Graph neural networks for urban drainage systems metamodeling

Alexander Garzón et al.

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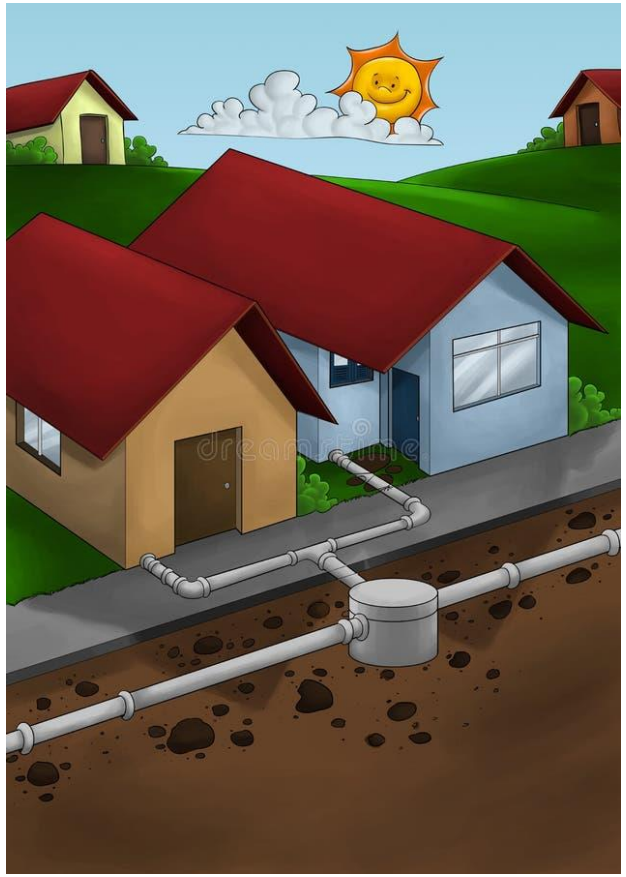
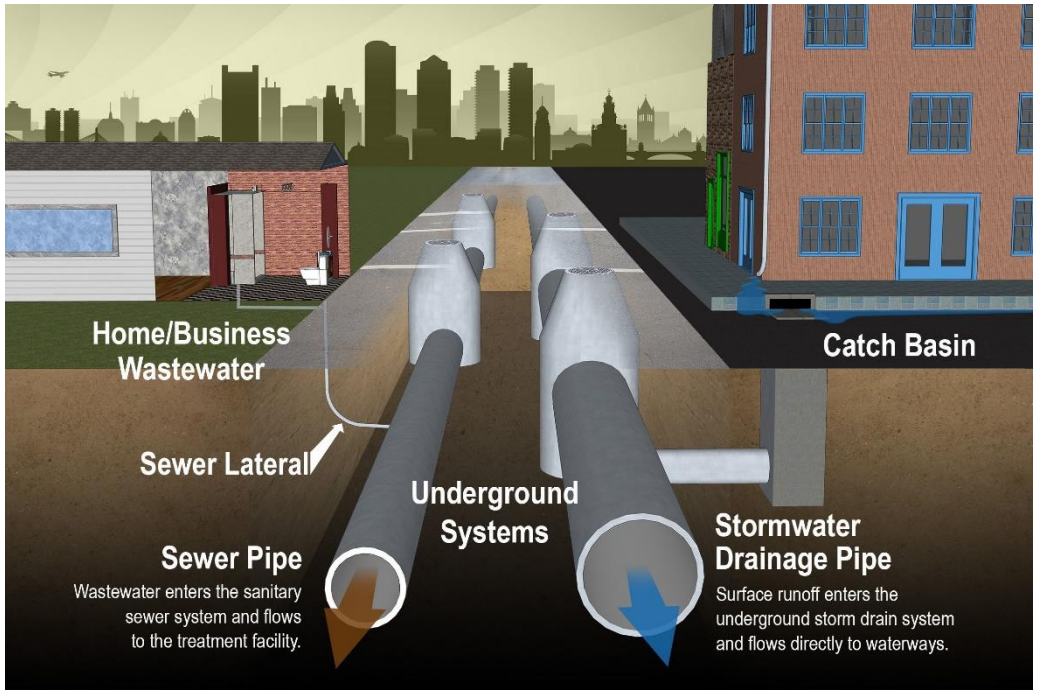
Urban drainage systems



Drain system house stock illustration. Illustration of plumbing - 25233271 (dreamstime.com)



AASHTO Specs for Storm Water Drainage Pipes, Manholes ETC. | LinkedIn

Infiltrerende stad - HvA

Rioolwater in watergang Hullerweg Nunspeet - Al het nieuws uit Nunspeet (nunspeethuisaanhuis.nl)

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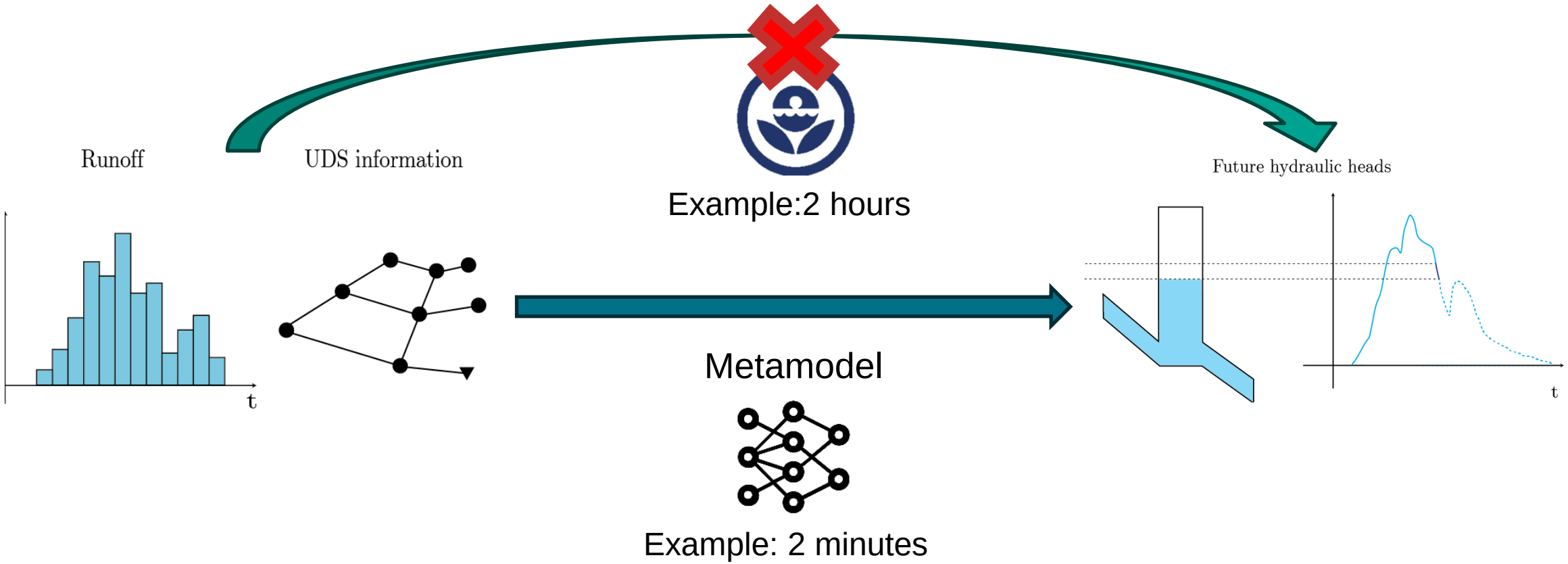
Metamodels

Computer intensive applications require fast simulators



(Garzón et al., 2022)

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Problem 1: Developing a metamodel can be time-consuming

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Problem 2: Metamodels are system specific

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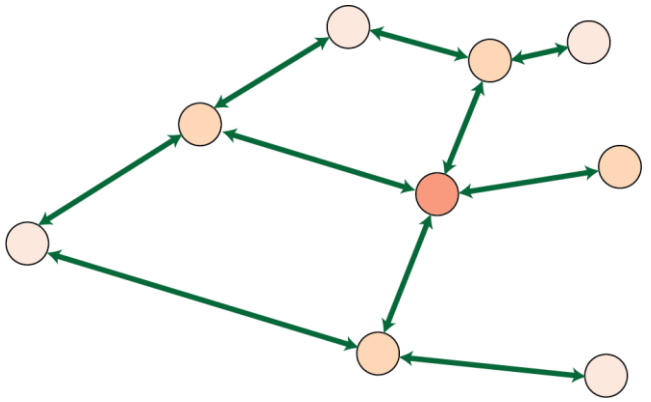
Proposal: Inductive biases in Machine Learning algorithms

Temporal

Graph-structure



Physical

(Battaglia et al., 2018)

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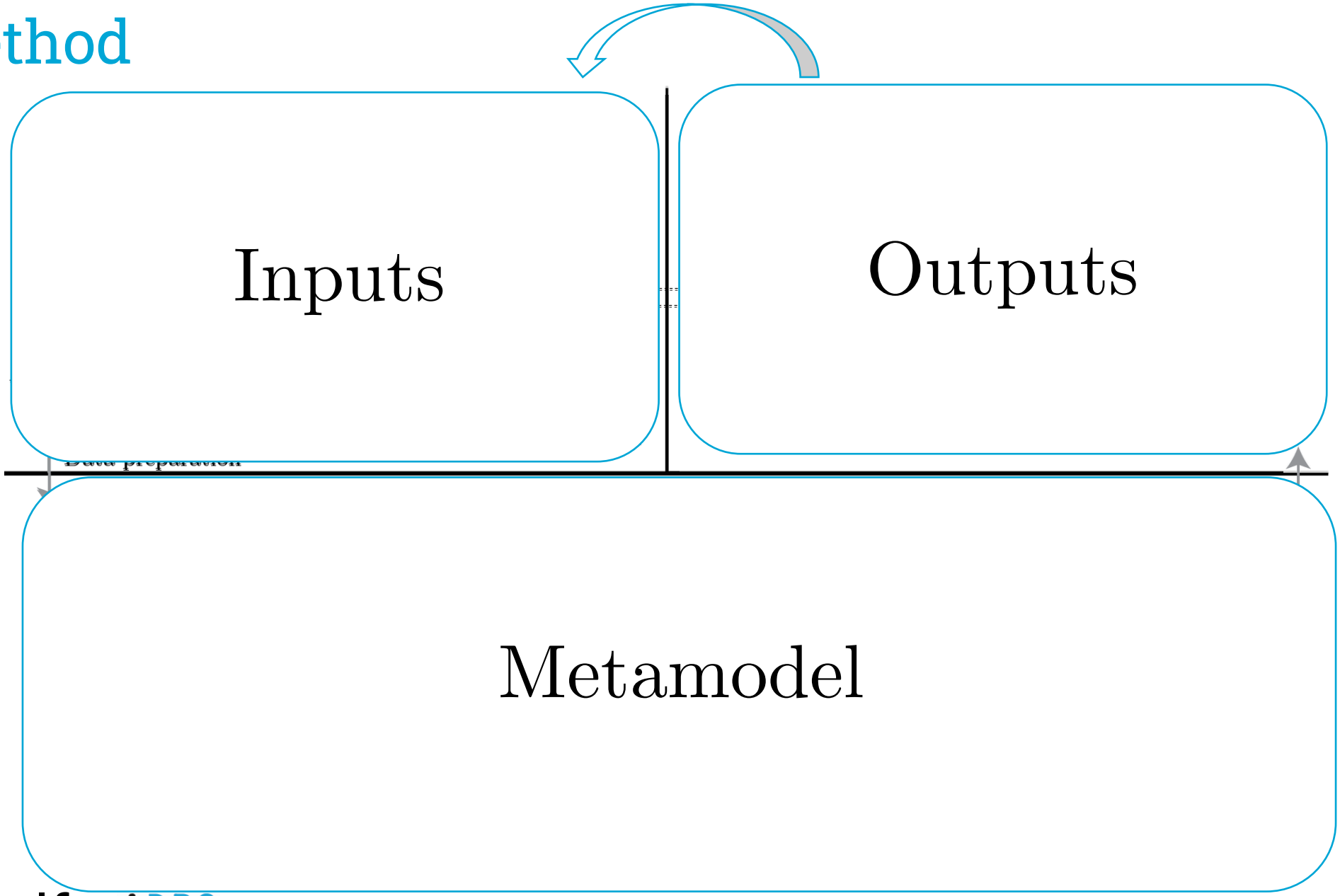
Method



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Case study

- Tuindorp.
  - Utrecht, The Netherlands

- Combined drainage system
  - Storm water drainage for this study

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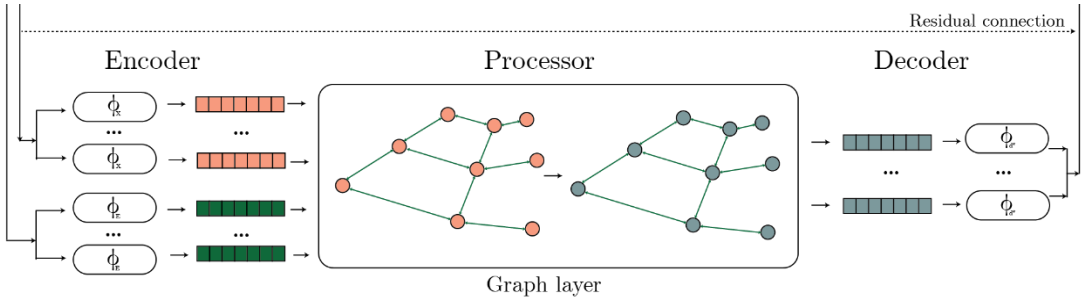
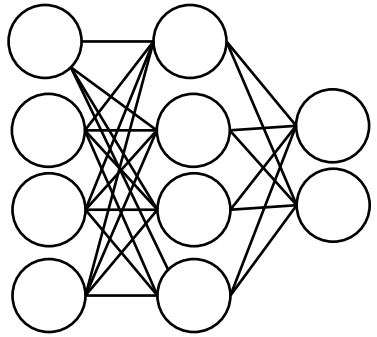
Metamodels

- GNN metamodel



~6.000 parameters

- MLP metamodel



~700.000 parameters

Same dynamic inputs

Same temporal and physical bias

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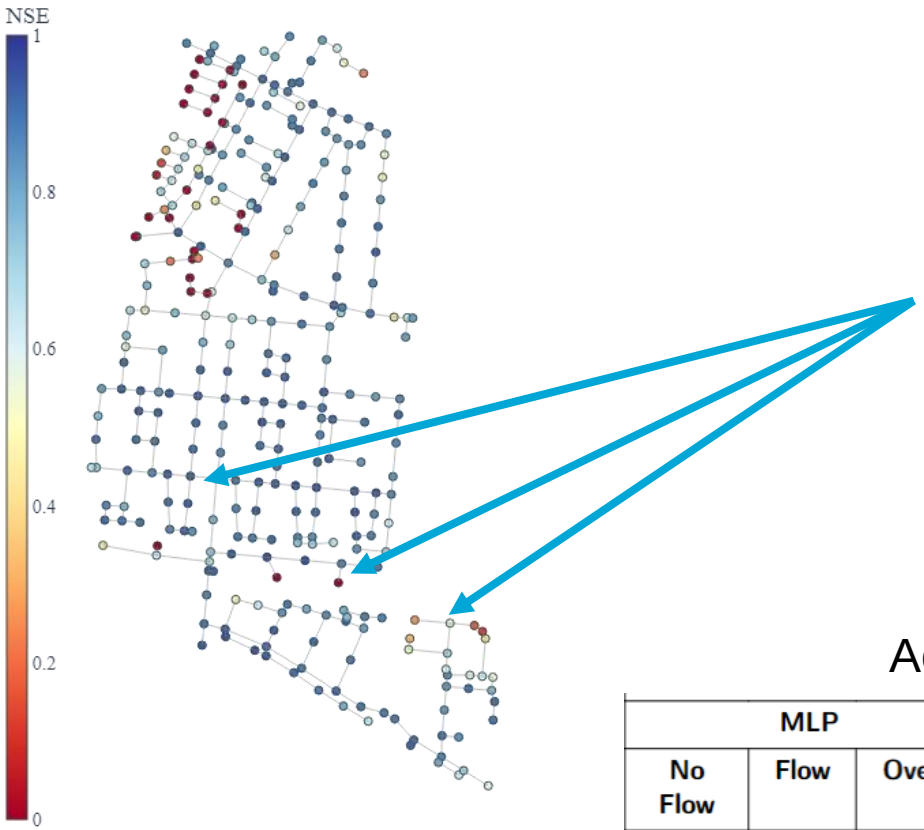
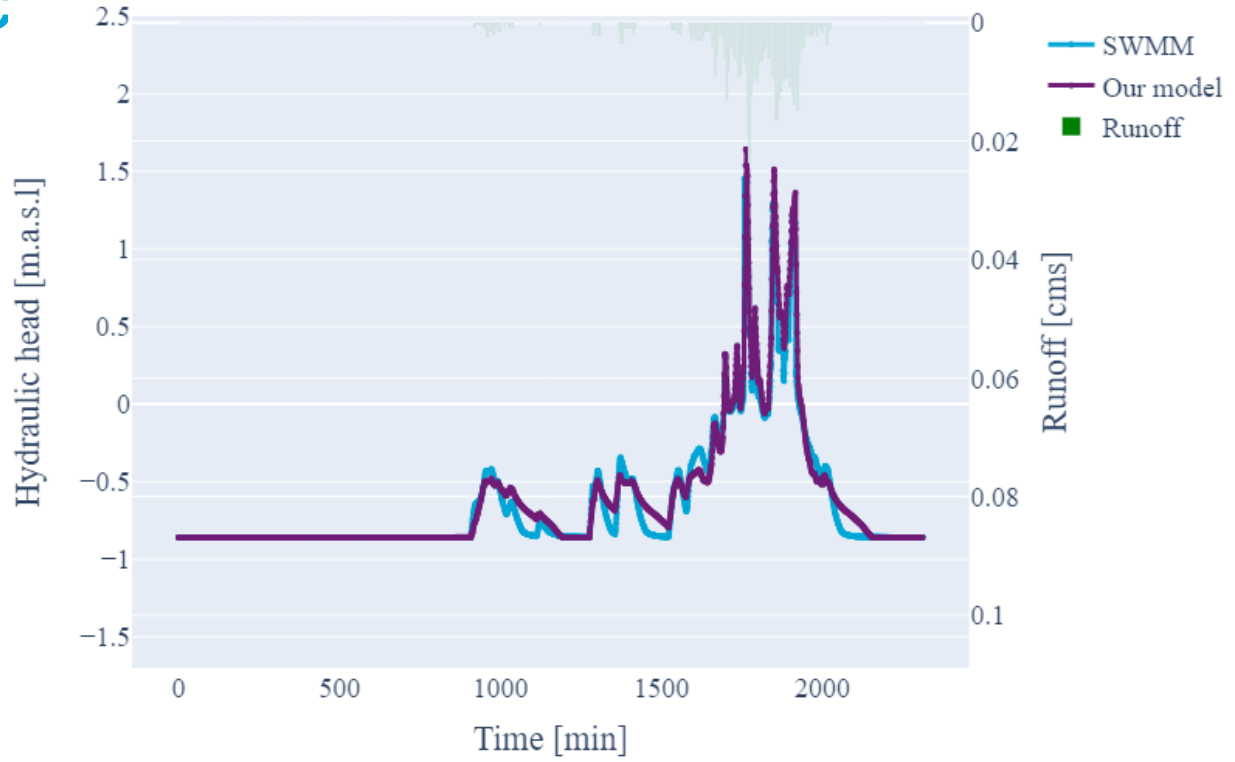
Results – Test Performanc





Accuracy

MLP			GNN		
No Flow	Flow	Overall	No Flow	Flow	Overall
1.0	0.908	0.976	0.997	0.924	0.981

Speed

MLP (CPU)	MLP (GPU)	GNN (CPU)	GNN (GPU)
Speed-up	Speed-up	Speed-up	Speed-up
11.96	35.04	3.69	17.39

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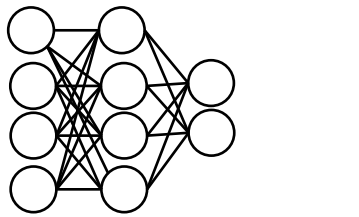
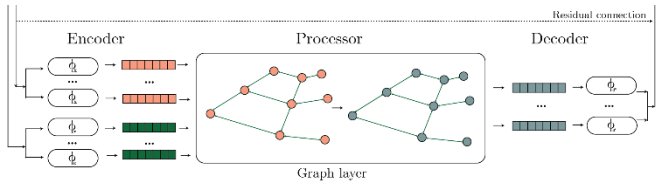
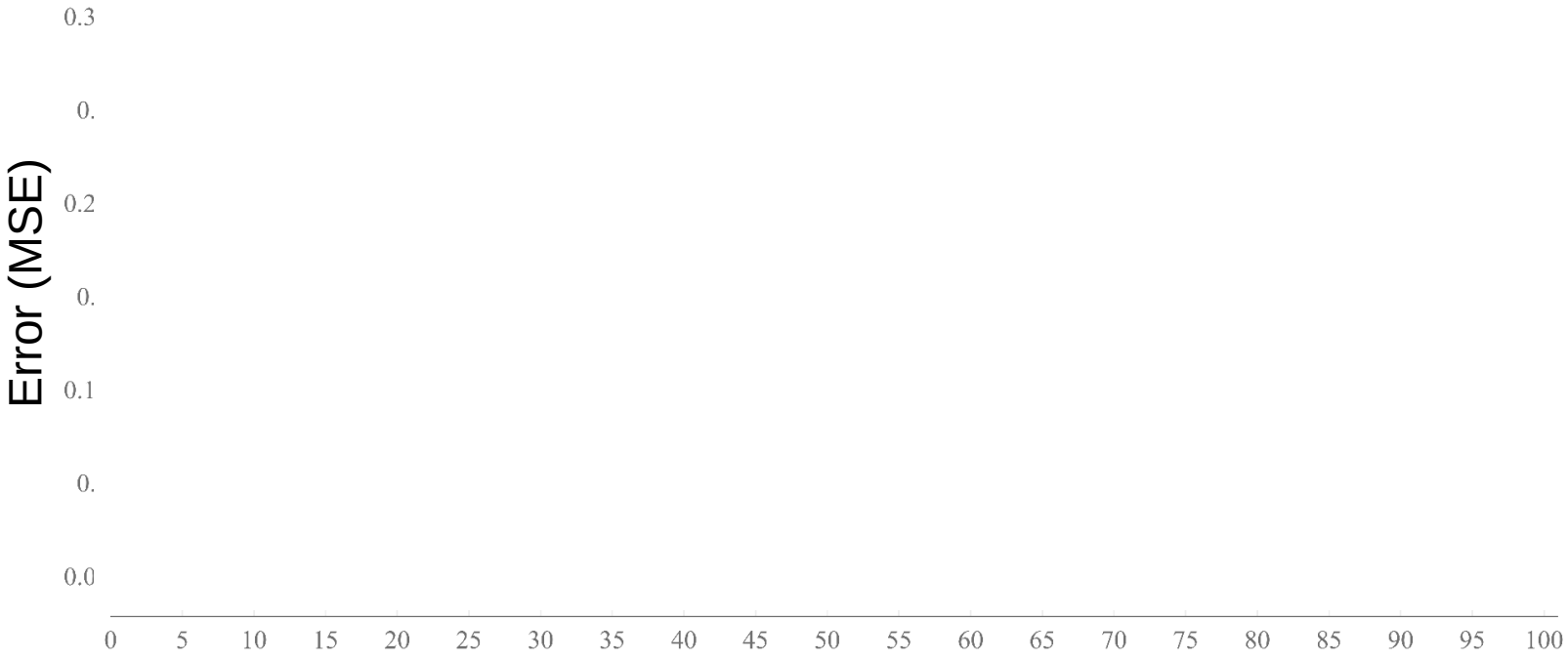
Results – Data Efficiency







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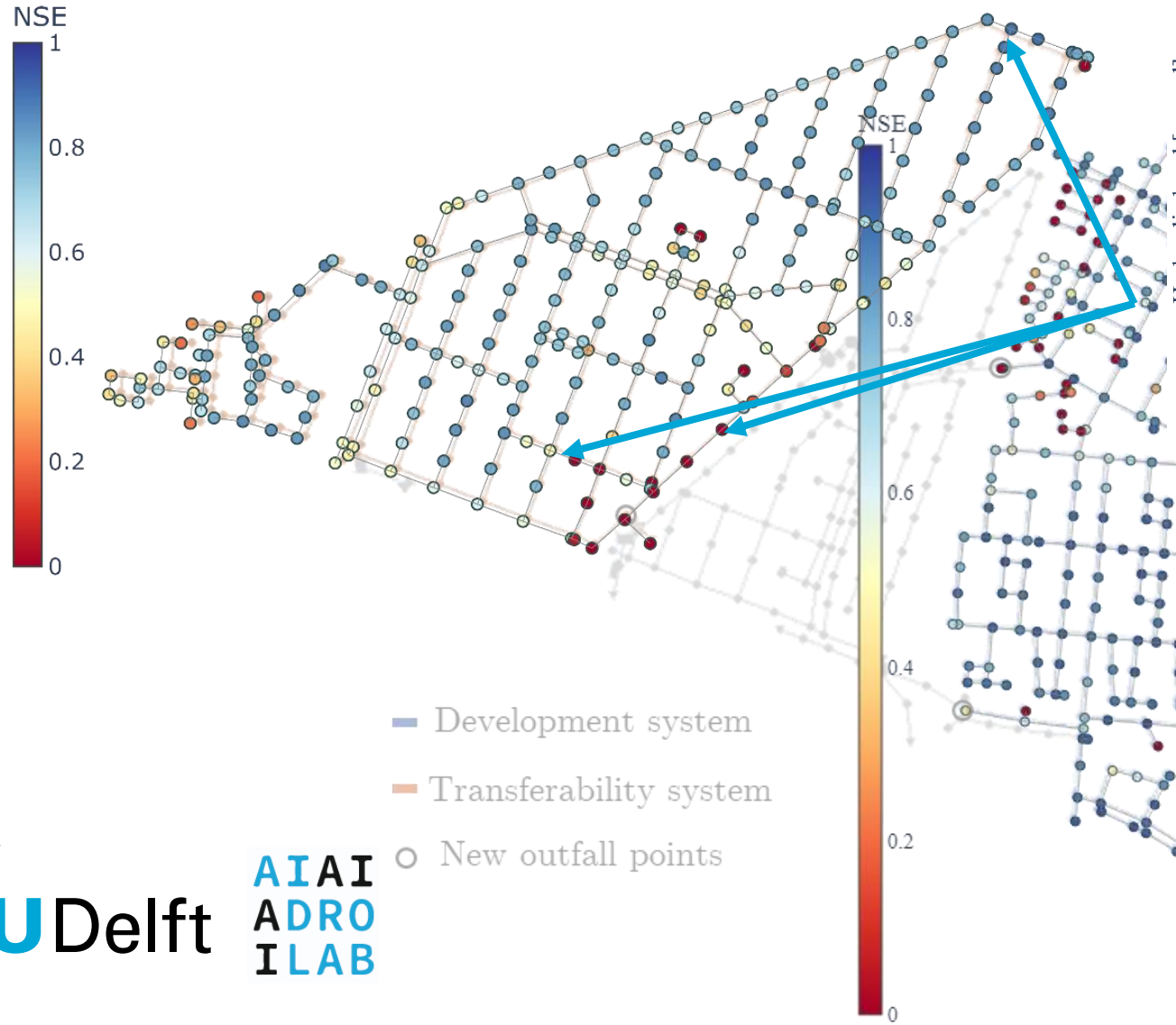
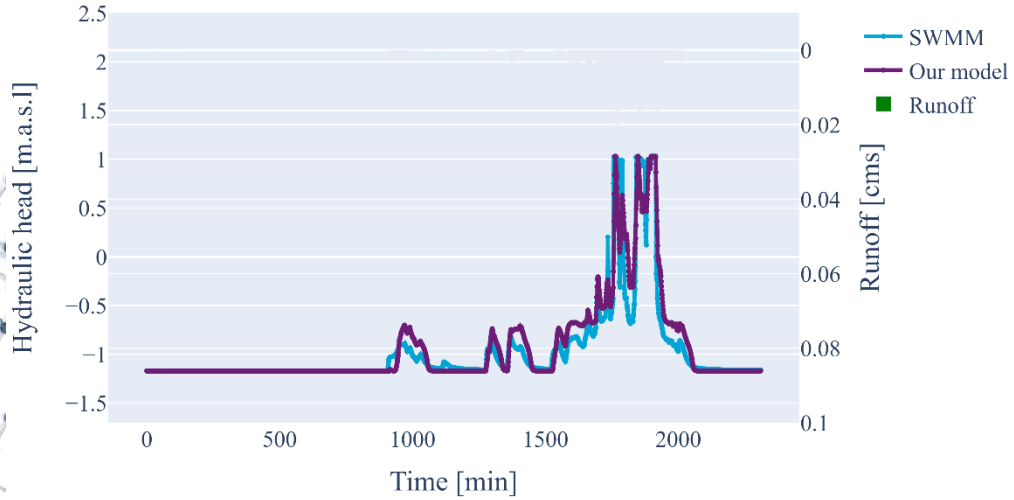
Results - Transferability





NSE			Speed up	
No-Flow	Flow	Overall	CPU	GPU
0.999	0.900	0.968	3.88	13.15

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Limitations – Future work

- Special components (Pumps, tanks, orífices, weirs, etc.)
- Dry weather Flow
- Flow estimation
- Other catchments
- Hyperparameter pre-selection

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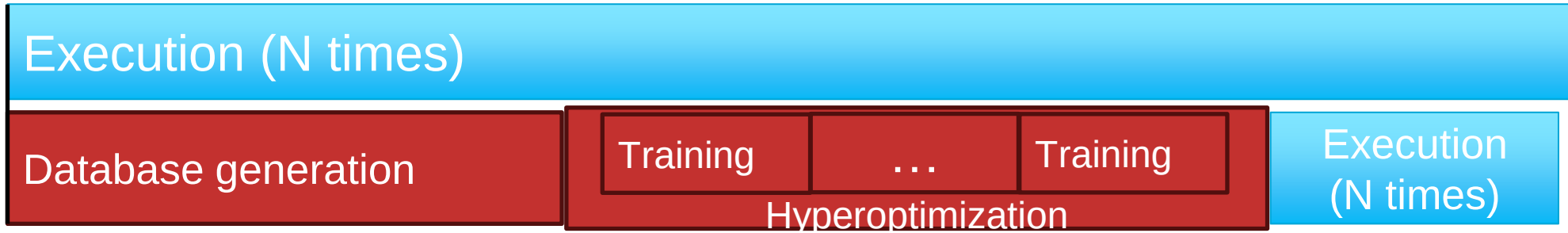
Required time

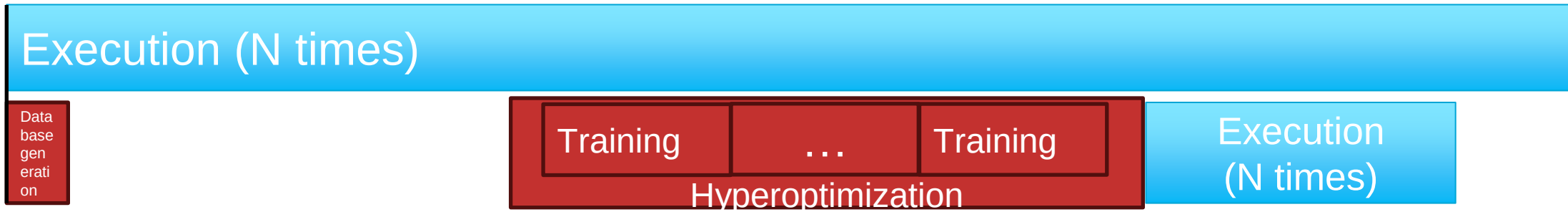
SWMM

Metamodel



SWMM

Metamodel



SWMM

Metamodel

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Thank you for your attention

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References

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- Garzón, A., Kapelan, Z., Langeveld, J., Taormina, R., 2022. Machine learning-based surrogate modelling for Urban Water Networks: Review and future research directions. Water Resources Research , e2021WR031808URL: https://onlinelibrary.wiley.com/doi/full/10.1029/2021WR031808https://onlinelibrary.wiley.com/doi/abs/10.1029/2021WR031808https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2021WR031808, doi:10.1029/2021WR031808.
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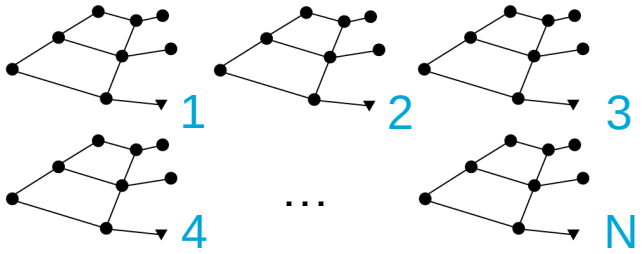
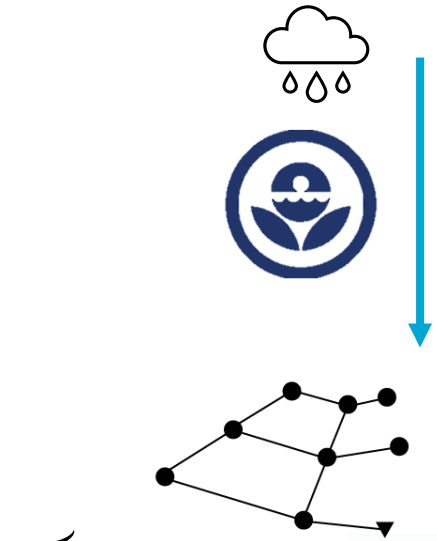
Motivation

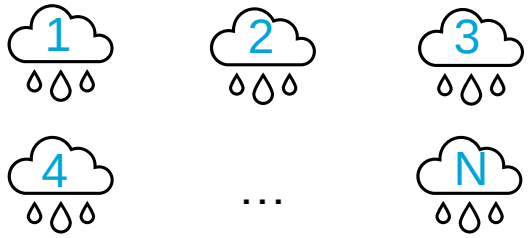
Some critical applications require a fast simulator

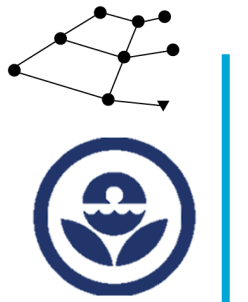
- Optimisation

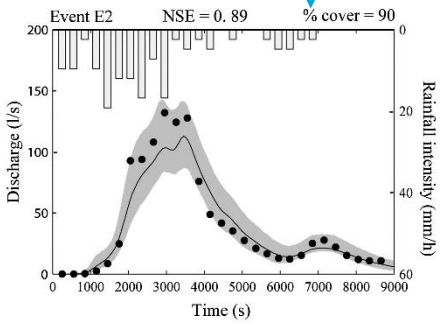




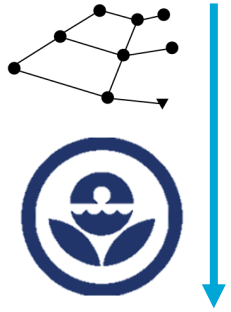
- Uncertainty analysis

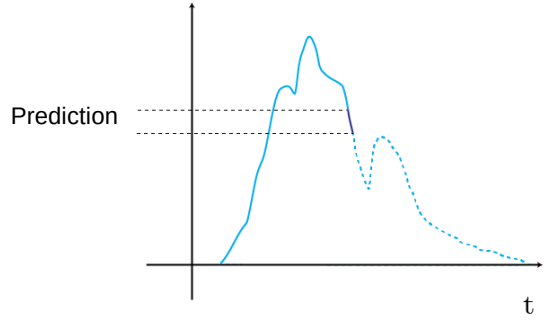






- Real-time forecast





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Problem 1: Developing a metamodel can be time-consuming

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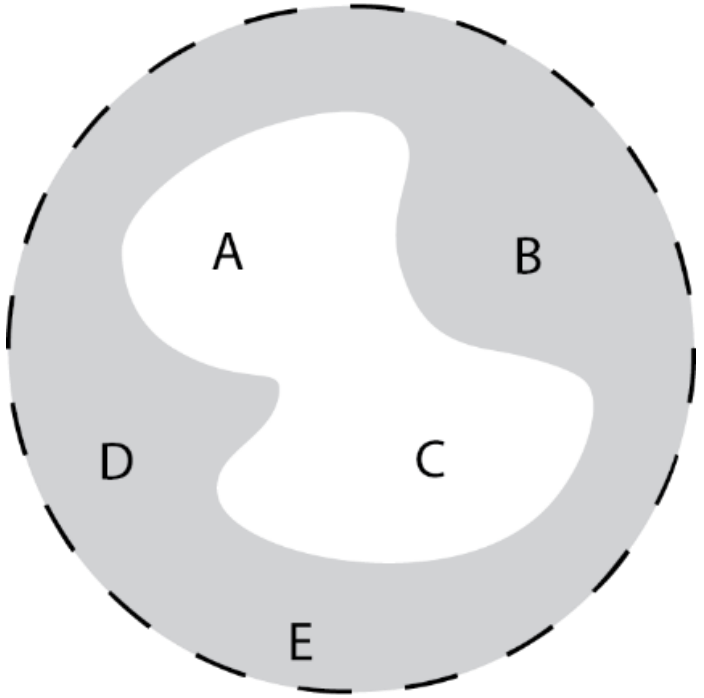
Proposal: Inductive biases in Machine Learning models

Expression of **assumptions** about either the data-generating process or the space of solutions.

It **prioritizes** some solutions over others.



Practical implications:

➞ Requires less training examples

➞ Generalization of learned features

(Battaglia et al., 2018)