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CoSim Toolbox - Making HELICS Co-Simulations Easier

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Summary

Co-simulation is a technique for creating larger and more complex time-series system models by facilitating data exchange between two or more models during runtime. This data exchange allows boundary states in models which may have been defined through static values or historical values to be dynamically generated by models in other simulator instances. This dynamic data exchange allows for system models that transcend individual simulation tools, modeled domains, and modeled subsystems. FMI (FMI, 2025), particularly as implemented in Modelica (Association, n.d.) and Mosaik (Steinbrink et al., 2019), are examples of popular co-simulation platforms.

HELICS (Hardy et al., 2024) is the US Department of Energy's publicly available co-simulation platform and has been under development since 2017. HELICS provides the necessary simulation time management and facilitates the data exchanges between simulator instances (called "federates"). HELICS has been successfully used in a number of published studies such as evaluating transactive retail market in power systems (Theisen et al., 2024), evaluating the roles of distributed power inverters on power system frequency response (Bharati et al., 2023), evaluating the impact of electric vehicle charging in a metropolitan area (Panossian et al., 2023), and cyber-security analysis of power systems (Lardier, 2020). Due to its origins as a power system tool, many of the existing studies are connected to that domain but HELICS itself is domain agnostic and is suitable for use in any time-series simulation.

Statement of Need

CoSim Toolbox (CST) is built on top of HELICS and has the goal of making any HELICS-based co-simulations easier to manage and HELICS users are the target audience for CST. Based on years of experience using HELICS, we have found a number of pain points around data and metadata management and HELICS federate creation that CoSim Toolbox is designed to alleviate. Specifically, we have integrated the following tools and code to make HELICS easier to use:

- **Docker** - Docker containers are used to distribute HELICS, the CST API as well as any CST-enabled simulation tools. This allows the use of CST on all Linux, macOS, and Windows while minimizing the maintenance of these codebases.
- **Generic Federate class** - To facilitate writing new federates more easily, CST provides a generic federate class for use when writing new Python federates. This class wraps the HELICS APIs and facilitates data exchanges using just Python data structures. By minimizing the amount of knowledge of HELICS APIs, we have seen those with no knowledge of HELICS be able to more easily implement a HELICS-based co-simulation using this CST federate class.

- **Time-Series Data Collection** - A Postgres database is used to collect time-series data being generated by every federate. A data collection federate has been written using the CST APIs to collect data generated by the HELICS-enabled data exchanges and automatically commit it to the Postgres database. This allows data to be stored and thus accessed in a central location, making it easier to monitor and post-process the co-simulation data. The Postgres database is implemented as a Docker container along with pgAdmin to provide a web interface for inspecting the Postgres database.
- **Metadata and Configuration Management** - HELICS federates require significant configuration which has historically been accomplished by JSON files on disk. Particularly for larger federations, this leads to a significant number of JSON files, sometimes leading to confusion about which files correspond to the data produced in a given co-simulation run. To help manage this configuration data, CST uses MongoDB to store the configuration information with the CST federate class designed to automatically retrieve a given federate's configuration. The MongoDB database is implemented as a Docker container along with Mongo Express to provide a web interface for inspecting the MongoDB database.

The capabilities provided by CST are not otherwise available to HELICS users, at least as an integrated capability. Some of this functionality is similar to what the Mosaik co-simulation platform provides (mosaik-web as a data visualization tool, adapters to use InfluxDB, Timescale, and SQL for data storage), while others like the generic federate class and metadata management are not.

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