M9 – Design and systems engineering of wind turbines and plants:

OWFgraph: A graph database for the offshore wind farm domain

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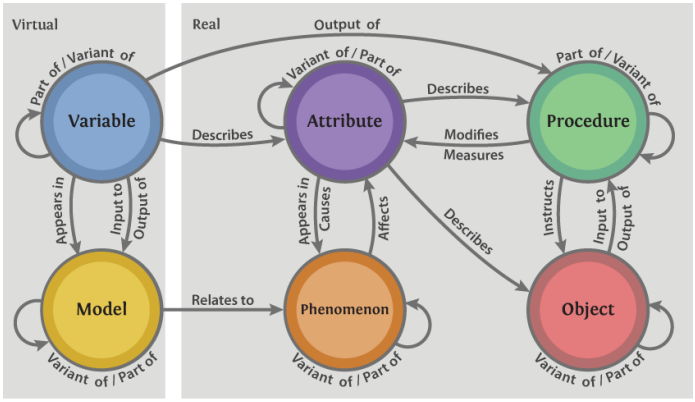
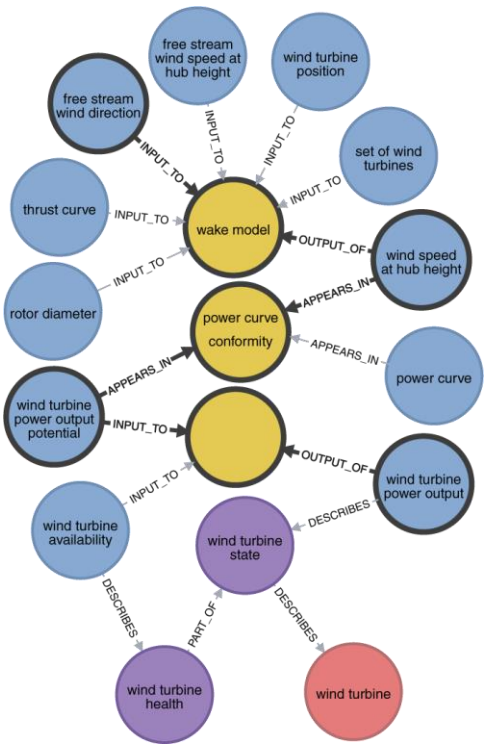
The construction and management of an offshore wind farm involves many disciplines, e.g. meteorology and economics. It is hard for a single researcher to keep an overview of all the relevant concepts, models, and tools from these disciplines. Nevertheless, this is needed when performing integrated modeling or analysis in the offshore wind farm domain. To help researchers keep this overview, we present *OWFgraph*, a knowledge base for the offshore wind farm domain, implemented as a graph database that is meant to be open and ever-improving.

A graph database stores content in *nodes* and *relationships*. A relationship is a directed edge between two nodes. In our implementation, each of the nodes and relationships can have multiple *properties*, i.e., key-value pairs; moreover, nodes can have multiple *labels*, whereas relationships have only a single *type*.

The above setup provides great flexibility. In fact, there is too much freedom to be able to consistently add or effectively query for content. Therefore, we have designed a *foundational ontology* that classifies the domain's concepts and relationships. It is small enough to be manageable, but nevertheless large enough to be sufficiently expressive. It partitions the domain in two: the 'real' part describes physical phenomena and procedures & objects and their attributes; the 'virtual' part describes mathematical variables and models, including computational tools. A meta-graph representation of the ontology is given on the right.





There are numerous potential *applications* of OWFgraph. It could be used as support for teaching, e.g. for exploration of the domain, or to analyze how the different disciplines involved are coupled, etc. We use it for *uncertainty propagation* and for *evaluation of multidisciplinary design analysis and optimization workflows*: The 'real' part acts as a mind map, to describe the parts of the domain we want to model. This helps us in completing the 'virtual' part with relevant models and tools. We use this latter part to determine the ways in which the models and tools of the domain can be coupled to arrive at some variable of interest and to identify the variables involved. On the left, as an example, we show output for a query that looks for the shortest path between the variables 'wind speed' and 'turbine power output'.

We have experienced that multiple users can easily contribute concurrently. Individual nodes and relationships can be added without consideration of the larger context and *the domain overview emerges* due to the connections provided by the relationships. Based on our experience, we conclude that the approach and the proposed ontology are potentially suitable for other applications as well. Next, we want to explore and expand the use of the database in a larger, more diverse—online—community.

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