Coping with Semantic Variation Points in Domain-Specific Modeling Languages

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**eXecutable Domain-Specific Modeling Languages (xDSMLs)**

- Modern systems: Too big to be addressed only as a whole.
- Domain-Specific Languages (DSLs) capitalize domain knowledge (security, fault tolerance, etc.) as language constructs.
- Modeling Languages (MLs) provide user-friendly abstractions for domain experts.
- eXecutable DSMLs ease the design, verification and validation of modern systems.
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**Semantic Variation Points**

Semantic Variation Point (SVP) $\triangleq$ language specification part left intentionally under-specified to allow further language adaptation. Usually dealt with:

- Further refinement of the specification (e.g., stereotypes or profiles in UML).
- Arbitrary choices in the implementation (e.g., multithreaded programs in CPython or Jython, fUML, etc.).
- Tool vendors responsible for specifying and documenting the implemented solution.
Example: Priorities of conflicting transitions in Statecharts

When Event “StopEvent” occurs in States “On” and “Playing”.

- Original formalism: Transition from “On” to “Off” is fired.
- UML/Rhapsody: Transition from “Playing” to “Paused” is fired.

Courtesy of the comparative study of the different Statecharts dialects and their SVPs by M. Crane and J. Dingel [3].

Figure 1: Simple music player statechart.
**Vocabulary Clarification**

- **Language**: syntax and semantics specification that may contain SVPs.
- **Dialect**: language implementation, making choices about some – possibly all – its SVPs.
Problem

- SVPs usually identified informally in the syntax and semantics specification documents.
- Tools usually only provide one dialect, constraining the end-user.
- Complicates cooperation between tools (providing different dialects) and users (who may assume different meanings for the same syntax).
- Hinders cooperation in larger projects using different variants of the same language that may be better fit for some aspects.
**Summary of our Contribution**

- A concurrent executable metamodeling approach enabling the specification of **Concurrency-aware eXecutable Domain-Specific Modeling Languages**.
- Specification of operational semantics that makes explicit the language concurrency concerns in an adapted formalism based on concurrency theory.
- That allows to explicitly specify and implement xDSML’s SVPs.
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Designing xDSMLs

Language design

\[ \text{Language} \triangleq \text{AS} + \text{SD} + \mathcal{M}(\text{AS}, \text{SD}) \]

Where:

- **Abstract Syntax (AS):** concepts and relations between concepts
- **Semantic Domain (SD):** meaningful existing language
- **Semantic Mapping (\(\mathcal{M}(\text{AS}, \text{SD})\)):** maps concepts from the AS to their meaning in the SD.

Three main approaches to the Semantic Mapping: Axiomatic, Translational (incl. Denotational) and Operational.
Overview of the GEMOC Approach

Separation of Concerns (SLE 2013 [2])
Split the Semantic Mapping in:

- **Semantic Rules**: Operational specification of the model runtime state evolution.

- **Concurrency Model**: Partial ordering of abstract actions in a formalism inspired by concurrency theory.

- **Communication Protocol**: Relates abstract actions and Semantic Rules.
Concurrency Model

- Called Model of Concurrency and Communication (MoCC) in GEMOC.
- Focuses on concurrency, synchronization and the, possibly timed, causalities between actions.
- Actions are opaque (data manipulations are abstracted).
- Given as an EventType Structure which builds the Event Structure [10] for each model concurrent control flow.
COMMUNICATION PROTOCOL

- Relates the Concurrency Model and the Execution Functions
- See *Weaving Concurrency in eXecutable Domain-Specific Modeling Languages* (SLE 2015) [8].
Class Diagram of the Concurrent Executable Metamodeling Approach
Execution

Translation
Model-specific specifications are generated (i.e., Semantic Rules, Communication Protocol and MoCC all specific to the given model).

Runtime
- The Event Structure (MoCC at the model level) gives a partial ordering over abstract events.
- Abstracts all the possible model executions paths (including all interleavings of concurrent events).
- Event occurrences are mapped to model runtime state changes by the Communication Protocol.
- Nondeterministic situations are resolved by runtime heuristics.
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Event Structure for our example model

At the Language Level

- Main EventTypes: `Event.et_occur`, `Transition.et_fire`
- Main constraints: When an `Event` occurs, one of the `Transitions` it triggers will be fired.

Event Structure
Nodes are configurations: Unsorted set of event occurrences which occurred at this execution point.
Illustration of the Separation of Concerns at the Model Level
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Event Structures and SVPs

- Nondeterminism in Event Structures gives potential SVPs.

- SVPs can be implemented by constraining the Event Structure partial ordering.
- Done at the language level in the Event Type Structure.
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**Example: Conflicting Transitions SVP**

**Main Idea**

- Most of the concurrency concerns are shared by Statecharts dialects.
- Statecharts MoCC specifies the superset of possible partial orderings.
Example: Conflicting Transitions SVP (2)

SVP Implementations

- Dialects extend the common MoCC to restrict partial orderings.

- Removes 0n20f for UML/Rhapsody dialects, and Playing2Paused for Original dialect.
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IMPLEMENTATION

- **GEMOC Studio**\(^1\) implementation based EMF [7].
- Abstract Syntax: Ecore (EMF implementation of EMOF [9]).
- Semantic Rules: Kermeta 3 [6] (based on Xtend [1]).
- Concurrency Model: MoCCML [4] and ECL [5].
- Communication Protocol: Gemoc Events Language (GEL) [8].

\(^1\)http://www.gemoc.org/studio
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Overview of our contribution

- SVPs are usually poorly identified in language specifications.
- GEMOC concurrent executable metamodeling approach, based on *Event Structure* for the *Concurrency Model* of concurrency-aware xDSMLs provides potential SVPs as nondeterministic situations.
- Restricting the partial ordering defined in the *Concurrency Model* implements SVPs.
- SVP implementations are weaved in the language definition, allowing the execution tool to remain independent from any arbitrary choice.
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- Distinguish wanted nondeterminism from potential SVPs (forbid restrictions).
- Other kind of SVPs using Semantic Rules and/or Communication Protocol.
- Integration with SVPs at the syntax level, both abstract and concrete.
- Experiment the use of variability management techniques to handle dialects.

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Thank you for your attention.
Questions?
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