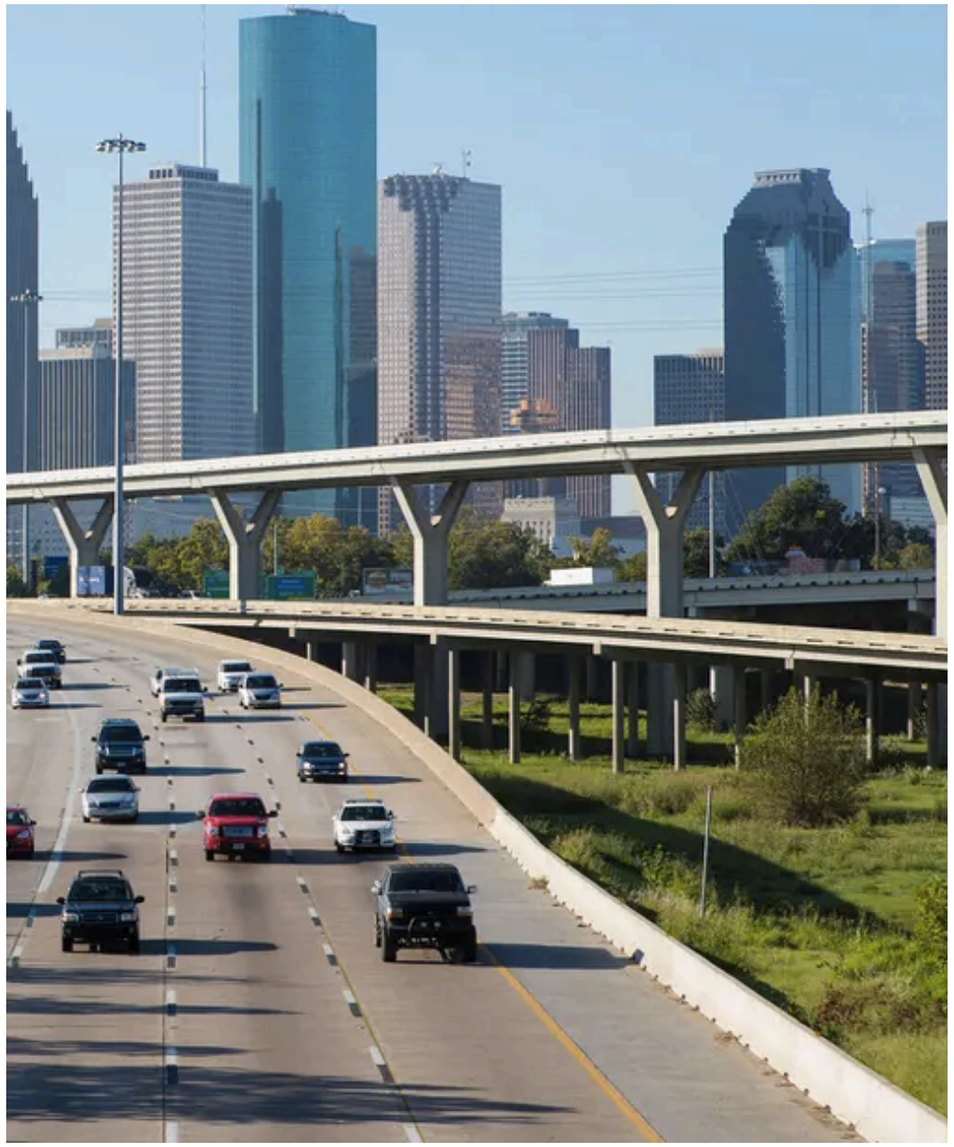
Multi-output neural processes

Zinzan Gurney

Supervised by Prof. Richard Turner

24 November 2021

What problem are we addressing?



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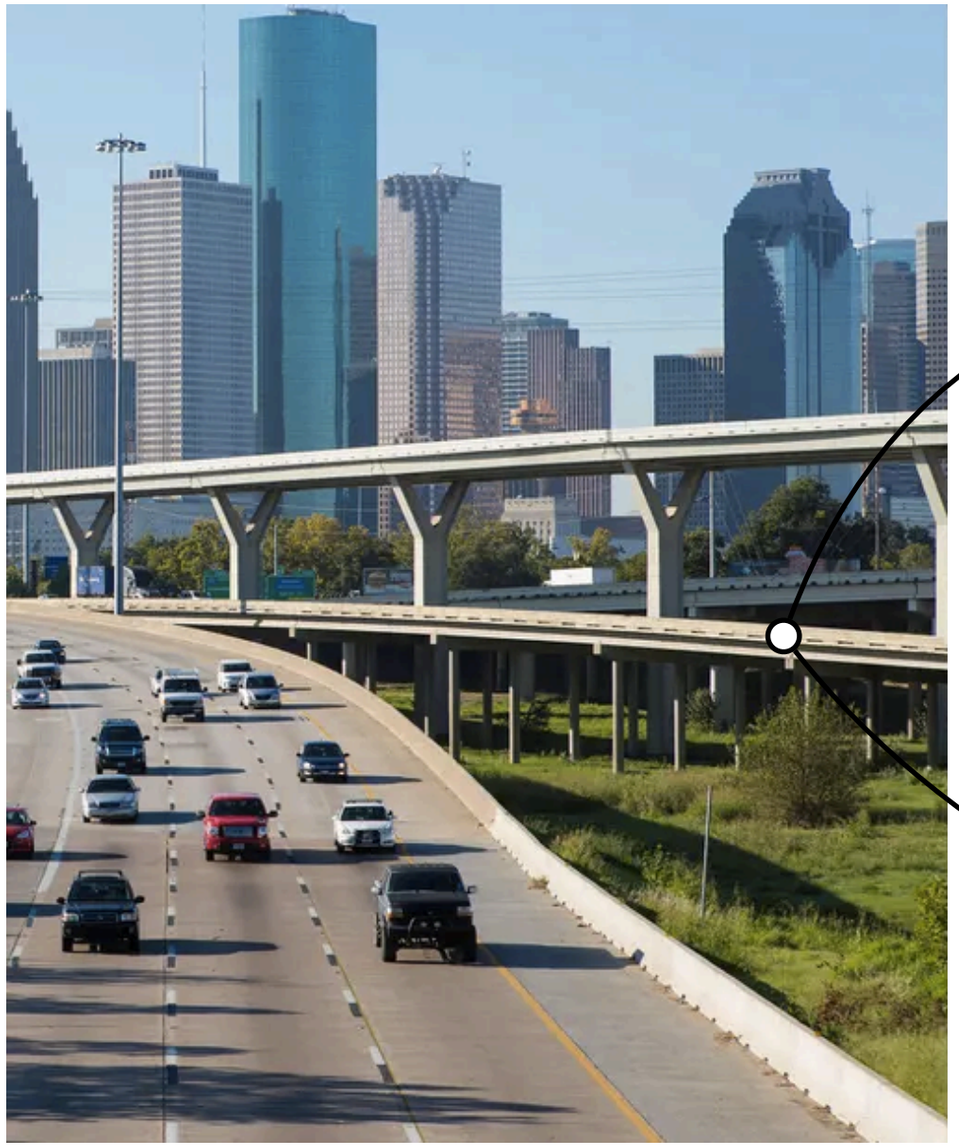

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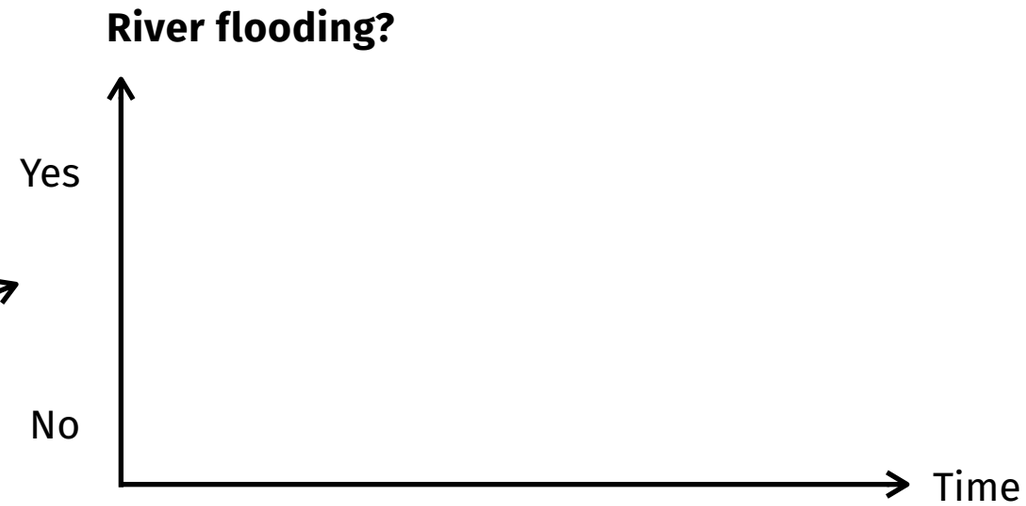

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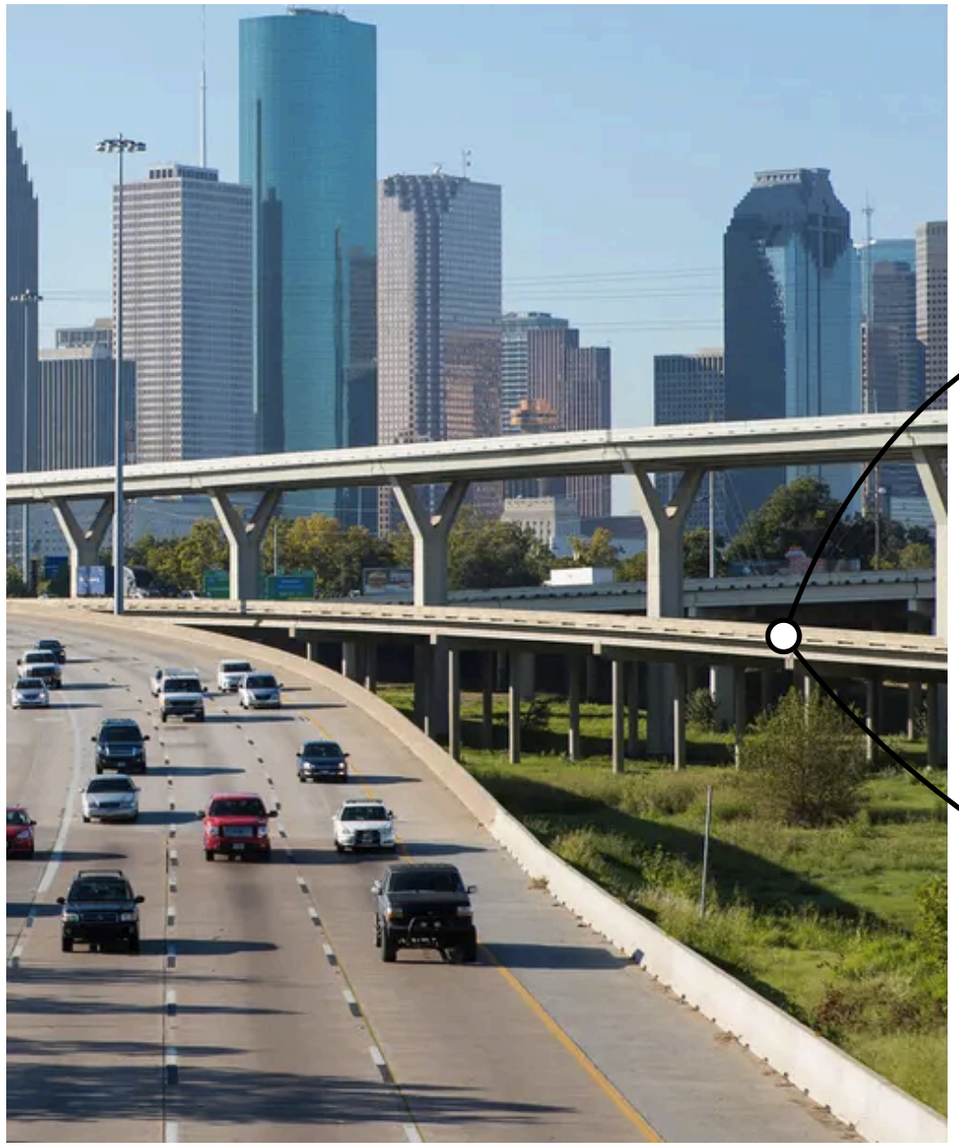

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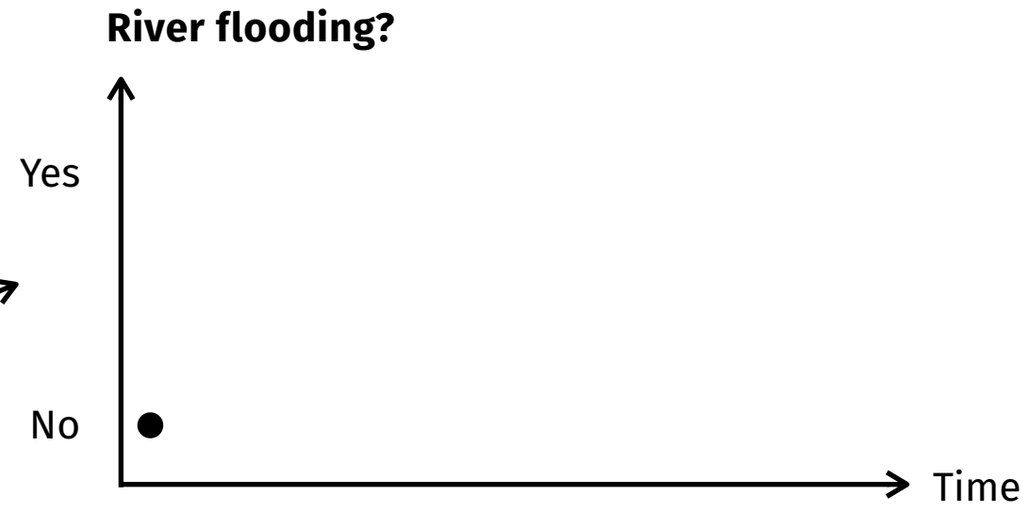

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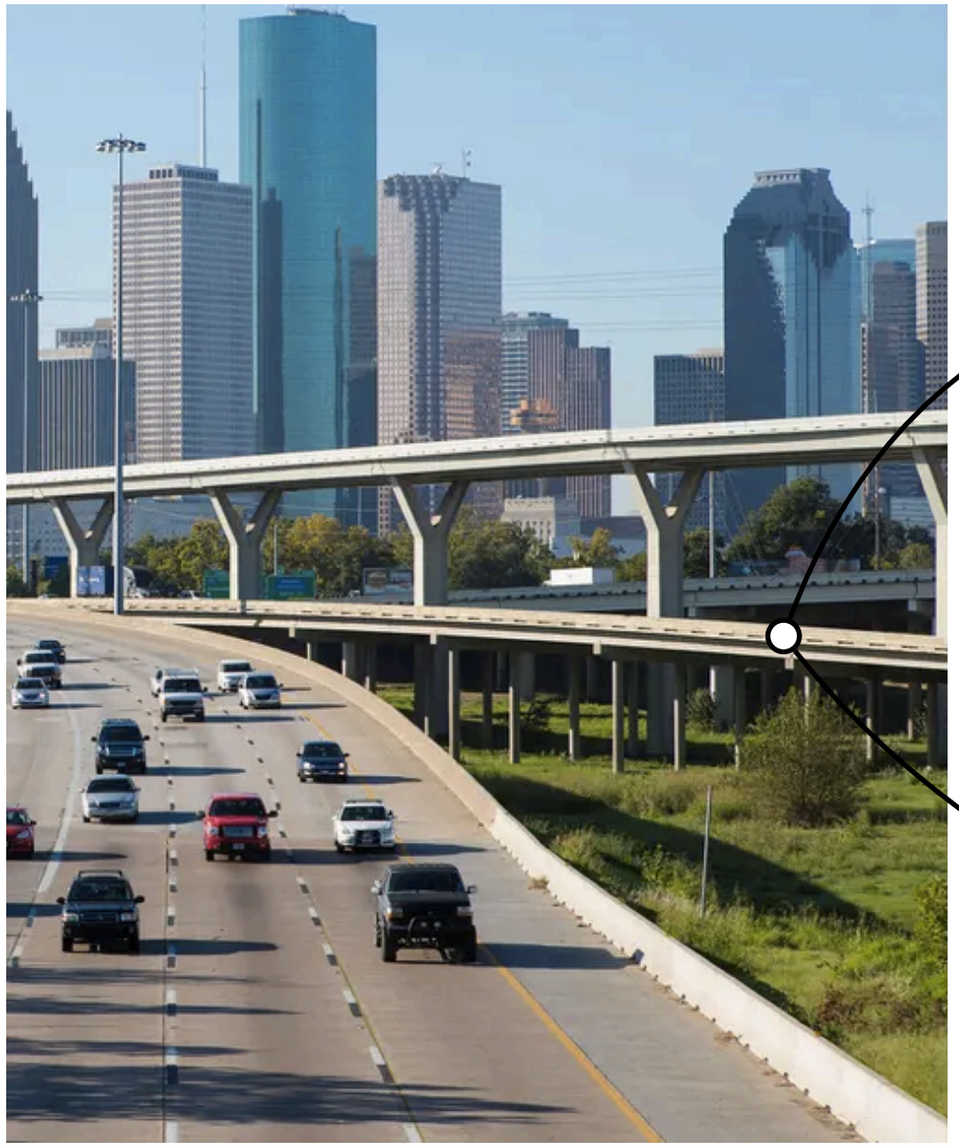

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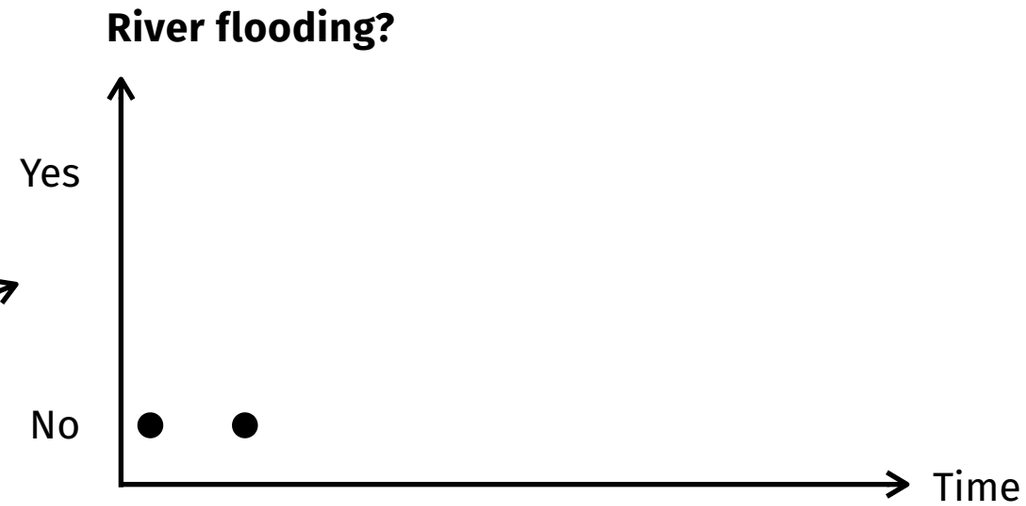

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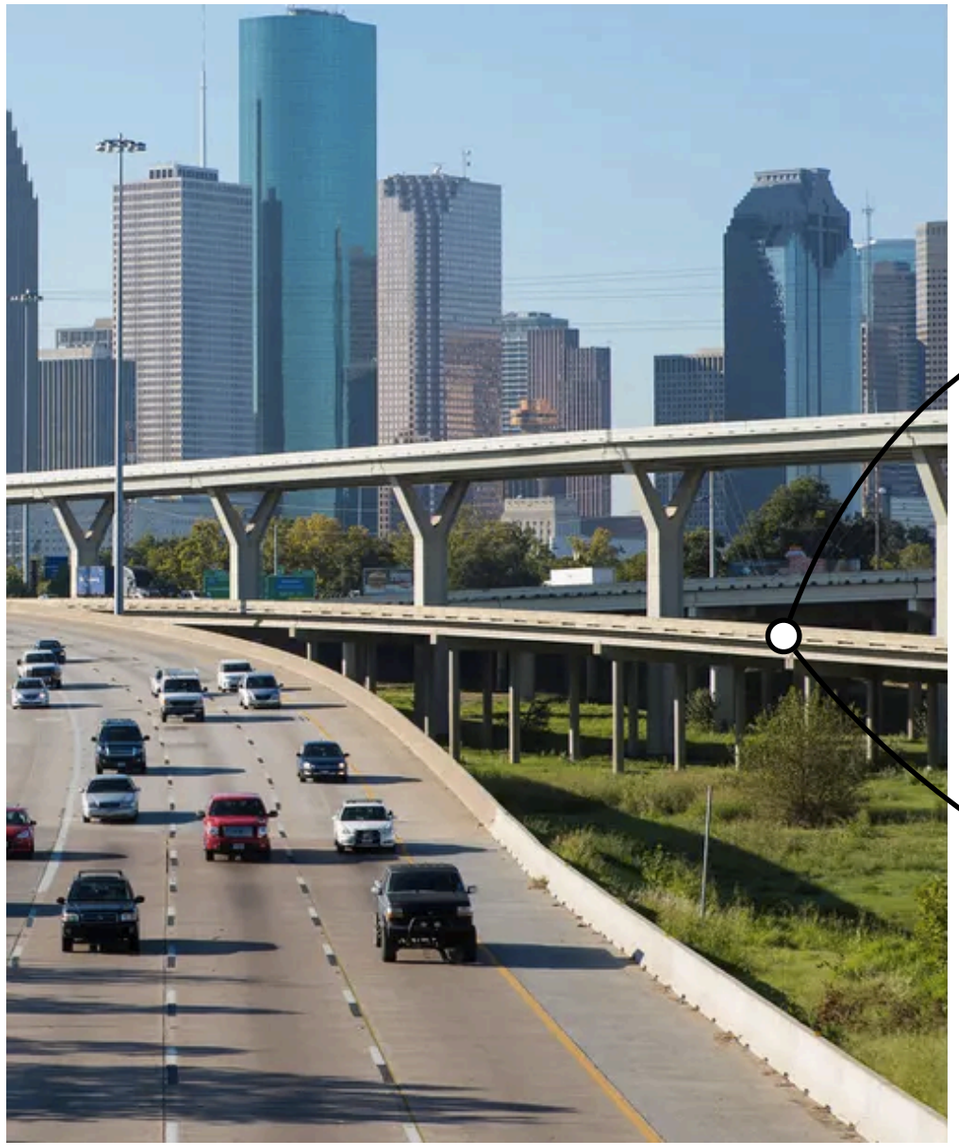

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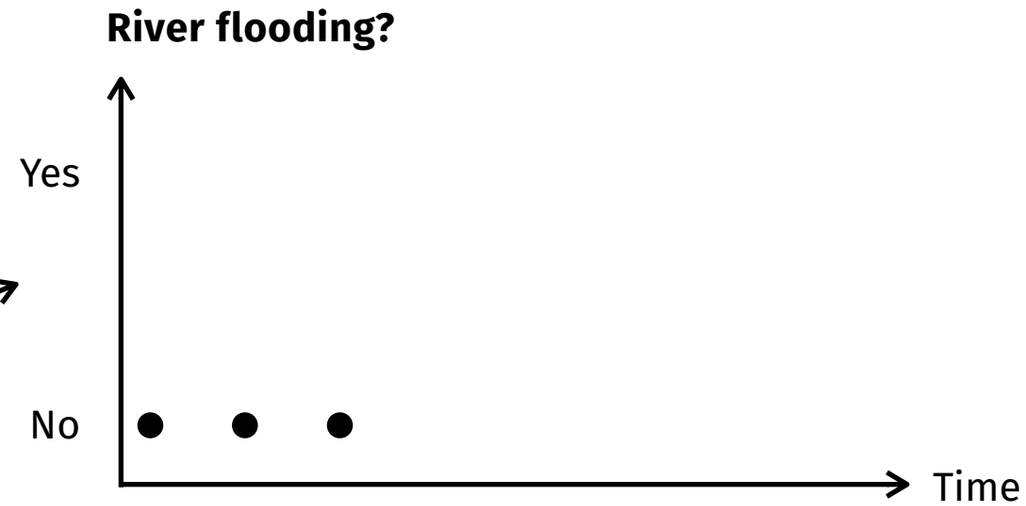

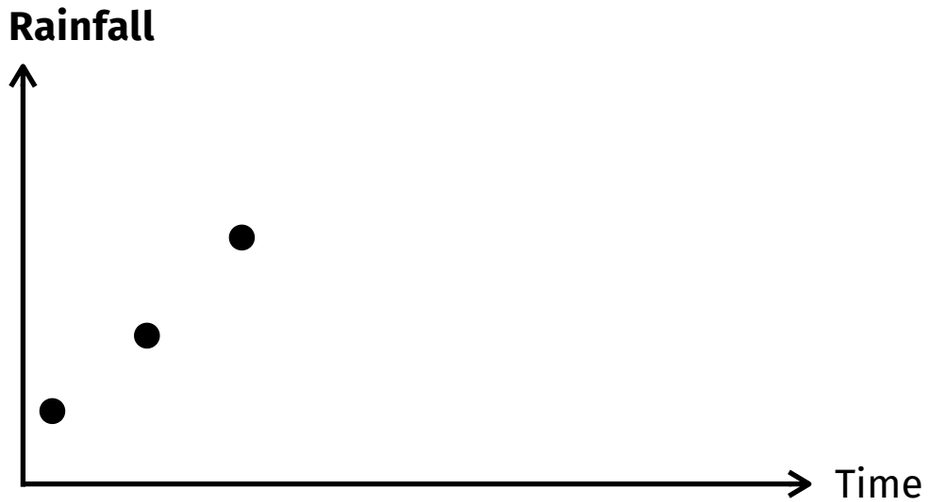

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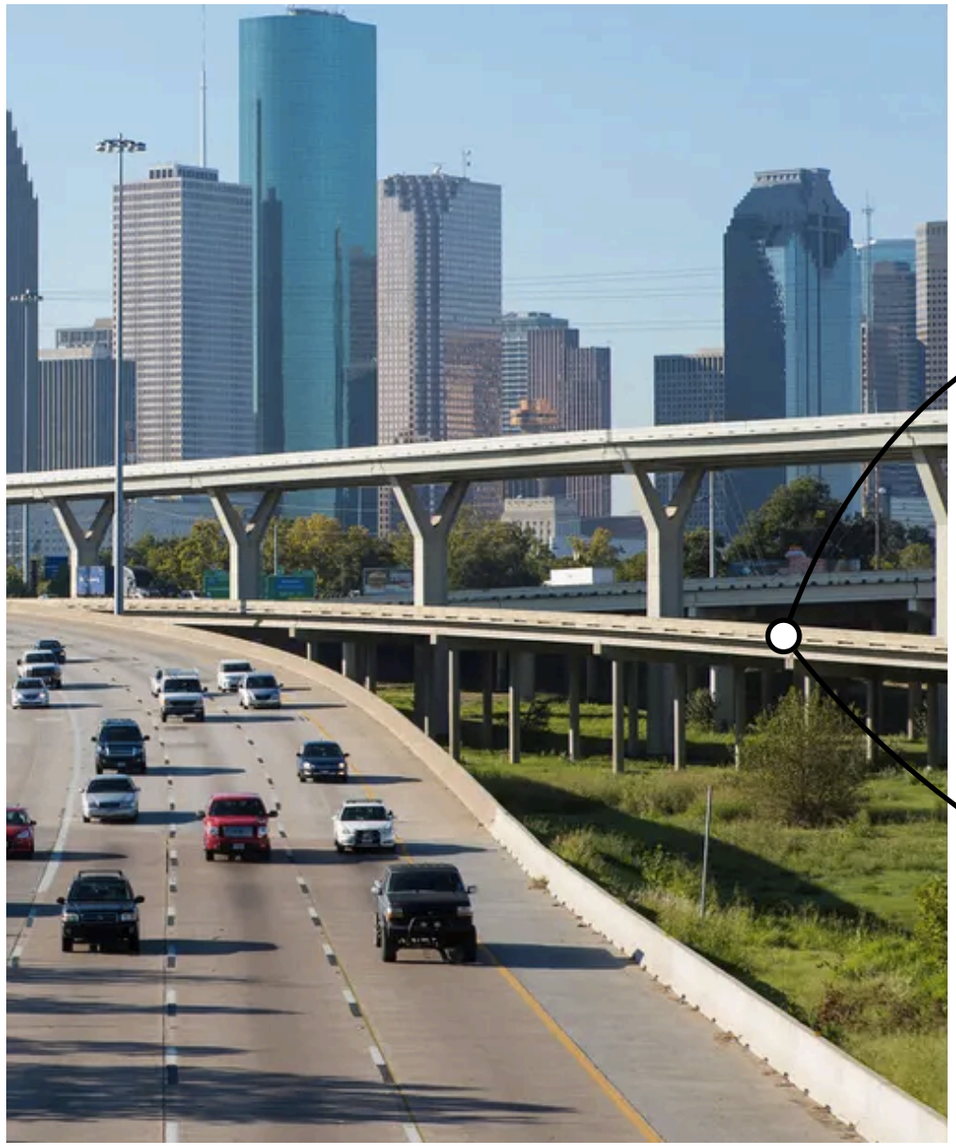

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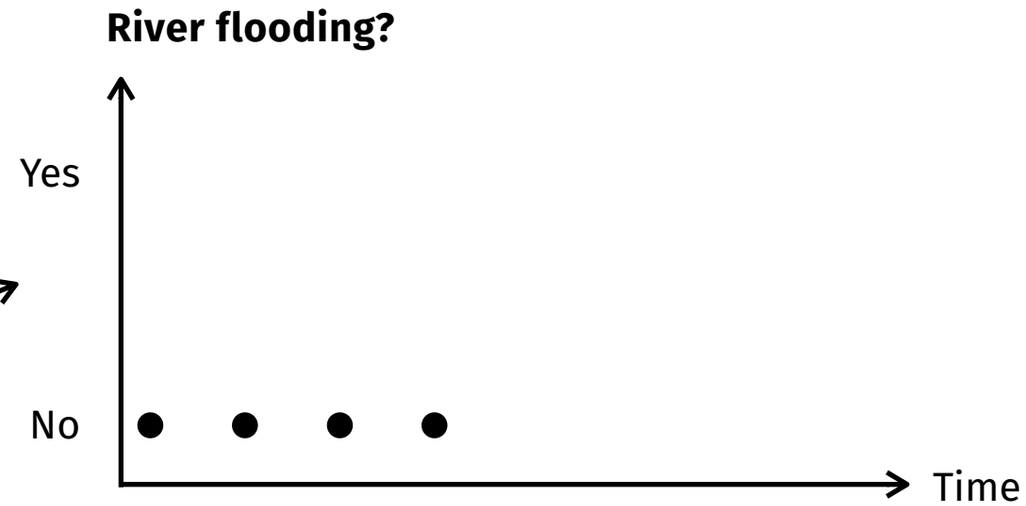

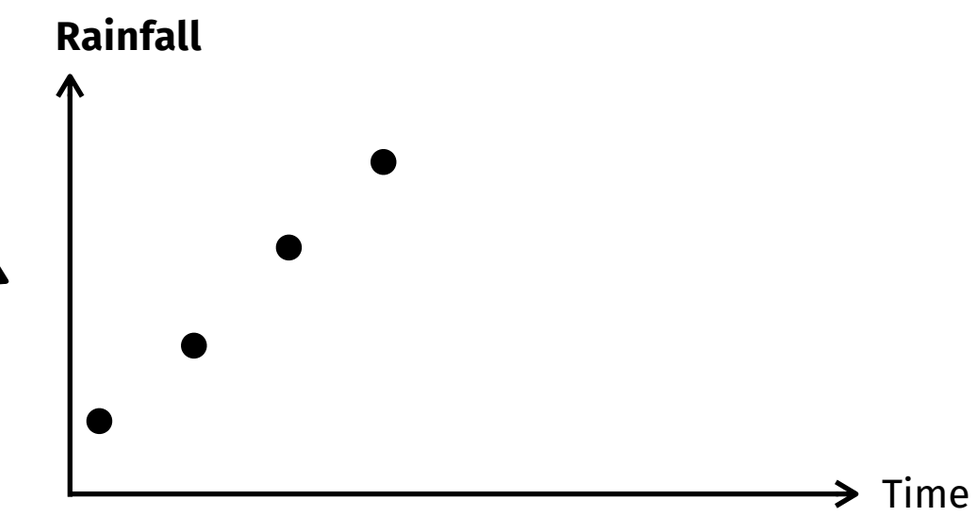

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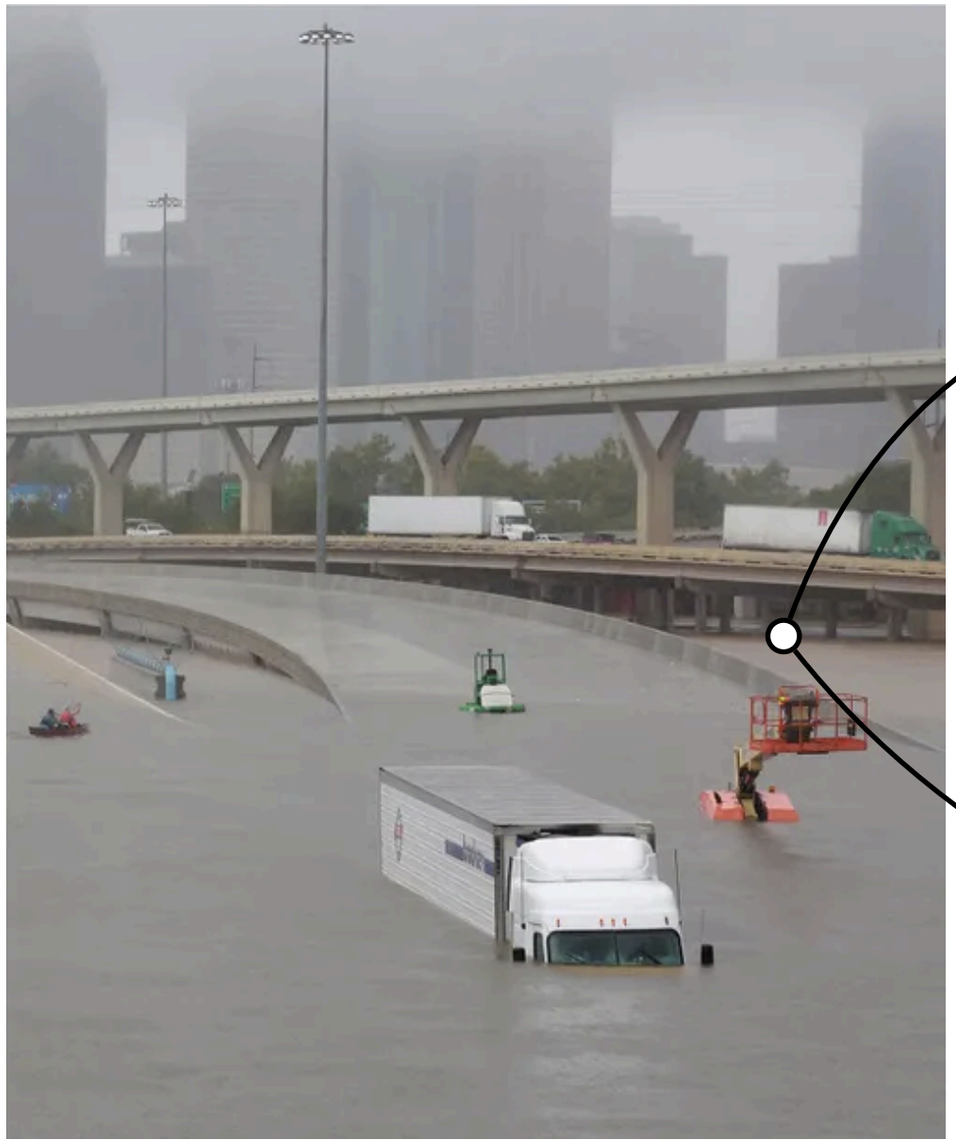

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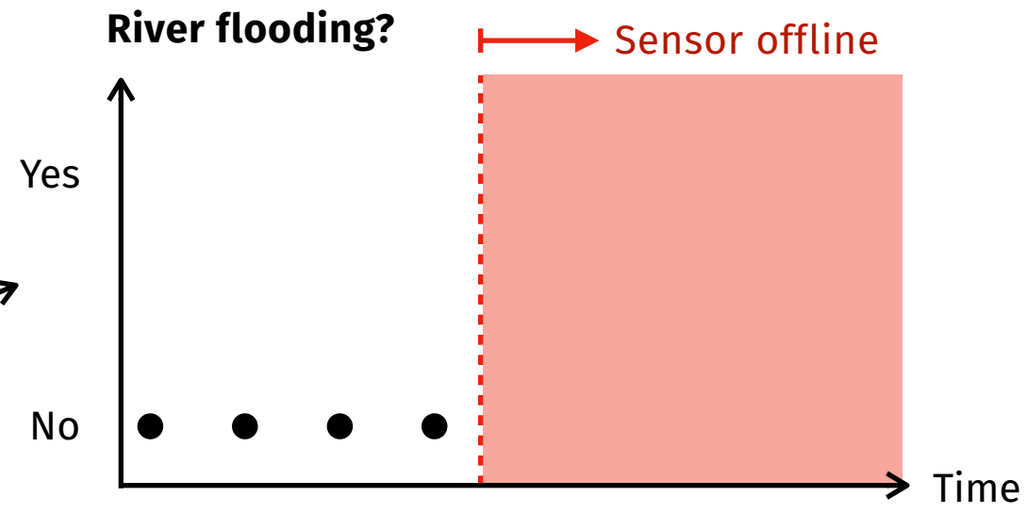

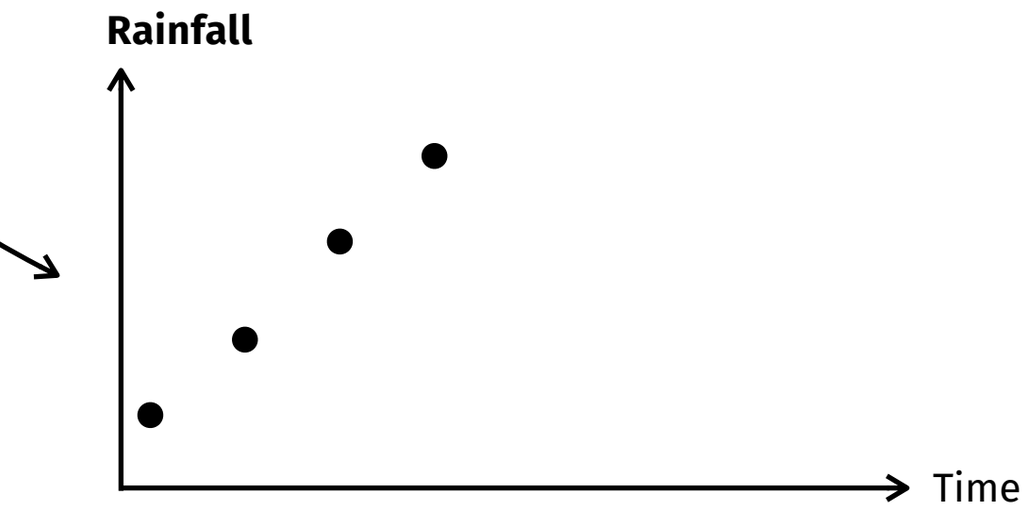

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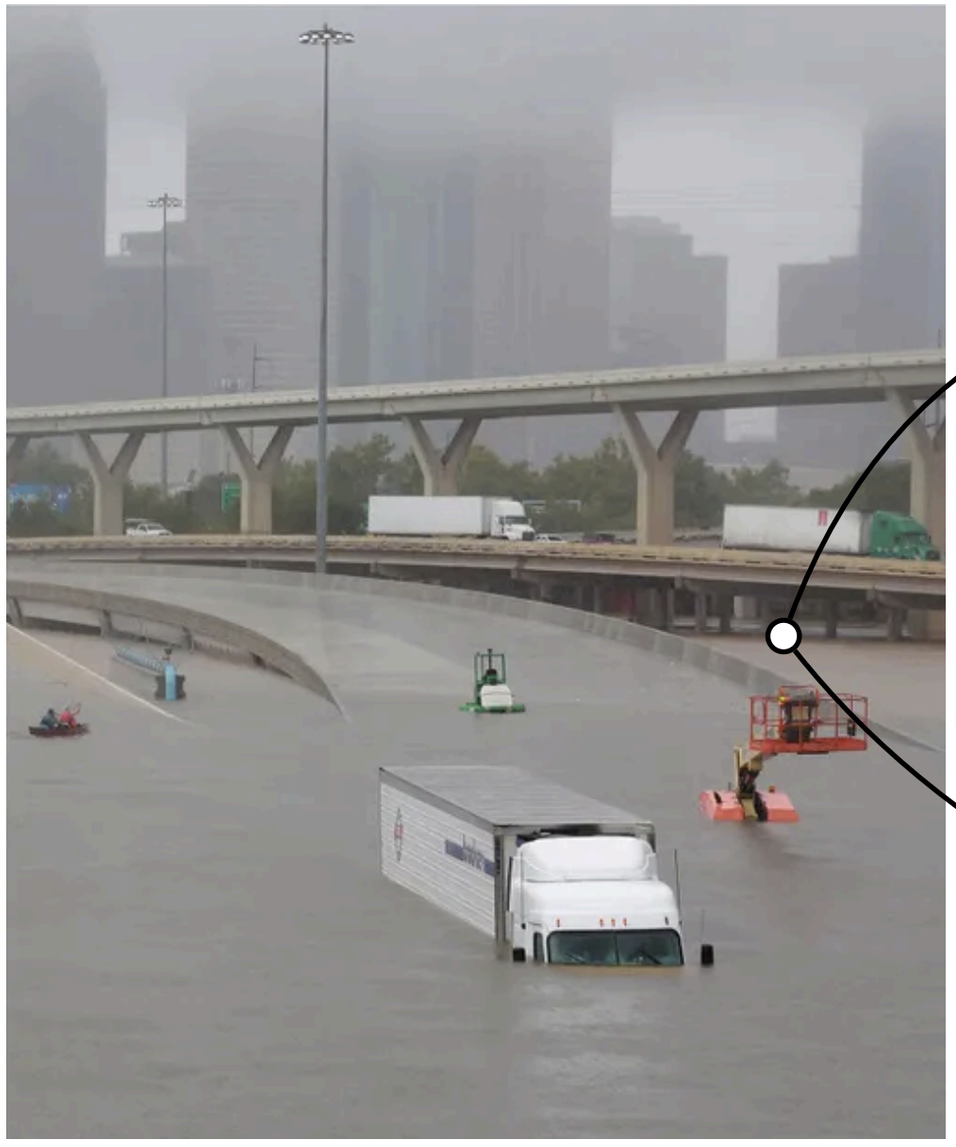

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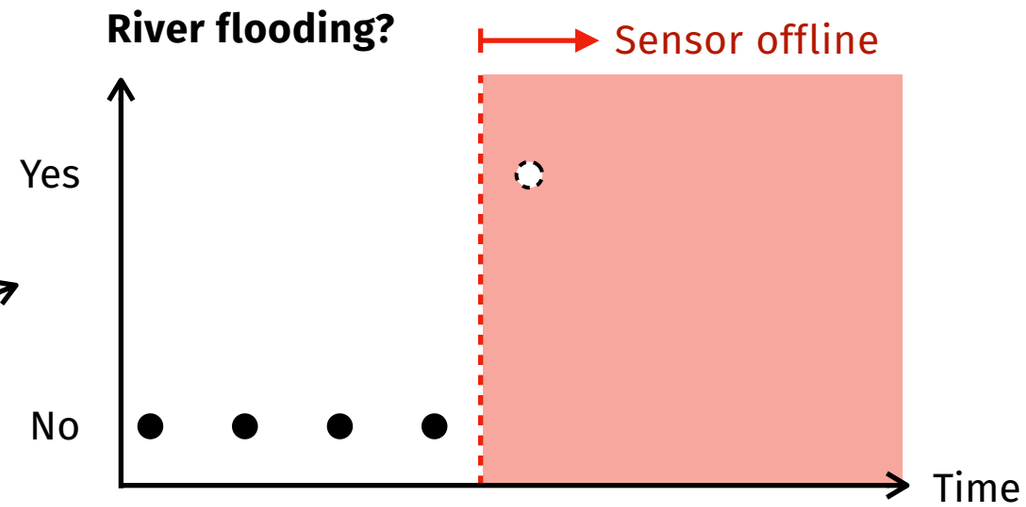

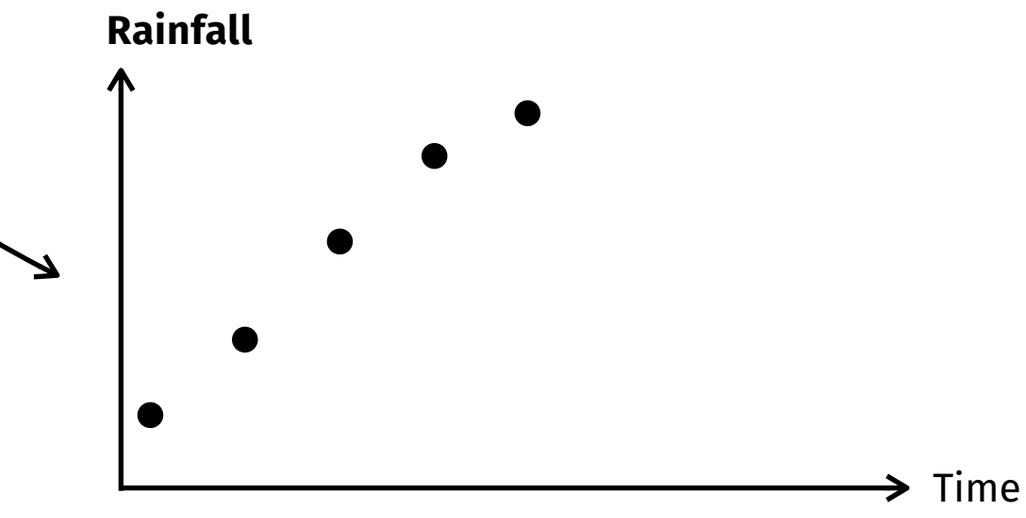

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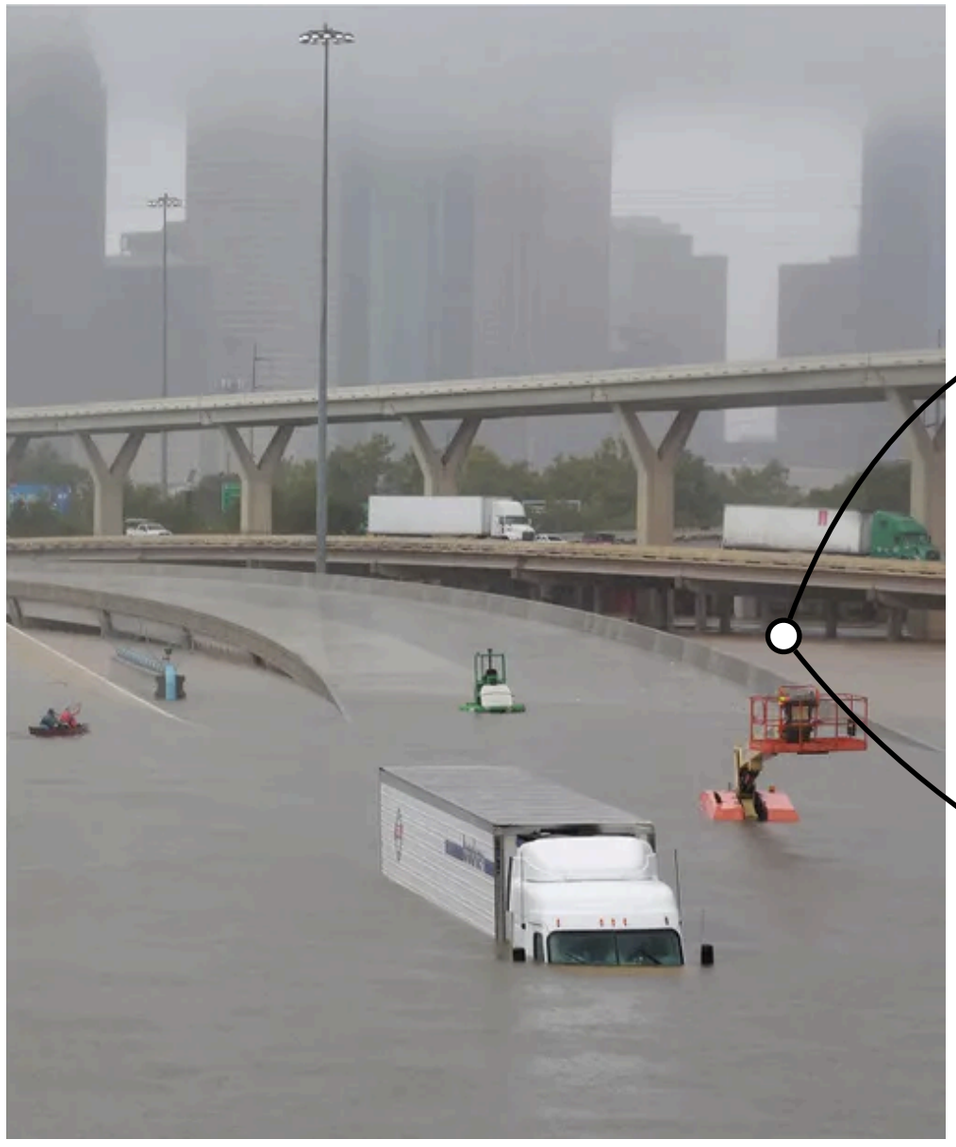

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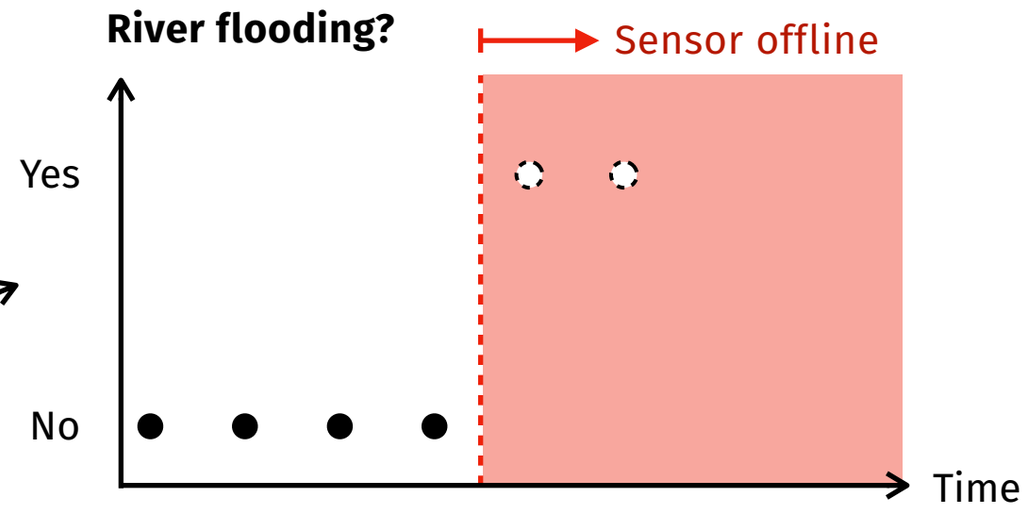

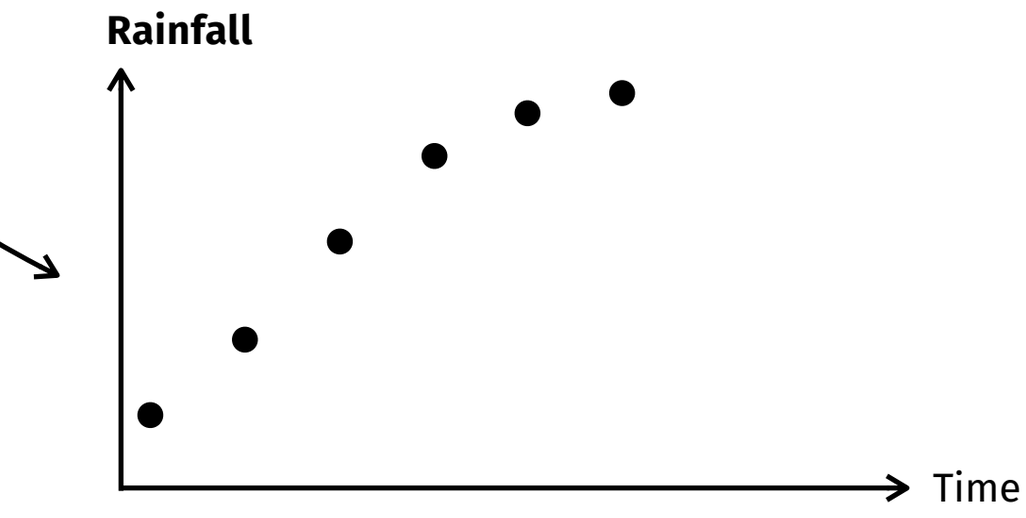

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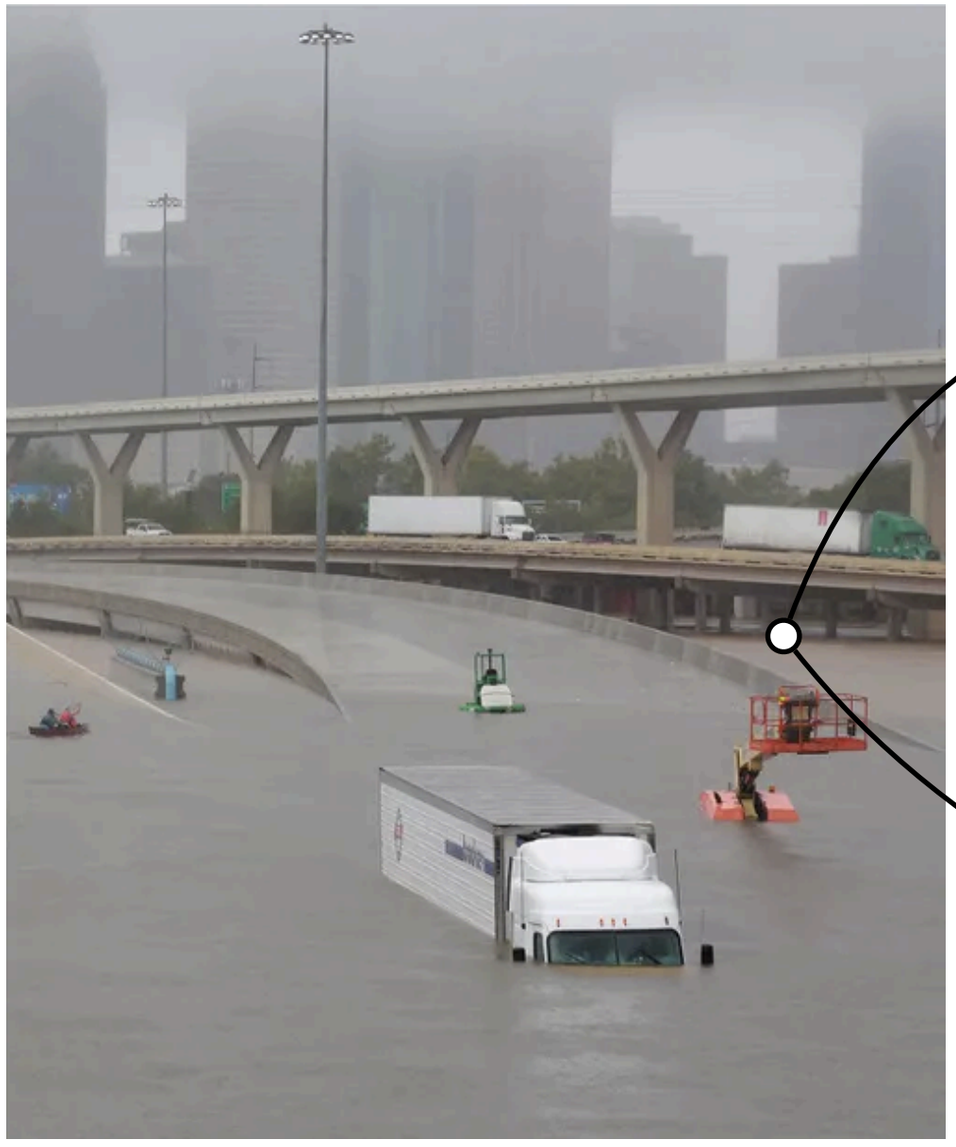

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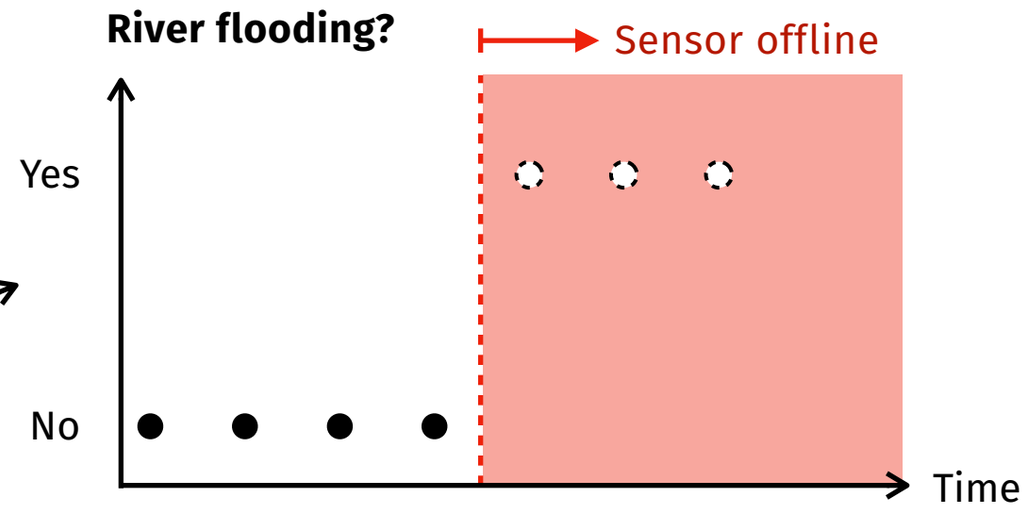

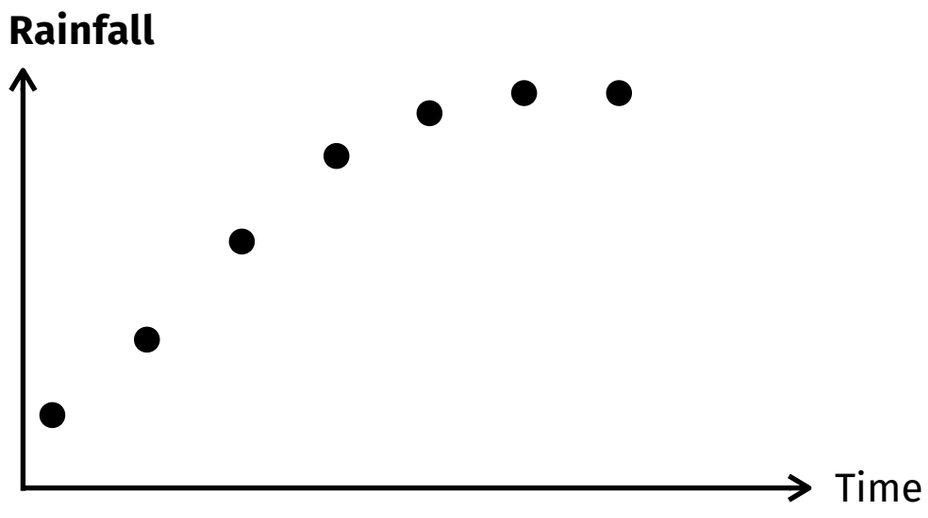

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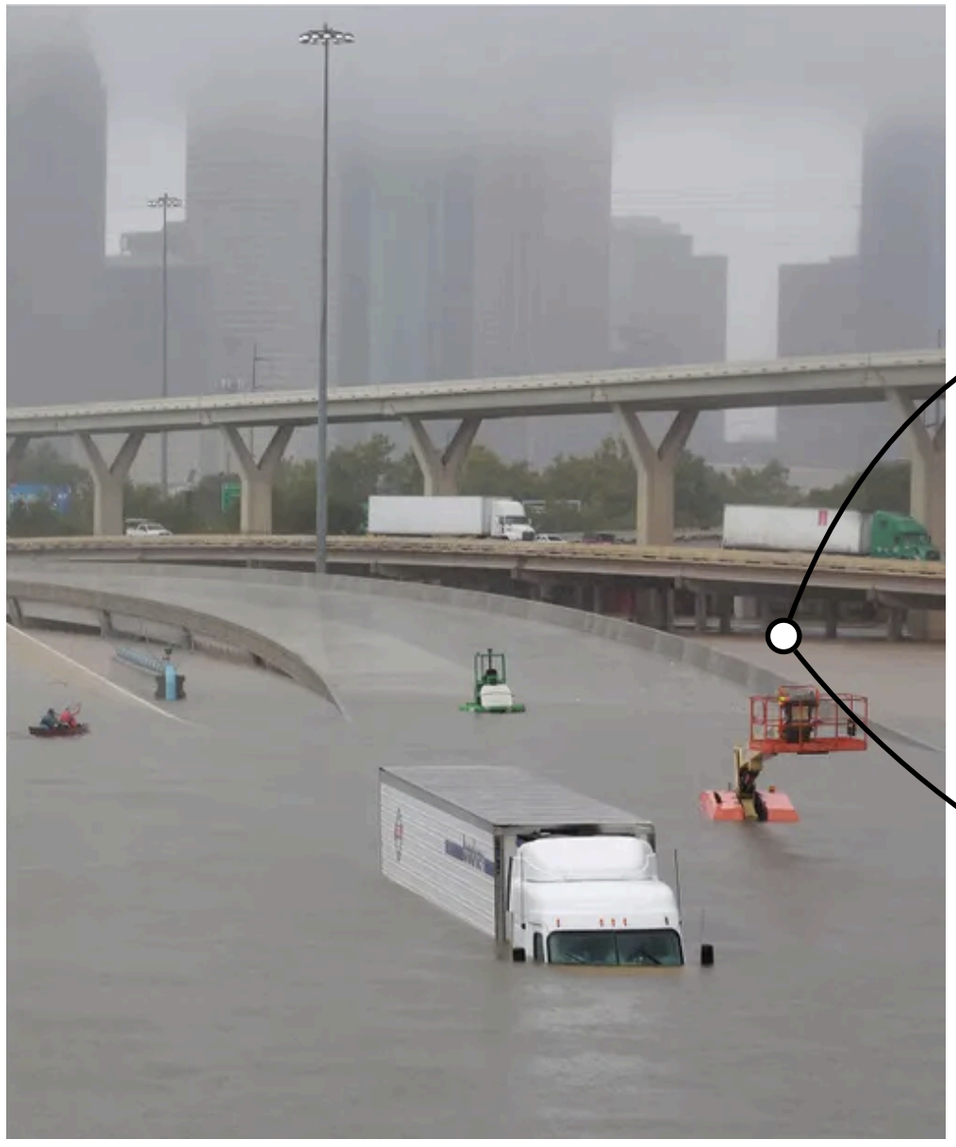

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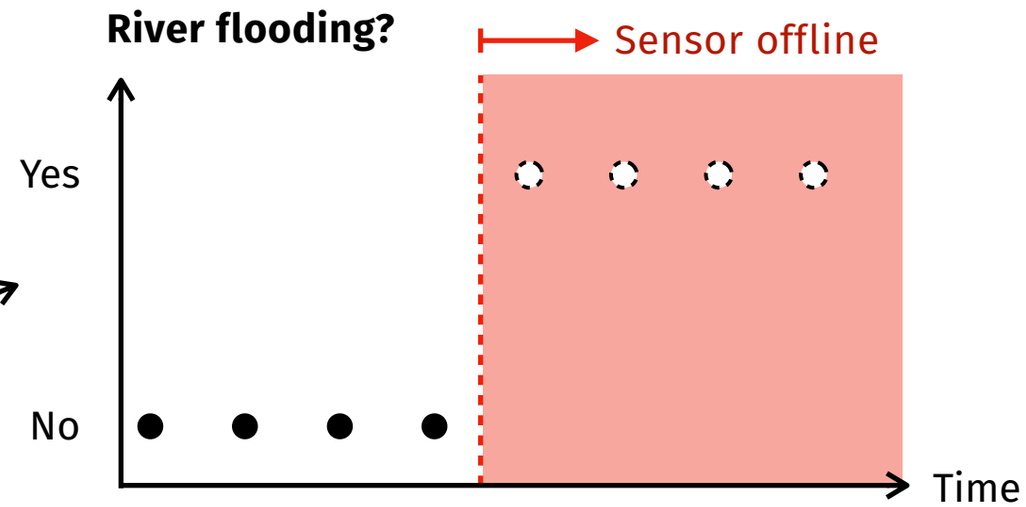

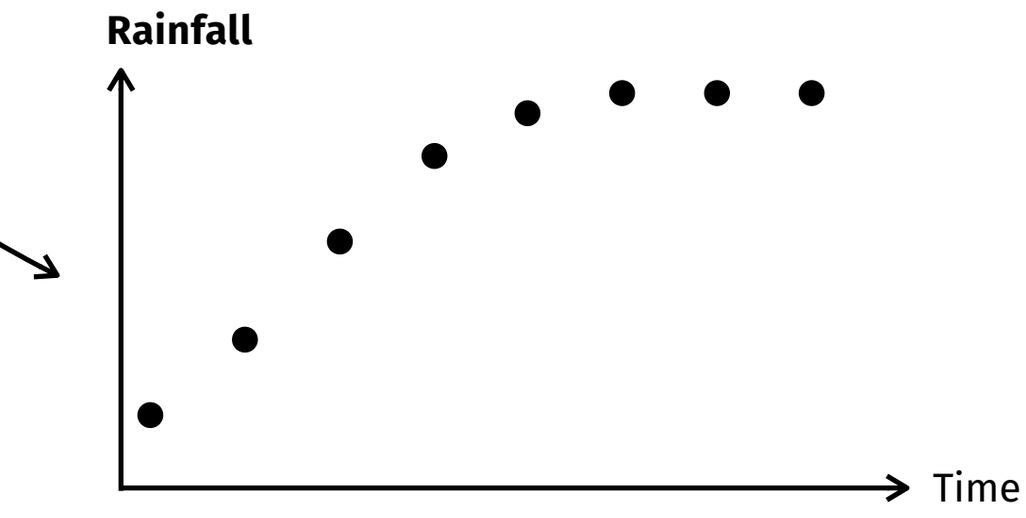

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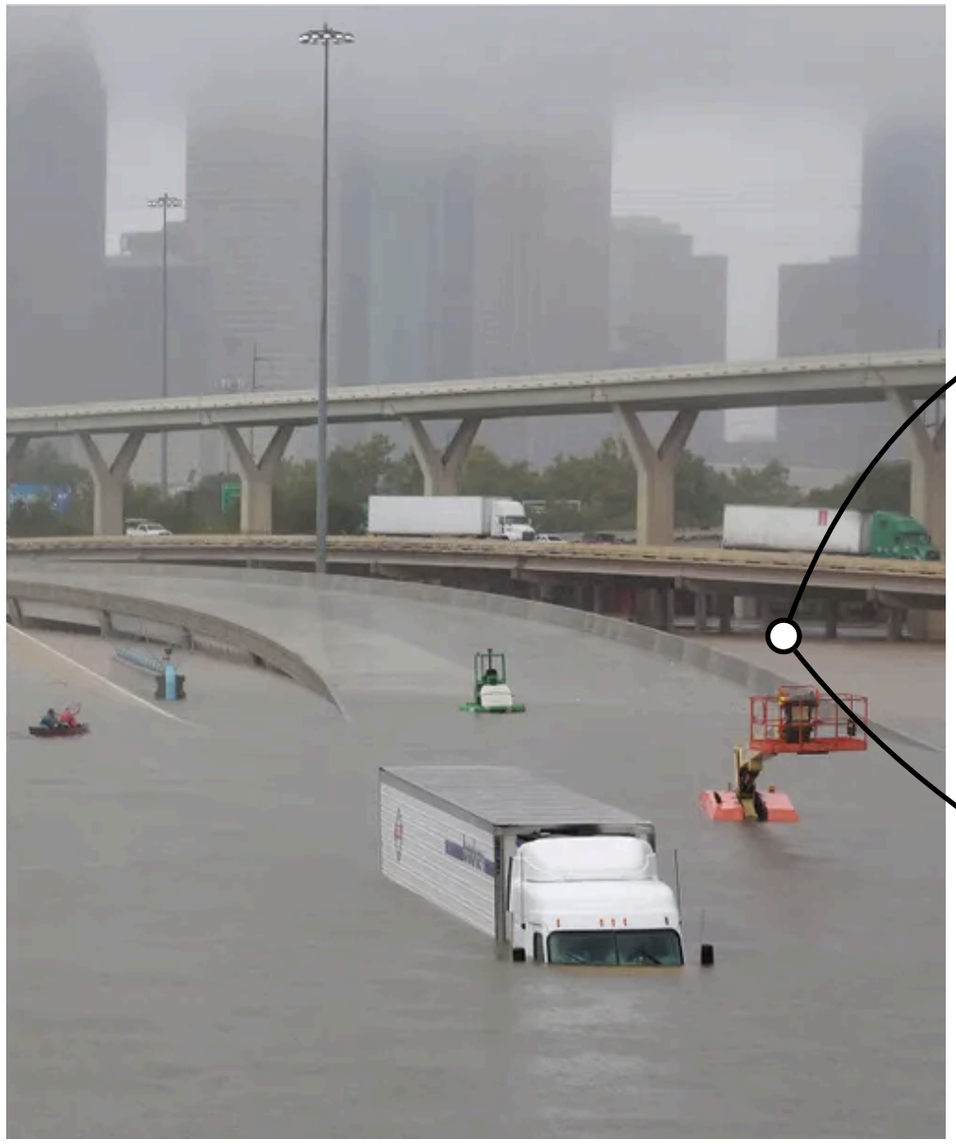

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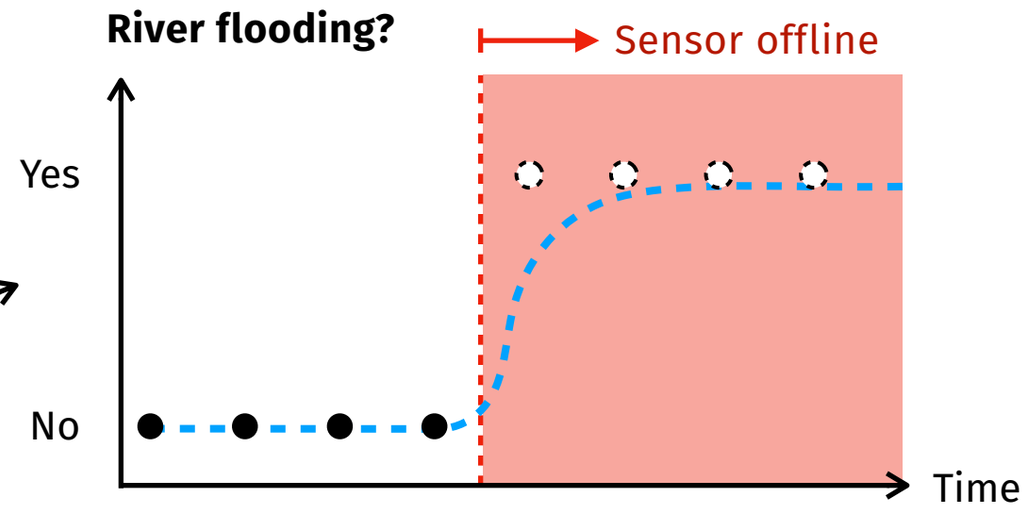

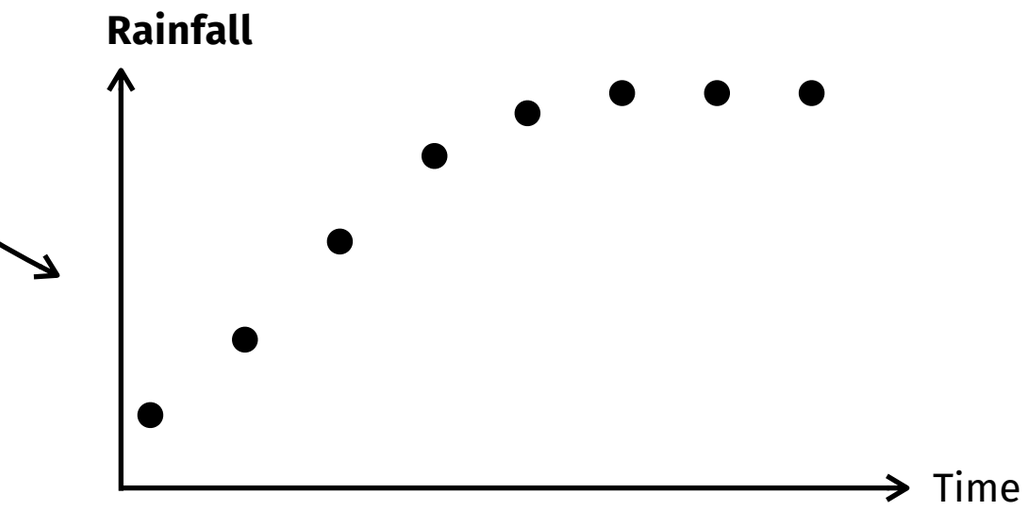

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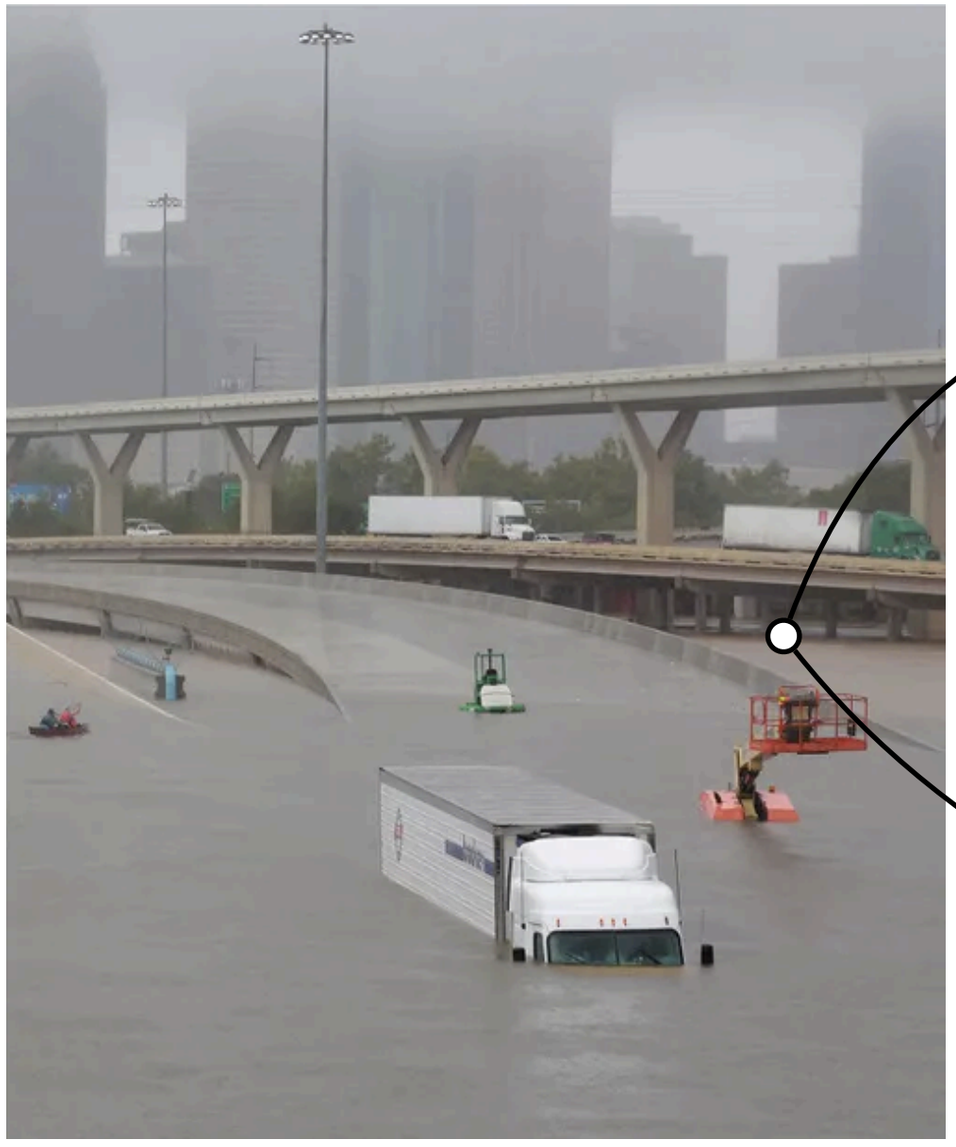

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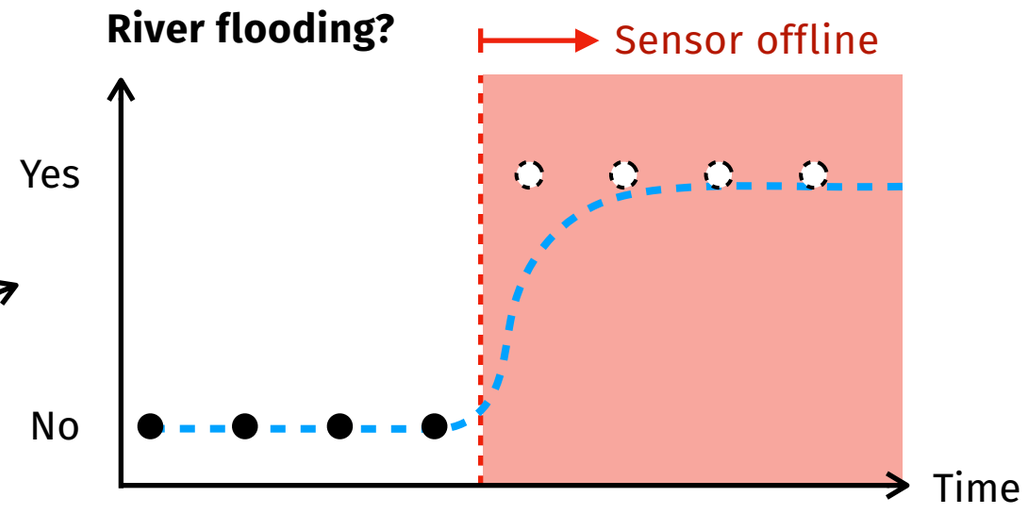

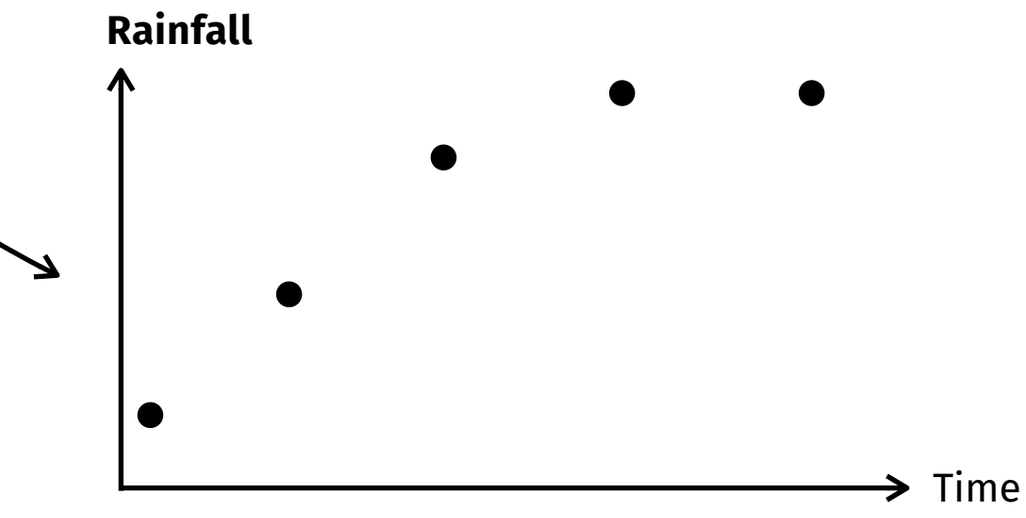

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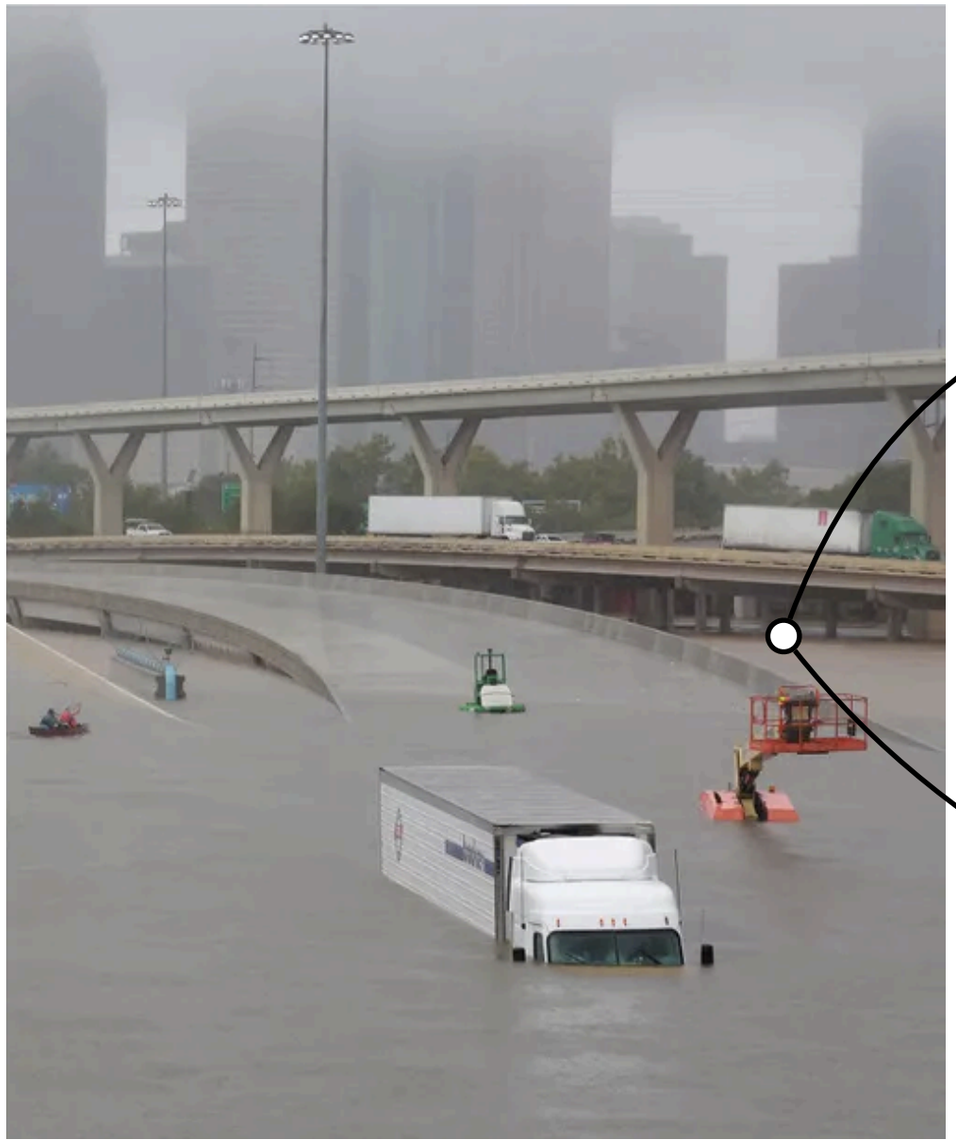

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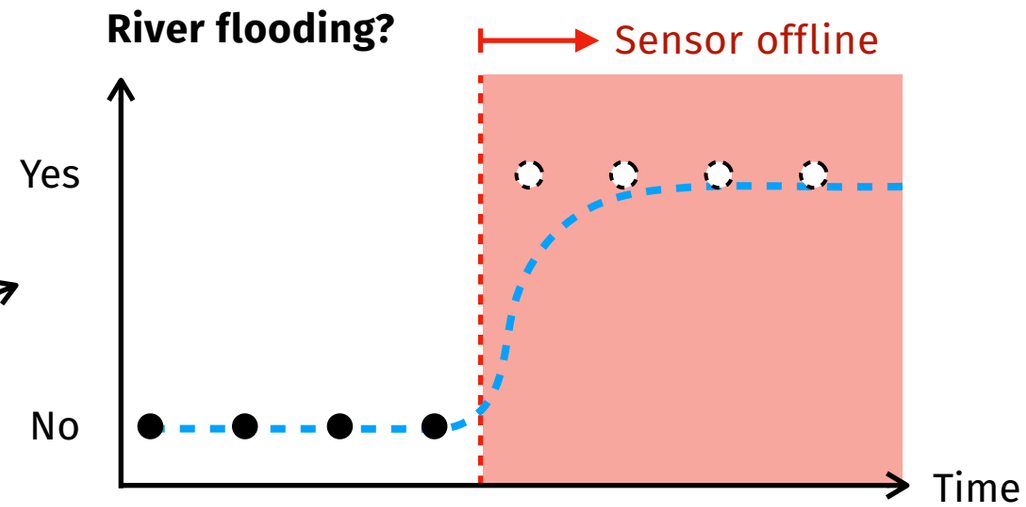

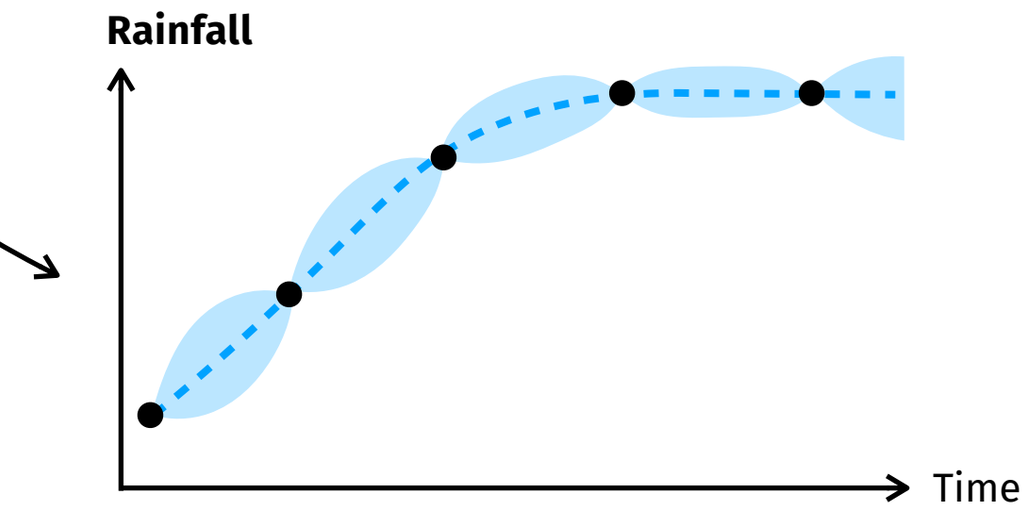

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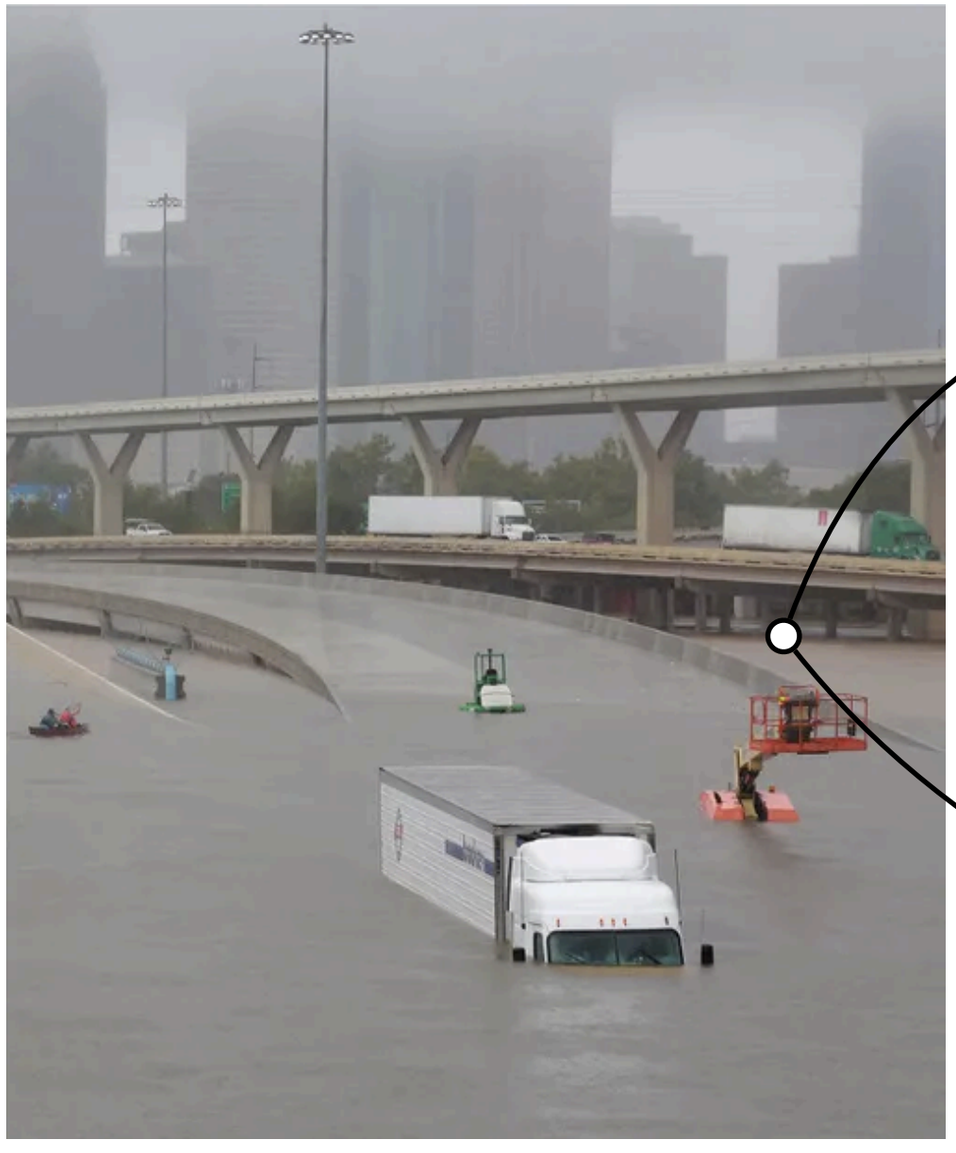

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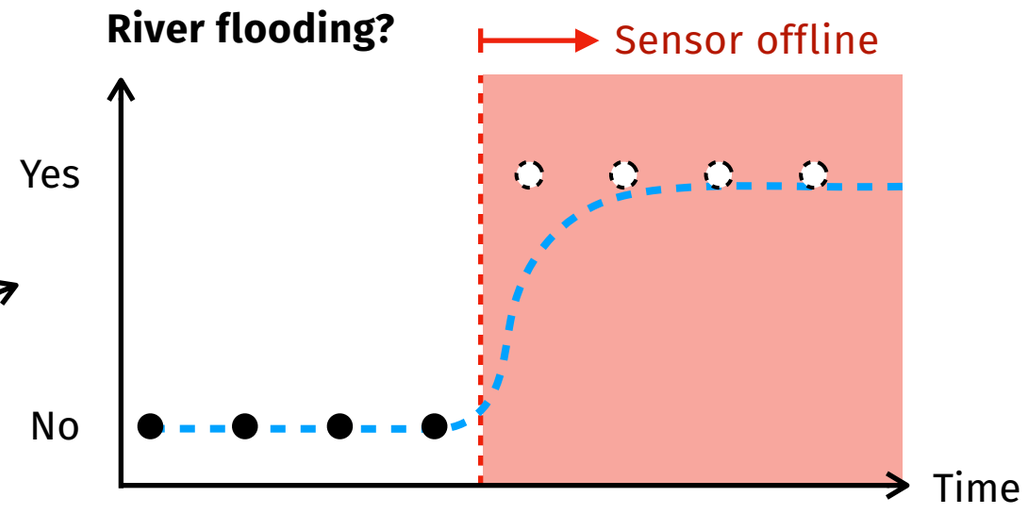
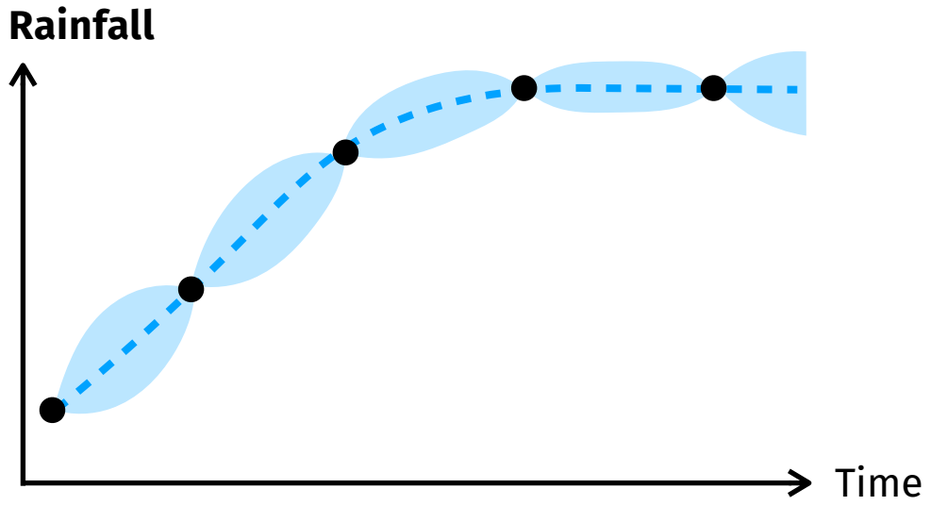




Can we make joint predictions over multiple outputs where data is missing with uncertainty?

Multi-output neural processes

What are neural processes?

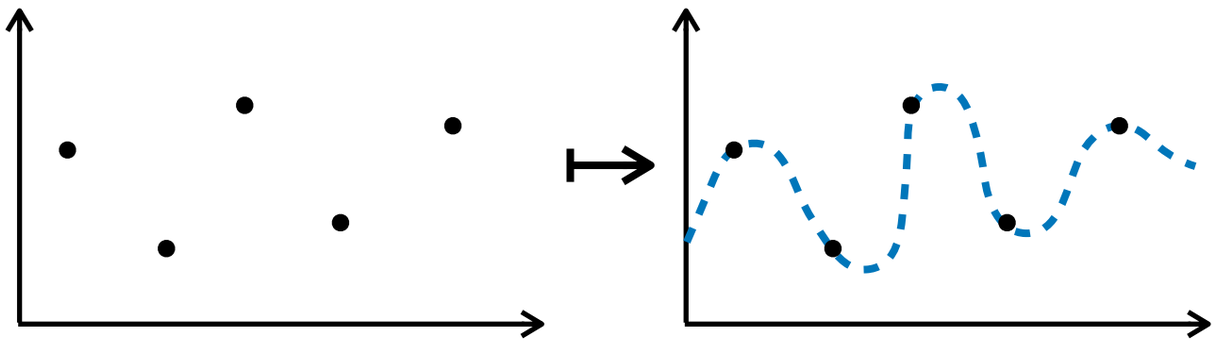
Traditional supervised learning

Neural processes

What are neural processes?

Traditional supervised learning

Dataset $\mathscr{D}$ $\longmapsto$ Prediction $f(x)$



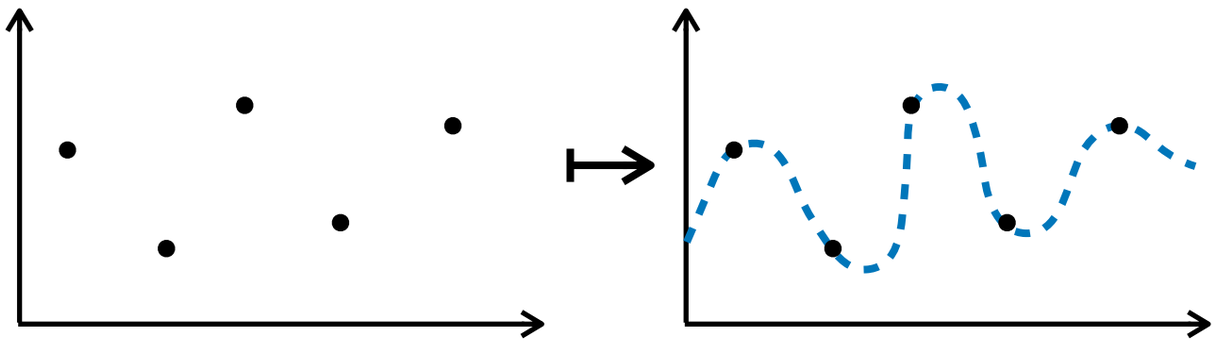
Training

Neural processes

What are neural processes?

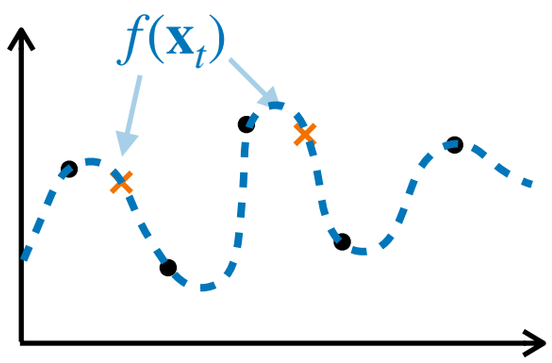
Traditional supervised learning

Dataset $\mathscr{D}$ $\longmapsto$ Prediction $f(x)$



Training

Test



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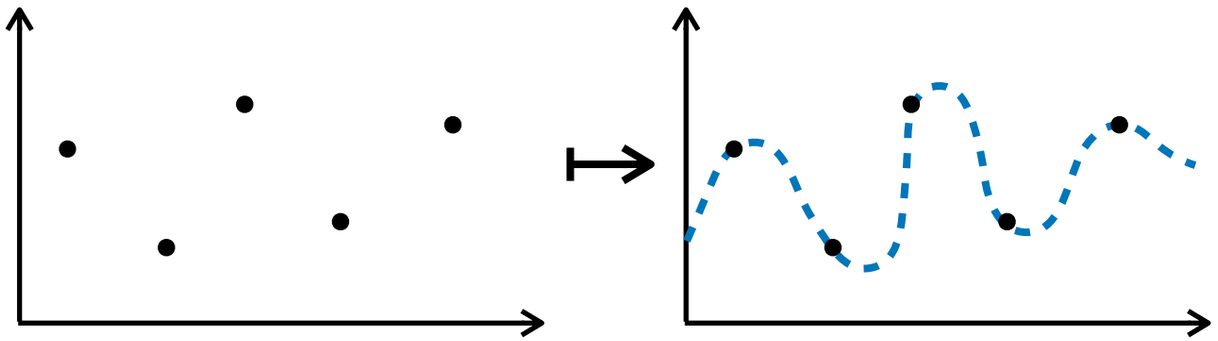
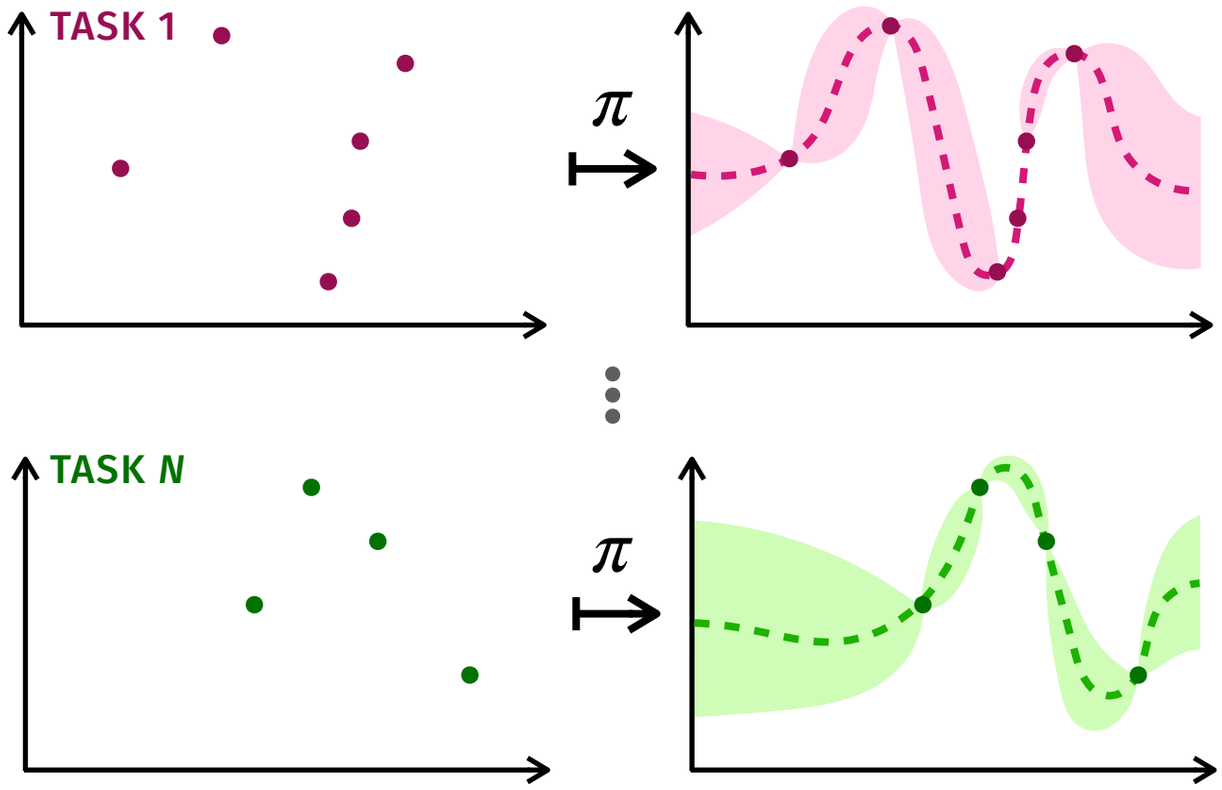


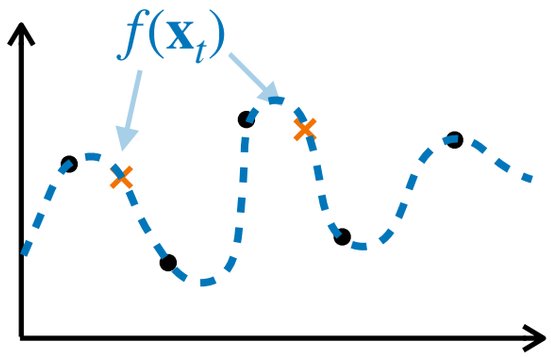
Neural processes

Dataset $\mathscr{D}$ $\overset{\pi}{\longmapsto}$ Prediction $p(\mathbf{y}_t \mid \mathbf{x}_t; \mathscr{D})$



Training

Test



What are neural processes?

Traditional supervised learning

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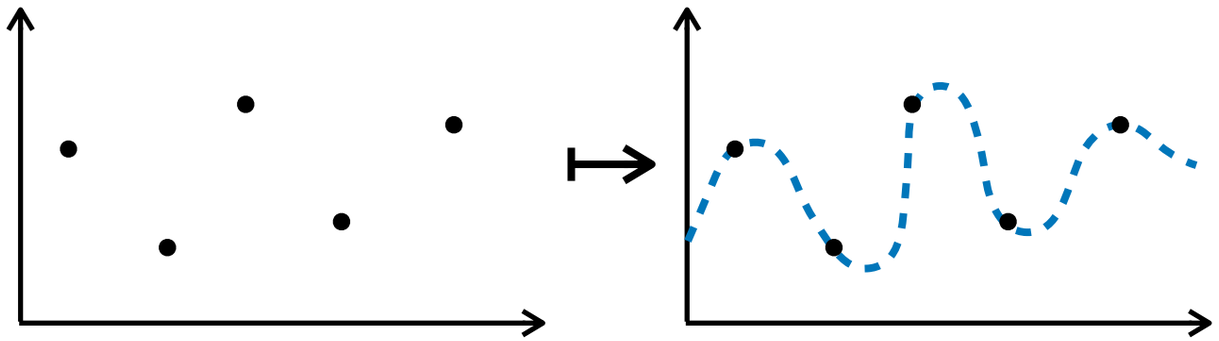

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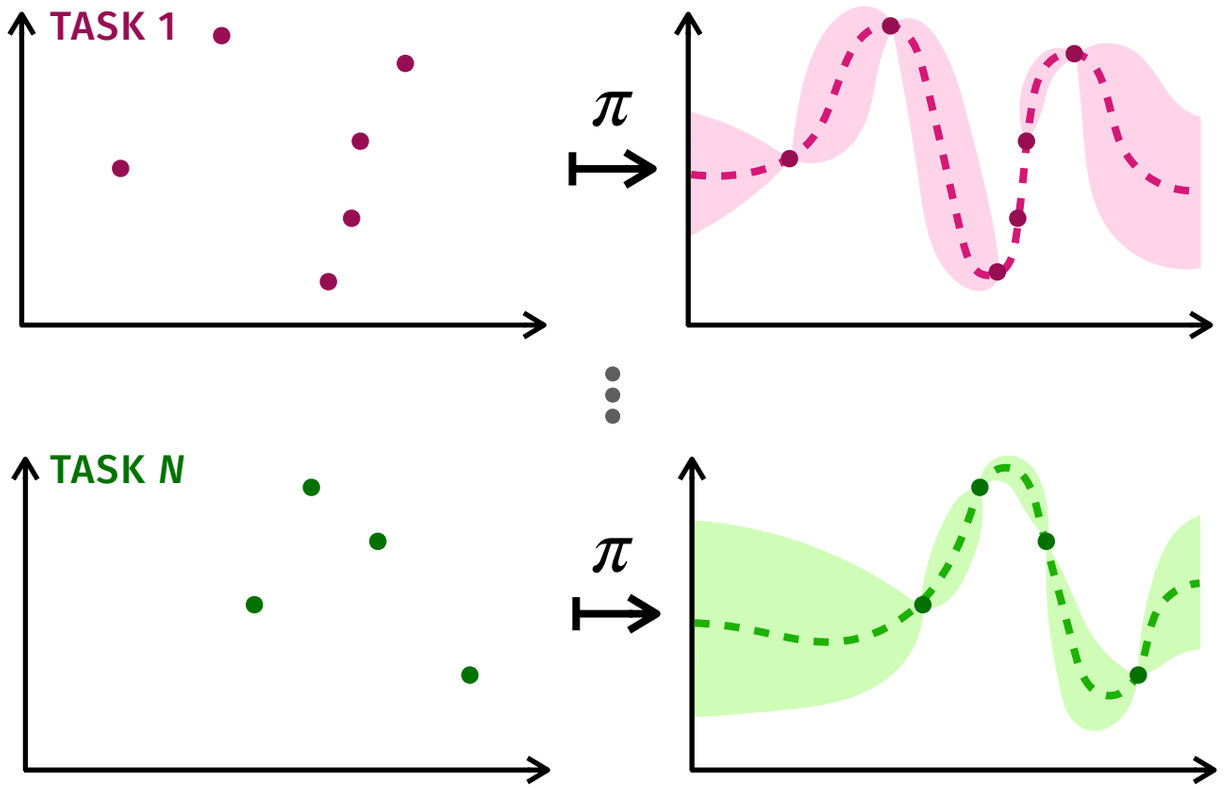

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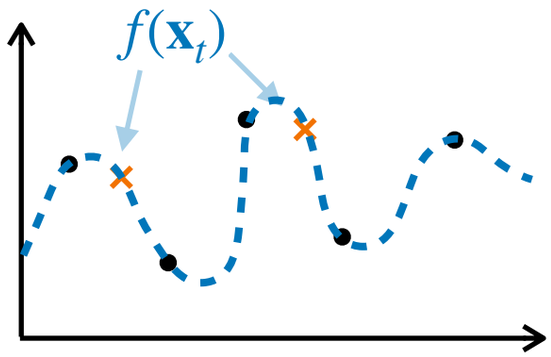
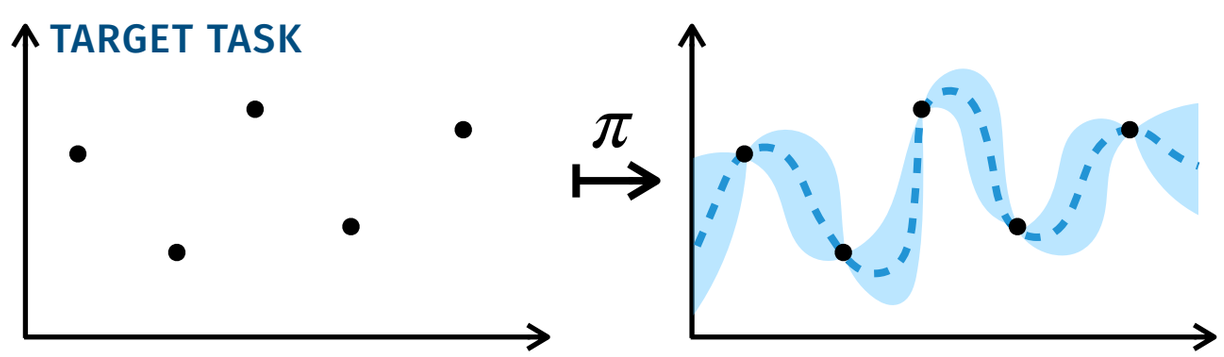
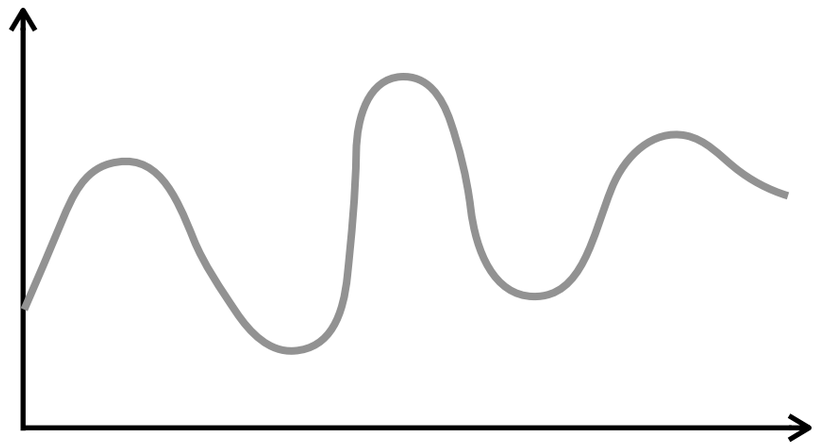




How do neural processes work?

● Context ✕ Target —— Underlying function



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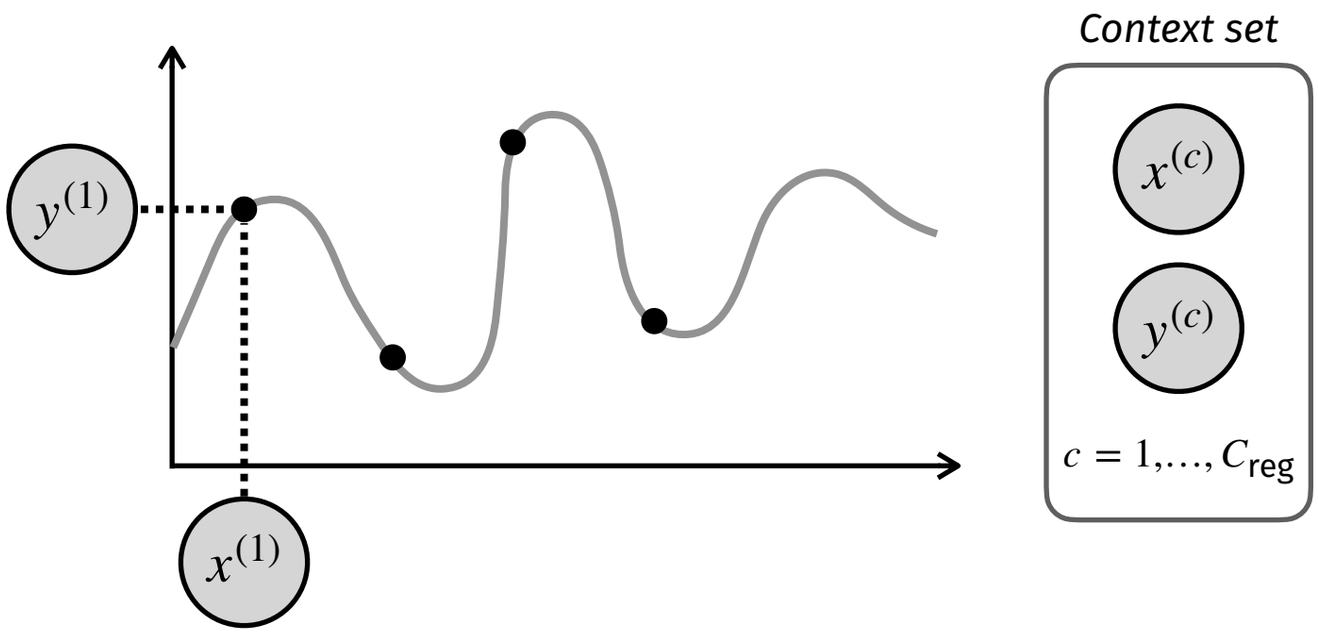


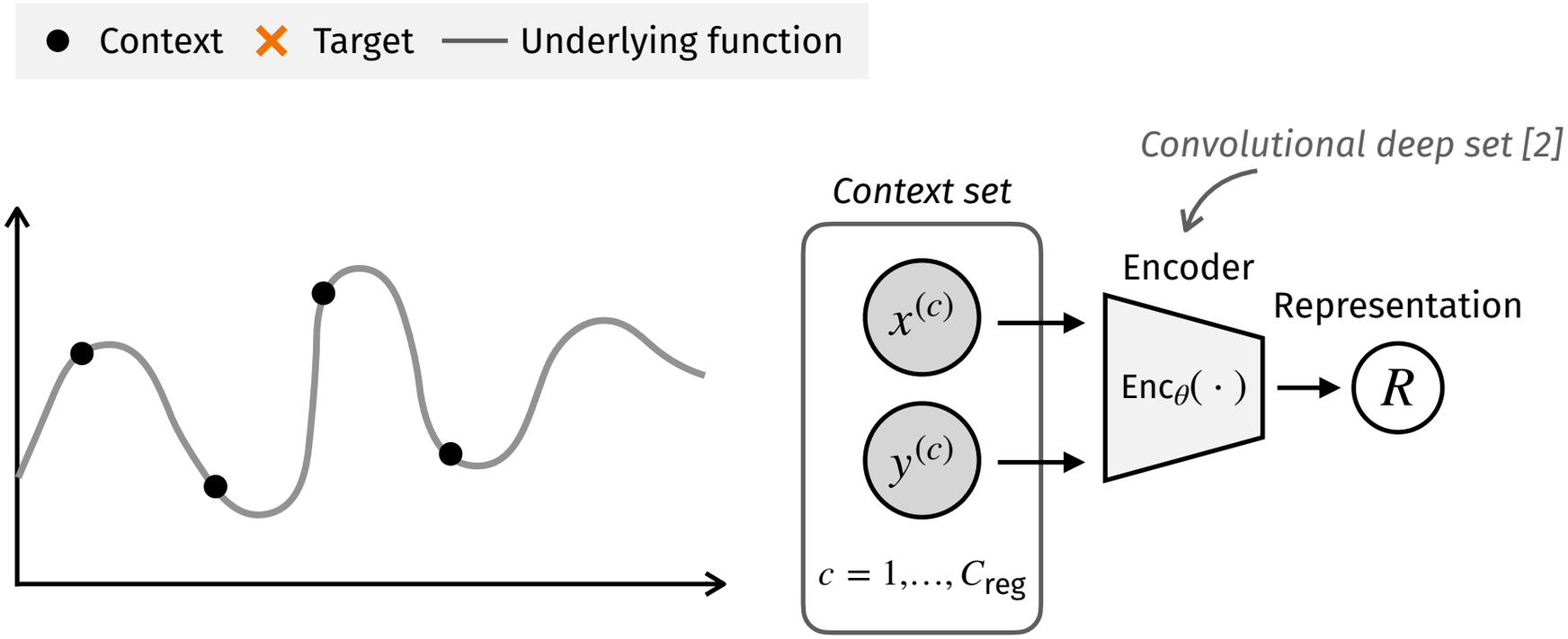
Context set

$x^{(c)}$

$y^{(c)}$

$c = 1, \ldots, C_{\text{reg}}$

How do neural processes work?



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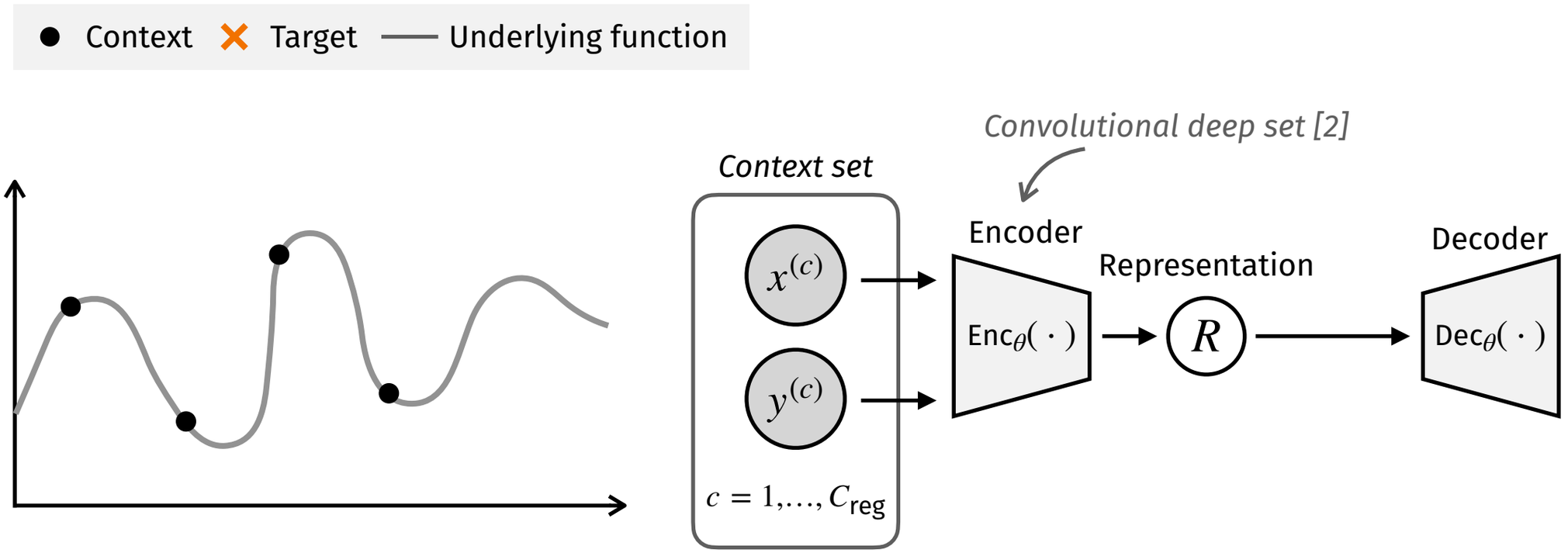

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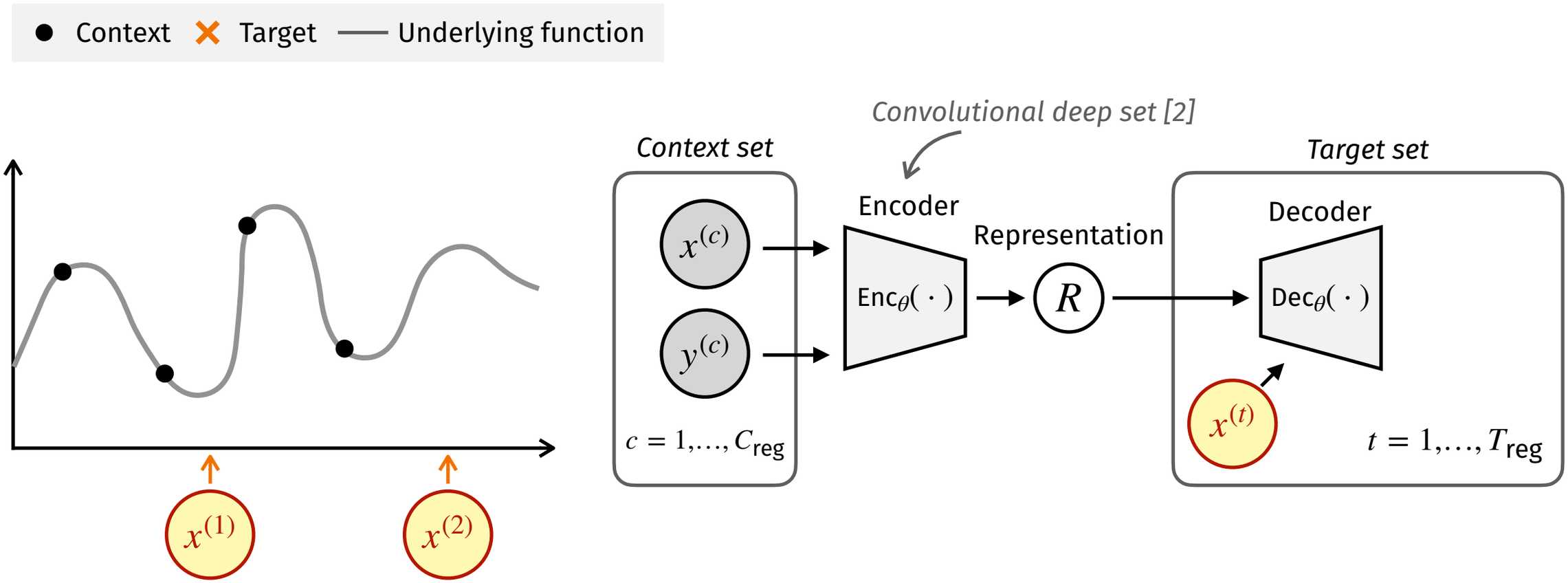
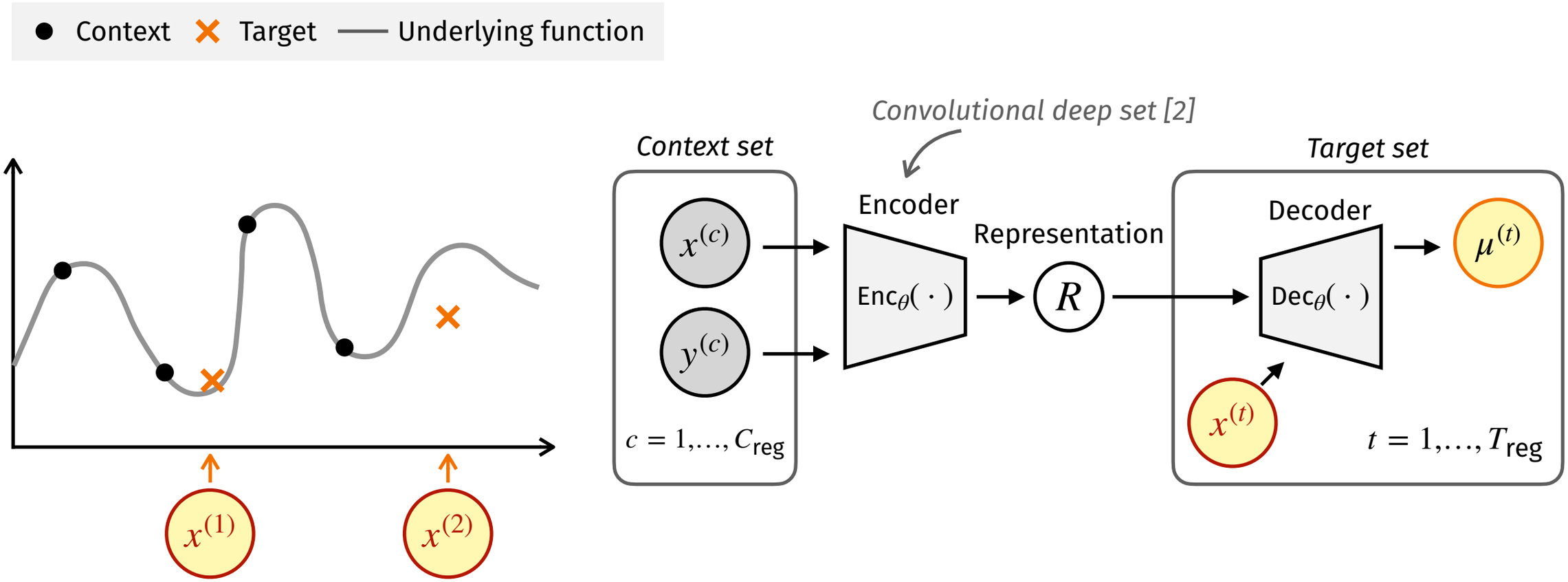


How do neural processes work?



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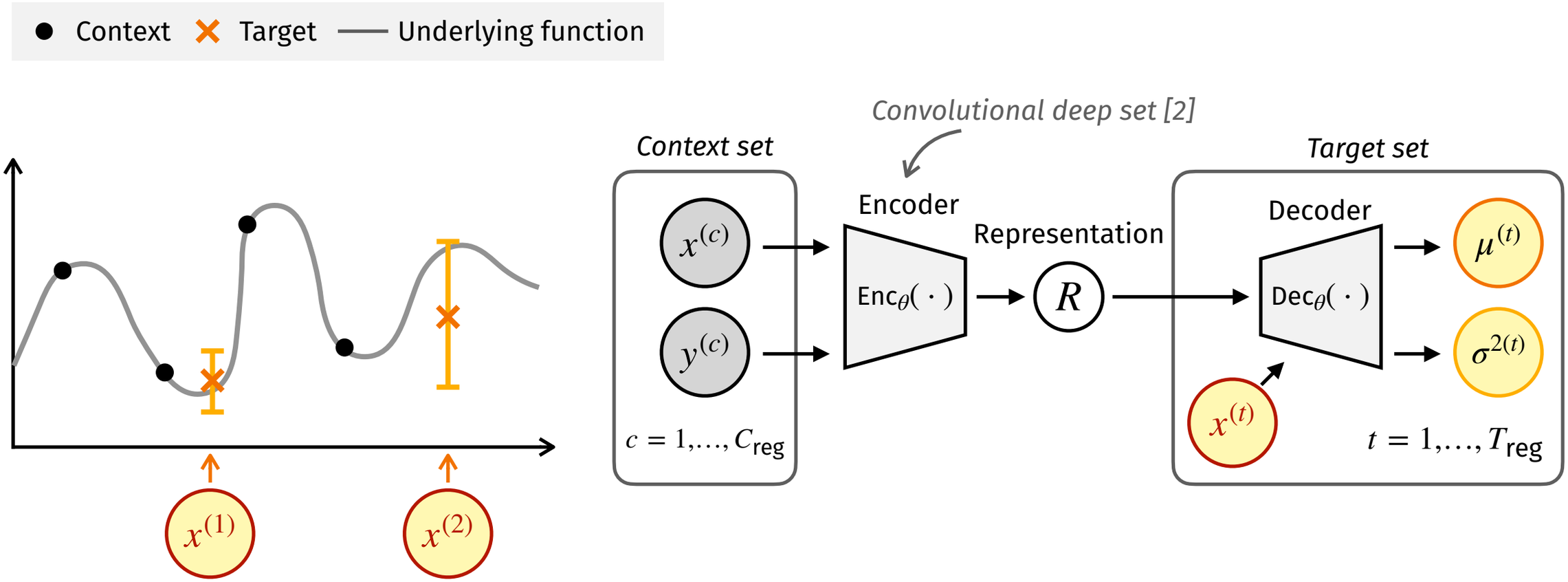
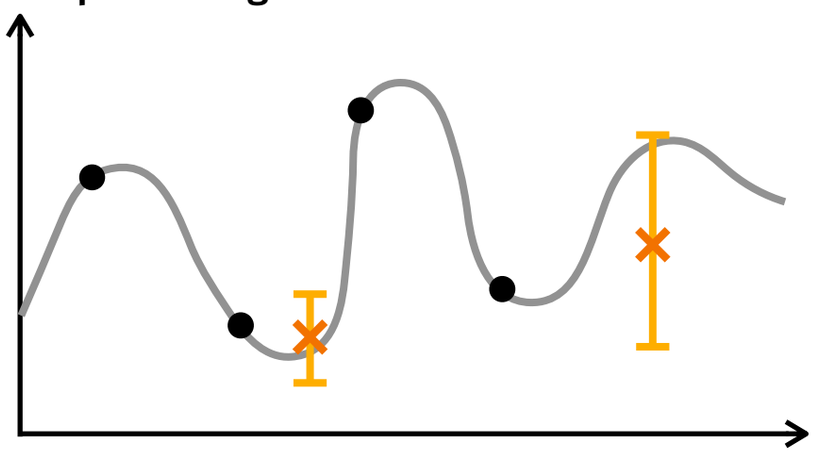


How do neural processes work?

● Context ✕ Target —— Underlying function

Output 1: Regression



Convolutional deep set [2]

Context set

$x^{(c)}$

$y^{(c)}$

$c = 1, \ldots, C_{\text{reg}}$

Encoder

$\text{Enc}_\theta(\cdot)$

Representation

R

Target set

Decoder

$\text{Dec}_\theta(\cdot)$

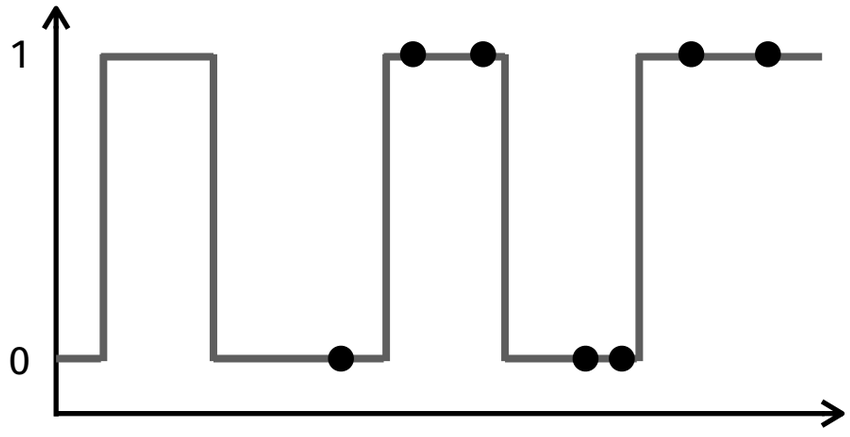
$\mu^{(t)}$

$\sigma^{2(t)}$

$x^{(t)}$

$t = 1, \ldots, T_{\text{reg}}$

Output 2: Classification



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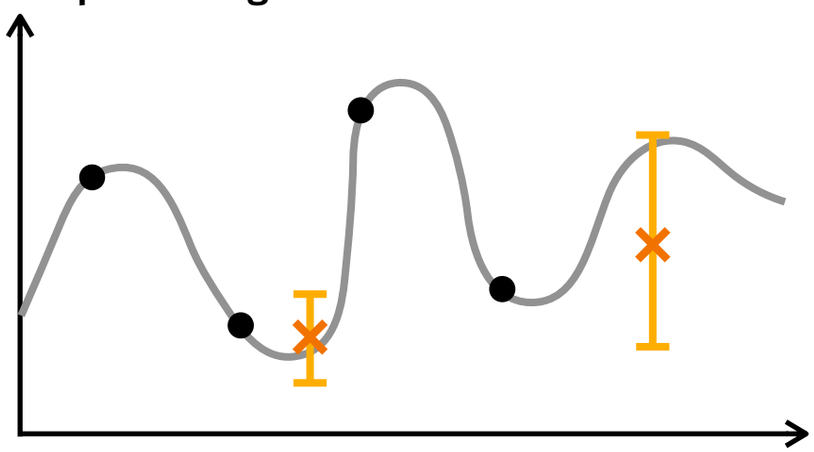

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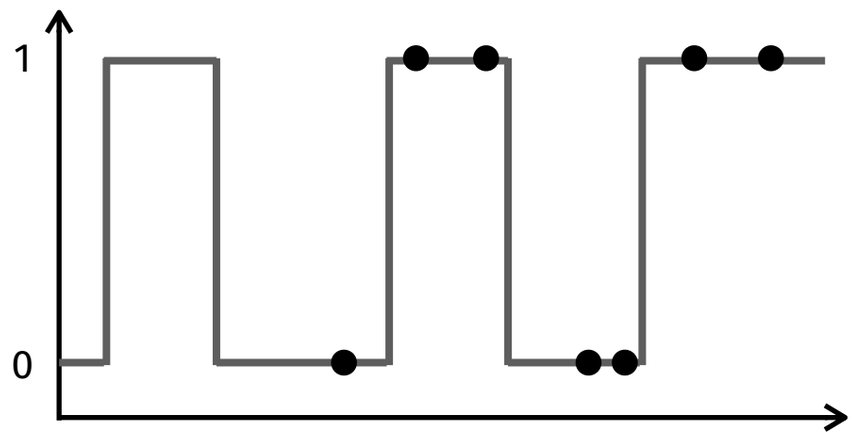


$x^{(c)}$

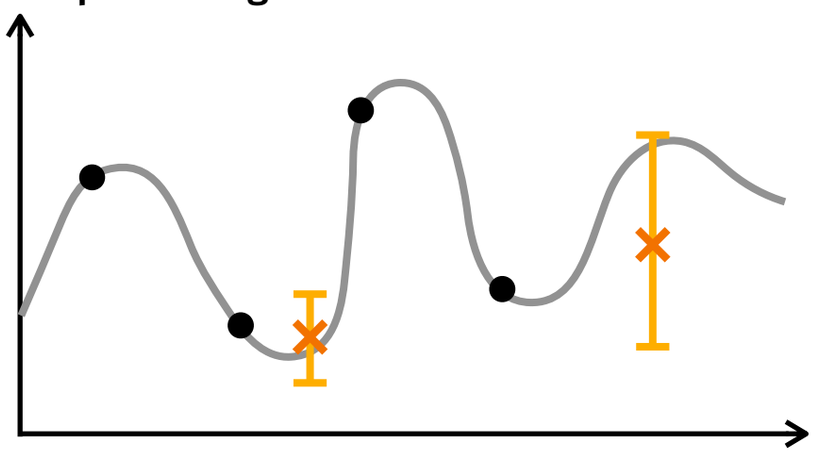
$y^{(c)}$

$c = 1,\ldots,C_{\text{class}}$

How do neural processes work?

● Context ✕ Target —— Underlying function

Output 1: Regression



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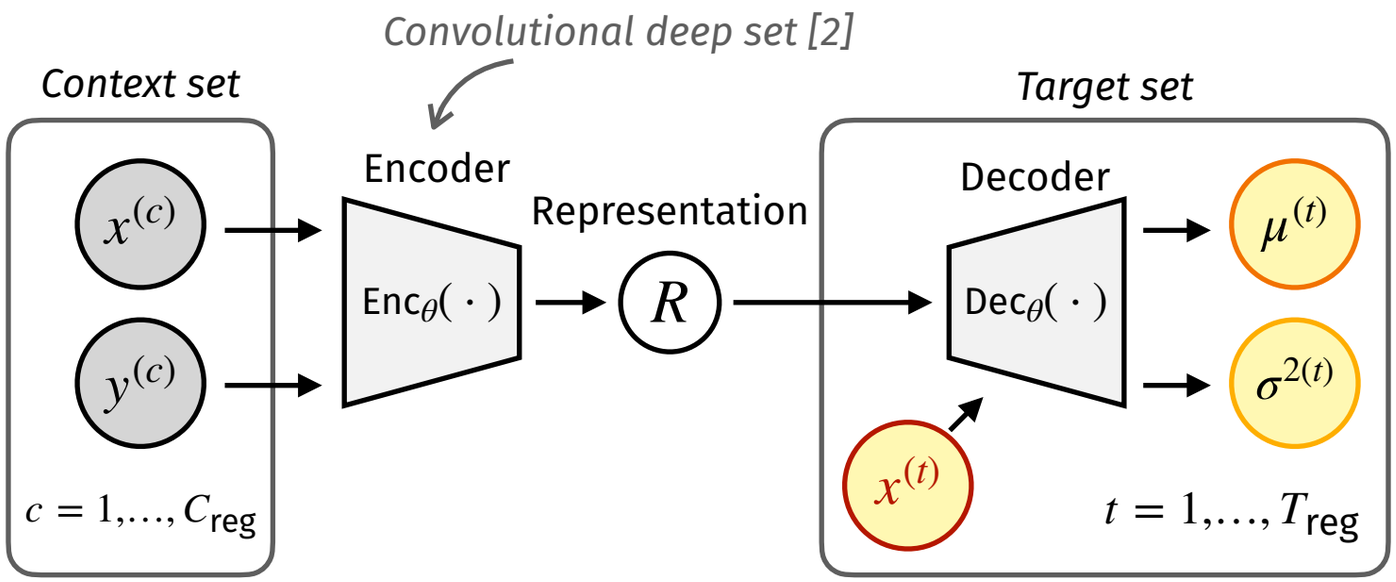
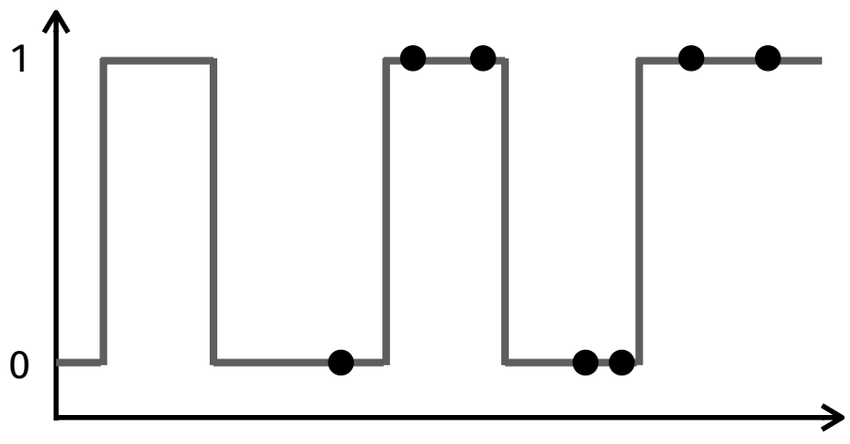
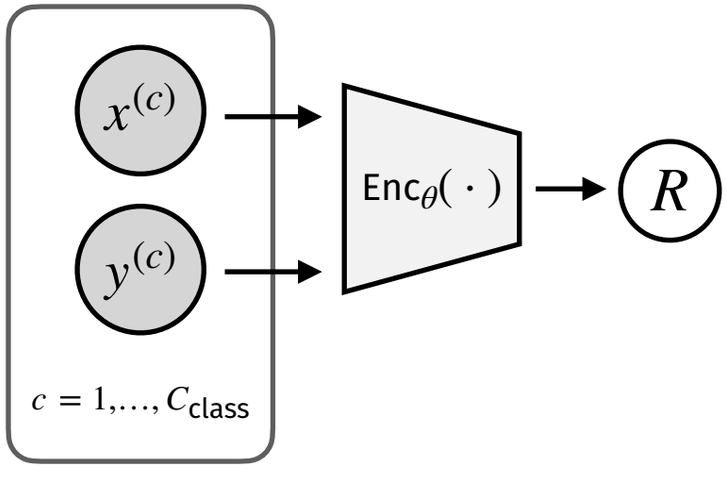


Output 2: Classification





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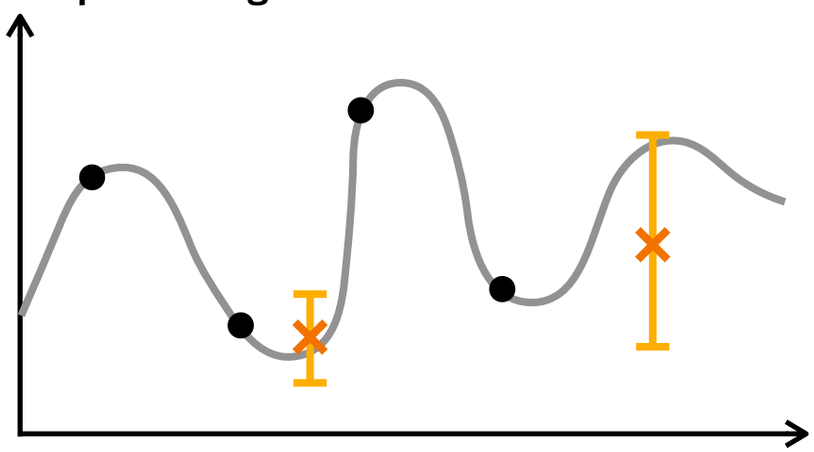
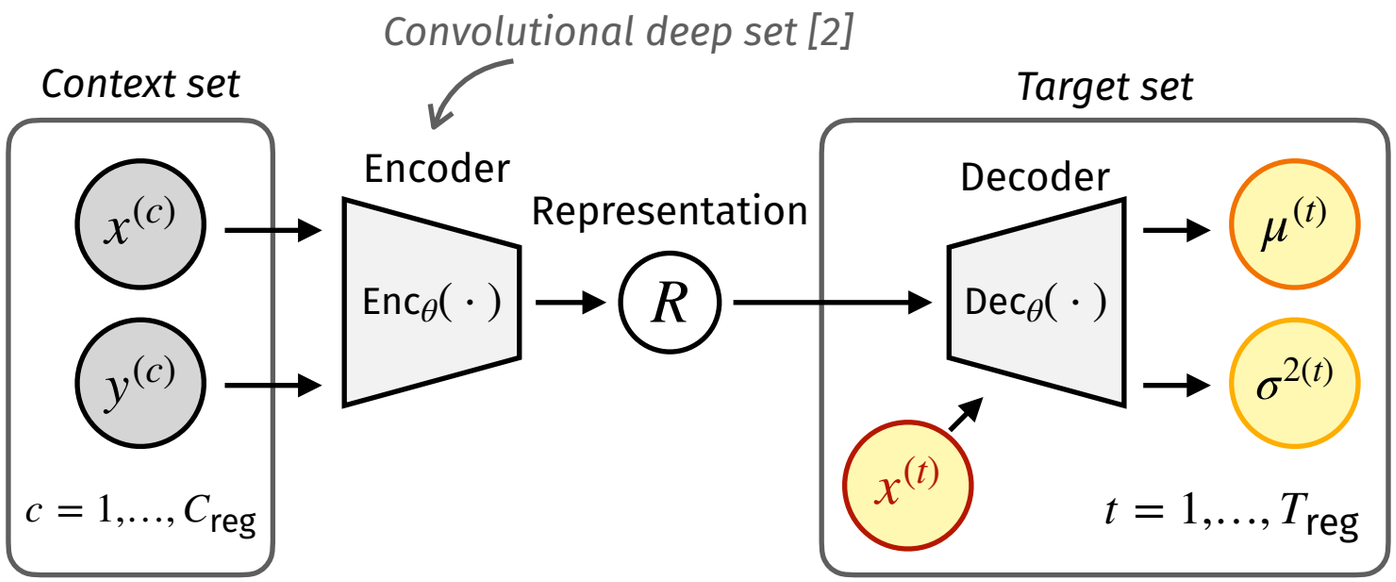
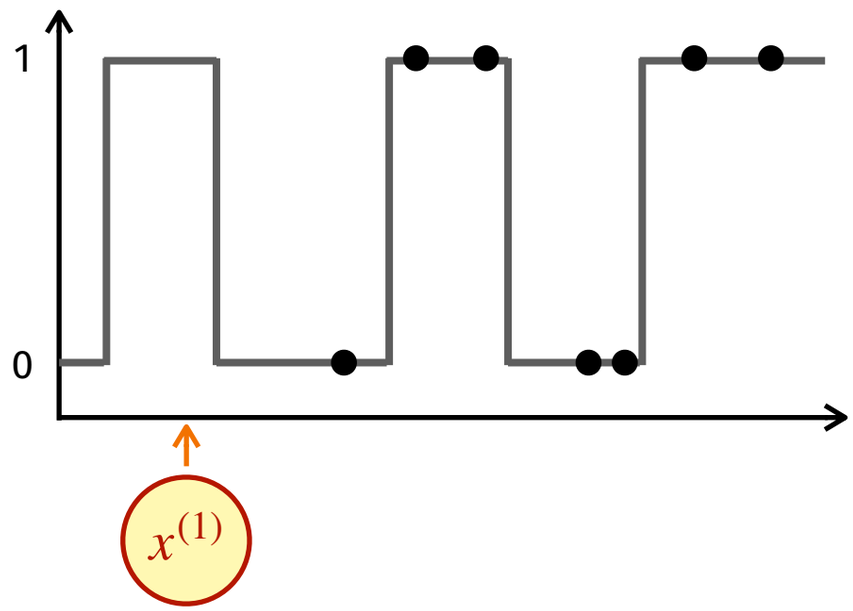
Output 1: Regression

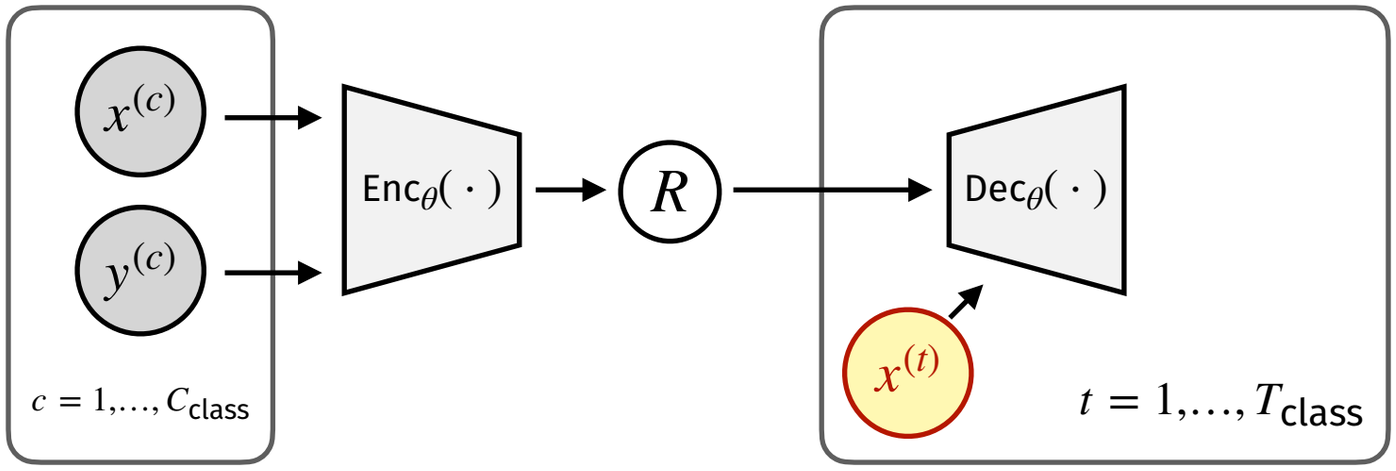


Convolutional deep set [2]



Output 2: Classification





How do neural processes work?

● Context ✕ Target — Underlying function

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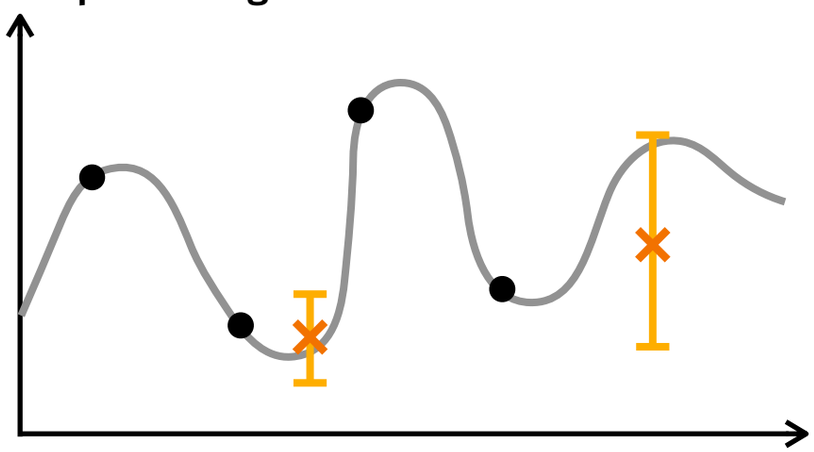
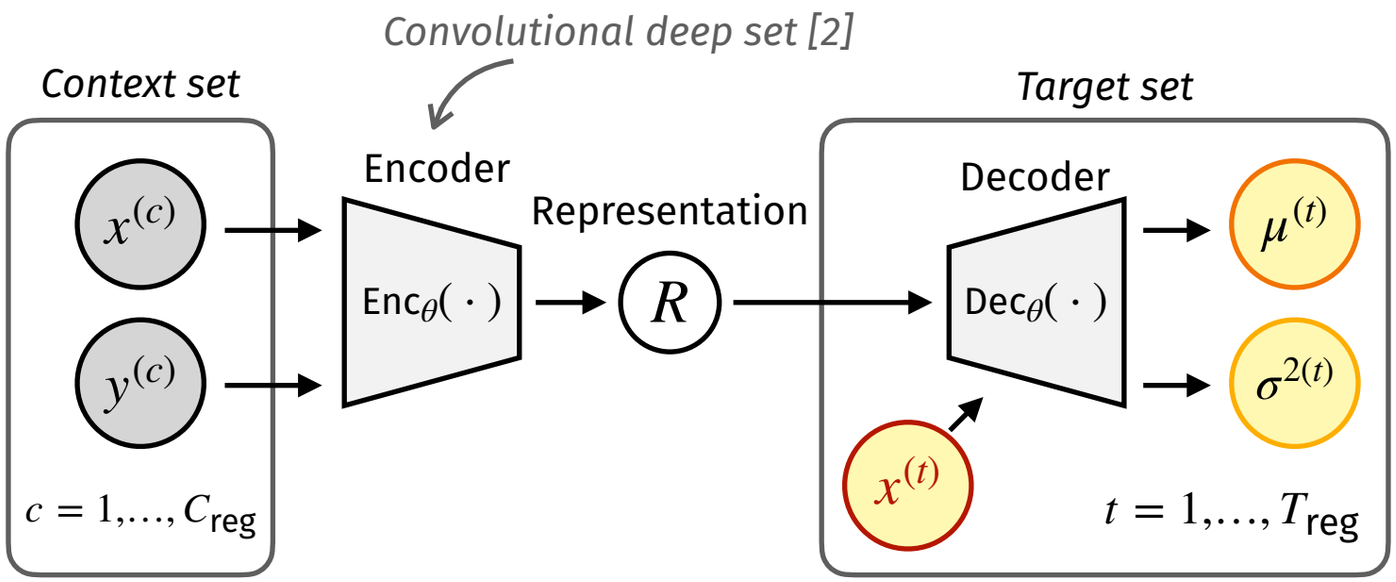
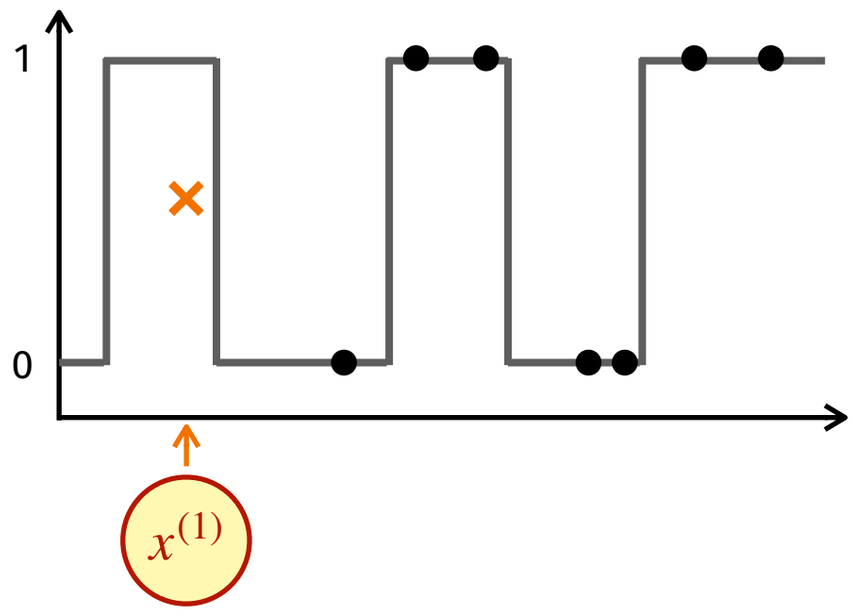
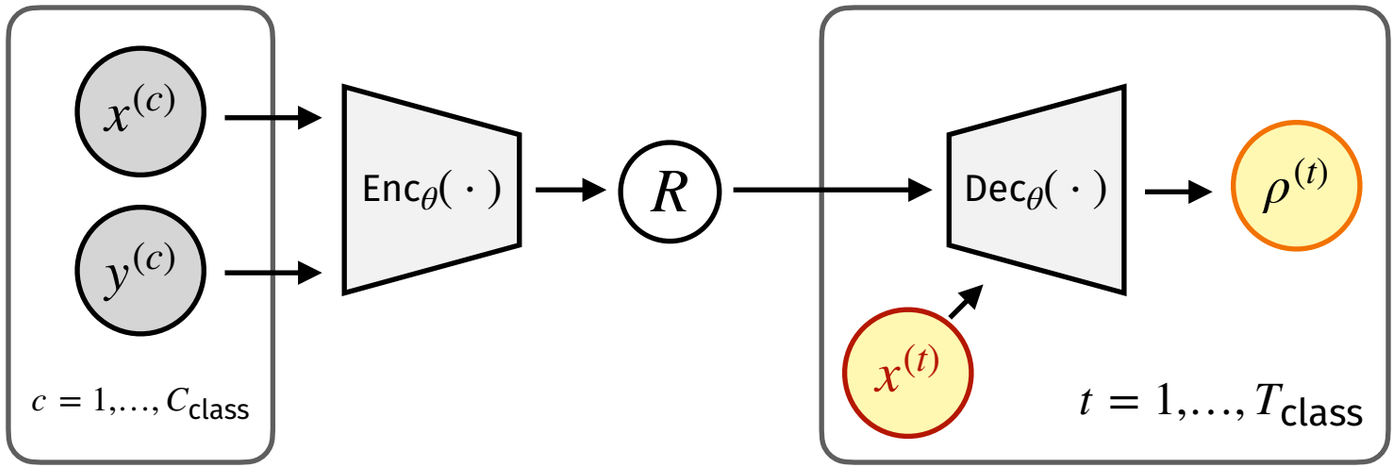


Convolutional deep set [2]



Output 2: Classification

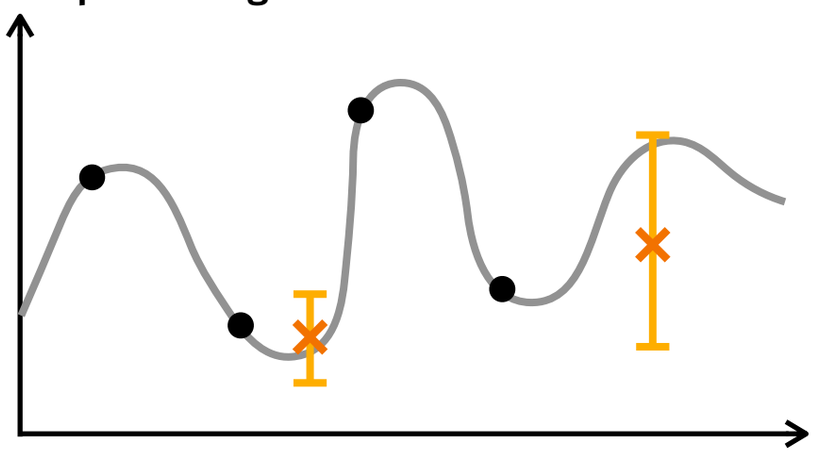




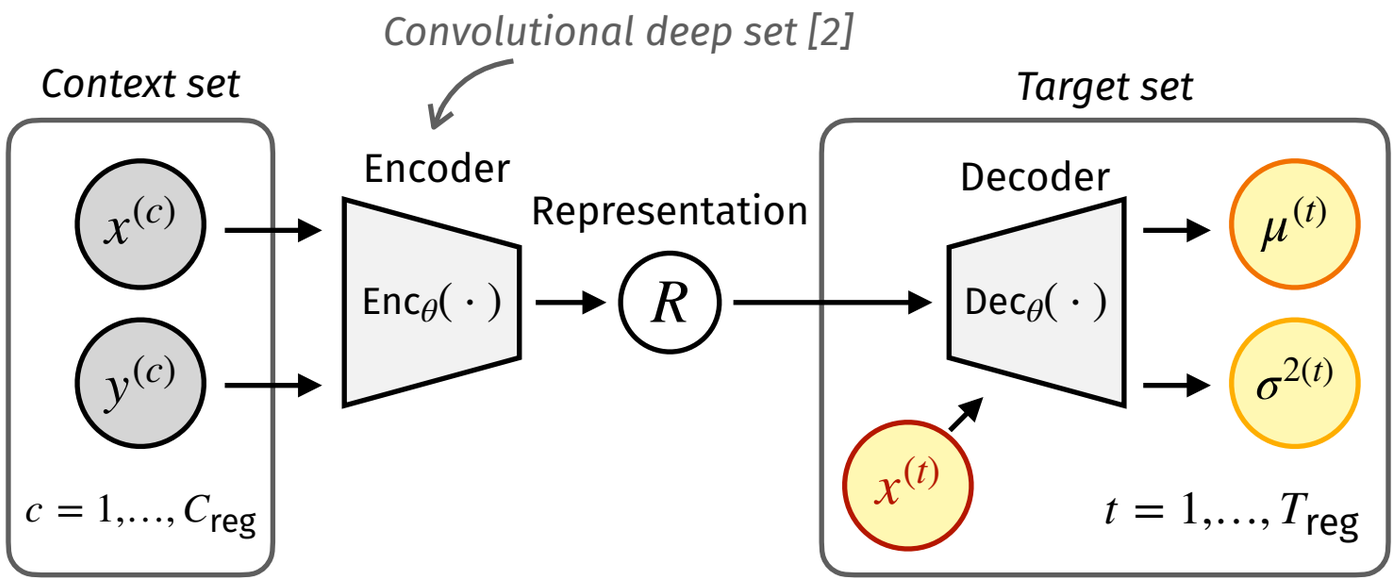
How do neural processes work?

● Context ✕ Target — Underlying function

Output 1: Regression



Convolutional deep set [2]



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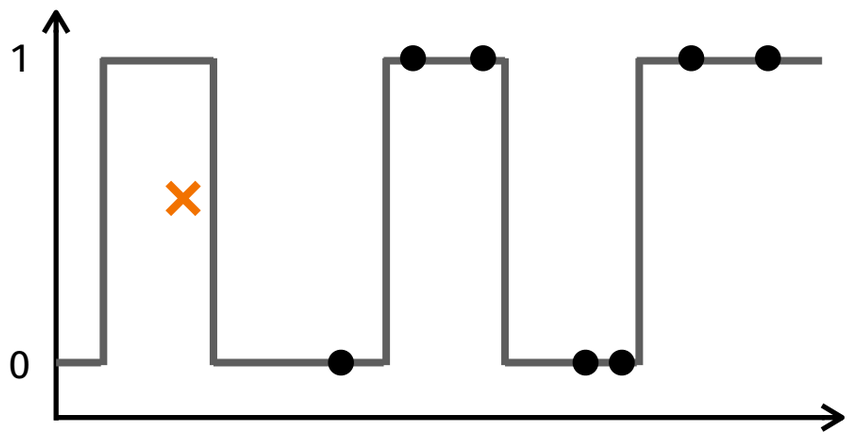
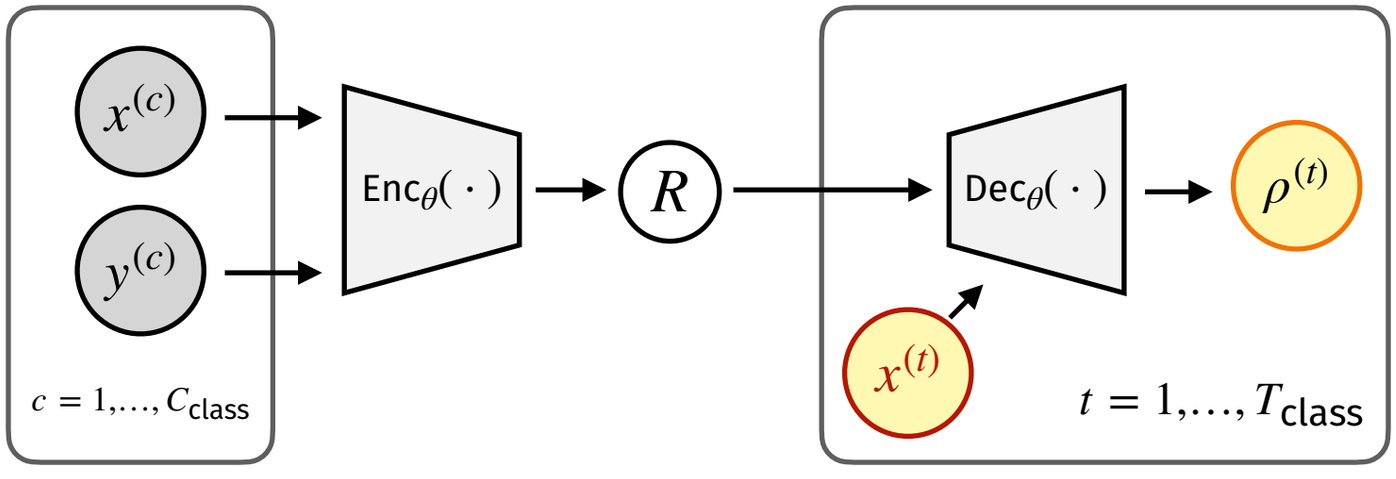
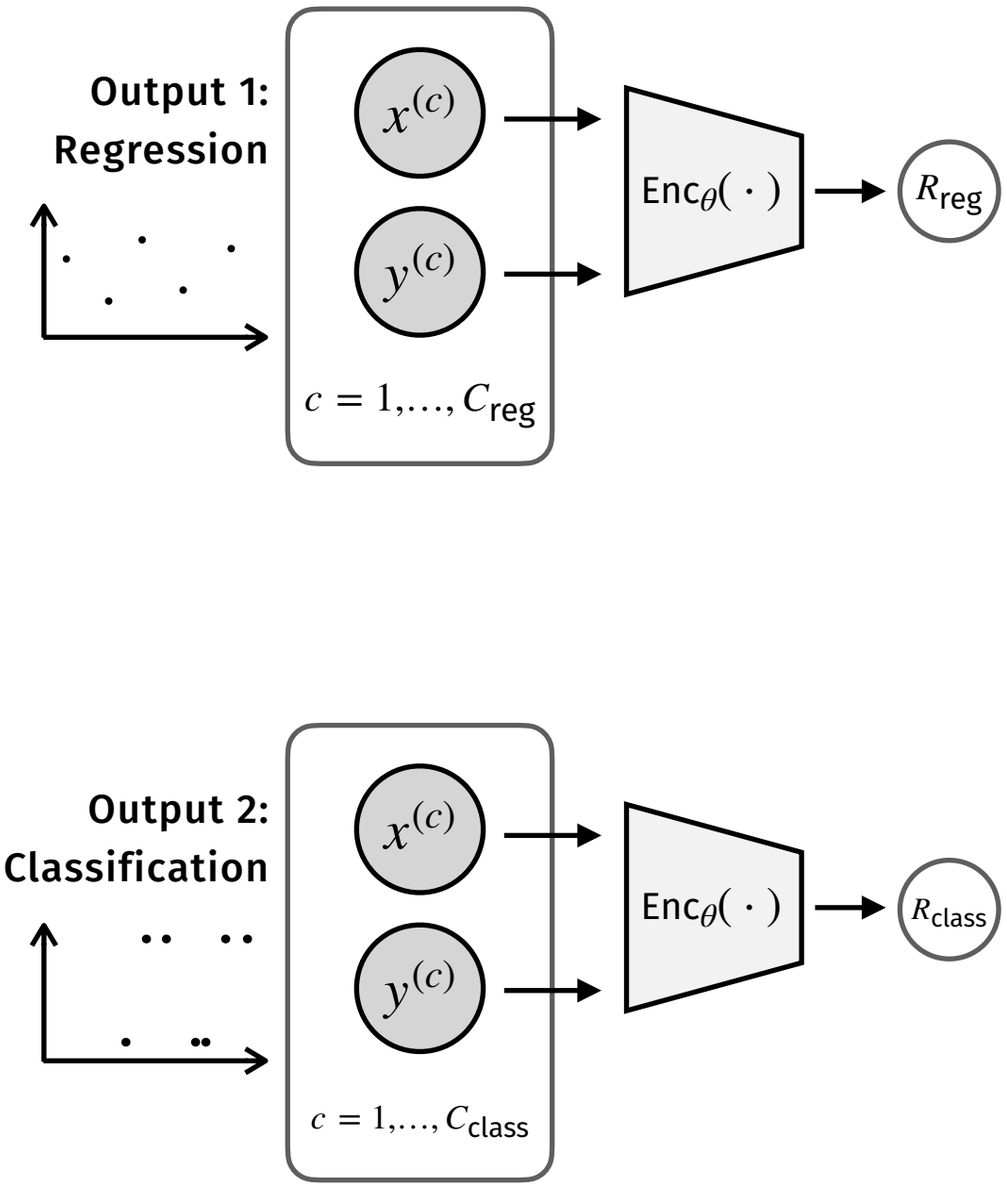


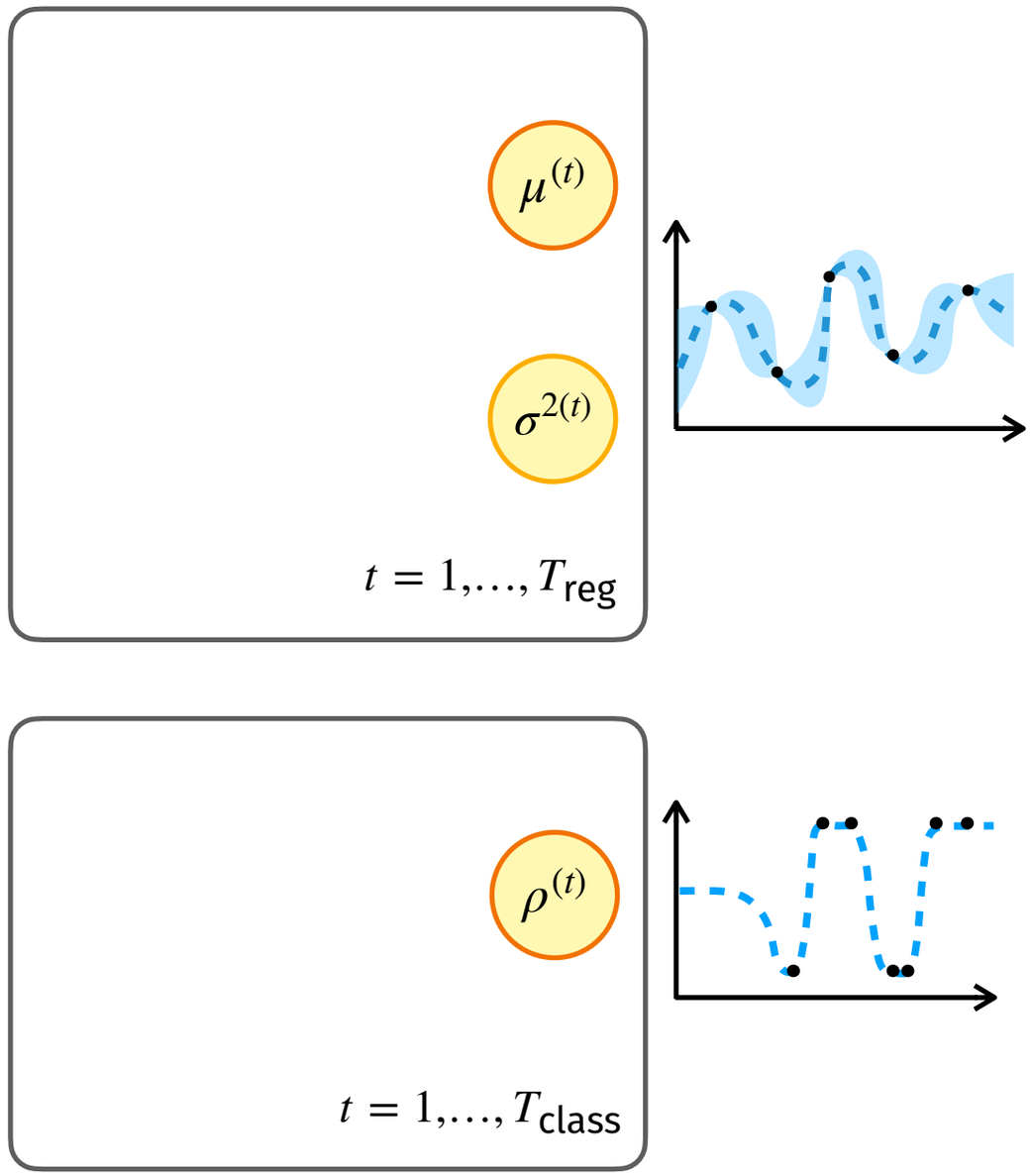
How can we connect these architectures so that our predictions are informed by both outputs?



How can they handle multi-output data?

Dual-output architecture





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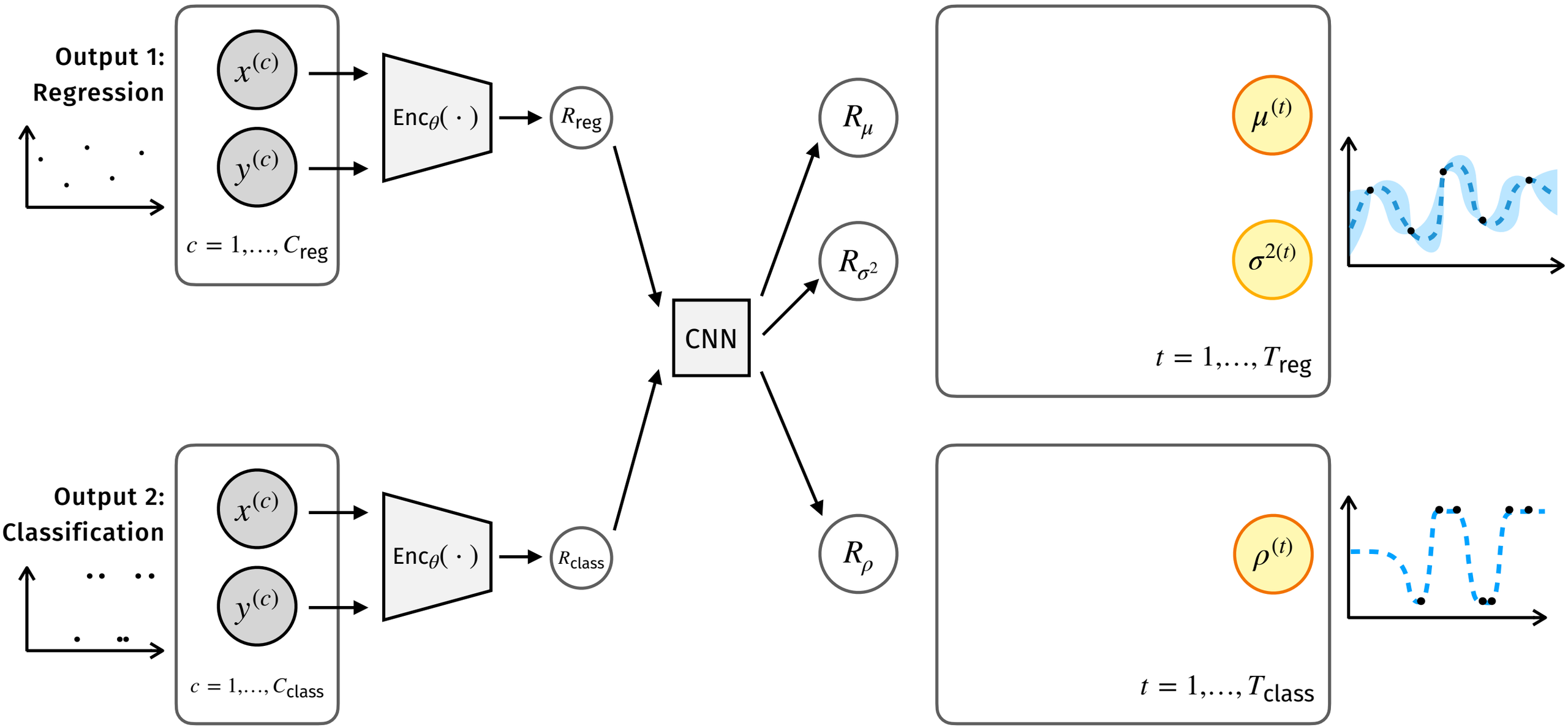

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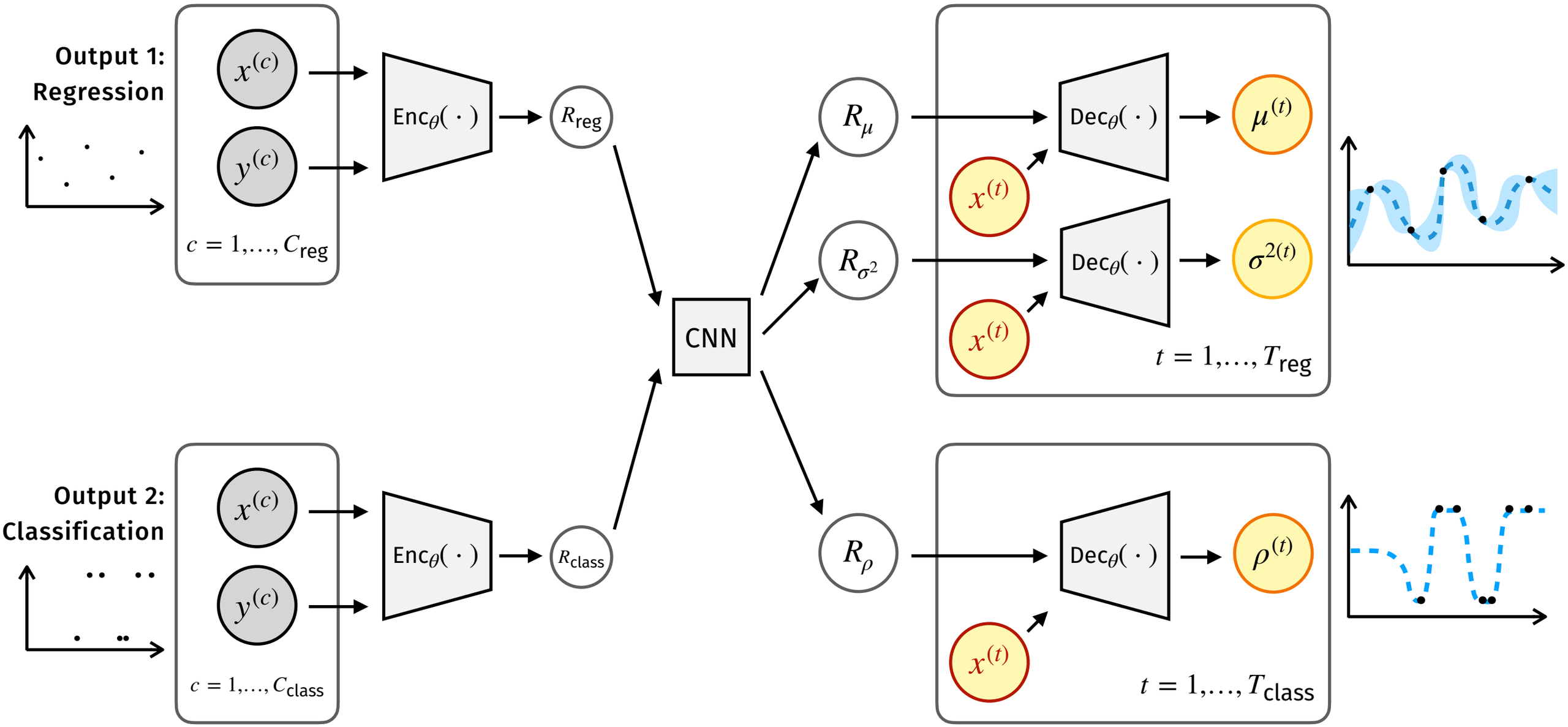

How does the dual architecture perform?

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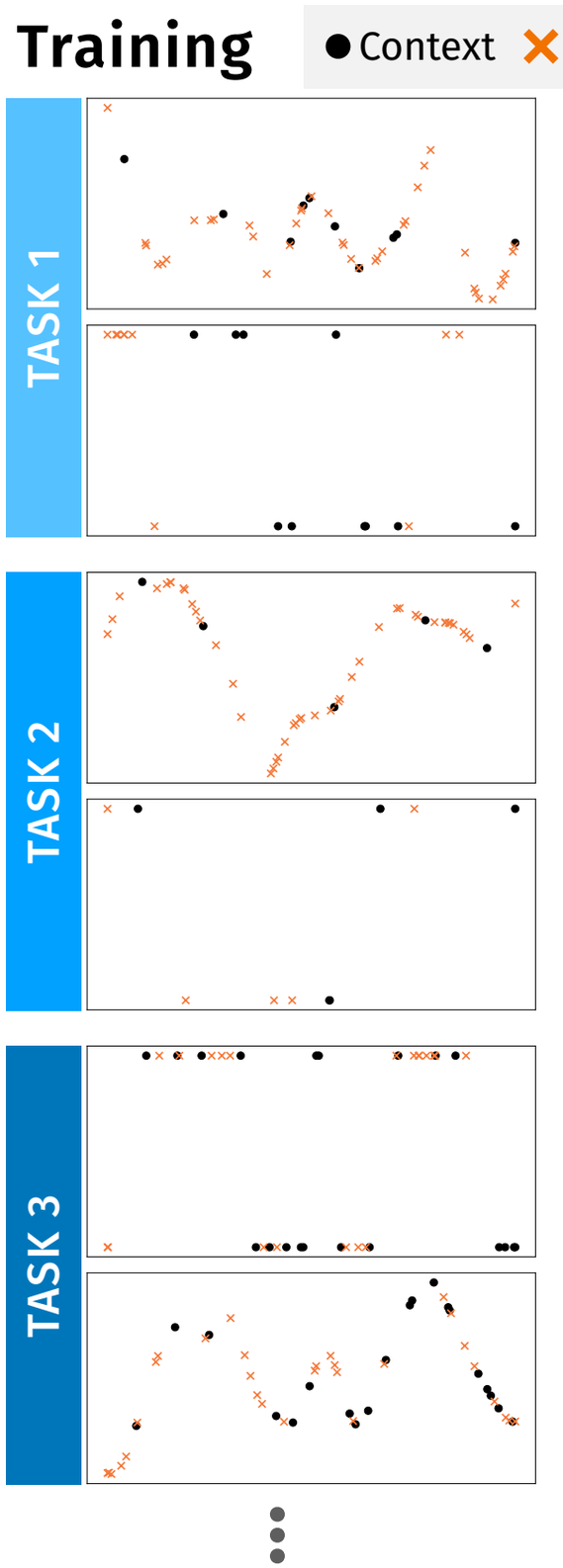

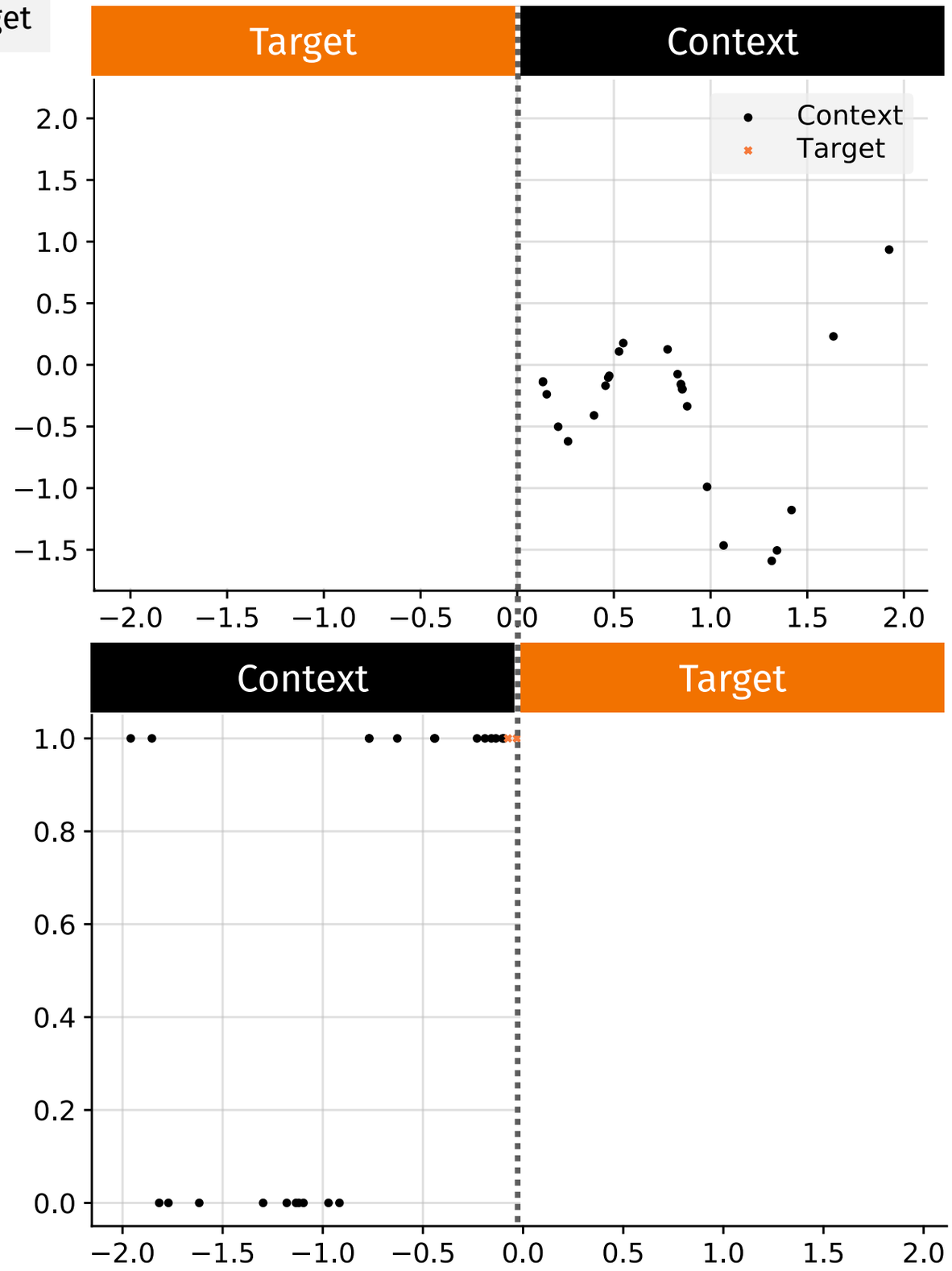

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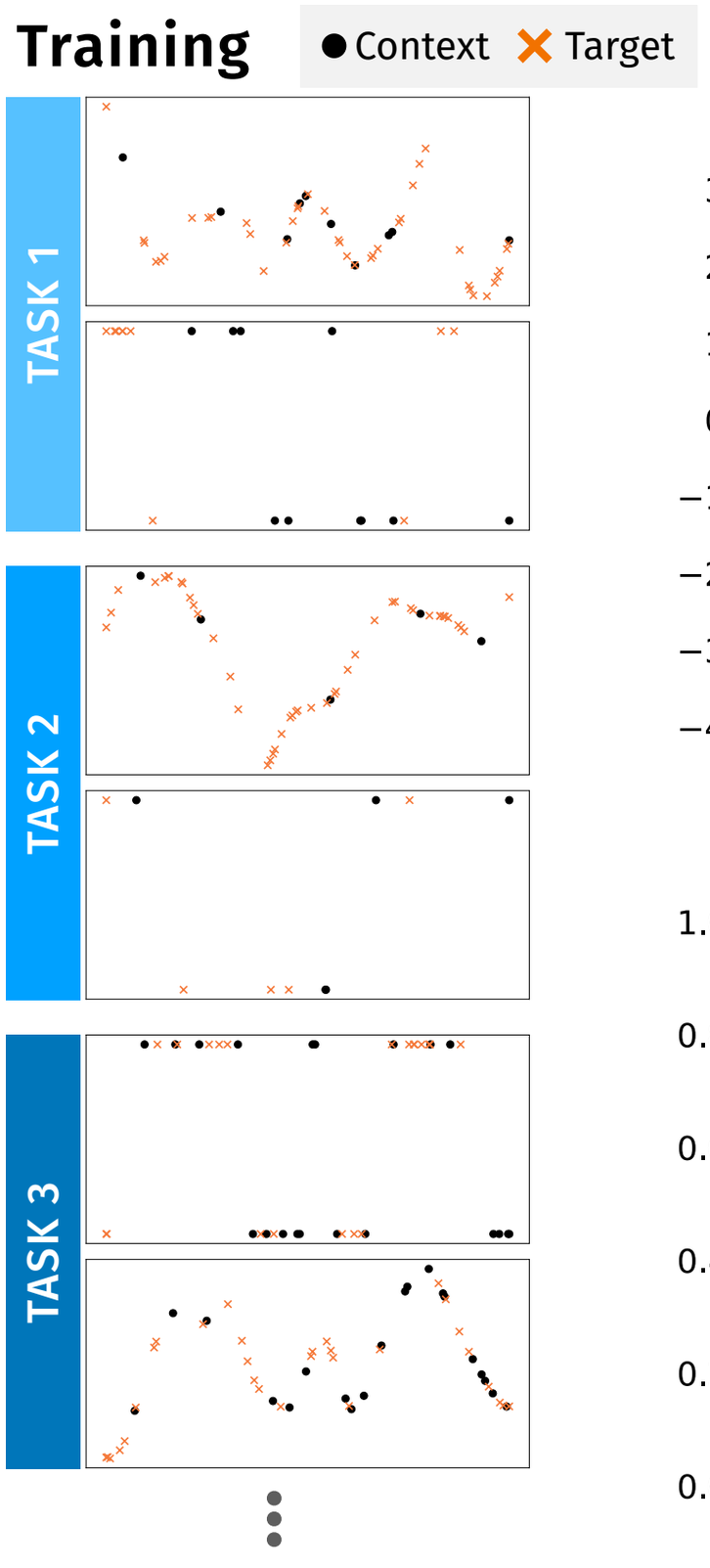

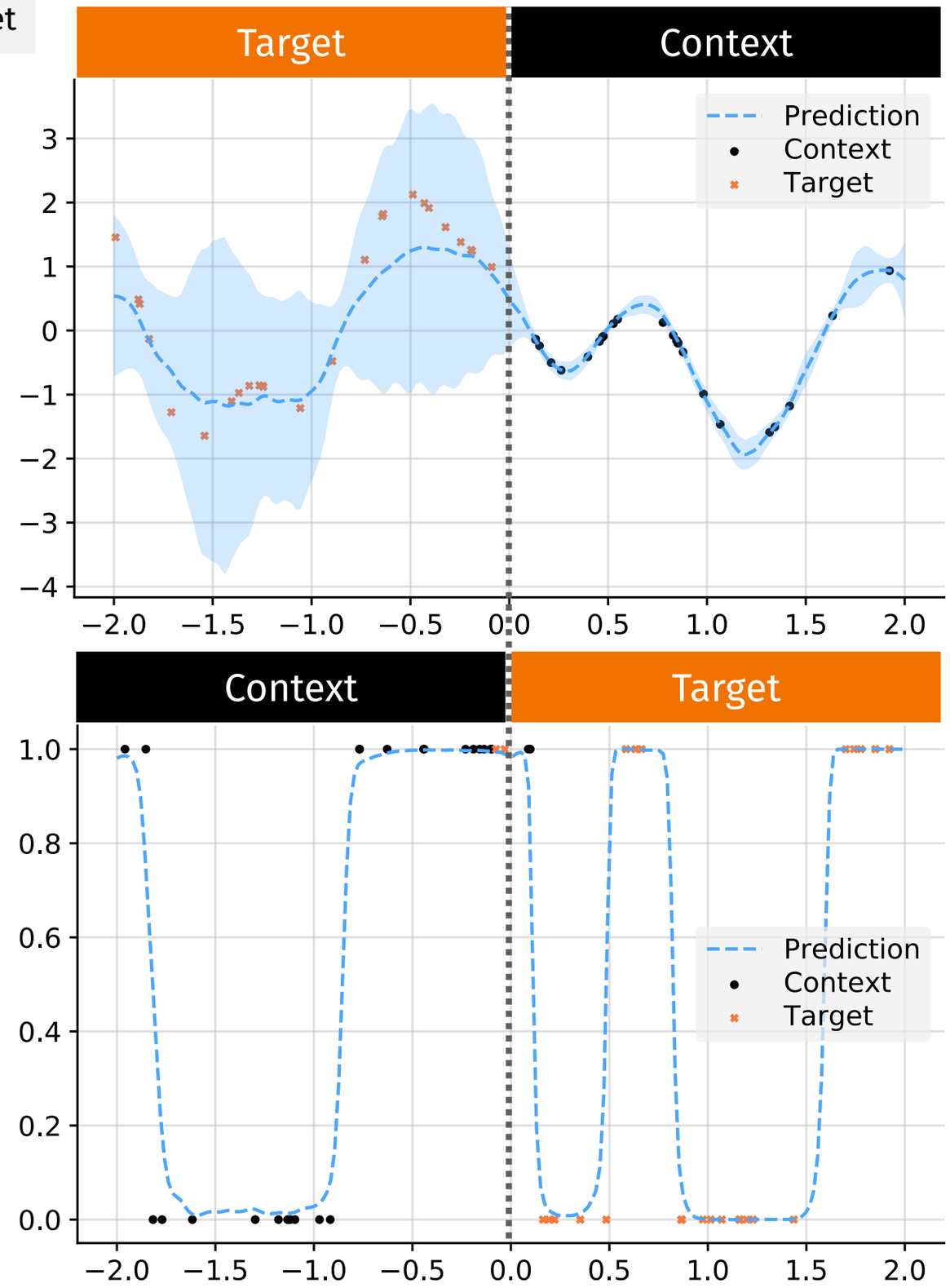

How does the single architecture perform?

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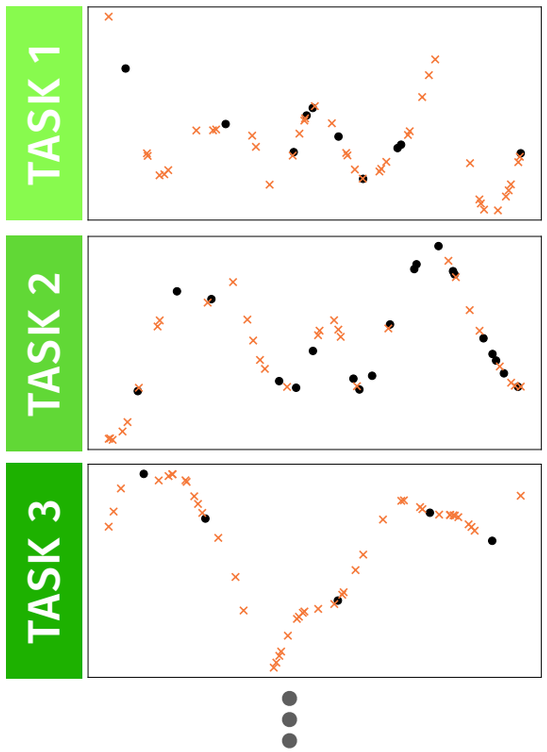

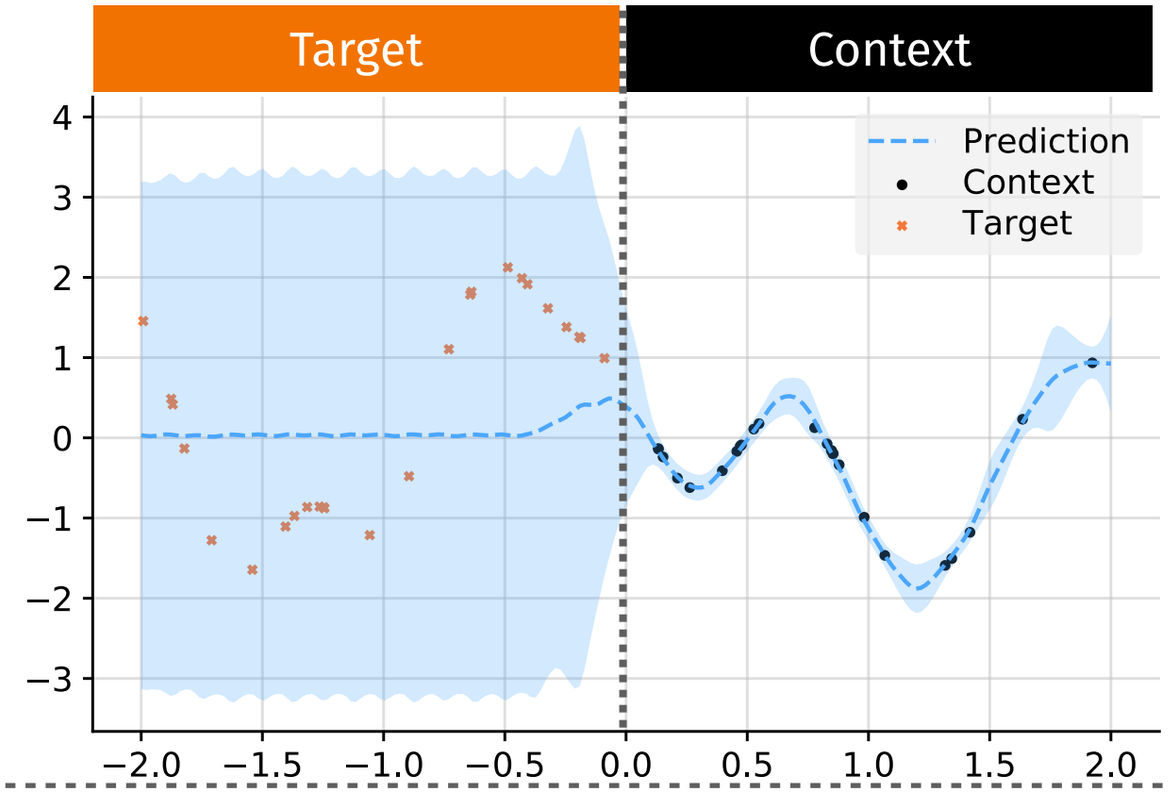

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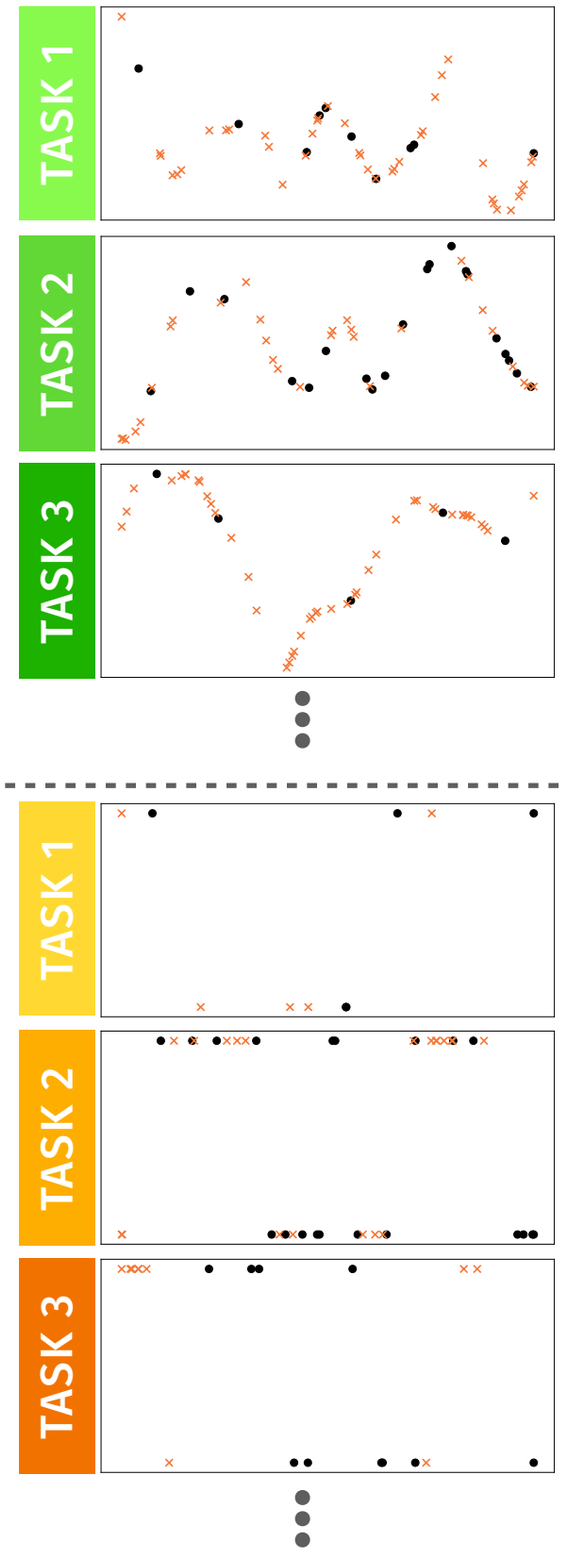
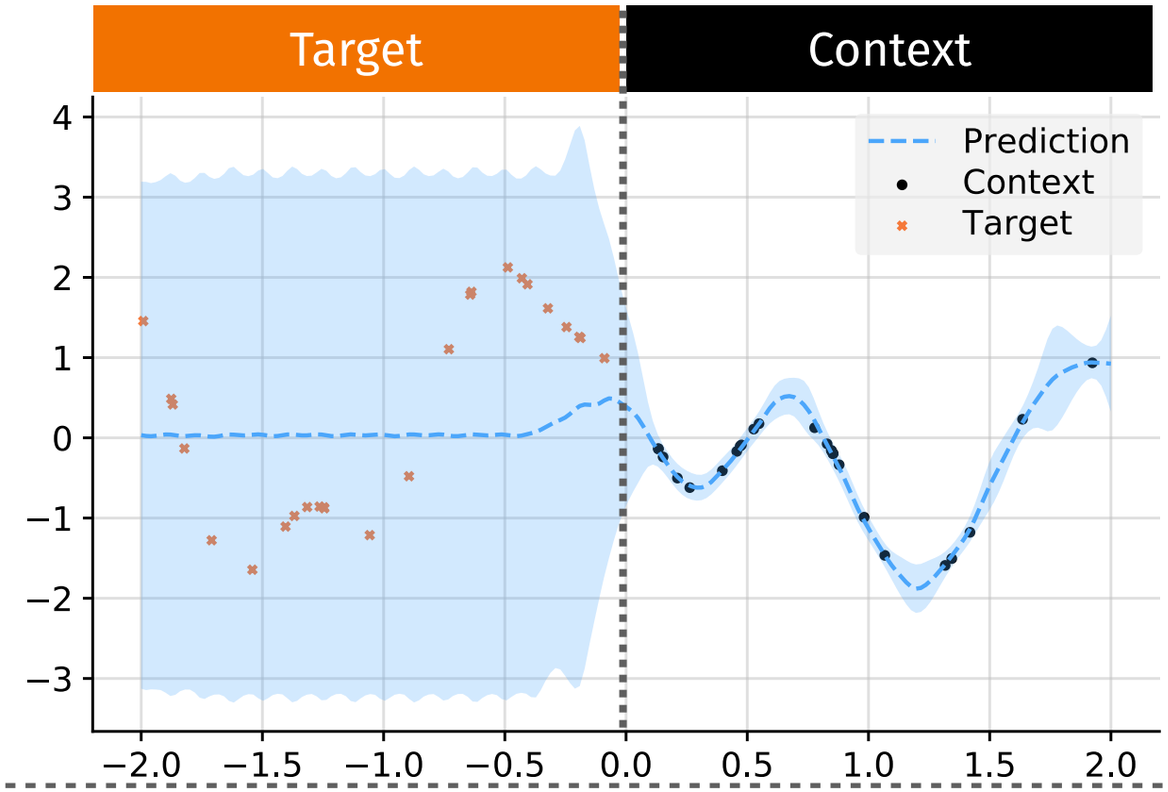
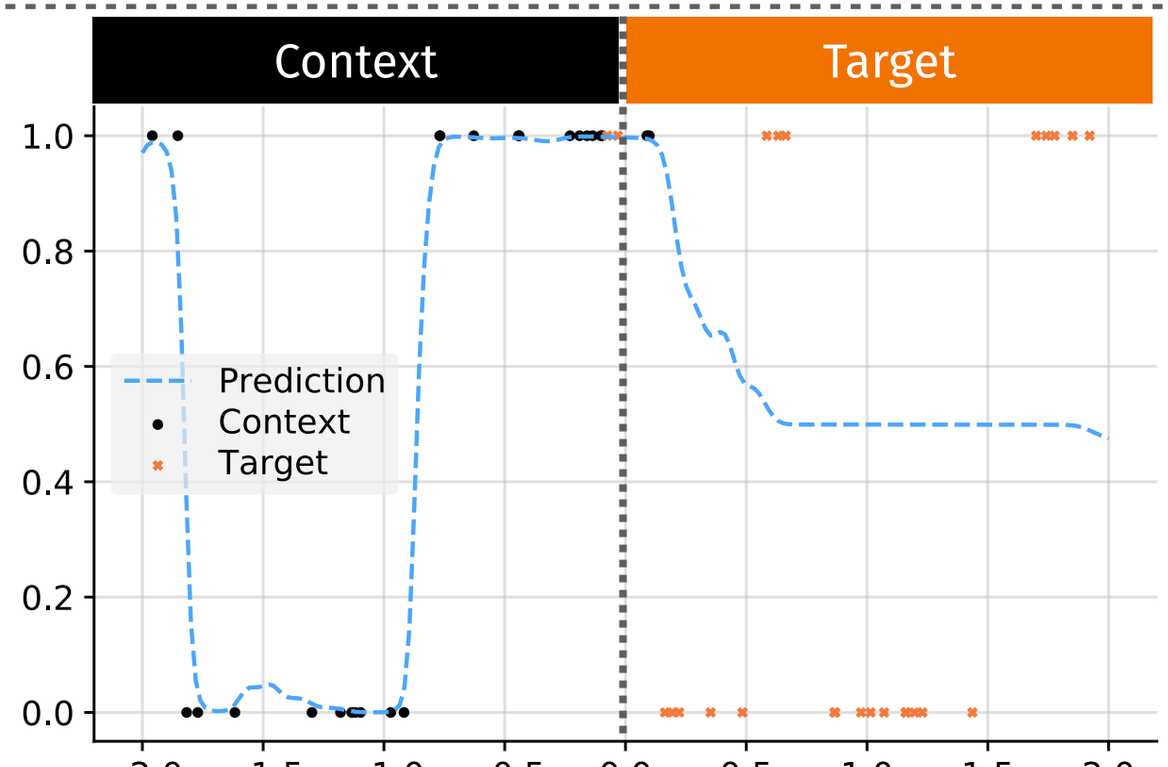






How does the dual architecture perform? 5/7

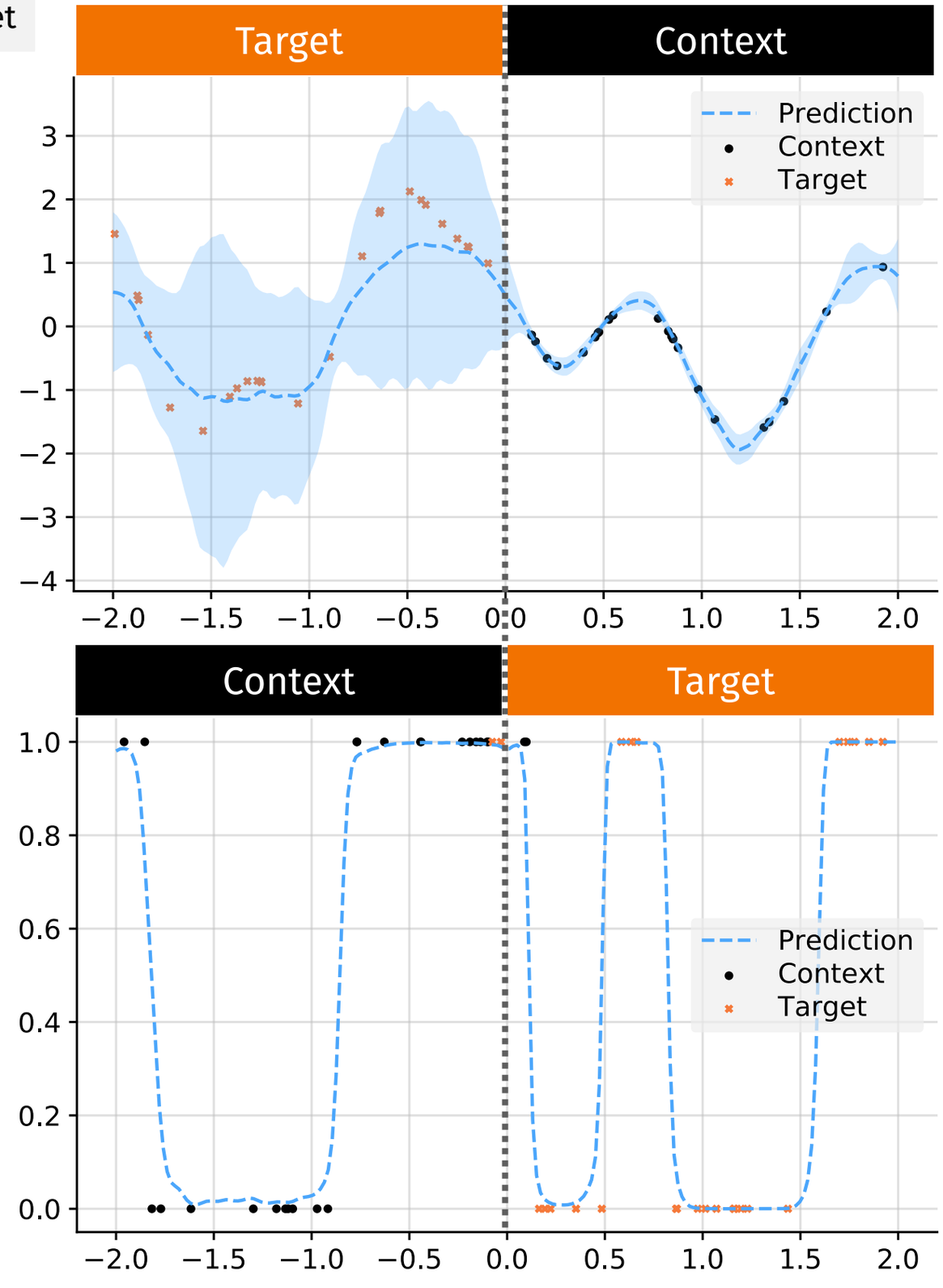
Training

● Context ✕ Target

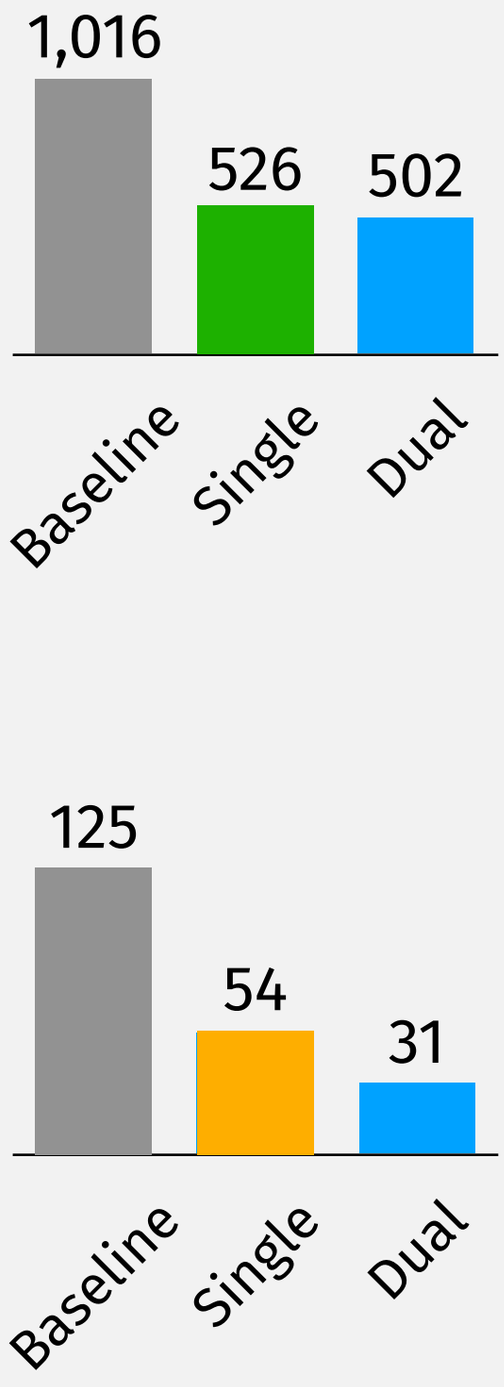
TASK 1

TASK 2

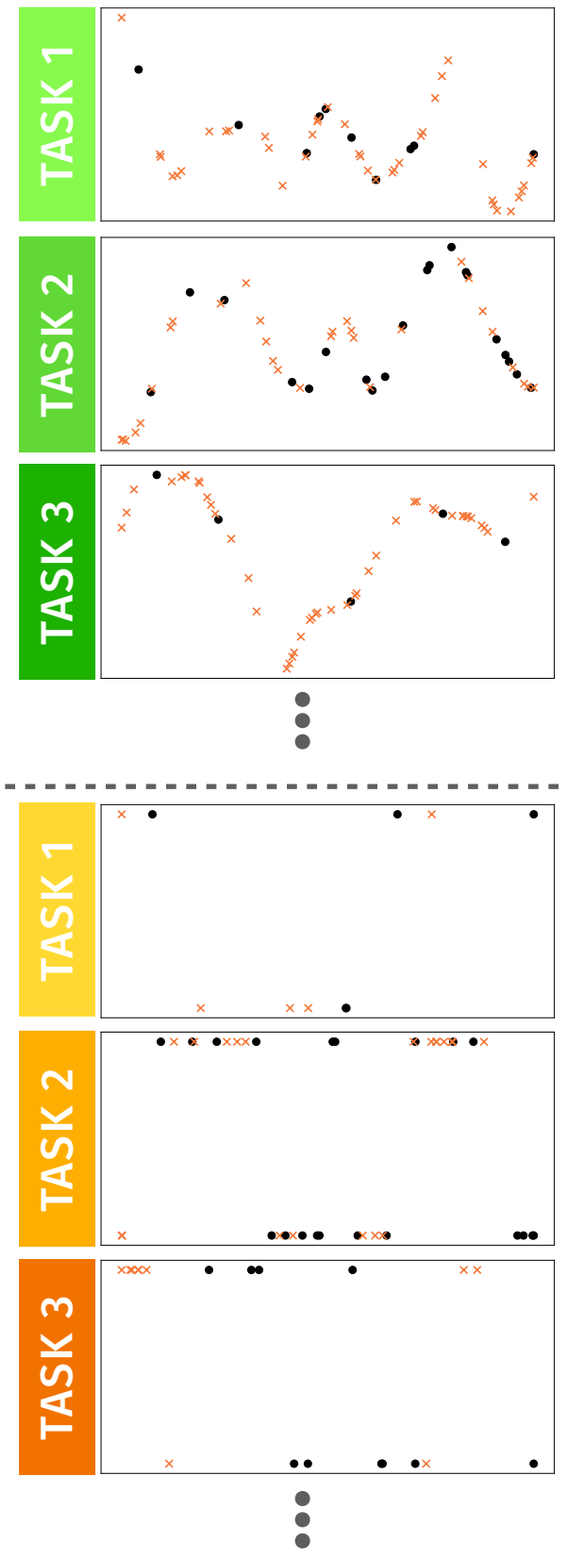
TASK 3

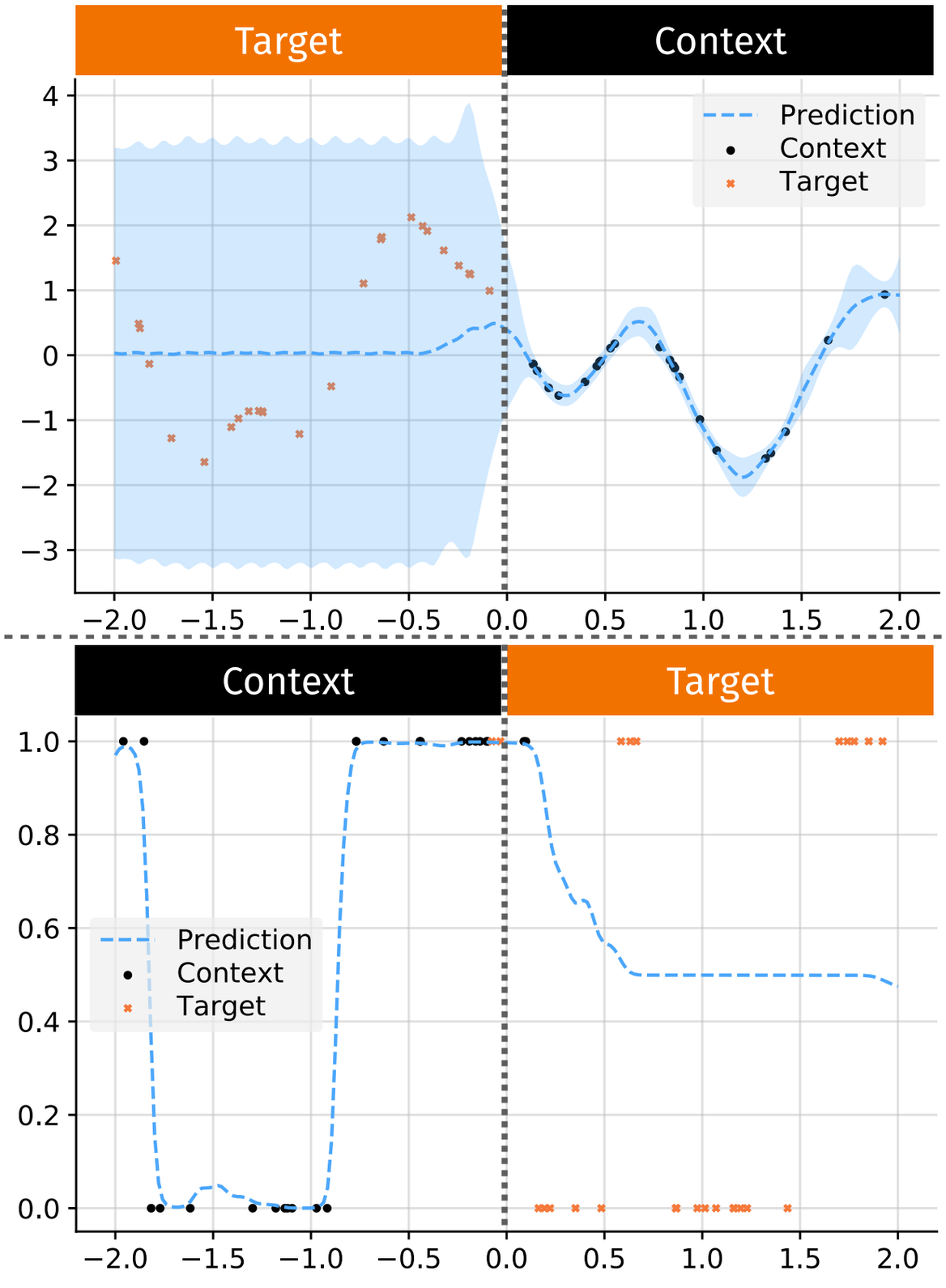


Losses

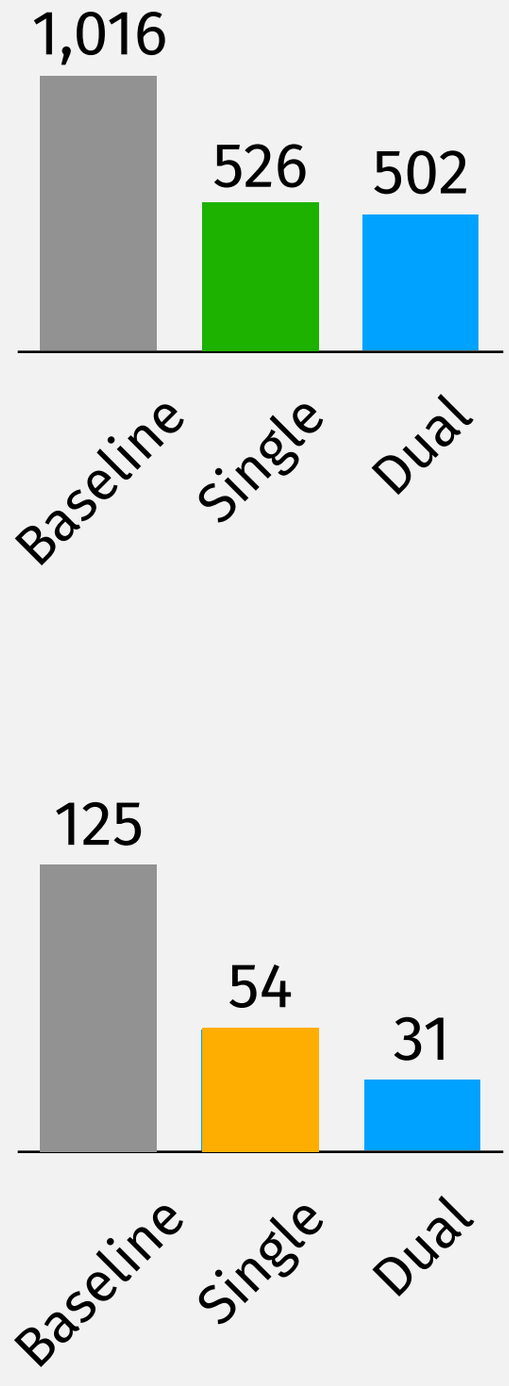


How does the single architecture perform? 6/7

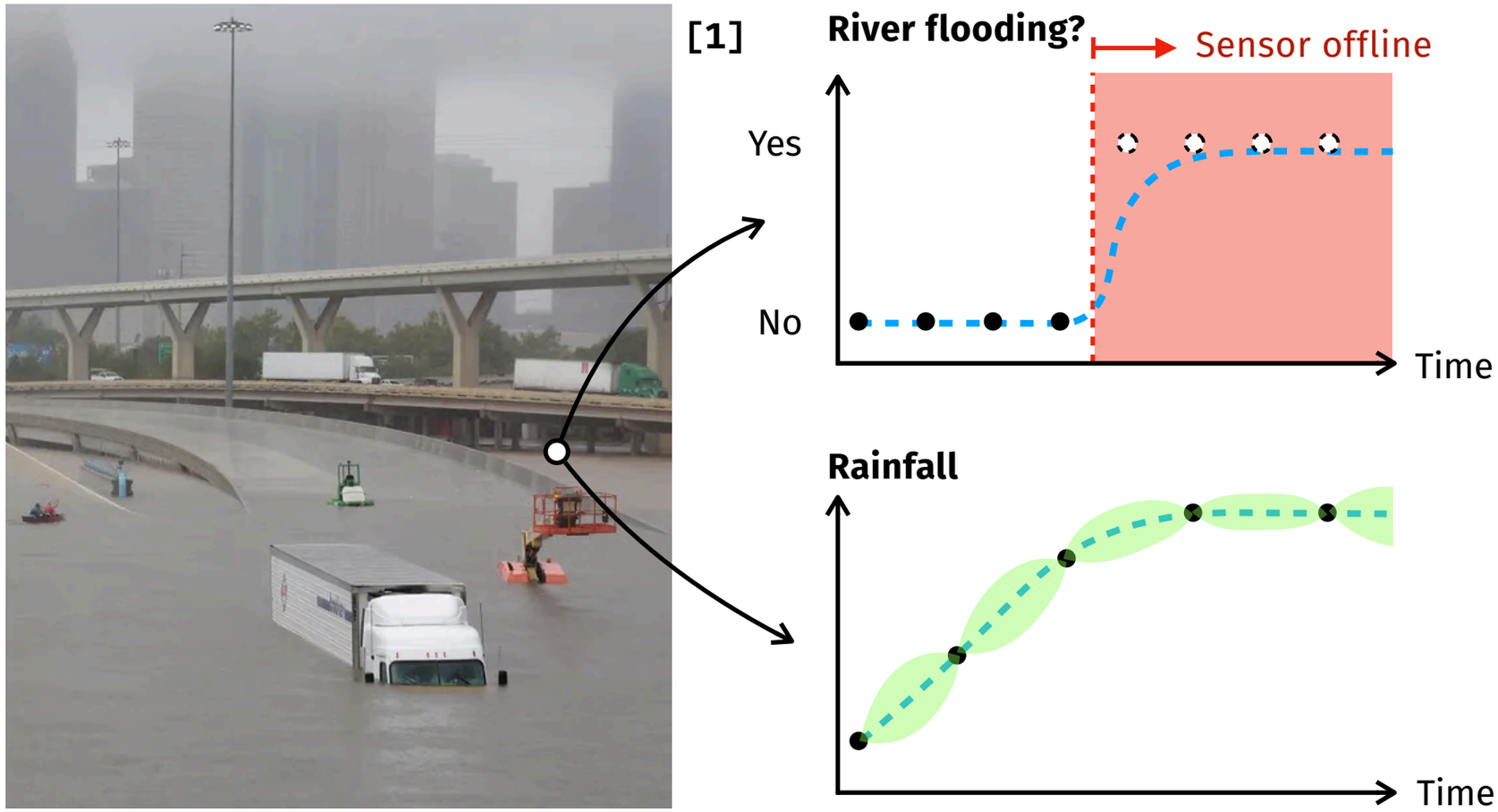




Losses



Conclusion



PLAN

Summer

- ☑ Understand **literature** on neural processes
- ☑ Build **dual architecture** from provided codebase

Term 1

- ☑ Train and test on **synthetic data**

Conclusion

PLAN

Summer

- [x] Understand **literature** on neural processes
- [x] Build **dual architecture** from provided codebase

Term 1

- [x] Train and test on **synthetic data**
- [ ] Deploy on **real-world dataset** from environmental science

Term 2

- [ ] Explore different **computational architectures**

References

1. Livsey, Anna. ‘Before and after: Images Show How Hurricane Harvey Swamped Houston’. *The Guardian*, 29 Aug. 2017. *The Guardian*, https://www.theguardian.com/us-news/2017/aug/29/before-and-after-images-show-how-hurricane-harvey-swamped-houston.

2. Gordon, Jonathan, et al. *Convolutional Conditional Neural Processes*. 2019. openreview.net, https://openreview.net/forum?id=Skey4eBYPS.

3. Dubois, Yann, et al. *Neural Process Family*. 2020, https://yanndubs.github.io/Neural-Process-Family/.