Multi-Level Modeling with DEVS -
A Critical Inspection and Steps Towards a Feasible Approach

Background and Motivation

Complex systems call for consideration of **multiple abstraction levels**. While some parts can be expressed best at macro level, other parts require a micro level perspective. Many modeling formalisms allow for a hierarchical, modular construction of models, e.g., DEVS. To increase **reusability** and **clearness**, an explicit description of the higher level is needed, with a state and behaviour of its own. Thereby, a composed model becomes more than merely the sum of its parts.

Towards a Solution: Multi-Level DEVS

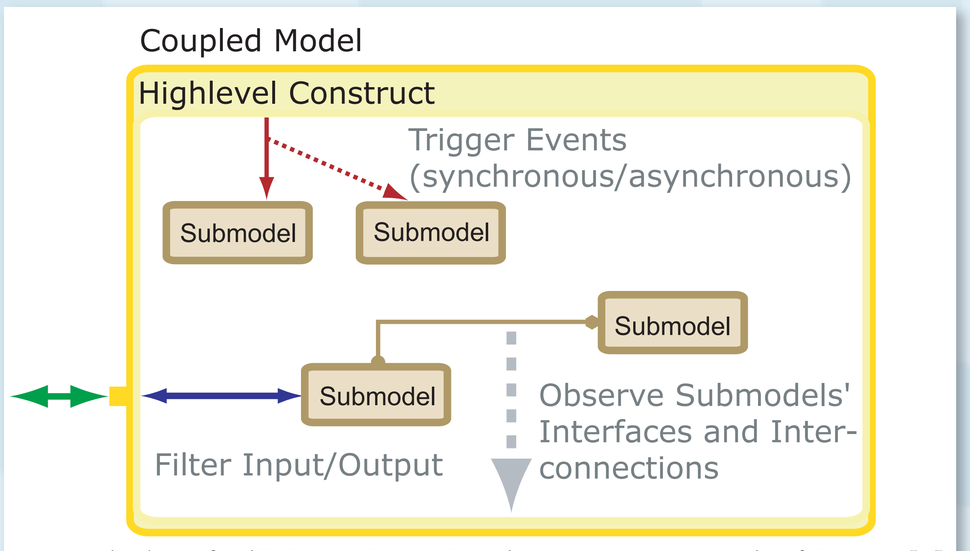
The presented formalism is based on the **rho-DEVS** formalism [1], which already provides **variable structures, ports,** and **multi-couplings**. Multi-Level DEVS (mlDEVS) enriches coupled models by **high-level constructs**, which represent the macro level of a system. Therefore, coupled models

- exploit **knowledge of their submodels' interfaces and interconnections**

- are able to **filter input and output**

- may **trigger own events**

These features enable us to **capture upward and downward causation** as well as **membrane-like behavior** (cf. brane calculi, e.g. [2]).



General Idea of mlDEVS. Some Similarities to Approach of Barros [3].

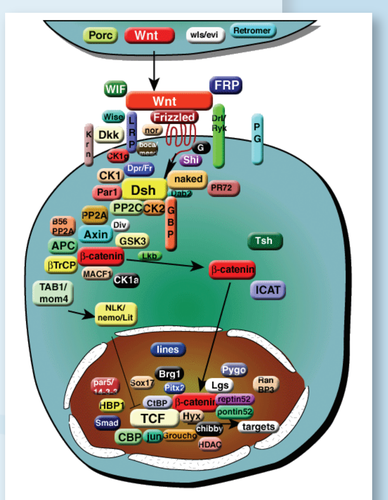
Implementation

We implemented a **sequential mlDEVS simulator** for the simulation system **James II** [4], which is written in **Java**. High-level constructs detect structural changes of their associated model via the **Listener Pattern**, which **avoids unnecessary memory consumption**, and are dynamically assigned to coupled models.

Evaluation

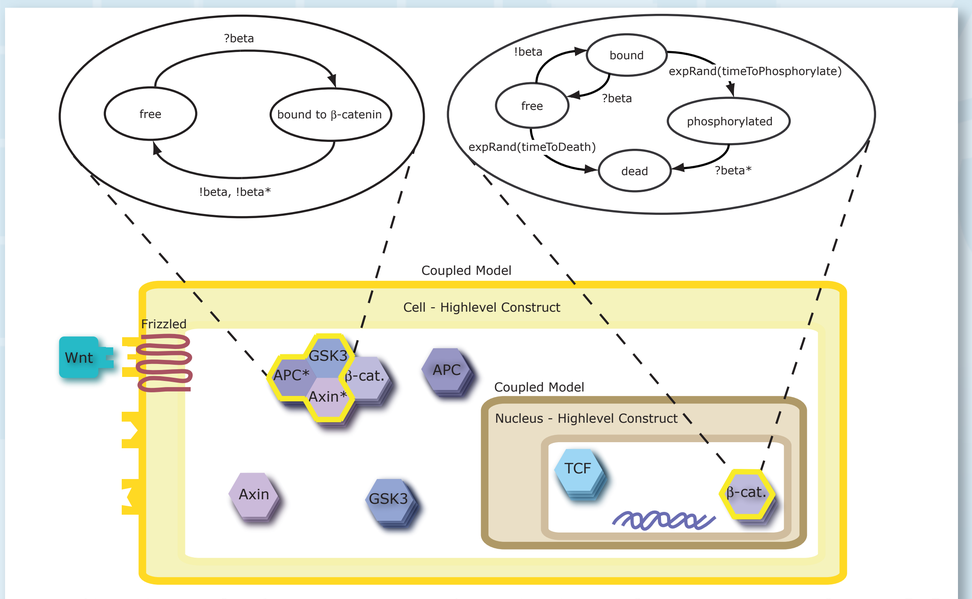
We use mlDEVS for an individual-based model of the canonical **Wnt pathway** (see [5]). Wnt molecules play an important role in embryonic neurogenesis, etc.

As a prototype, we modeled a compartment by delegating the collision scheduling for individual molecules to a high-level construct, which is based on the Gillespie algorithm [6]. More advanced constructs can be plugged in on demand.



Outlined Wnt Pathway. Modified, from [7].

Current work addresses adequate **modeling of protein complexation** in mlDEVS using rhoDEVS' variable structures.



Application of mlDEVS. For description of automata refer to [8].

Conclusion and Outlook

The mlDEVS formalism provides expressive means to model multiple abstraction levels and their interaction. It can be proven that mlDEVS is still equivalent to basic DEVS, i.e., it can be combined with other DEVS variants (e.g., hybrid models). This will be subject of future research.

References

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