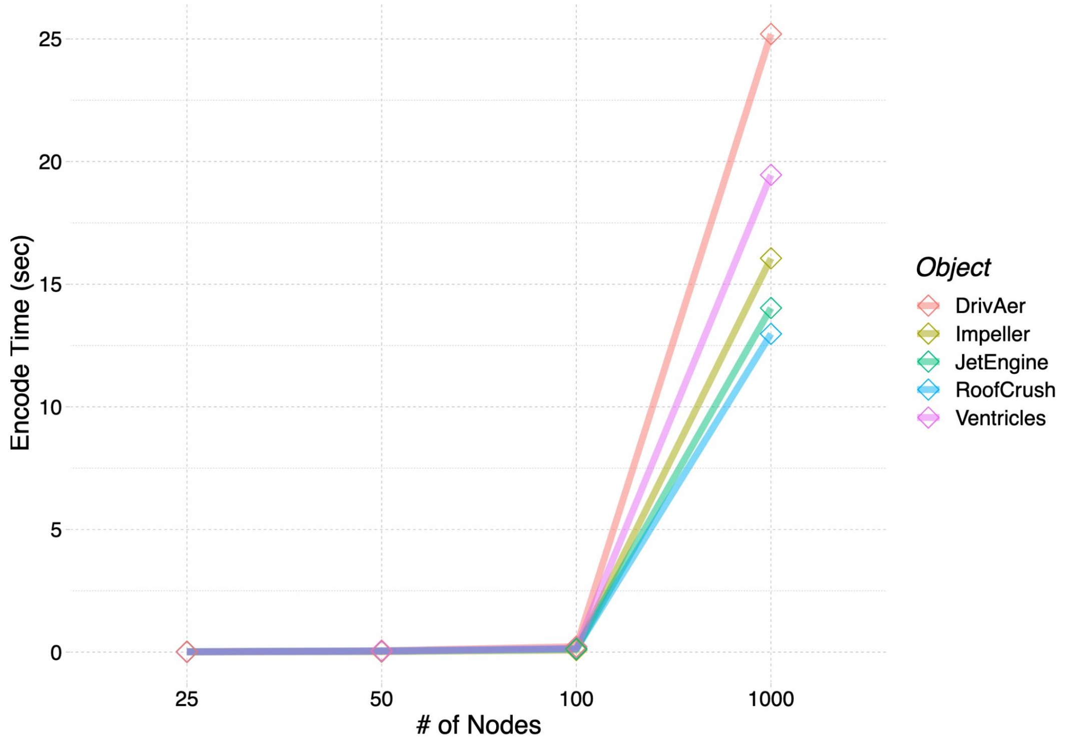
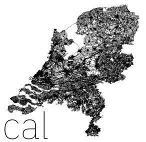
Compression Ratio Varied by Object



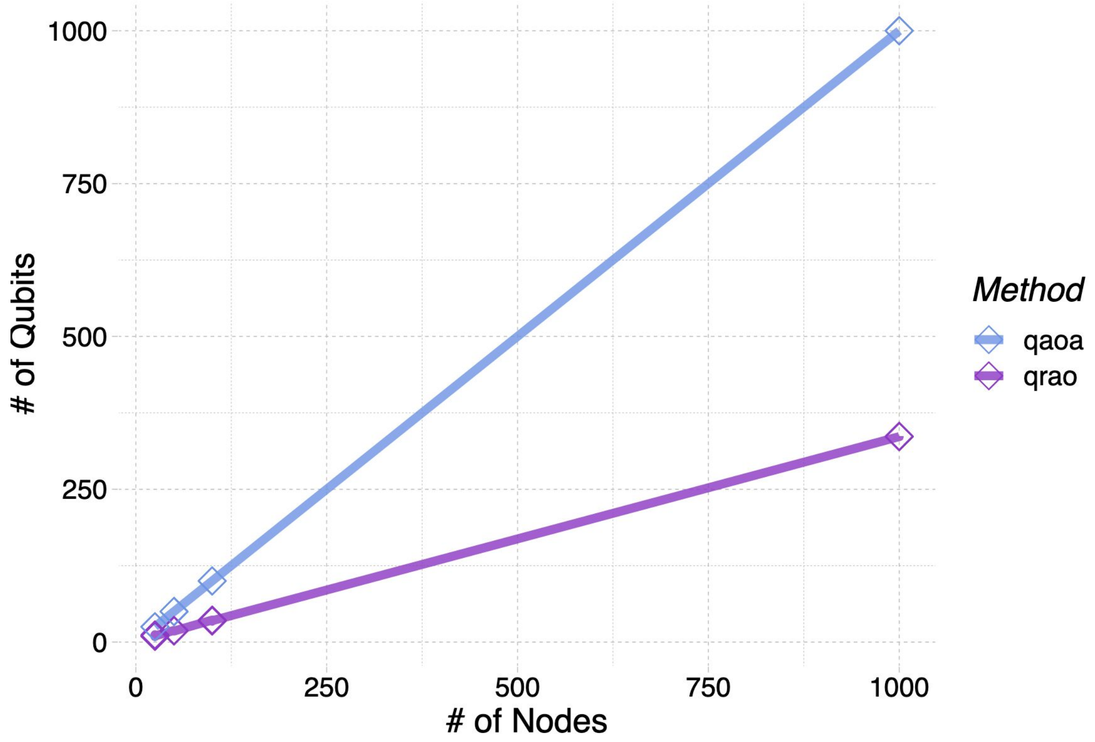


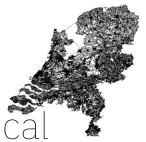
Encoding Time Scaled Exponentially





Still Seemed Preferable to QAOA





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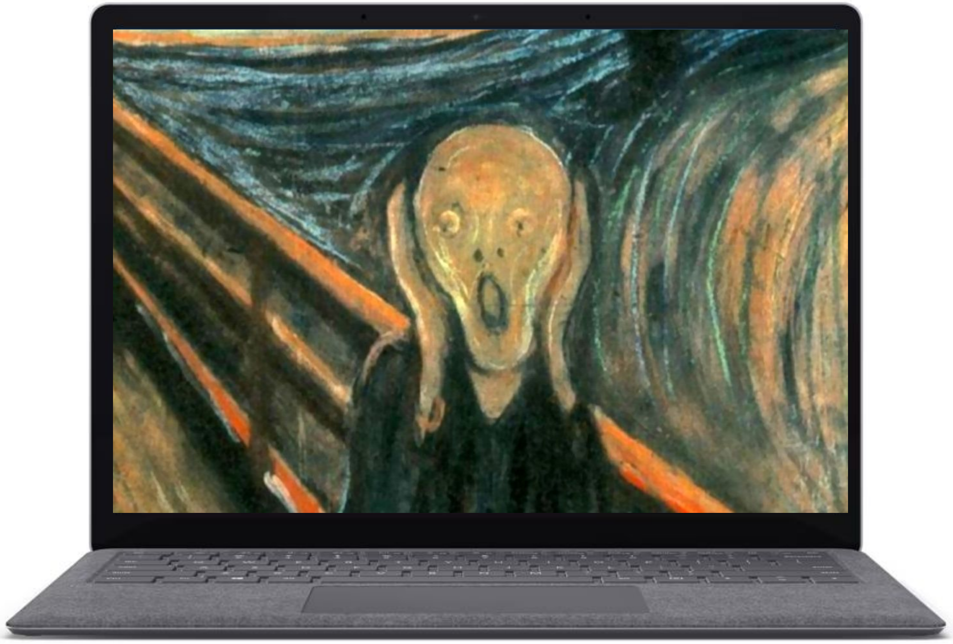
Trouble!



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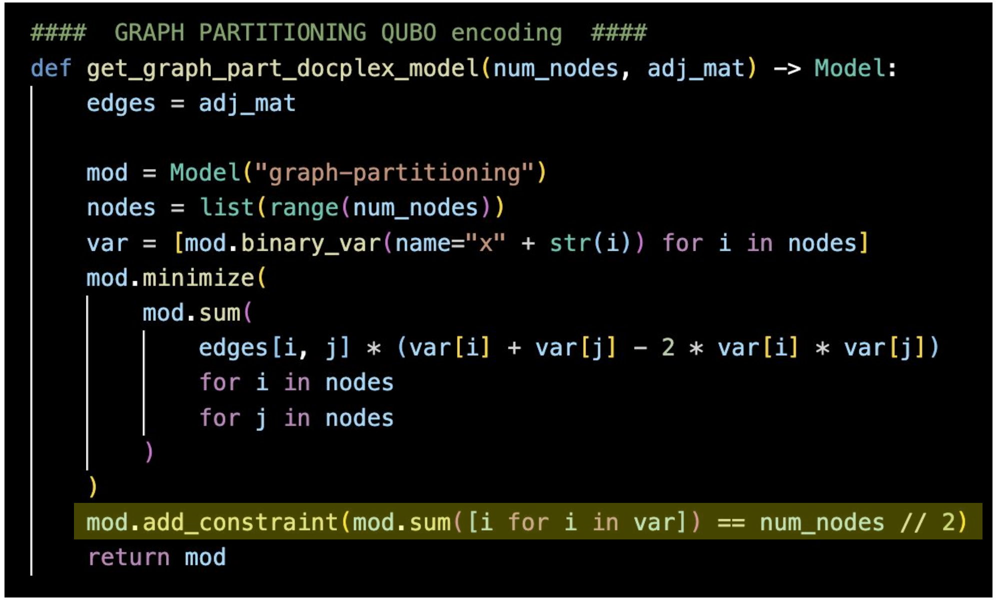
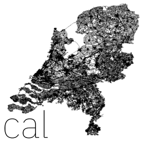
Balancing Constraint Removes Encoding Benefits



```
####  GRAPH PARTITIONING QUBO encoding  ####
def get_graph_part_docplex_model(num_nodes, adj_mat) -> Model:
    edges = adj_mat

    mod = Model("graph-partitioning")
    nodes = list(range(num_nodes))
    var = [mod.binary_var(name="x" + str(i)) for i in nodes]
    mod.minimize(
        mod.sum(
            edges[i, j] * (var[i] + var[j] - 2 * var[i] * var[j])
            for i in nodes
            for j in nodes
        )
    )
    mod.add_constraint(mod.sum([i for i in var]) == num_nodes // 2)
    return mod
```



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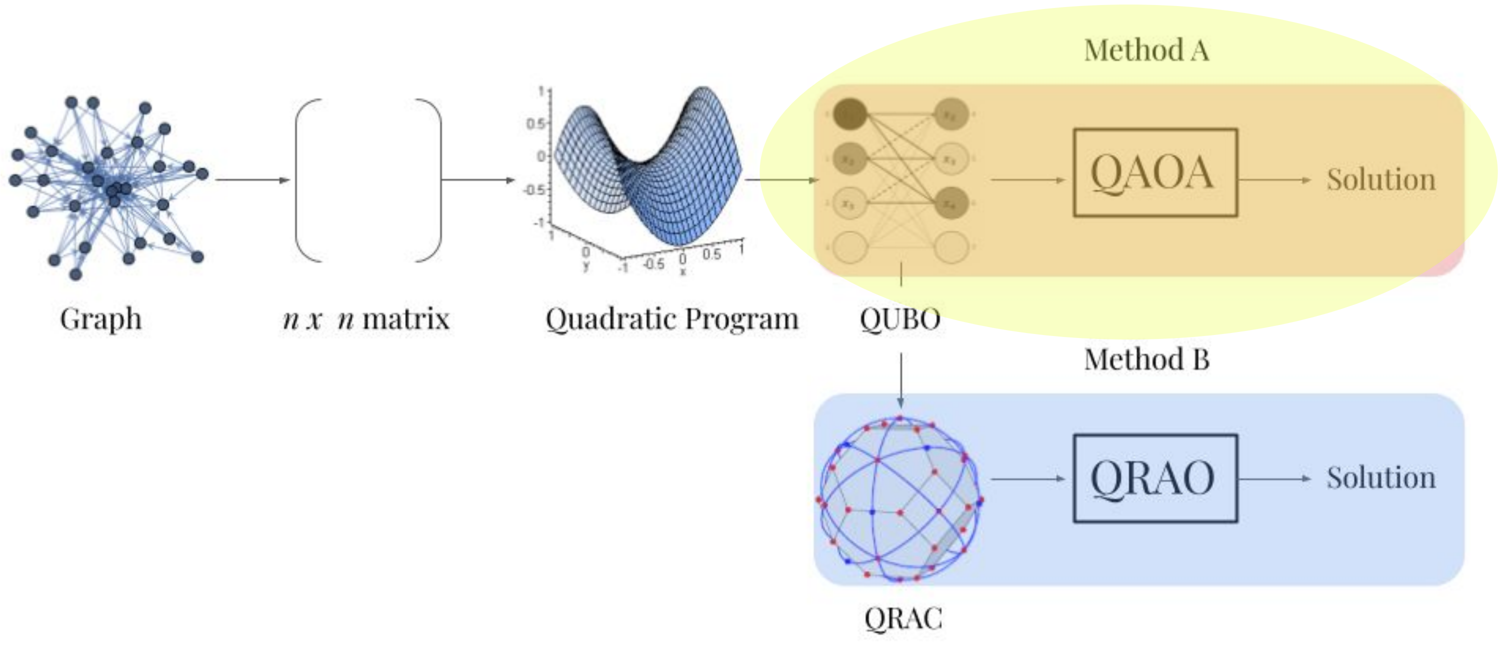
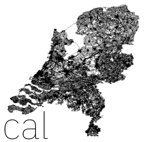
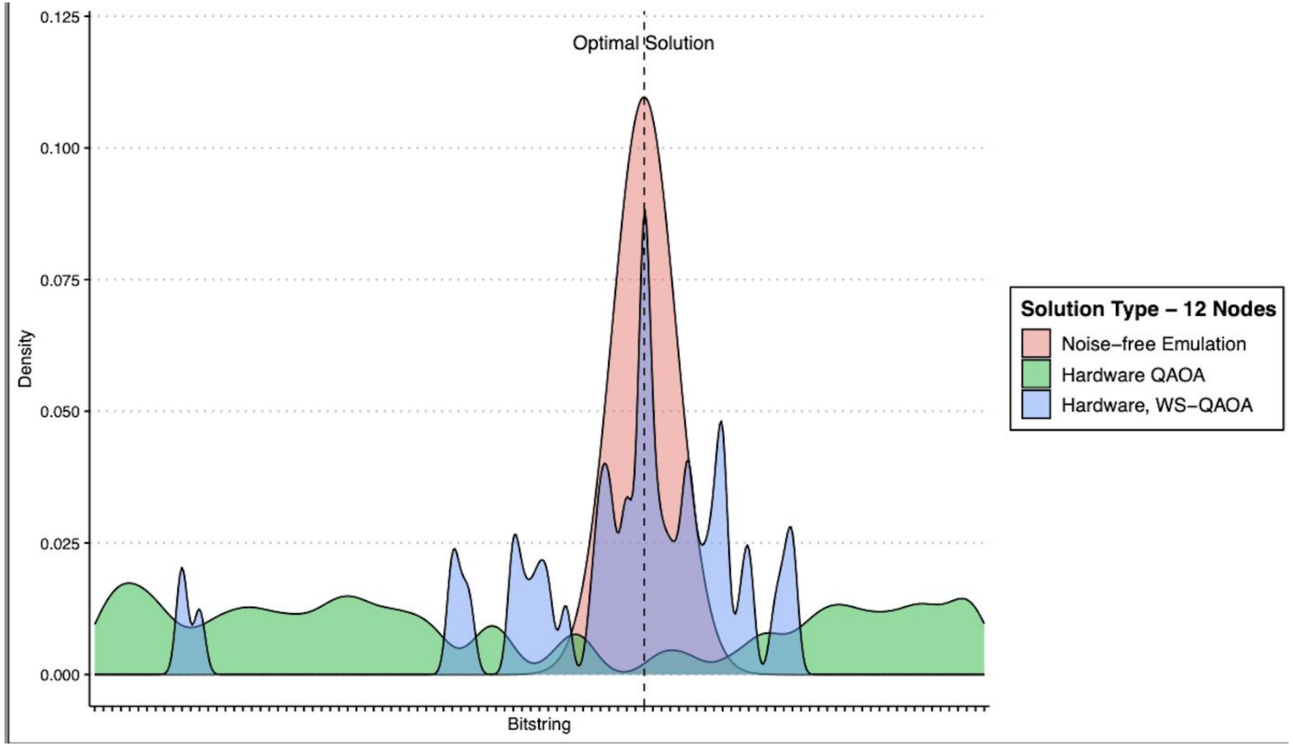


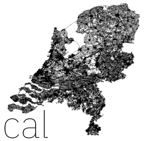


12 Nodes

Hardware Results :

Need Warm Start For Good Convergence





Technical

25 Nodes

Hardware Results :

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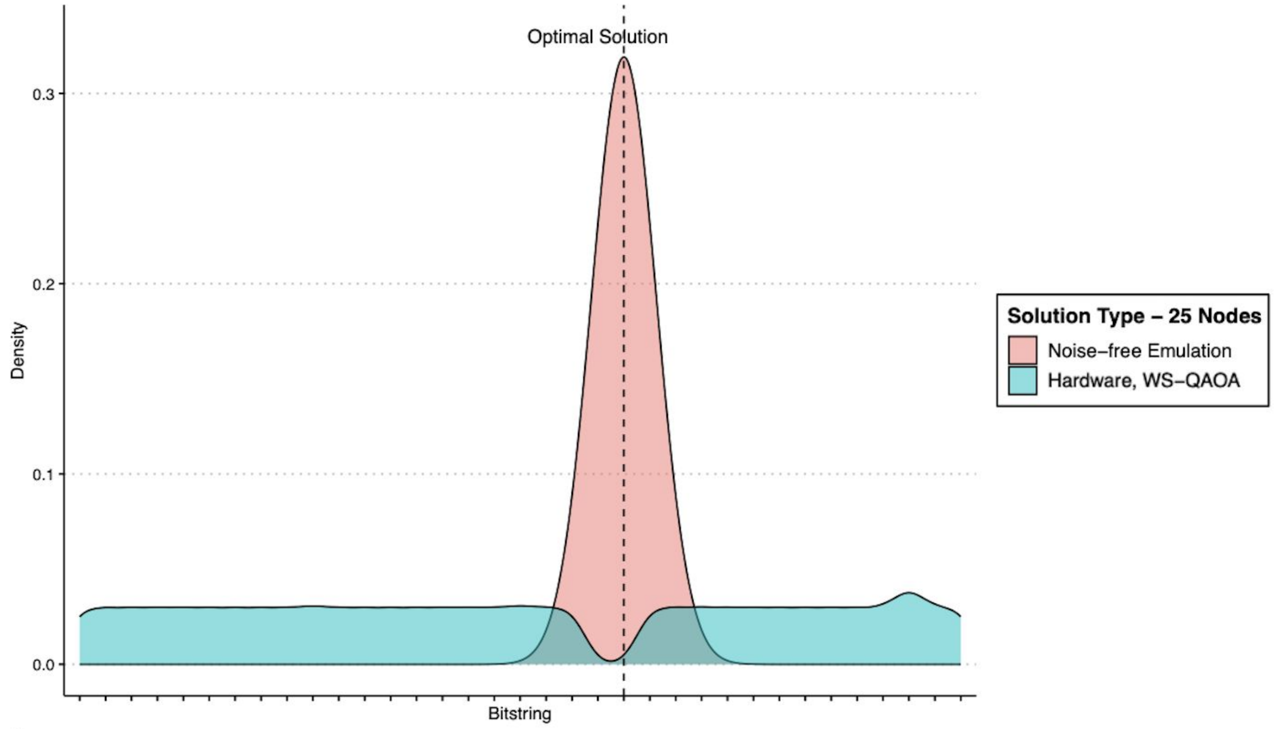

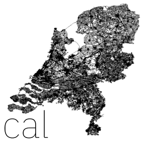

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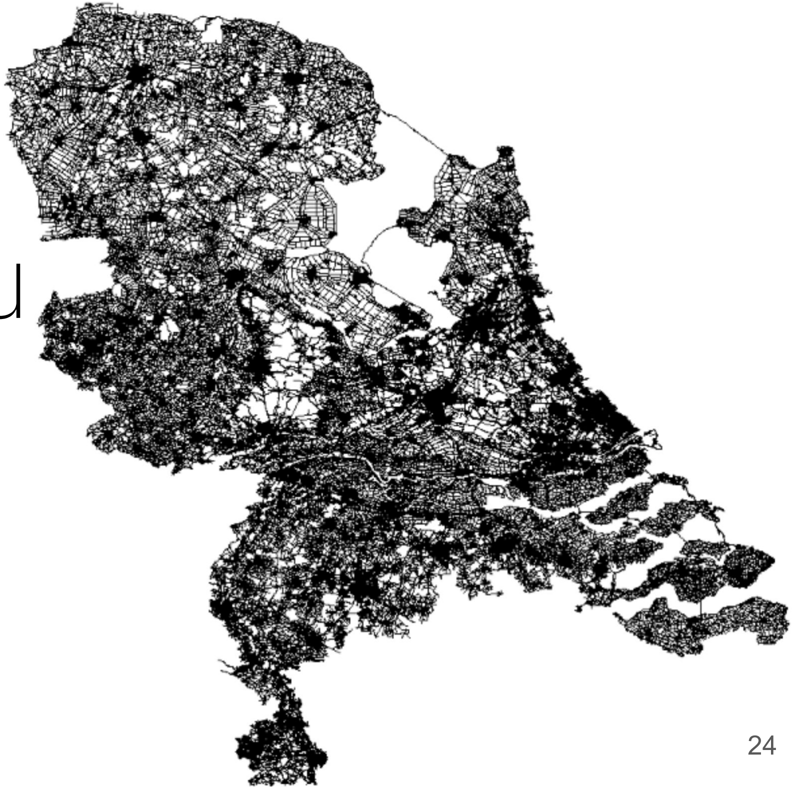

Thank You

Questions?

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25 Nodes

Hardware Results :

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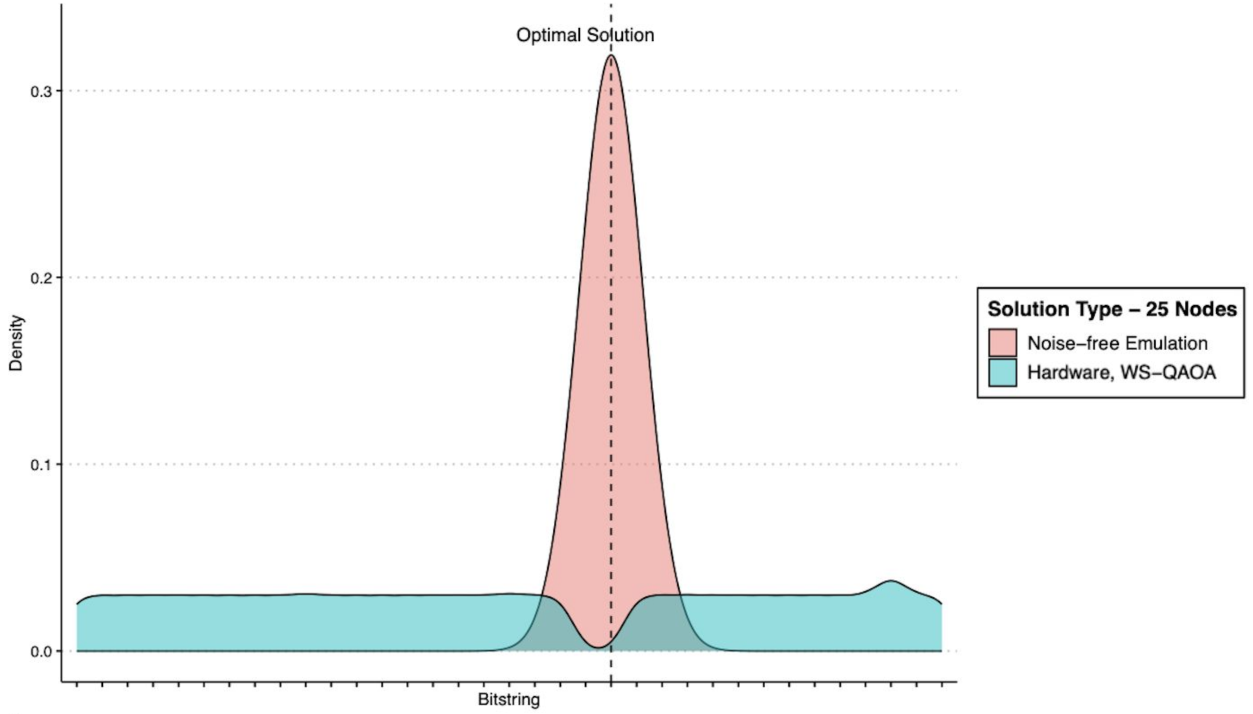

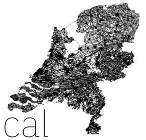

Technical