Towards Self-Adaptive Data Management in Digital Twins for Biodiversity Monitoring

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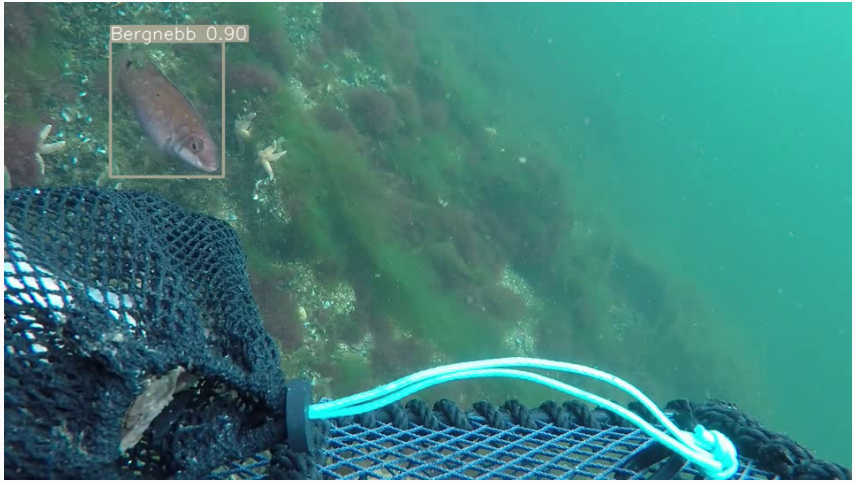
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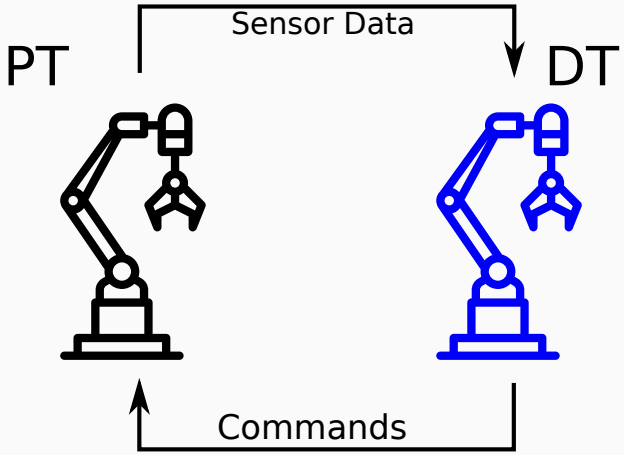
Environmental Digital Twins



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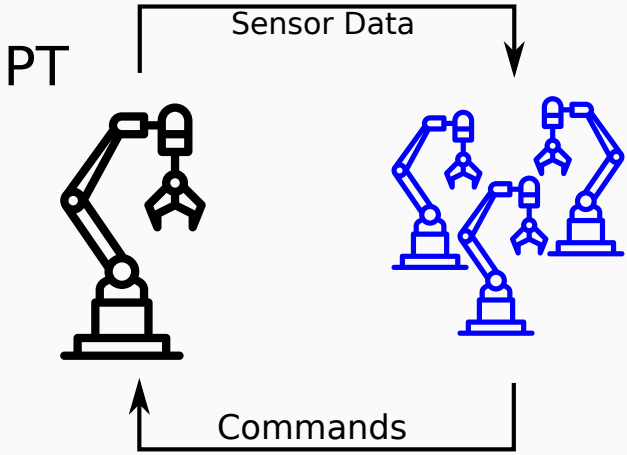

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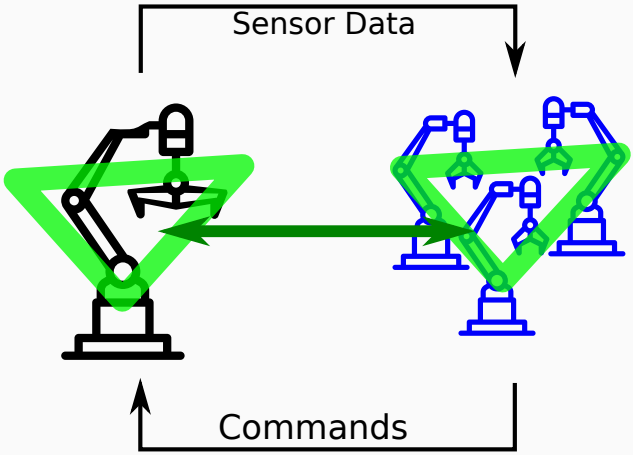

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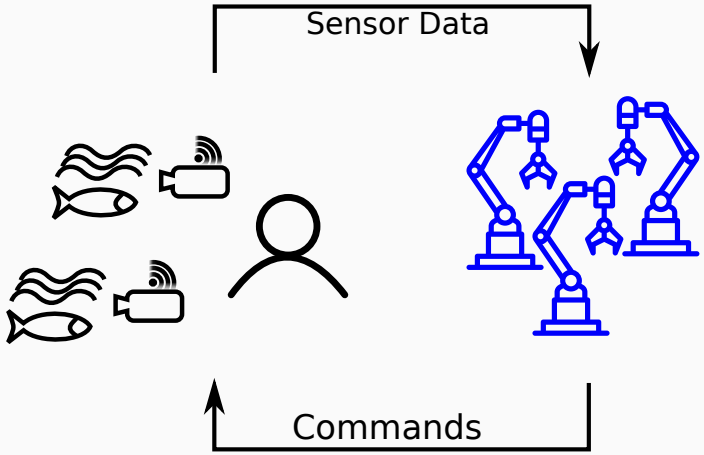

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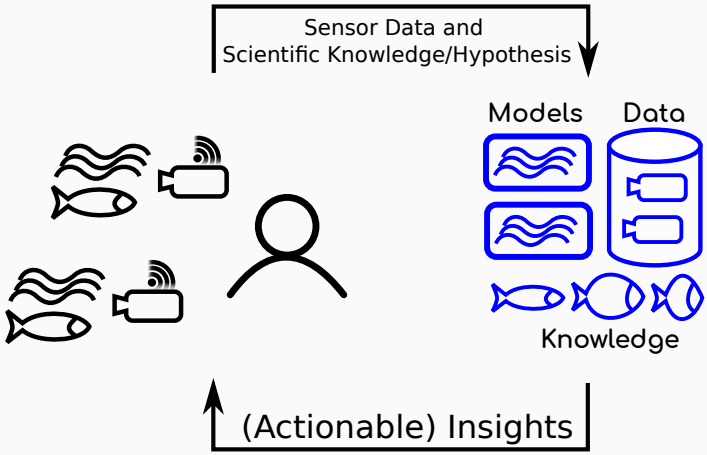

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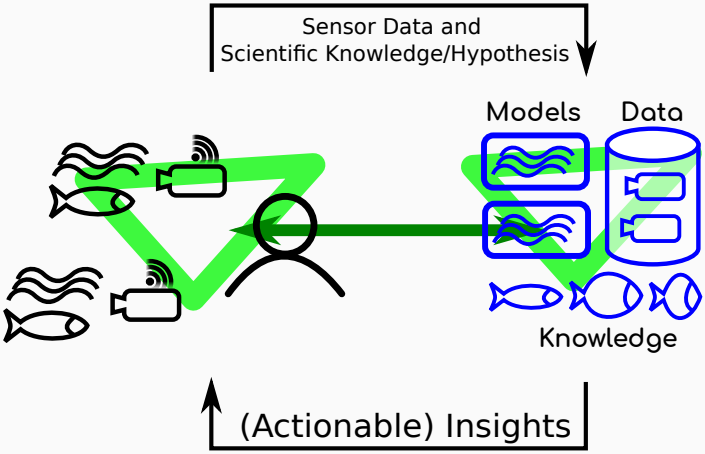

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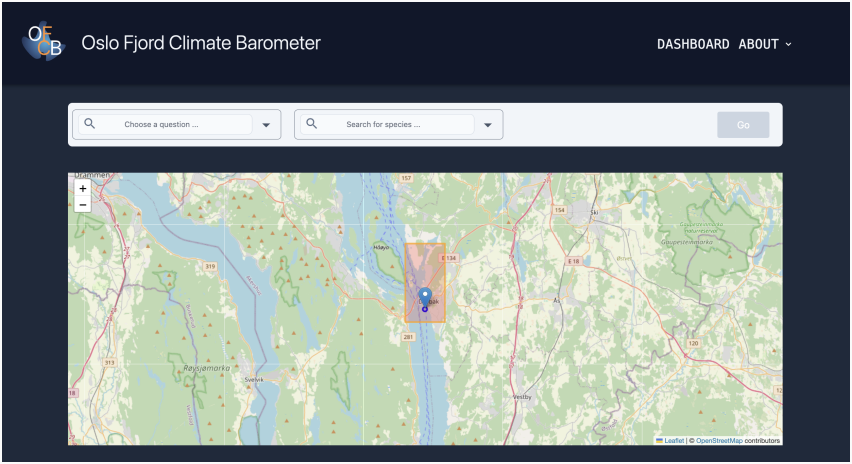
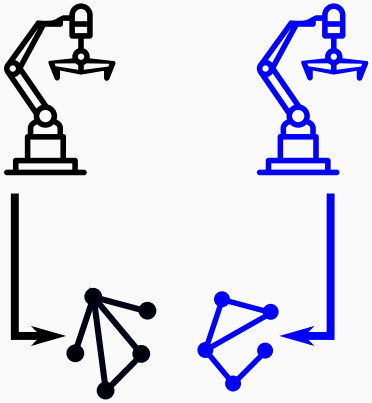


Environmental Digital Twins

Structural Self-Adaptation of Digital Twins



[Kamburjan et al. *Declarative Lifecycle Management in Digital Twins*, EDTConf'24]

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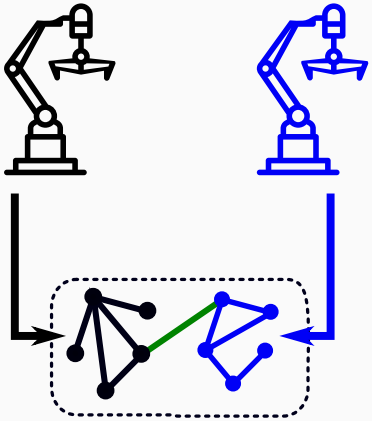

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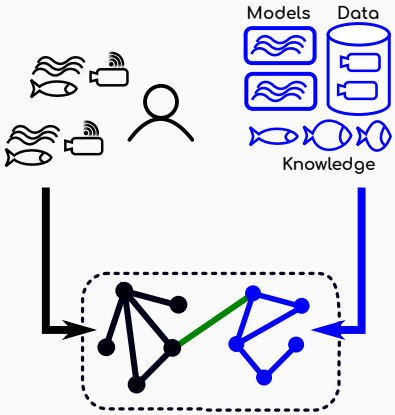

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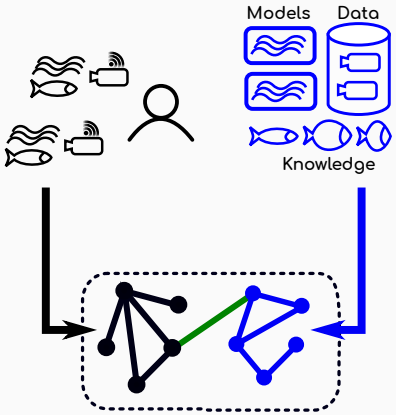

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- Can we reuse abduction-based self-adaptation for consistency from engineering Digital Twins?
- How to express the system model of the EnvDT?
- How to automatically adapt to new data sources?
- How to automatically adapt to changes in the monitored hypothesis?

Observational Network

Observational network

A data source $\mathrm{src} = \langle \mathtt{dat}, \mathtt{pos}, \mathtt{id} \rangle$ has data, a position and an id.

An observational network $\mathrm{onet} = \langle \mathrm{src}_i \rangle_I$ is a set of data sources.

Reasoning Network (I)

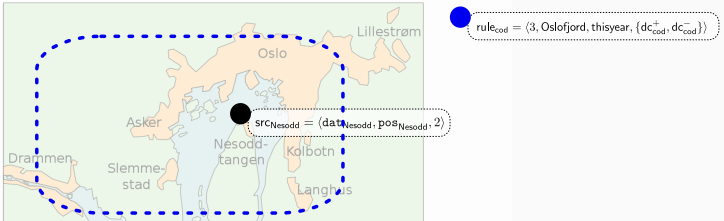
Rule

A rule $\langle rid, \text{sc}, \text{tc}, \text{DC} \rangle$ has a spatial condition (sc), a temporal condition (tc) and some data conditions (DC).

Example

Cod only occurred in the Oslofjord when water temperature was under 18°.

$$\text{dc}^{+}_{\text{cod}} = \text{No cod observed when } t < 18 \qquad \text{dc}^{-}_{\text{cod}} = \text{Cod observed when } t \geq 18$$

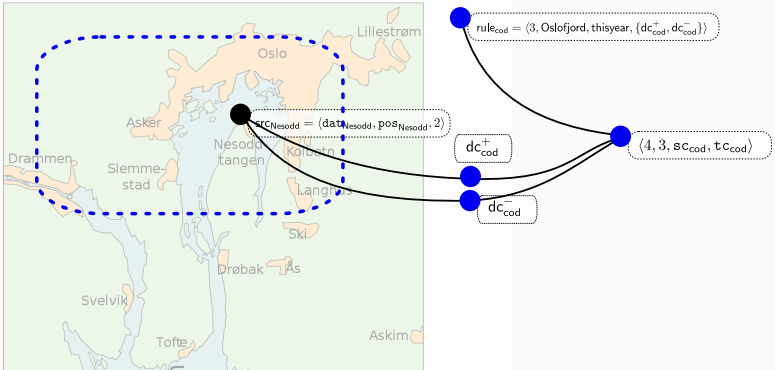


Reasoning Network (II)

Reasoning Network

An monitor $\langle aid, \text{rule}, \mathtt{sc}, \mathtt{tc} \rangle$ has an id, a rule and its own spatial and temporal conditions. A link $\langle aid, id \rangle$ is a pair of monitor and data source ids.

A reasoning network $\text{rnet} = \langle \text{Mon}, \text{Link} \rangle$ is a pair of a set of monitors and a set of links.



Digital Twins and Evolution

Digital Twins

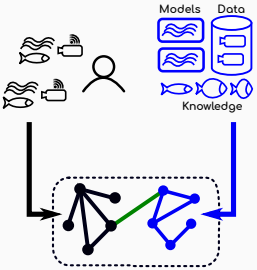
A digital twin is a triple $\langle \text{onet}, \text{rnet}, \text{Rule} \rangle$

A digital twin is consistent if for each monitor :

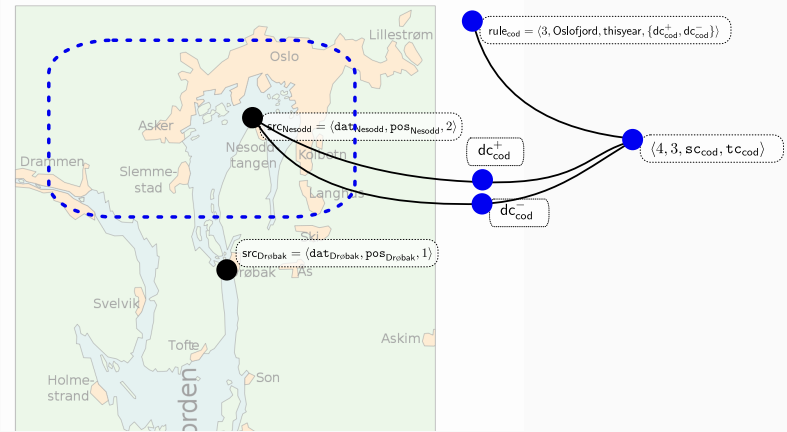
1. Each data source within its spatial region is linked to it.
2. Each linked data source is described by the data conditions of the rule.

Self-Adaptation

- Links model a data processing pipeline.
- Self-Adaptation is abduction over knowledge graphs



Evolution and Consistency



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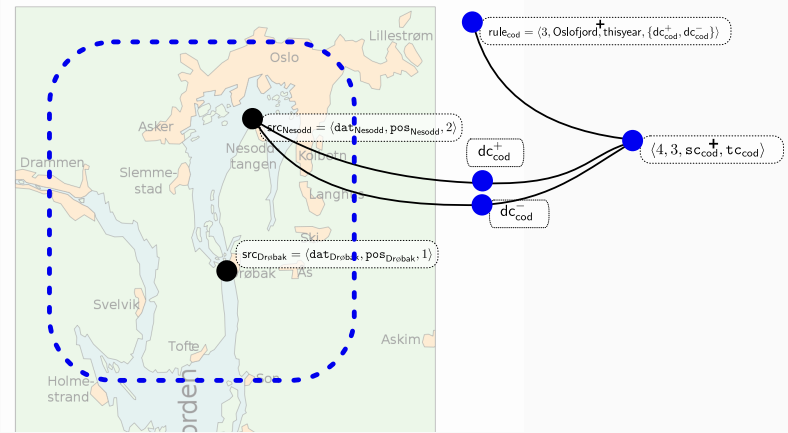

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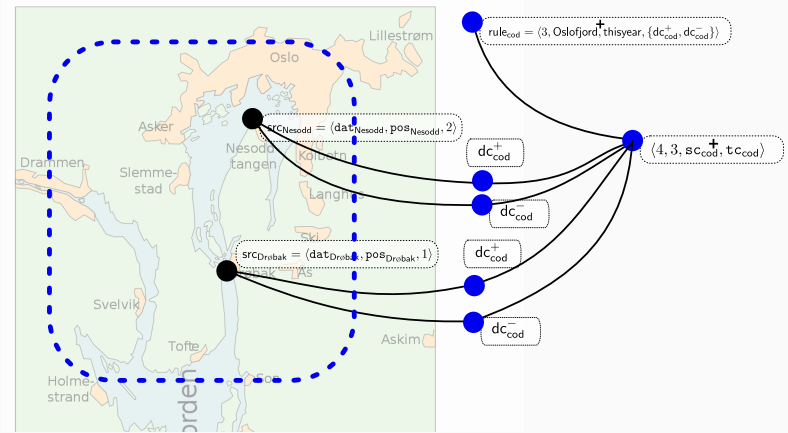

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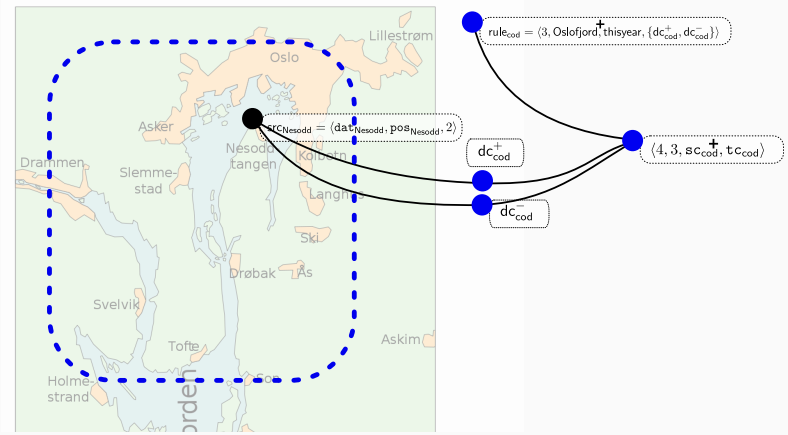

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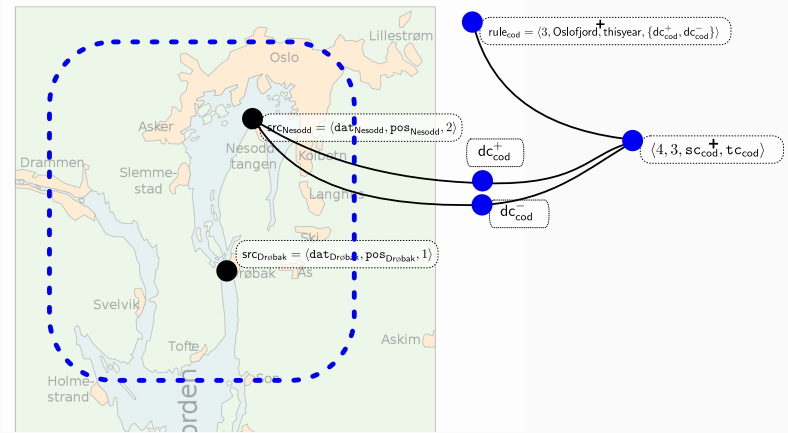

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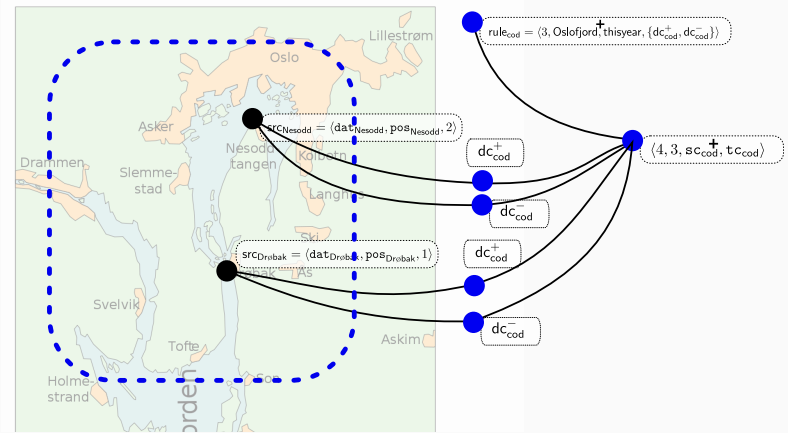
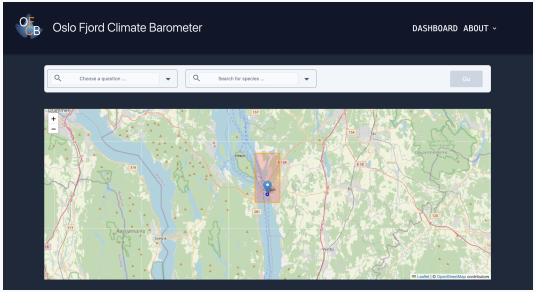
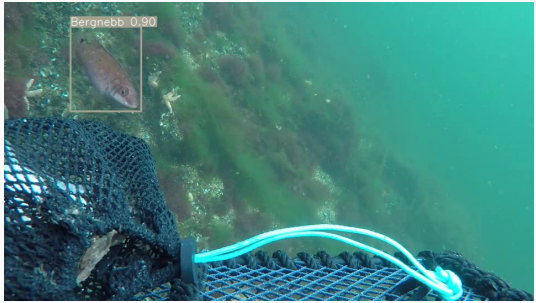


Evaluation

Oslofjord Digital Twins

- Needs to set up a CV system to react to new cameras and recorded videos
- Needs to react to changes in the scope of the queries region
- Integration possible once system model was provided





Conclusion

Summary

- Consistency and self-adaptation ideas from engineering digital twins carry over to environmental digital twins
- Challenge: Lack of asset models and structural system models, more ad hoc development of software and physical components

Future Work and Expected Benefits

Simplify development and maintanance of EnvDTs through self-adaptation

- Connection with European infrastructure through knowledge graphs
- Foundation for model and data integration through system model

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Thank you for your attention