Towards Scalable Multidimensional Execution Traces for xDSMLs

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Outline

Plan

Context – xDSMLs and traces

- Recently, a lot of effort in the executable Domain Specific Languages (xDSMLs) field
- Executability of models opens possibilities in terms of early verification and validation (V&V) of systems, including the possiblity to rely on **dynamic V&V approaches**

Central concept in dynamic V&V approaches: **execution traces!**

Examples of trace usages in dynamic V&V:

- **Debugging:** a trace can be replayed
- **Model checking:** counter example in the form of a trace
- **Runtime monitoring:** checks if a trace satisfies a property

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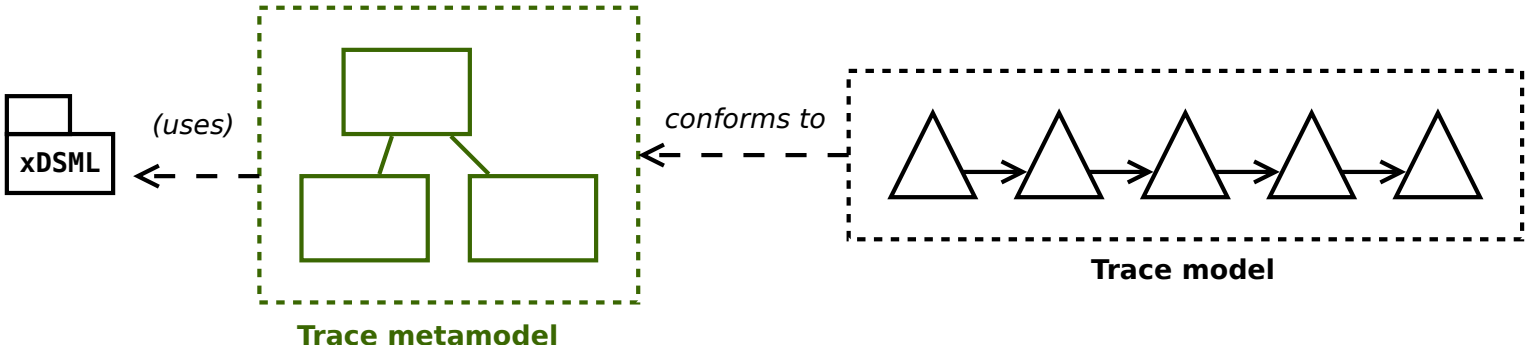
Context – trace metamodel(s)

- We want to manipulate traces from various xDSMLs

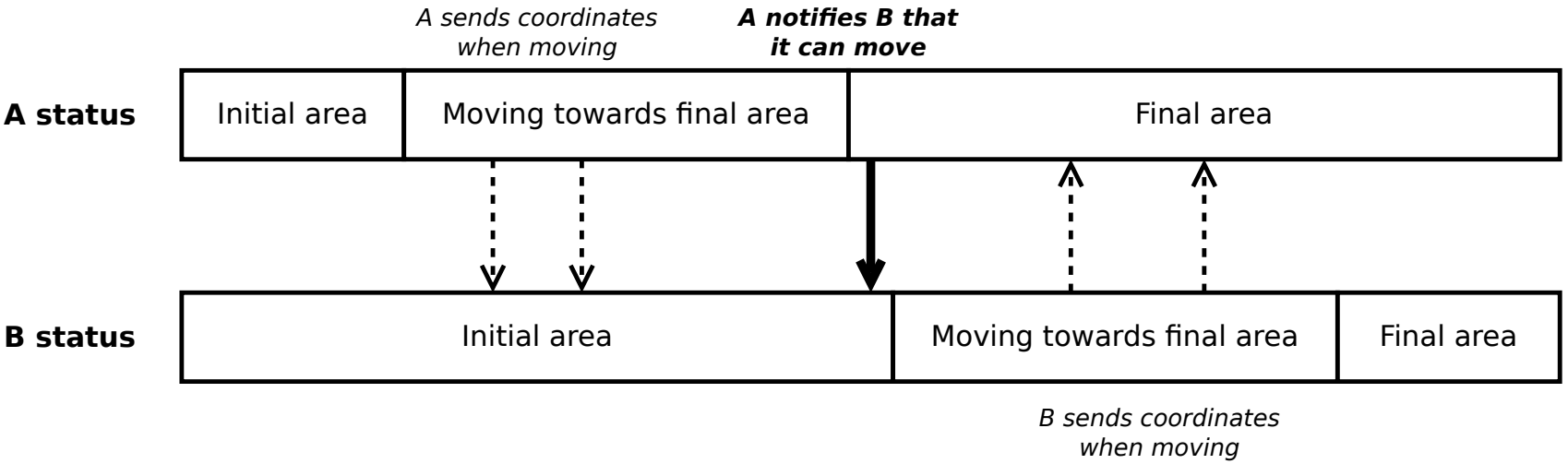
→ Need for **trace metamodel(s)**

Problem: what do we want in trace models, and thus in trace metamodels?



Motivating example: RoboML model and scenario

- RoboML: xDSML to model the behavior of robots
- Timed automata with domain concepts (e.g. GPS coordinates)



Two properties:

(a) B starts moving 5 seconds after A.

(b) Each time a robot covers 1 meter, it sends a message to the other one with its new coordinates.

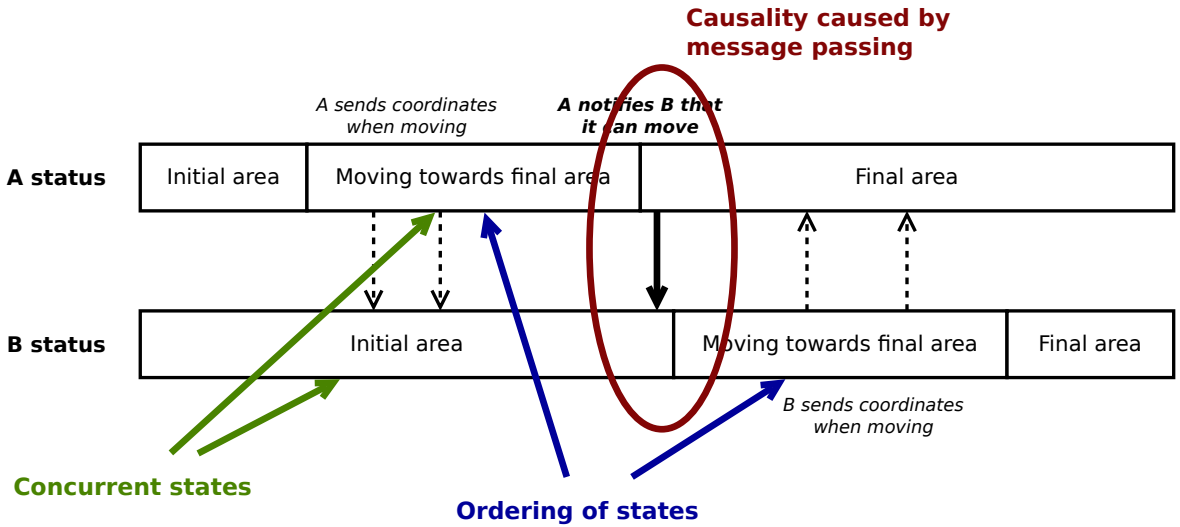
Plan

Pb. 1 – Concurrency modeling

Model execution can involve:

- One or multiple models, each with multiple variables
- Model states may be (partially) independent from one another
- More generally, **variables states may or may not be independent from other variables states**

RoboML scenario illustration



Pb. 2 – User-defined additional information

- During an execution, we have access to runtime data which depends on the xDSML semantics.
- Yet some properties may concern **derived or external data**, not available in the state of a given executed model

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(b) *Each time a robot* **covers 1 meter**, *it sends a message to the other one with its new coordinates.*

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Pb. 3 – Scalability in space

- Traces can be **arbitrarily large**, as some complex systems are monitored continuously in case a failure occurs
- Scalability in space must be managed offline (file or database storage) or online (in memory)

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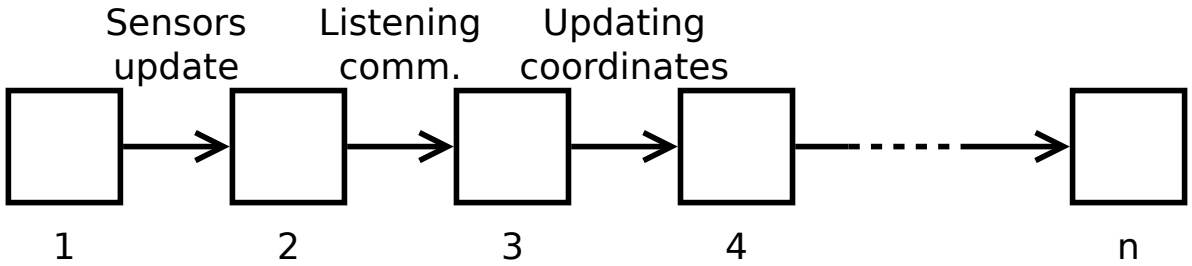

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Pb. 4 – Modularity

- To allow the removal/add of information within a trace and to allow traces with partial information
- Important in order to:
  - trace only a subset of the runtime data
  - extract a subset of the information of a trace
  - add information to the trace (e.g. derived variables)

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Pb. 5 – Manipulation safety

- **Generic trace metamodels** exist to model all kinds of traces for any executable language.
- However, constructing traces with such metamodels may lead to **inconsistent trace models**, since their genericity does not forbid one to create a trace whose states are not relevant to the concerned xDSML.

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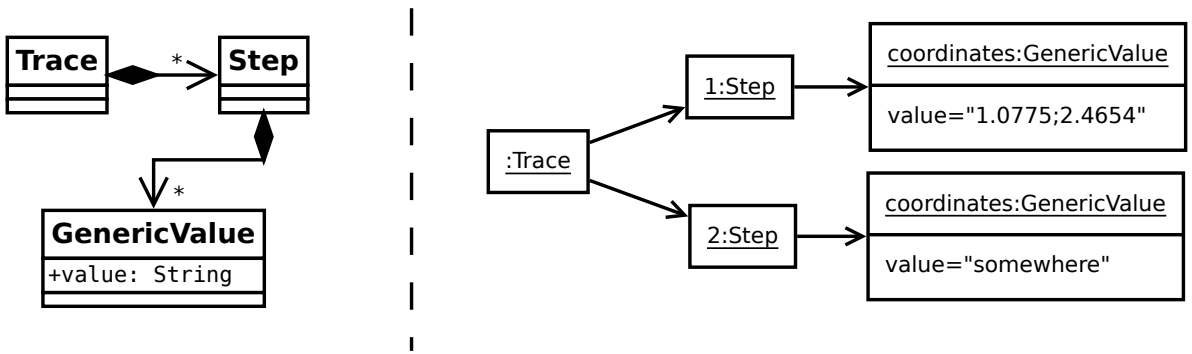

Pb. 6 – Reuse of trace manipulations

- Trace verification implies trace querying, thus **operations to manipulate traces**
- Important need: to be able to **reuse** such operations from a trace to another, from a system to another, or even from an xDSML to another

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Verifying property (a) requires an operator that checks all states that are found 5 seconds after a specific situation, which can be generalized in a *within* operator.

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Pb. 7 – Scalability in time

- Analyzing traces may require to **iterate over all its steps**. The potentially large size of a trace compromises the capacity to make queries in a reasonable time.
- Moreover, if some variable referenced in a property only changes lately in a trace, we would still have to iterate through all steps before noticing that change.

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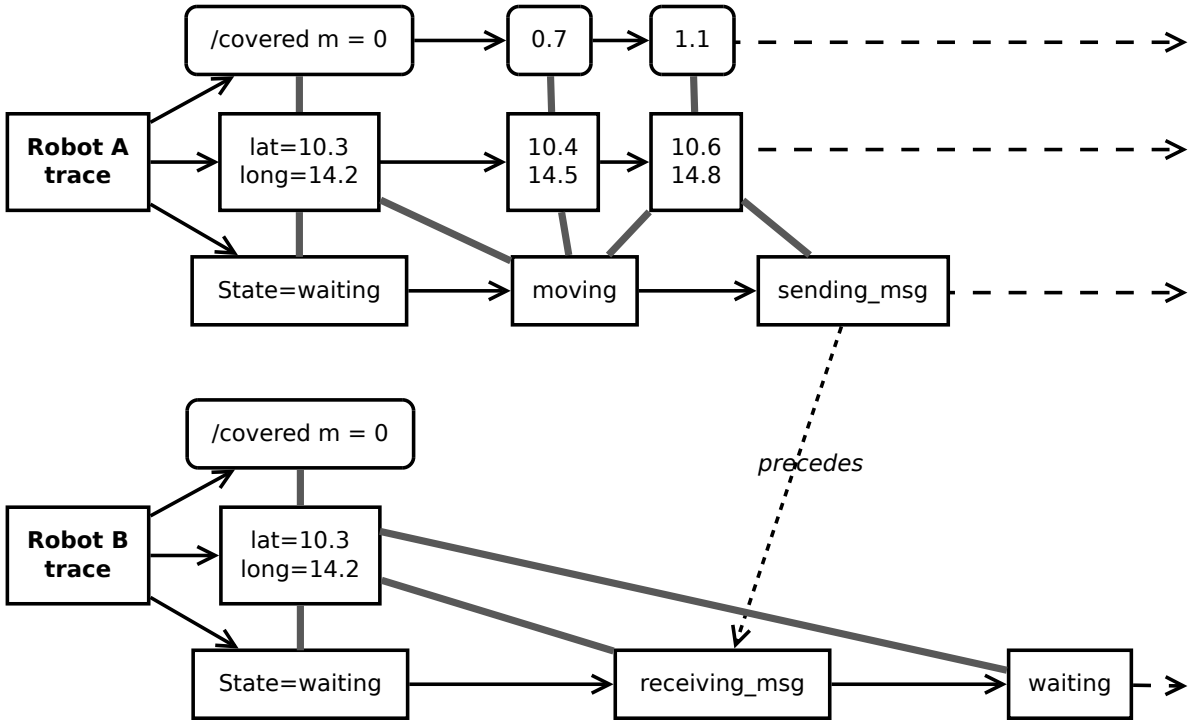
Idea 1 – Multiple dimensions

- Within a trace, very likely that only a subset of the variables really change from a state to another.
- Idea: consider **multiple dimensions in a trace**, each being a set of mutable elements of the executed model.
- A trace would then be a set of **subtraces**, each being the evolution of a specific dimension.

Problems it solves

- concurrency relationships can be defined (Pb. 1)
- adding or removing subtraces gives us modularity (Pb. 4)
- adding subtraces is a way to enrich the trace (Pb. 2)
- we can iterate separately on different dimensions, which could improve scalability in time (Pb. 7)

Example (sketch): a trace from the RoboML scenario



- 6 dimensions (3 per robot: covered meters, coord., state)
- precedence relationship with the message sending.
- Covered meters being not in the runtime data, it is added as a new dimension derived from coordinates

Idea 2 – Data sharing

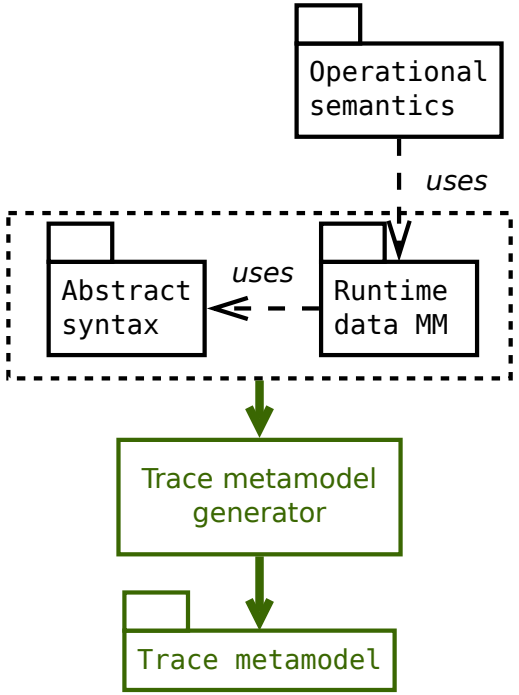
- From one step of a trace to another, there can be redundant data when dimensions values are used multiple times in the same run
- Idea: each dimension states are stored in a **dedicated storage structure** in order to be referenced by the steps of the same dimension.

Problems it solves

Helps with scalability in space (Pb. 3)

Idea 3 – Domain specific trace metamodels

- Given some xDSML semantics, we know what kind of runtime data is manipulated when executing a model
- Idea: a **domain-specific trace metamodel** that completely matches our xDSML, precisely defining the set of all possible traces of a given xDSML
- Drawback: requires a generative approach



Problems it solves

manipulation safety for trace models (Pb. 5),

Idea 4 – Trace API

- If we generate domain specific trace metamodels, then operations defined for one trace format are not compatible with another trace format
- Idea: a **common generic API** for all trace metamodels, whose operations can be automatically generated along with the metamodel
- Examples: *filter, merge, slice, during*, etc.

Problems it solves

operations reuse (Pb. 6), both those defined in the API and those using the API

Plan

Conclusion

- Verification and validation of executable models is a challenge that requires the modeling of execution traces.
- We identified a selection of problems that must be considered when modeling traces
- Our idea: **multidimensional traces** coupled with a trace manipulation API.
- Takes into account concurrency, scalability, modularity among other aspects.

Further work

A first implementation of the approach and its application to RoboML, along with memory/time measures to compare with "naïve" traces

Done!

Thank you for your attention ☺