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Interaction Modeling for Independent Water and Energy Models with Distributed Simulation

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ABSTRACT

Modeling the interactions between separate models contributes to building flexible hybrid simulation frameworks. Interaction models facilitate the development of composition of disparate that are separately developed models. As such, given different types of models, they can be combined using other models. This is achieved using the Knowledge Interchange Broker (KIB) approach. The nexus of disparate models to be composed defines Interaction Models. This approach is grounded in modular input/output components with explicit specifications for time, data mapping, synchronized control, and concurrent execution. The Parallel DEVS and RESTful framework is used as a realization of this approach for modeling and simulating an exemplar Water-Energy system for Phoenix, Arizona. Specifically, a DEVS-based Interaction Model (DEVS-IM) framework is developed based on System Theory, KIB, and componentized WEAP (i.e., for water models) and LEAP (i.e., for energy models) simulators.

1 INTRODUCTION

Creating models for large and complex systems generally follows the divide and conquer principle. The development of models for hybrid systems (e.g., water-energy) benefits from the use of different modeling specification methods. Building and evaluating simulations for hybrid models can be simpler when whole models are composed of parts that have well-defined syntax and semantics. The composition of hybrid models, following the KIB approach, refers to *(i)* a set of models that are composable and *(ii)* the interactions between them are also specified as first-class models (Sarjoughian 2006).

The relationship between composed models can be defined as Interaction Models. An *interaction model* has some inputs and outputs that are connected to the other models. It has data mapping, synchronization, concurrency, and timing specifications for the structure and dynamics of the nexus of the composed models. An interaction model receives and sends disparate data types subject to time and mapping for some specified synchronization and concurrency regime. The aim is to develop a heterogeneous model composition framework for componentized independent water and energy models using interaction modeling and RESTful services (https://acims.asu.edu/modsim/weap-kib-leap/) and demonstrate its use for modeling and simulating the nexus between the Phoenix water and energy systems.

2 EXPLICIT MODELING OF INTERACTIONs BETWEEN WATER AND ENERGY MODELS

Domain experts can participate in collective work using existing tools and better use of previously acquired knowledge and experience. The Water Evaluation and Planning (WEAP, http://weap21.org/) and Low

Emissions Analysis Platform (LEAP, https://leap.sei.org/) tools are used to model, simulate, and evaluate water and energy systems. These systems can be combined using data sharing and sequentially simulated.

An Interaction Model is developed for composing WEAP and LEAP models using the KIB approach and the Parallel Discrete EVent System (P-DEVS). The DEVS Interaction Model (DEVS-IM) is defined using Input and Output Connectors, Process, and Task elements. A process (an instance of Process) and its tasks (instances of Task) are P-DEVS models with their input/output ports and couplings that define time-driven data transformations. The connectors use the schemas defined for external systems. The schemas serve as interfaces for communication between the DEVS-IM and the componentized WEAP and LEAP systems. The DEVS-IM is supported by a RESTful framework to define the models' structures and store them in MongoDB database. The stored structure of the DEVS-IM can be used to generate P-DEVS code. The Input/Output Connector elements, as a DEVS-Suite library, have predefined behavior. The behaviors of the Task and Function entities must be defined by modelers. The DEVS-IM framework supports reusability, flexibility, and maintainability essential for realistic simulations. The illustration of the DEVS-IM framework shown in Figure 1 highlights the Interaction Model with its corresponding WEAP and LEAP schemas for the REST WEAP and LEAP APIs. The componentized WEAP, LEAP, and DEVS-IM can be assigned to (distributed on) different computing platforms and concurrently simulated.

The DEVS-IM is validated for the Phoenix Active Management Area food-energy-water system that is also modeled and simulated using the internal linking mechanism (https://vader.lab.asu.edu//project/food-energy-water-va/). Regarding the need for component-based modeling and simulation, the Componentized WEAP and LEAP RESTful frameworks have been developed to automatically generate components for the entities of the WEAP and LEAP models. The use of this framework is demonstrated for the Phoenix water-energy system. As expected, simulations of the hybrid water-energy model via the internal linkage (i.e., data sharing) and DEVS-IM are nearly identical (Fard and Sarjoughian 2022).

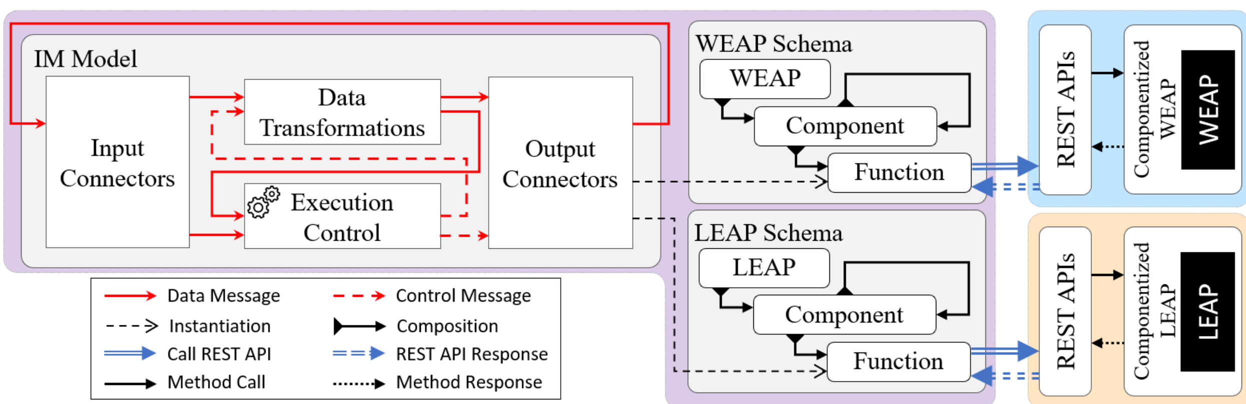

Figure 1: An abstract architecture for the DEVS-IM and simulation framework.

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