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# Science behind Dynamic Airspace Configuration

*Combining machine learning and  
optimization for Dynamic  
Airspace Sectorization*

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Research Scientist  
SINTEF Digital – Analytics and AI

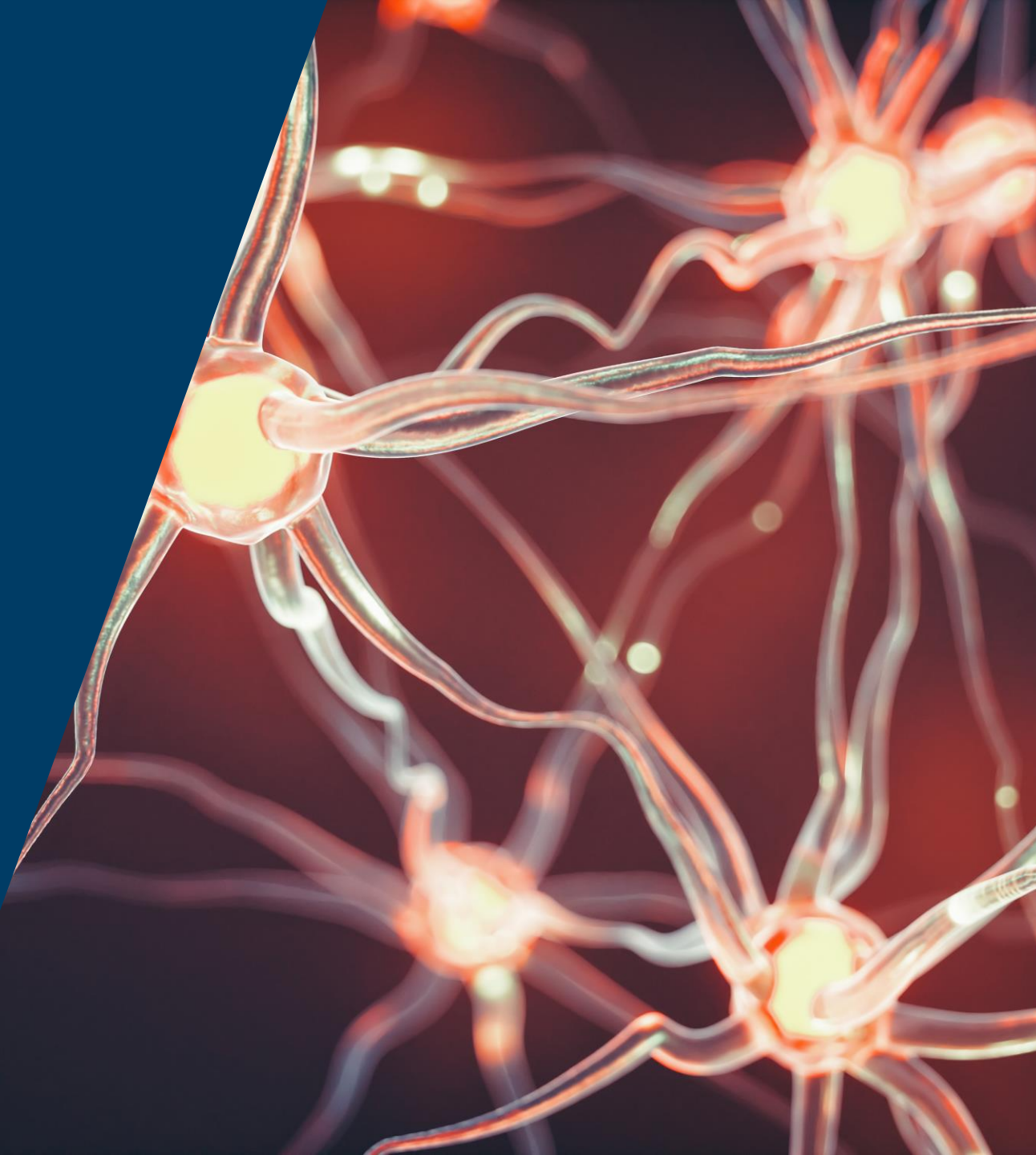


Teknologi for et bedre samfunn



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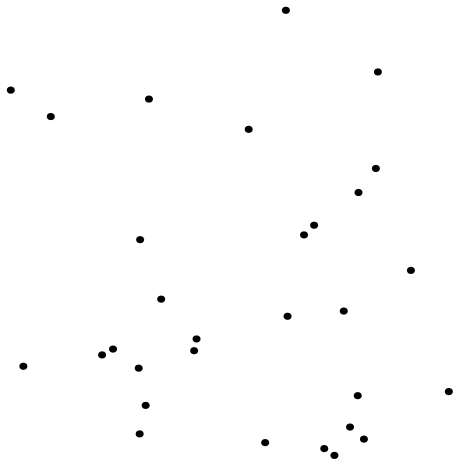
# Machine Learning and Combinatorial Optimisation





# Combinatorial Optimization and Machine Learning

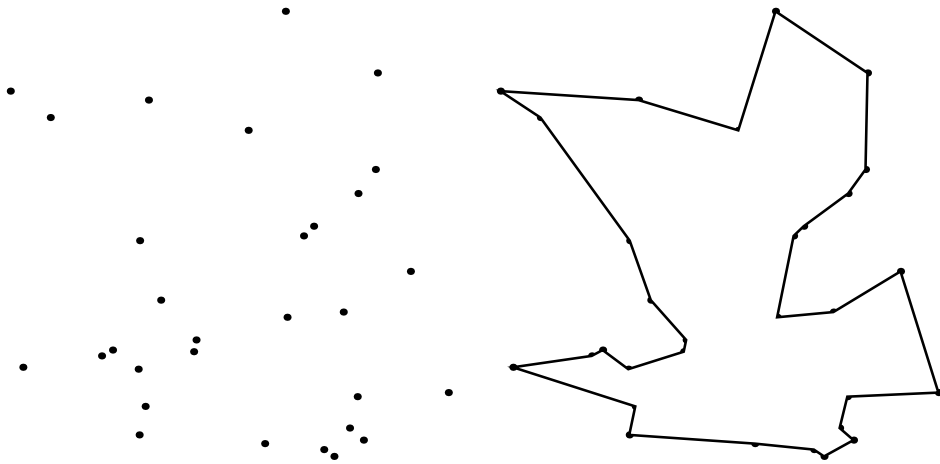
- Combinatorial Optimization:





# Combinatorial Optimization and Machine Learning

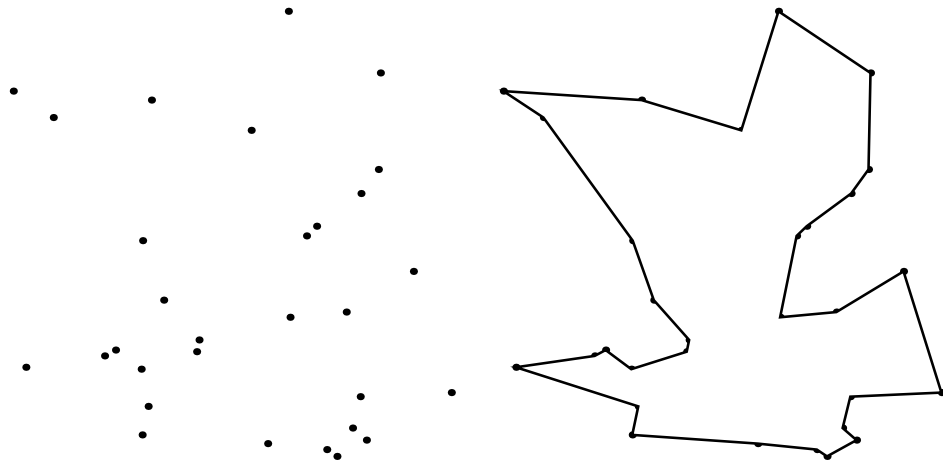
- Combinatorial Optimization:





# Combinatorial Optimization and Machine Learning

- Combinatorial Optimization:
  - Top-down approach

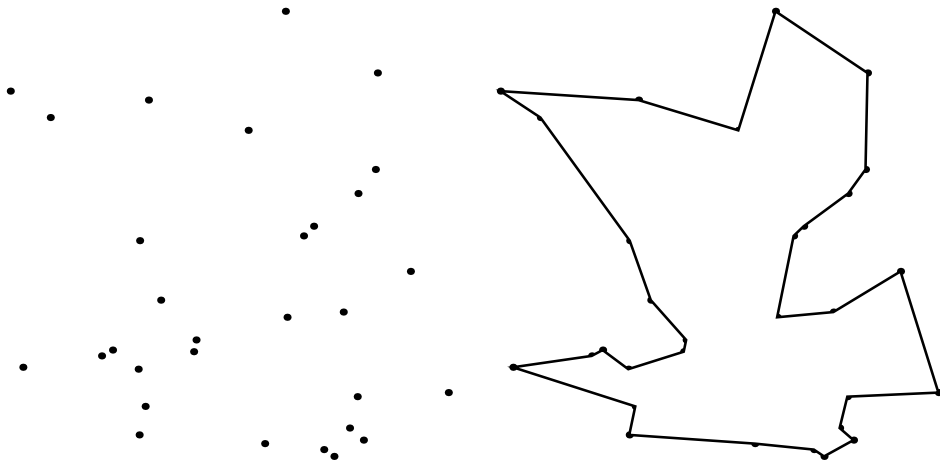




# Combinatorial Optimization and Machine Learning

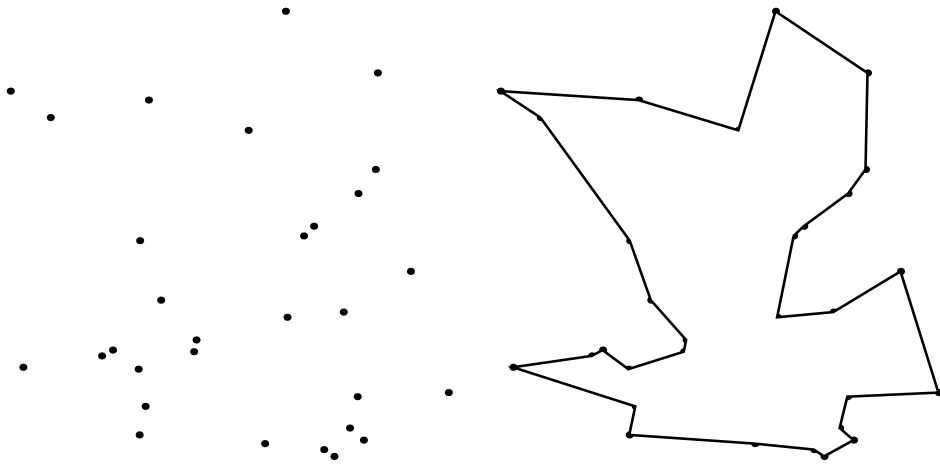
- Combinatorial Optimization:
  - Top-down approach

- Machine Learning



# Combinatorial Optimization and Machine Learning

- Combinatorial Optimization:
  - Top-down approach

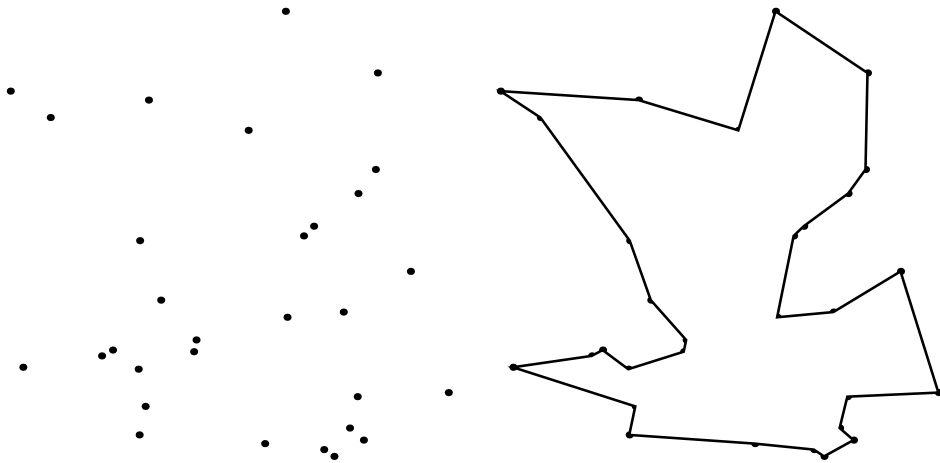


- Machine Learning



# Combinatorial Optimization and Machine Learning

- Combinatorial Optimization:
  - Top-down approach



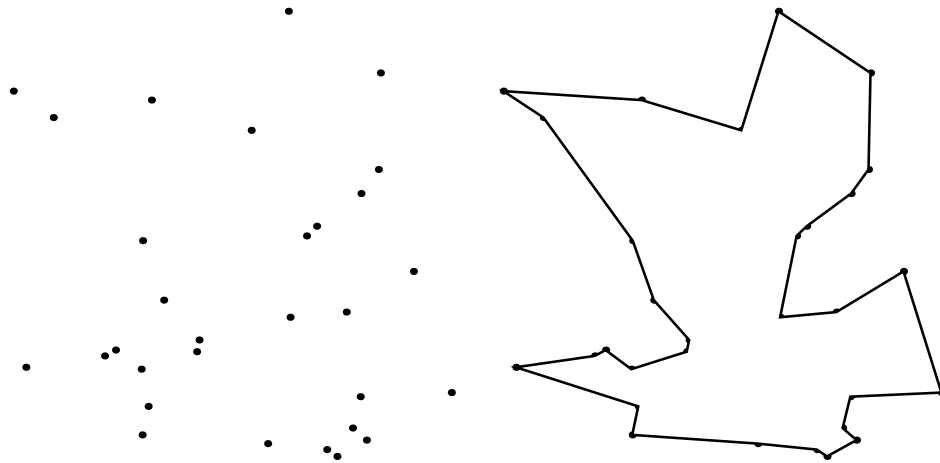
- Machine Learning
  - Bottom-up approach





# Combinatorial Optimization and Machine Learning

- Combinatorial Optimization:
  - Top-down approach

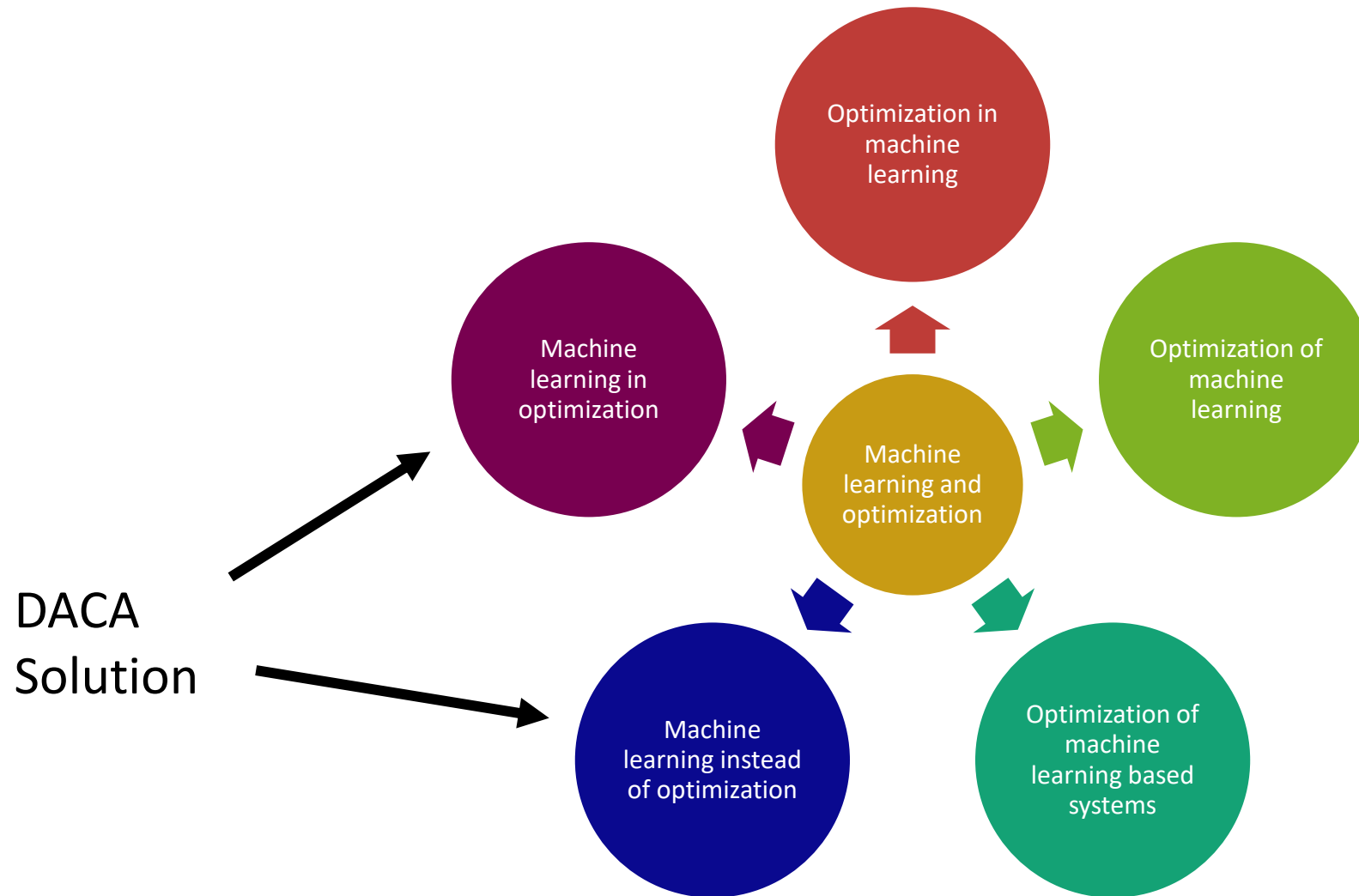


- Machine Learning
  - Bottom-up approach





# Interplay between machine learning and optimisation





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# The (static) airspace sectorization problem

Giorgio Grani, Carlo Mannino, Patrick Schittekat





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# Static airspace sectorization problem

- Finding a partition of the airspace suitable for human operators.

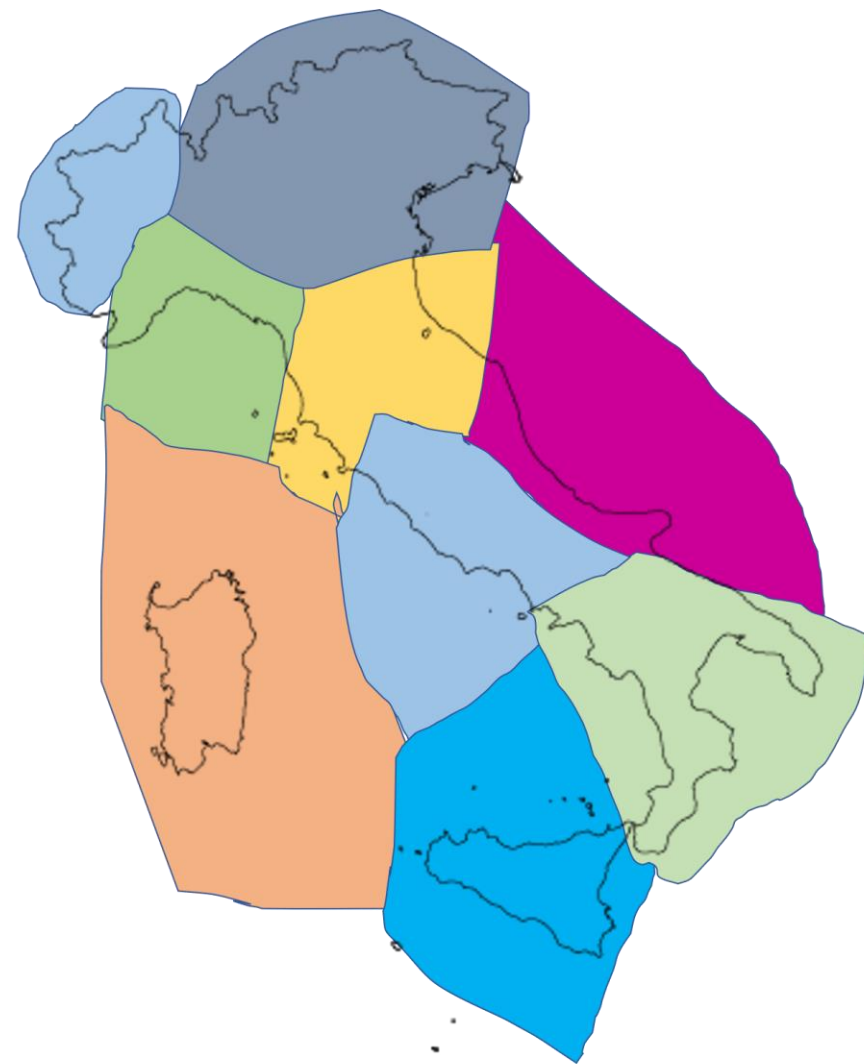




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# Static airspace sectorization problem

- Finding a partition!
  - All the space must be covered
  - Overlaps are not allowed
- Suitable for human operators.
  - Minimizing total workload
  - Minimizing workload unbalance





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# Static airspace sectorization problem

- How to represent sectors?



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# Static airspace sectorization problem

- How to represent sectors?
  - Polygons?





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# Static airspace sectorization problem

- How to represent sectors?
  - ~~Polygons?~~



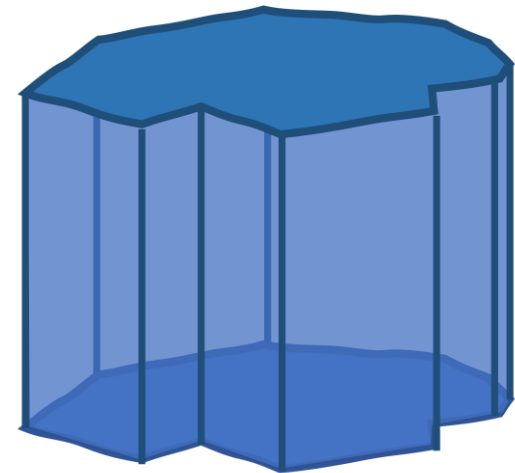




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# Static airspace sectorization problem

- How to represent sectors?
  - ~~Polygons?~~
  - 3D Prisms!

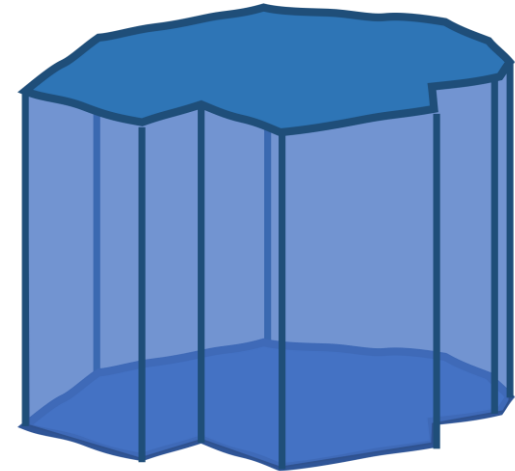




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# Static airspace sectorization problem

- How to represent sectors?
  - ~~Polygons?~~
  - 3D Prisms!
- Sectors are subject to operational constraints to be workable:
  - Contains no sharp angles
  - Contains no 'thin' subspaces





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# How to measure workload?

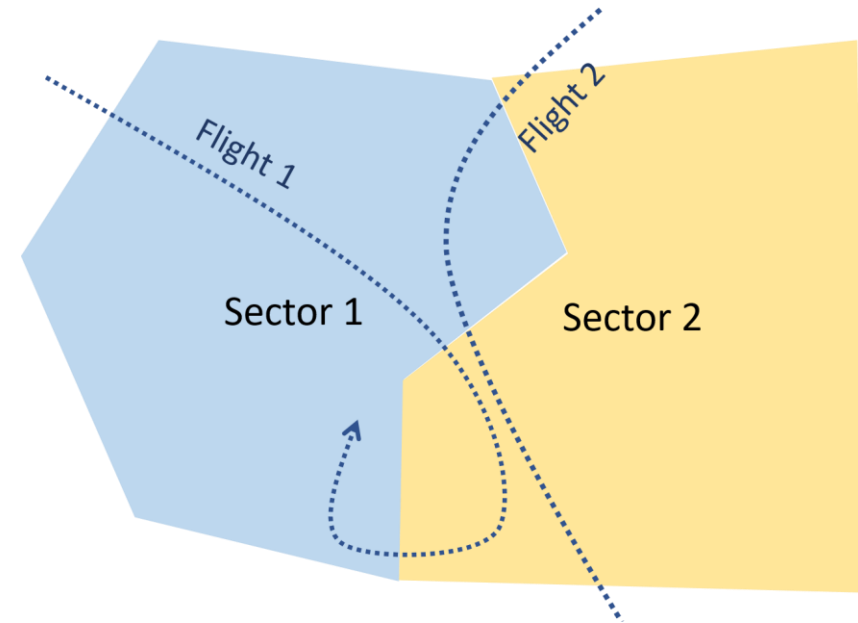




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# How to measure workload?

- Defining the workload function
  - Affected by regulatory rules

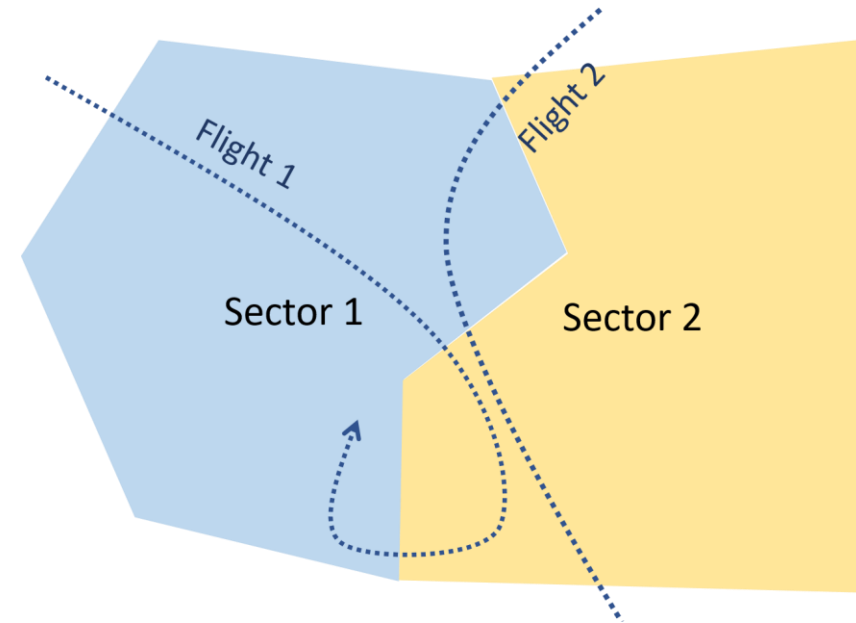




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# How to measure workload?

- Defining the workload function
  - Affected by regulatory rules
- Several factors
  - Average flight time
  - Conflicting flights
  - Number of flights entering sector
  - Flights near the border
  - ...

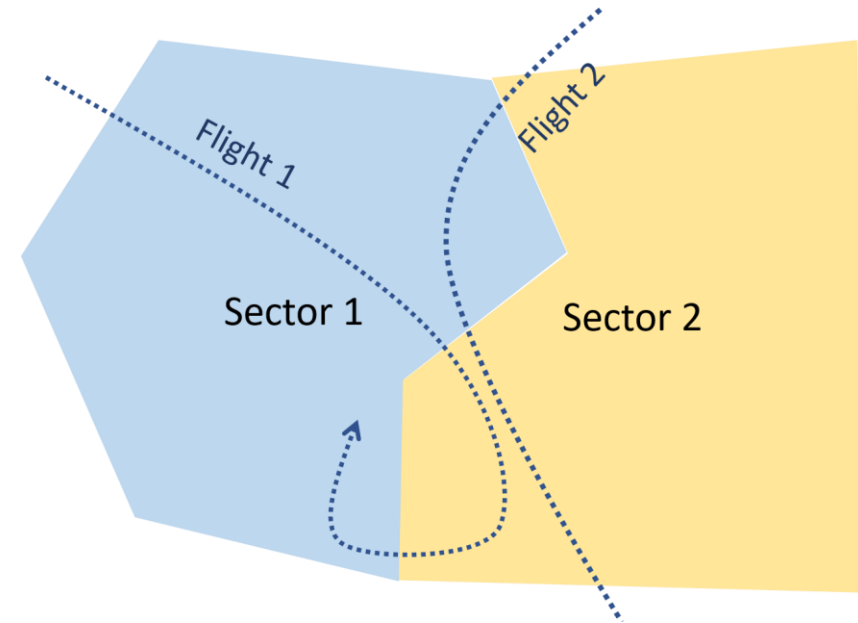




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# How to measure workload?

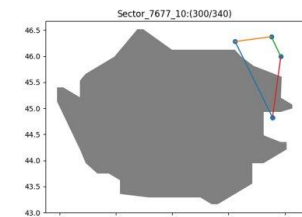
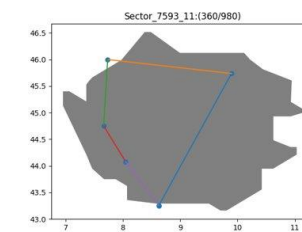
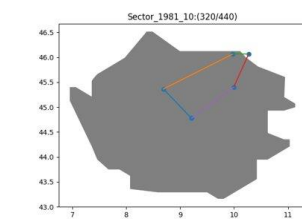
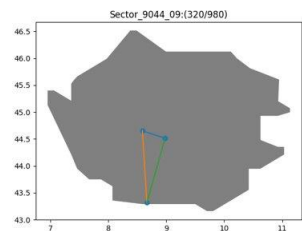
- Defining the workload function
  - Affected by regulatory rules
- Several factors
  - Average flight time
  - Conflicting flights
  - Number of flights entering sector
  - Flights near the border
  - ...
- Problem: Very heavy to compute!





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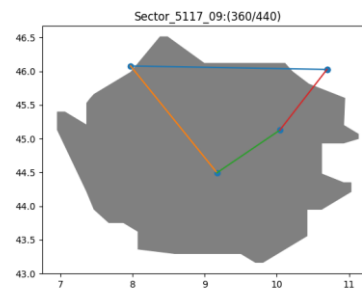
# Machine Learning to approximate workloads



Data set of  
random sectors  
with associated  
workloads

Machine  
Learning  
Model

Estimated  
workload of  
unknown  
sectors





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# Solving the Airspace sectorization problem







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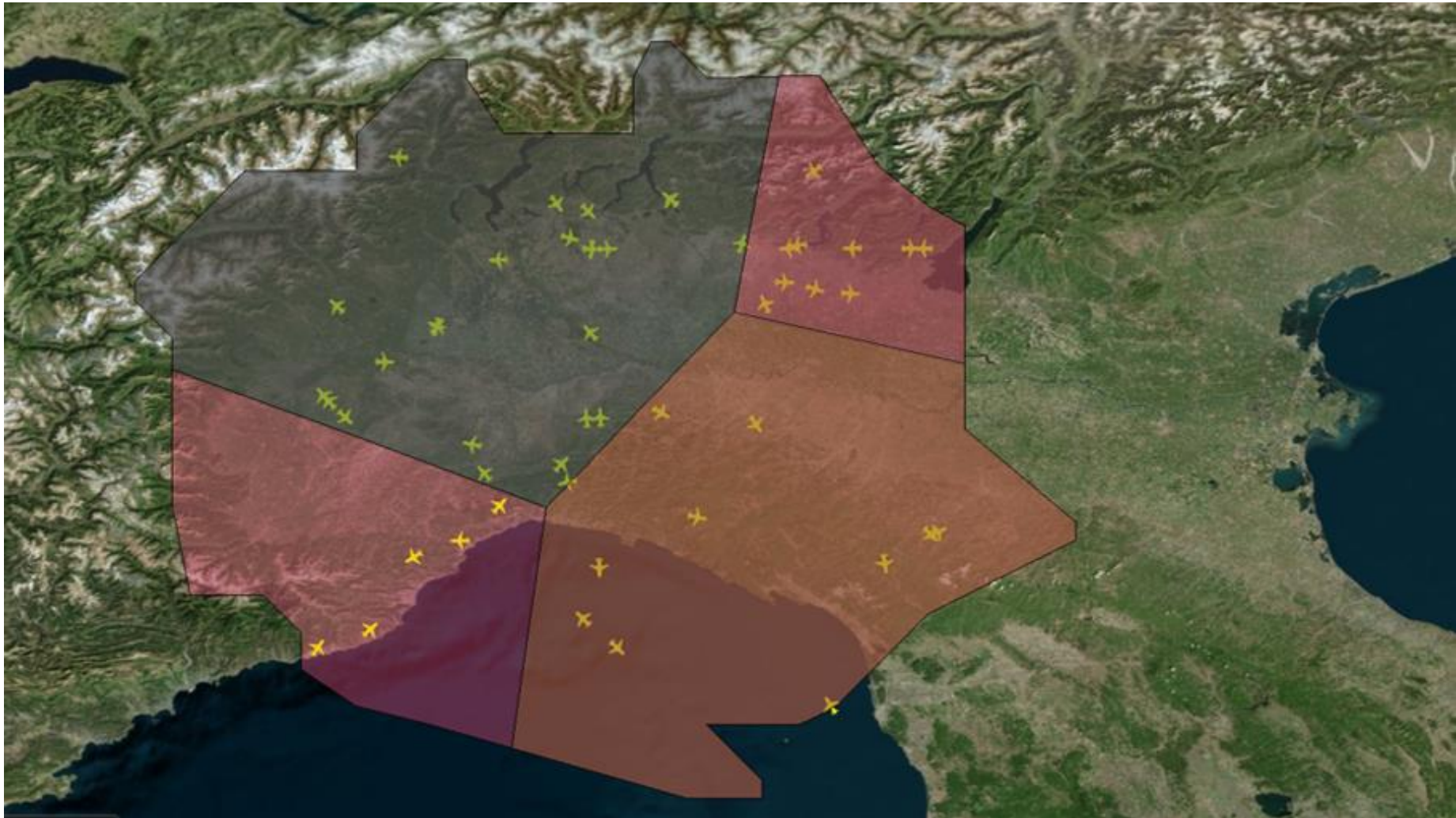
# Solving the airspace configuration problem





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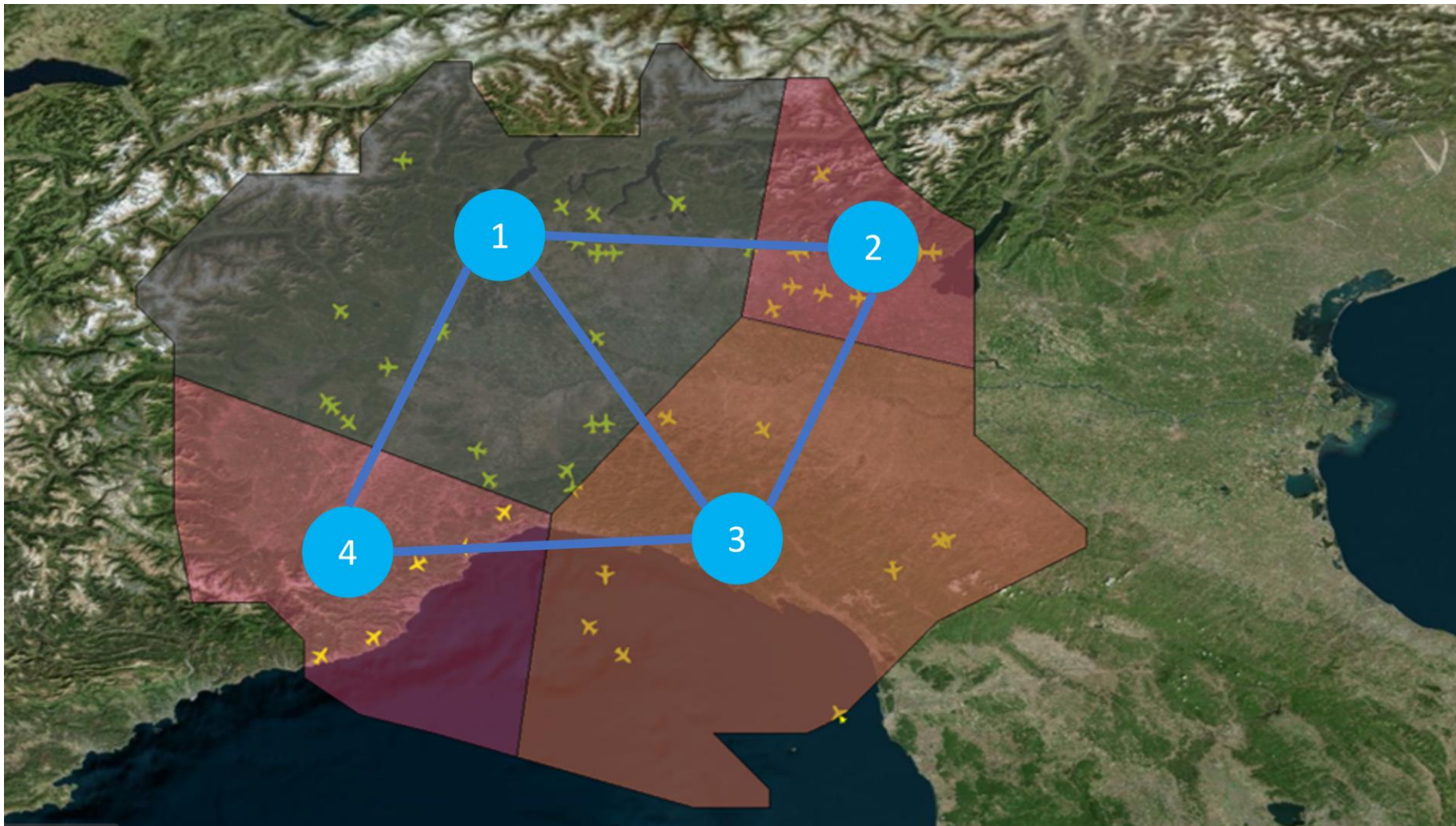
# Solving the airspace configuration problem





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# Solving the airspace configuration problem

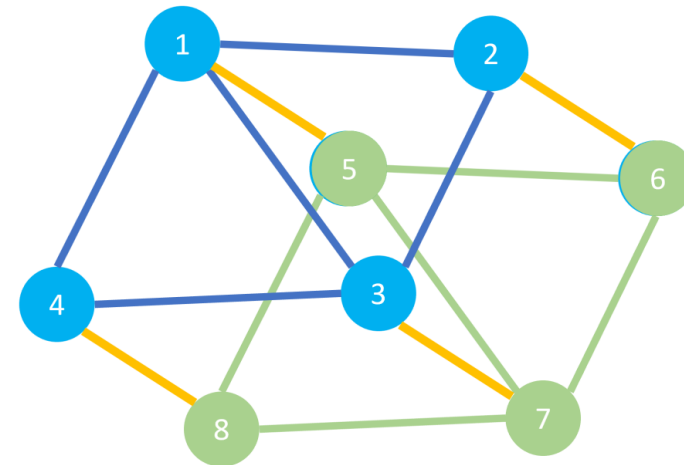
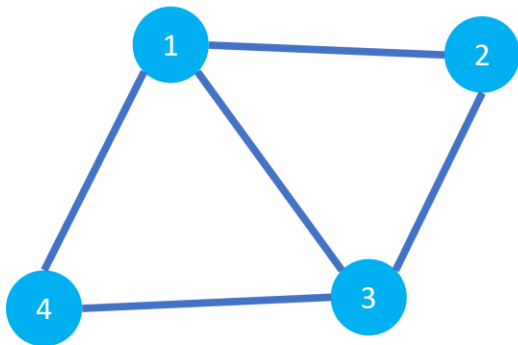




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# Solving the airspace configuration problem

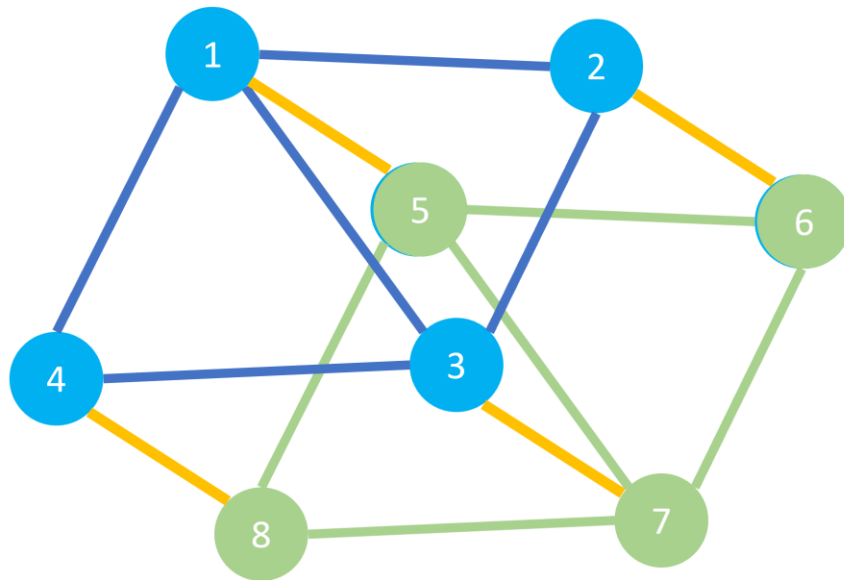
- From a 2D problem to a 3D problem.





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# The optimization solution



Of all the possible structures that we get by:

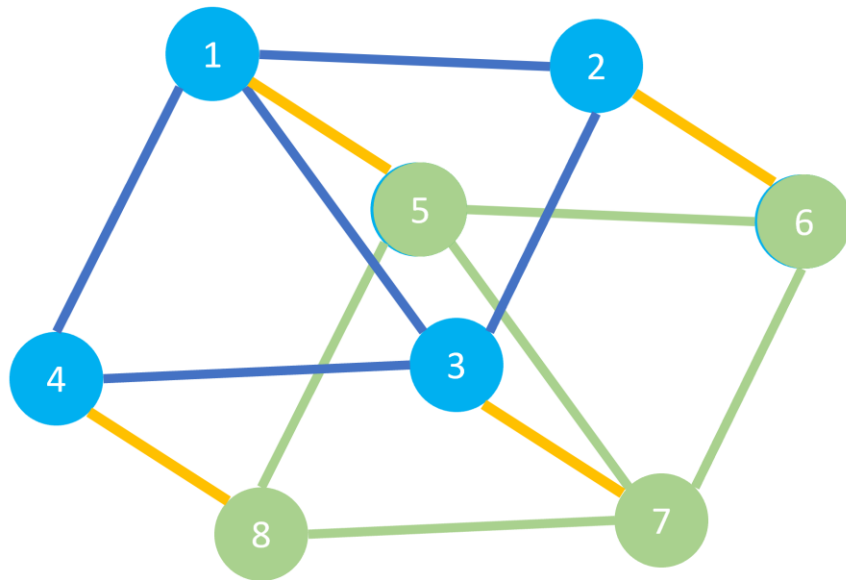
- Merging two sectors
- Splitting a sector in two

Which configuration leads to acceptable workloads?



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# The optimization solution



Of all the possible structures that we get by:

- Merging two sectors
- Splitting a sector in two

Which configuration leads to acceptable workloads?

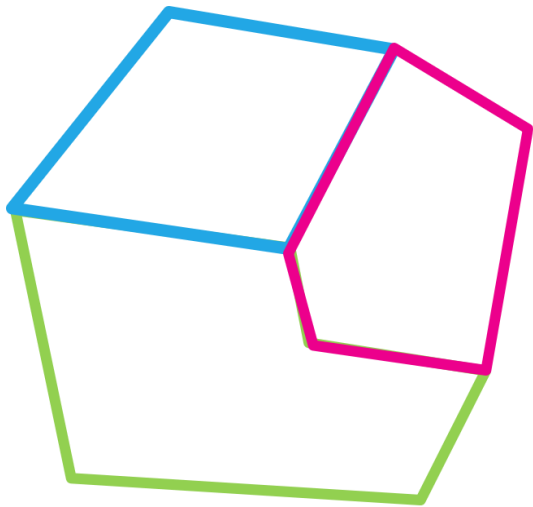
- The static case is now solved :)



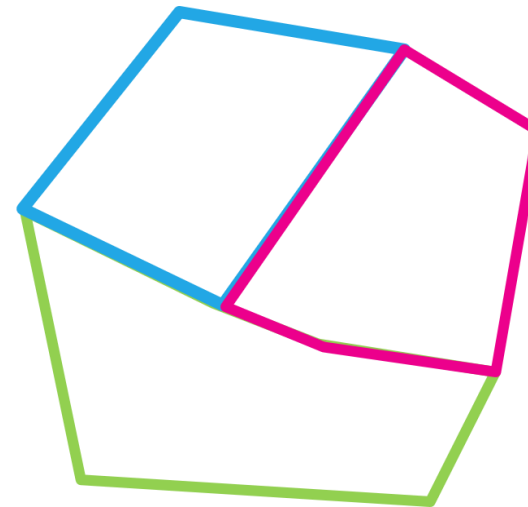
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# Dynamic sectorization

- A balanced sectorization at 9am may not be balanced at 11am!
  - Moving inner points towards a balanced sectorization.



9 AM



11 AM



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# Wrapping up – DACA overview



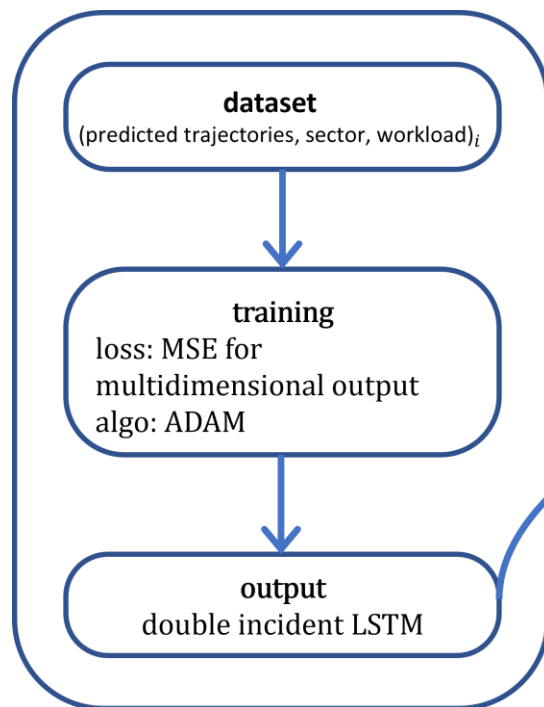




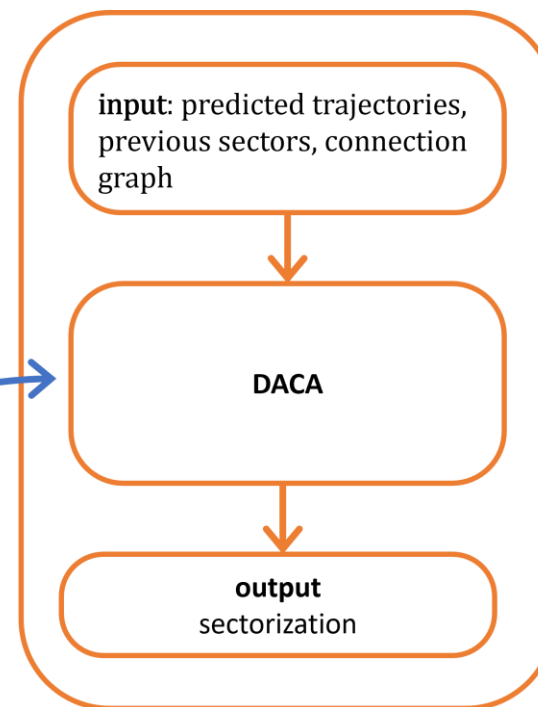
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# Overview of DACA

## Machine Learning



## Optimisation



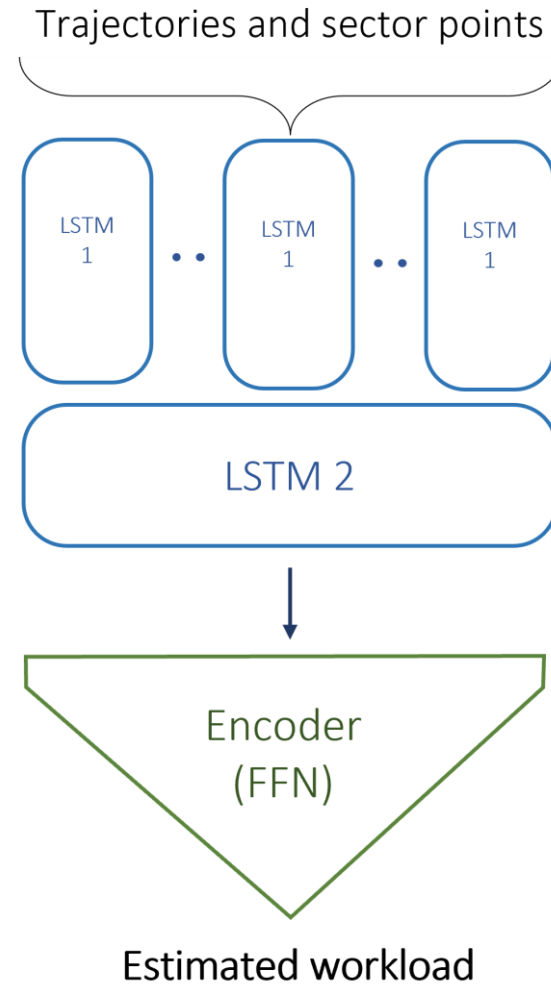


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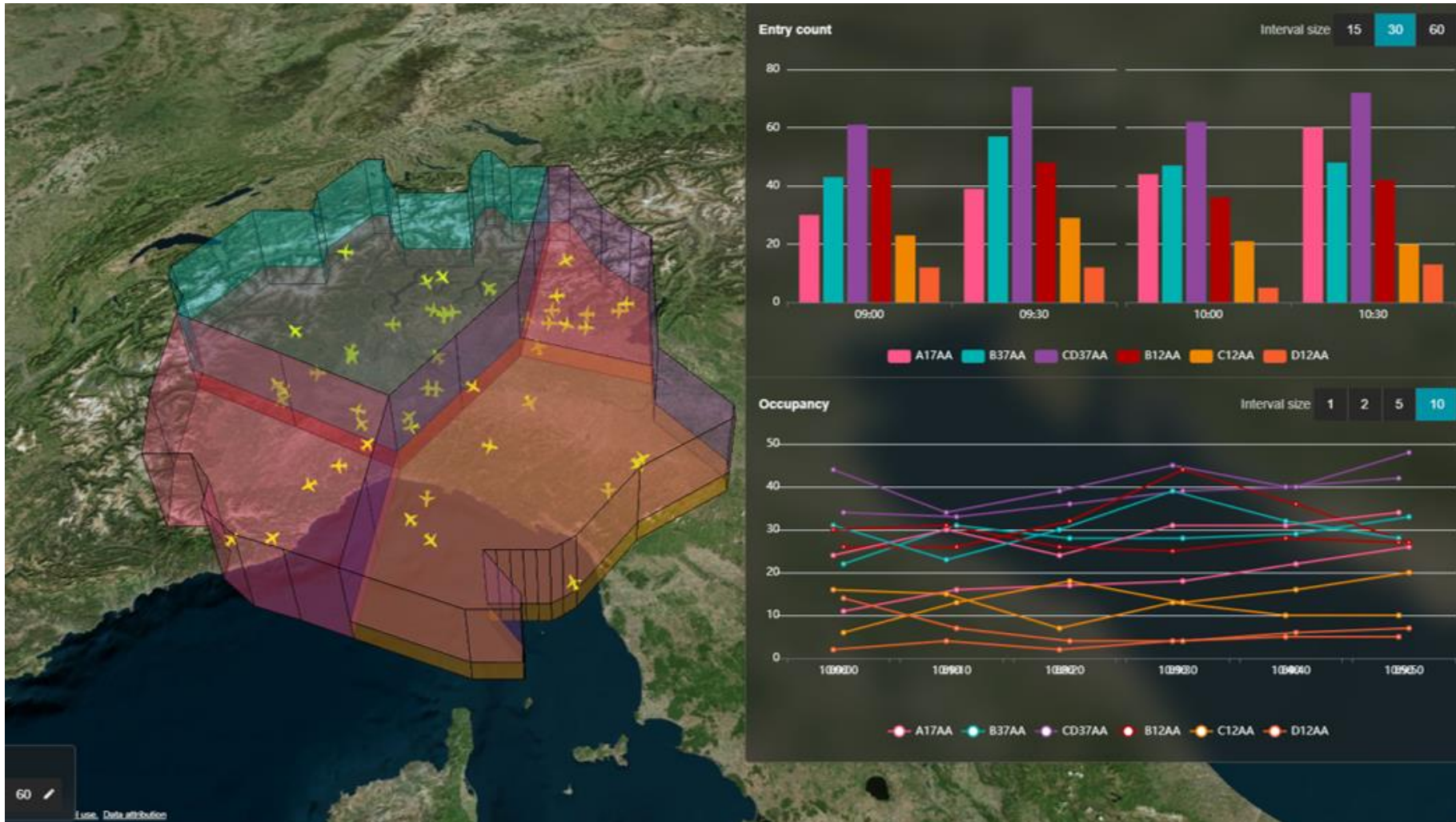
# The Machine Learning Solution





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# Application



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