Model Monitoring in the Digital Twin of the Oslofjord

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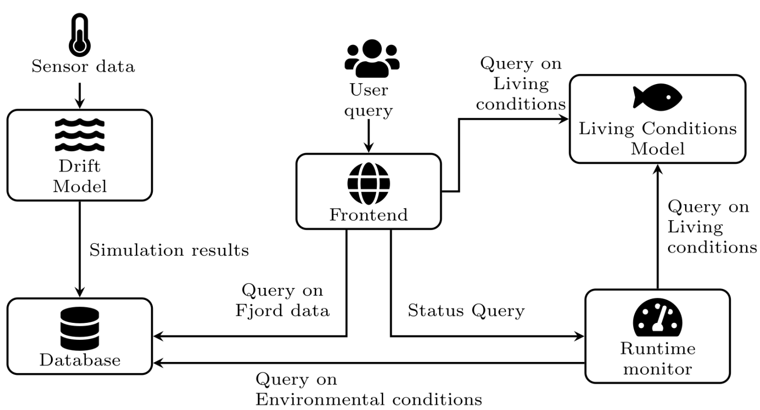
Introduction

The Digital Twin of the Oslofjord (https://ebjohnsen.org/project/oslofjord/) is an environmental Digital Twin that aims to monitor, assess and explore living conditions of maritime life within the Oslofjord. In its current state of development, it has two major classes of models. Simulation models, based on OpenDrift (https://opendrift.github.io/) are used to assess how particles drift throughout the fjord. The second type of models are ecology/habitat models, that capture scientific knowledge related to species traits, life cycles, habitat preferences, and interactions with other species. The twin is supported by data coming from an underwater lander in Drøbak, at the most narrow point of the fjord, as well as floating sensors for temperature, salinity and other physical properties. Its initial use case is to combine these two classes of models to assess how flooding events in the mountains surrounding the fjord influence the habitats of maritime life in the fjord.

As common in environmental digital twins, interoperability is a central issue [1], due to the interactions between different components, namely the different models. In our particular case, the knowledge base provides evidence-based knowledge about taxa in the Oslofjord, whereas the simulator and observational data show change in water quality and movement over time. To integrate them and answer queries about living conditions during an on-going or hypothetical flooding event, we employ runtime monitors, synthesized from an additional knowledge base, to monitor the output of the models and inform users about events.

Architecture and Runtime Monitoring

The architecture is pictured on the right. The sensor data together with the drift model outputs the simulation results into a database, while the living condition model is a static ontology. The user can ask queries to the twin *(E.g., "How will this flooding event affect cod?")* which is decomposed into queries for the database, the ontology and deployed monitors.



A monitor checks whether, for a user-selected geographical area, the data in the database fulfills the living conditions of a certain fish species at a given stage in life. Whenever this

condition changes, e.g., because flooding causes the temperature to rise, a message is sent to the user. A monitor can process both historical and live data.
The sensor data and the drift model form a digital shadow. They must be combined to have an overview about the fjord as a whole, because there are not enough observations to cover its area, and the drift models must be calibrated and synchronized with live data.

The runtime monitors are defined by a set of TeSSLa schemas that are parametric in the property (e.g., temperature, salinity) and upper and lower levels to monitor. Whenever a new runtime monitor has to be deployed, the following steps are executed.

1. The schemas are turned into full TeSSLa specifications, by instantiating the parameters with the required property and levels. The query contains only the species and property, so the levels are retrieved from the ontology.
2. A data transformation is set up that connects to the database, and transforms the data output by OpenDrift into the format required by TeSSLa.
3. The schema is synthesized into an executable monitor and deployed on a service-oriented platform, a common practice in digital twin monitoring [2].

On the level of data, the transformation makes the monitor and the simulation interoperate. However, the more important interoperability is on the level of knowledge: The runtime monitor enables us to reason about both knowledge about physical processes (as modelled in the drift model) and knowledge about biological processes (as modelled in the ontology).

Conclusion and Sketch of Presentation

In this paper, we have discussed the need for model monitoring in the Digital Twin of the Oslofjord. Model monitors are more lightweight than simulation-based Digital Shadows, and can be used to monitor either user queries or consistency conditions.

If accepted, we will give a demonstration of the Oslofjord as a whole, including its different kind of queries, and describe the ontology and components used to store temporal properties and generate runtime monitors out of them in detail. All material will be made available for the participants to try out.

We are in process of moving the schemas into the knowledge base themselves, and aligning the semantic representation with established ontologies to achieve interoperability with other digital twins, which will allow the project to connect to the European infrastructure surrounding the EU Digital Twins of the Ocean initiative.

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