Formal Models for Concurrent Reconfiguration of Component Assemblies

Vincent Lanore

December 10, 2015

Based on work done with Christian Pérez

Discrete Structures Day

Avalon Programming Model People

Subset of Avalon working on **programming models**

- for cloud
- for computing grids
- for High-Performance Computing (HPC)...

People

- Christian Pérez
- Hélène Coullon
- Jérôme Richard
- Pedro Silva
- myself

Thesis Approach

Programming model:

- Idea
- **Formal specification**
  - **formal syntax**
  - **formal semantics**
- **Properties?**
- Implementation
- Evaluation on use cases
  - performance
  - code metrics

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Benefits

- sturdier approach
- formal results
- connections with formal software engineering communities

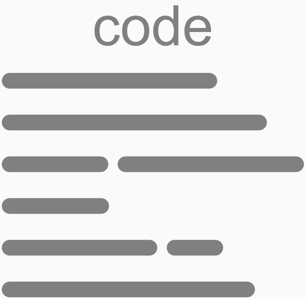
Plan

Plan

1. Context
   - Component Models
   - Reconfiguration
2. The DirectMOD Component Model
3. Other Problems
4. Conclusion and Perspectives

Component-Based Programming

How to ease reuse by third parties?



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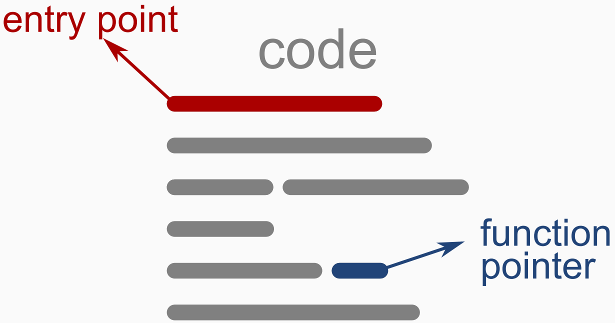

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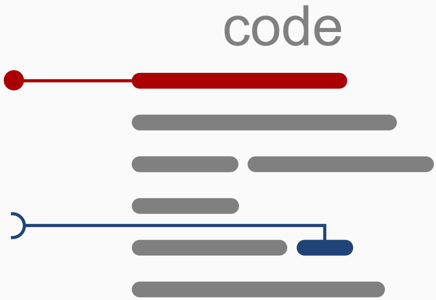

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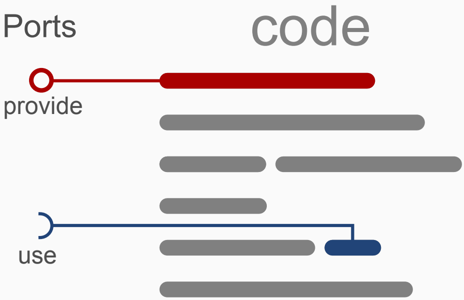

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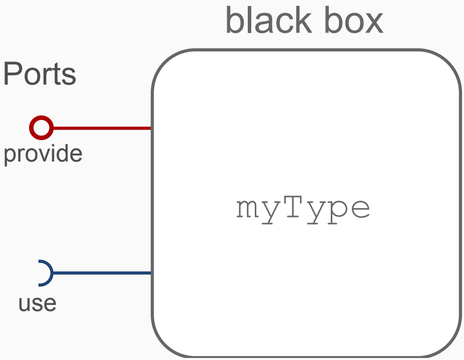

$\rightarrow$ a software component

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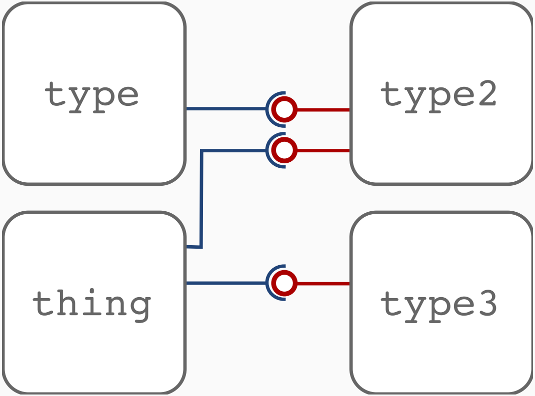
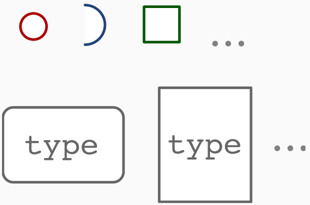


→ a component assembly

Ports/component definitions



Component Models

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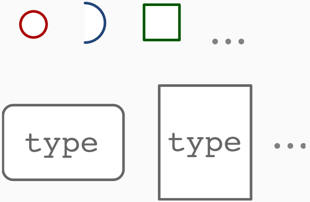

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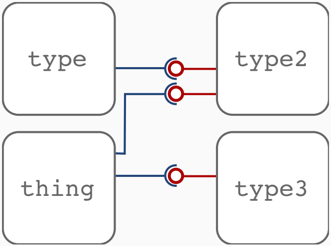

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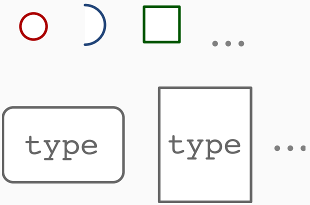

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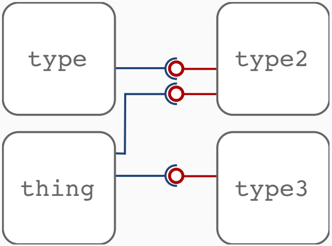

Benefits

- reuse
- separation of concerns
- structure-level view

Component Models

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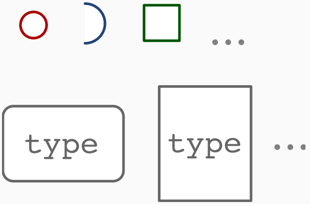

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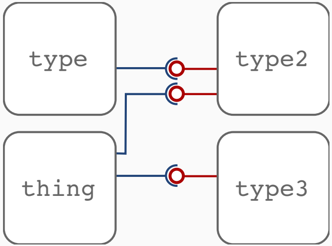

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HPC Component Models

- Examples: CCA, L2C...

Reconfigurable HPC Applications

Reconfigurable applications
application structure changes at runtime

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Example: Adaptive Mesh Refinement (AMR)

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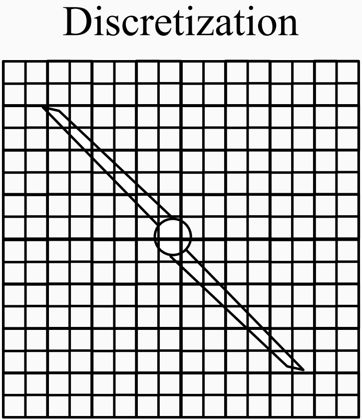

Reconfigurable applications

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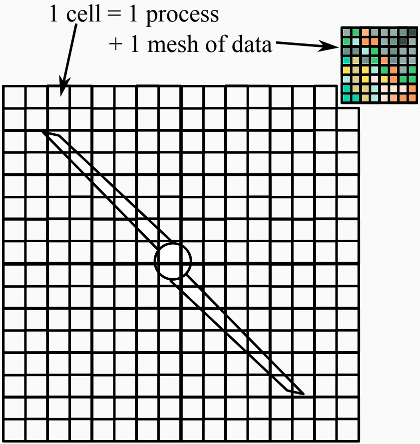

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- one process per cell

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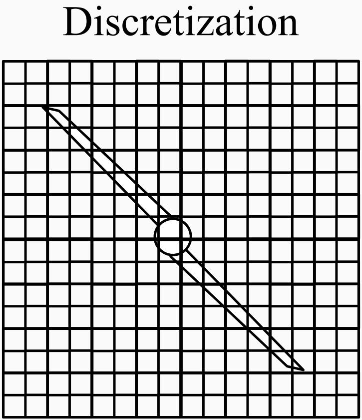

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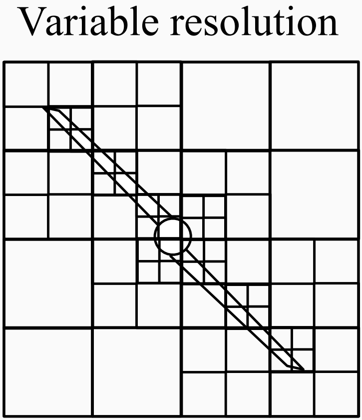

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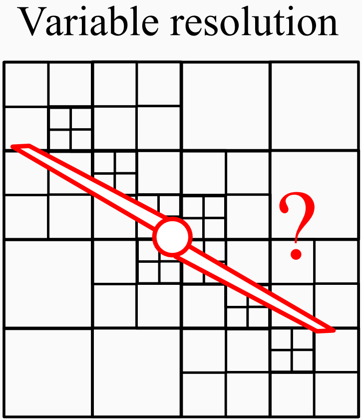

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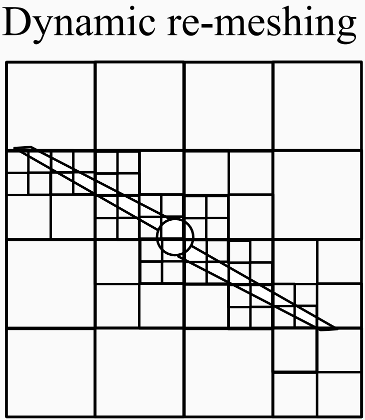
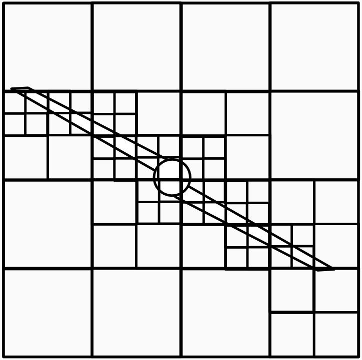


- fixed resolution cells
- one process per cell
- complex data structure
- dynamic process pool
- dynamic data structure

Reconfigurable applications
application structure changes at runtime

Example: Adaptive Mesh Refinement (AMR)

Dynamic re-meshing

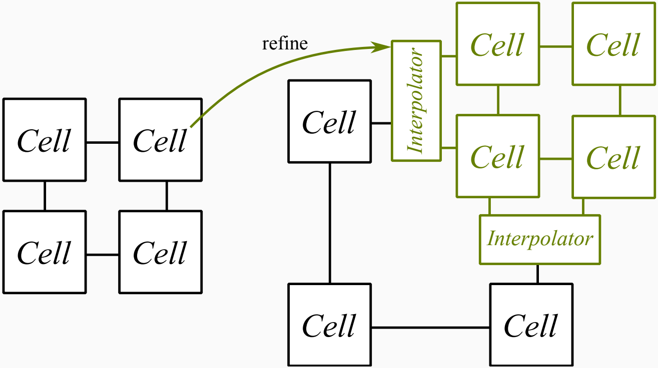


- fixed resolution cells
- one process per cell
- complex data structure
- dynamic process pool
- dynamic data structure

⇒**complex for programmers**

Structure-level Reconfiguration

One possible way to write AMR:



Pro

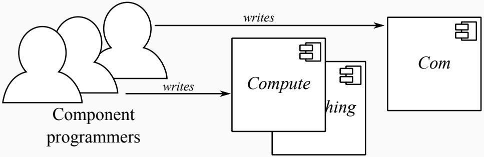
- structure-level reconfiguration

Challenges

- application model
- performance

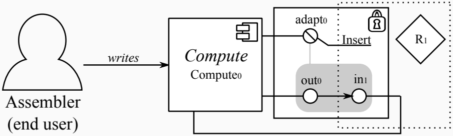
Plan

Programming Model Roles



reusable

application-specific



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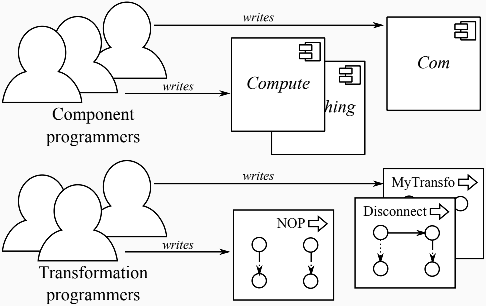

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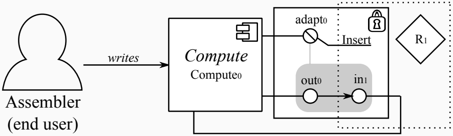

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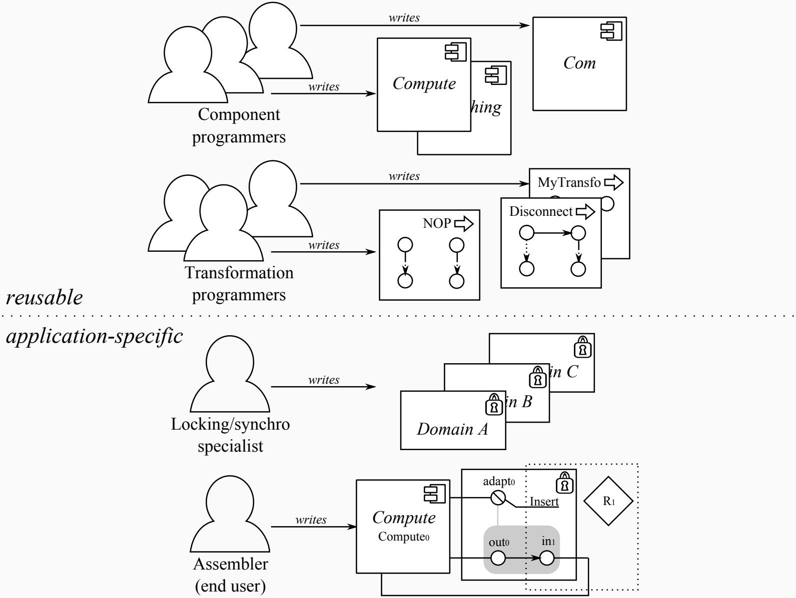


The DirectMOD Component Model

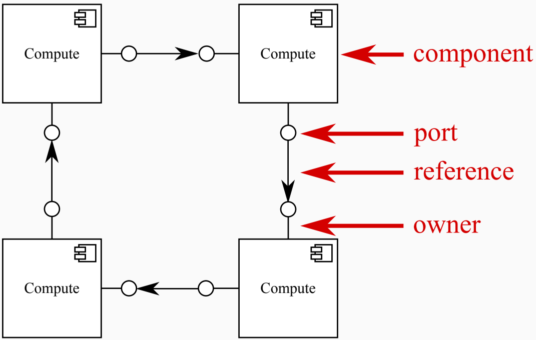
Base component model

- non-reconfigurable
- similar to L2C/CCA
- call-stack-based operational semantics (see manuscript)
- resource model (see manuscript)

DirectMOD: a full reconfigurable model

- additional concepts to
    - specify locking scope
    - specify reconfiguration
- extended syntax + reconfiguration semantics

Basic Assembly



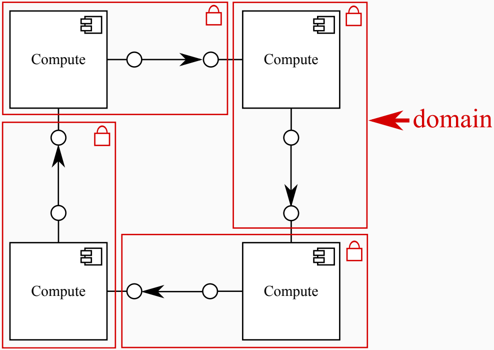
Elements

- components
- ports

Relations

- point-to-point references
- owner

Domains



New element: domains

- manages a subassembly
- unit of locking
- reconfigure its contents
- user-defined scope

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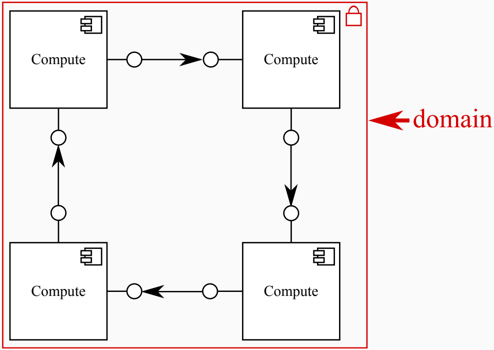

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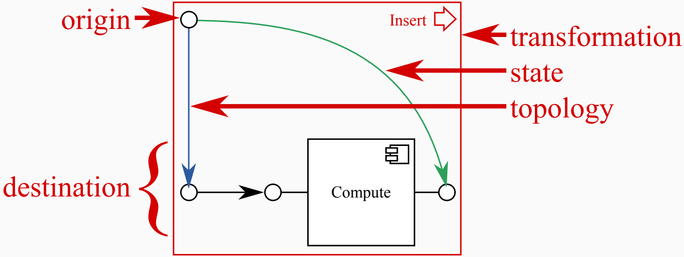
Transformations



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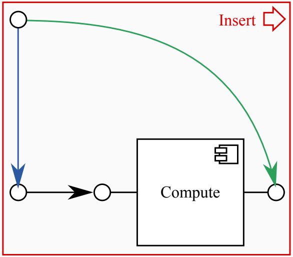

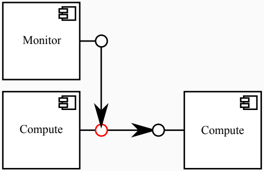

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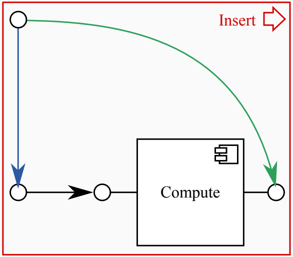

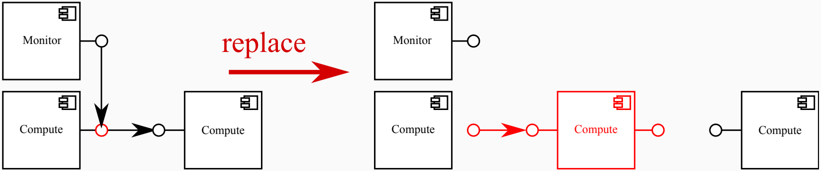

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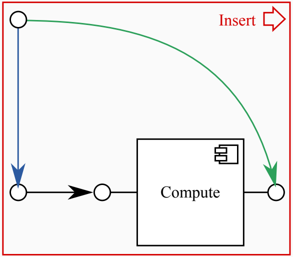

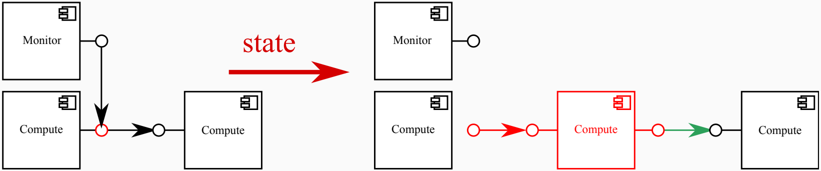

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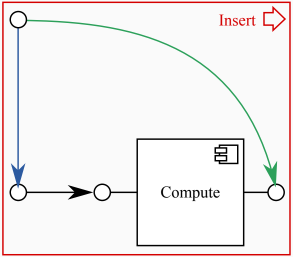
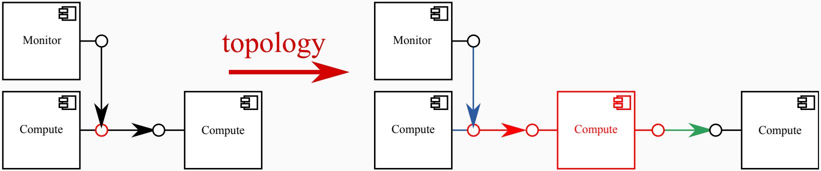
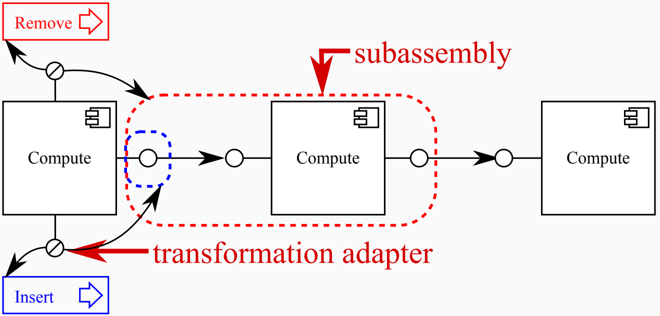


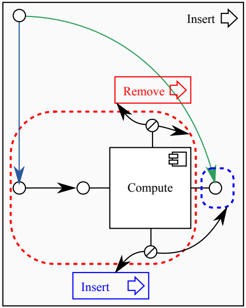


Adapters



- special kind of port
- links transformation to its target

Full DirectMOD Assembly



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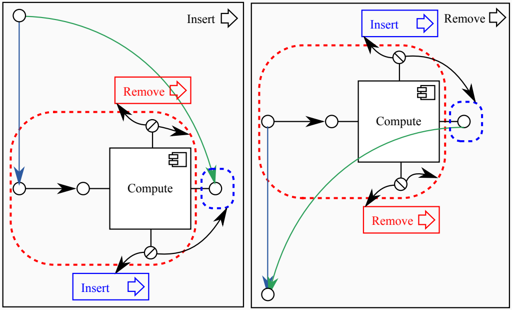

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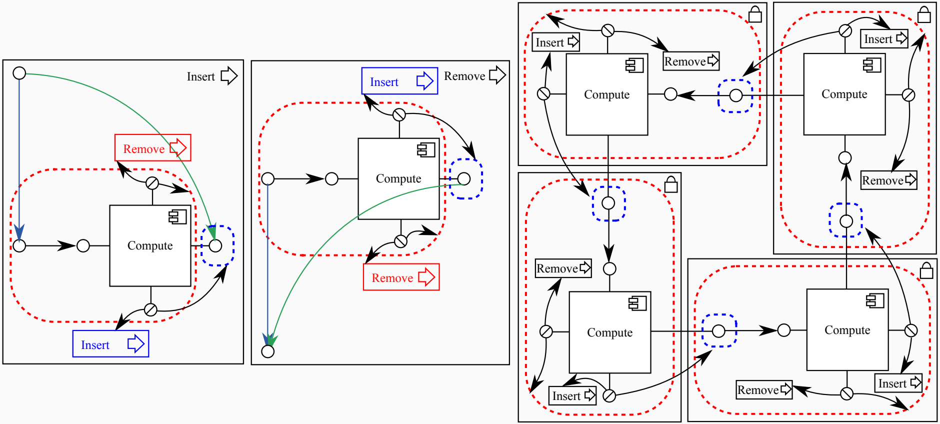

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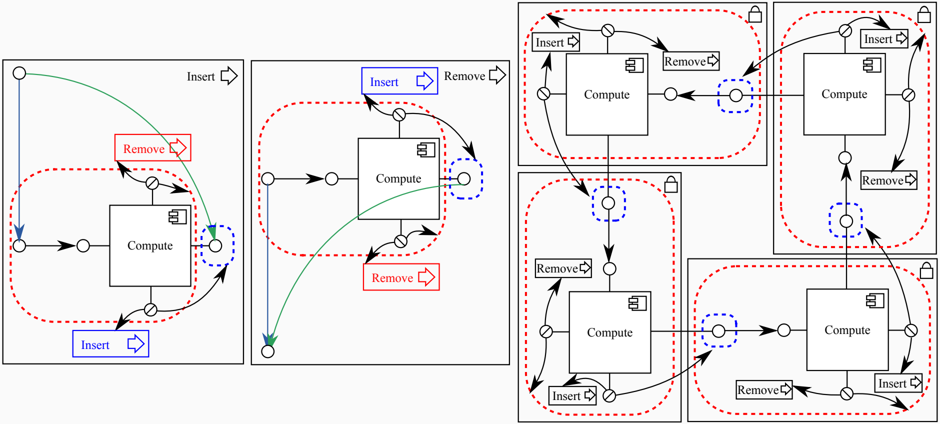


- specify starting assembly
- assembly representation during runtime

Definition Example: Ports

The set of DirectMOD ports on nameset $\mathcal{N}$ is defined by:

$$
\begin{aligned}
&\mathit{Ports}_{dmod}(\mathcal{N}) \\
&\quad = \{\mathit{USE}(\mathit{name}, \mathit{ref}) \mid (\mathit{name}, \mathit{ref}) \in \mathcal{N}^2\} \\
&\qquad \cup \{\mathit{PROVIDE}(\mathit{name}) \mid \mathit{name} \in \mathcal{N}\} \\
&\qquad \cup \{\mathit{ADAPT}(\mathit{name}, \mathit{transfo}) \mid (\mathit{name}, \mathit{transfo}) \in \mathcal{N}^2\}
\end{aligned} \tag{1}
$$

where :

- provide and use ports are defined as for the preliminary model;
- the $\mathit{name} \in \mathcal{N}$ in the ADAPT operator is the name of the adapter;
- $\mathit{transfo} \in \mathcal{N}$ is the transformation reference of the adapter;
- α is the target assembly.

Example Definition: Transformations

Let $\mathcal{A}$ be a set of assemblies and $\mathcal{N}$ a set of names. A *transformation* τ is of the form:

$$\tau = (\mathit{name}, \alpha, \omega, s, t) \tag{2}$$

where:

- $\mathit{name} \in \mathcal{N}$ is the name of the transformation;
- $\alpha \in \mathcal{A}$ is the *origin* of the transformation;
- $\omega \in \mathcal{A}$ is the *destination* of the transformation;
- $s : \mathit{Support}(\alpha) \rightarrow \mathit{Support}(\omega) \cup \{\bot\}$ is the *state mapping*;
- $t : \mathit{Support}(\alpha) \rightarrow \mathit{Support}(\omega) \cup \{\bot\}$ is the *topology mapping*.

The DirectMOD Component Model

The DirectMOD model

- specialized graph structure
  - components, ports, resources
  - concurrent semantics
- transformations

Challenges and perspectives

- proofs with transformations
- locking / deadlock detection

Plan

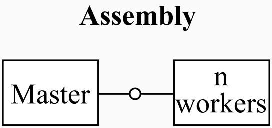
SpecMOD Principle

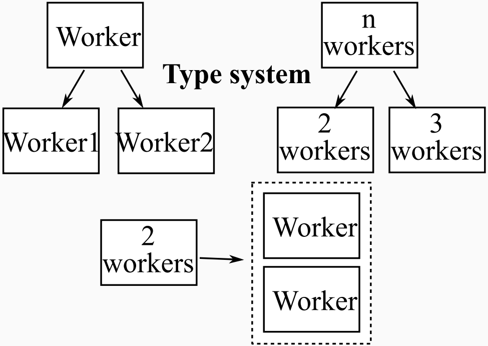
Very simple assembly model

- components (squares)
- endpoints (circles)
- edges

Rich type system

- component types
- endpoint types
- specialization relations





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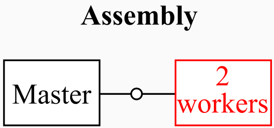

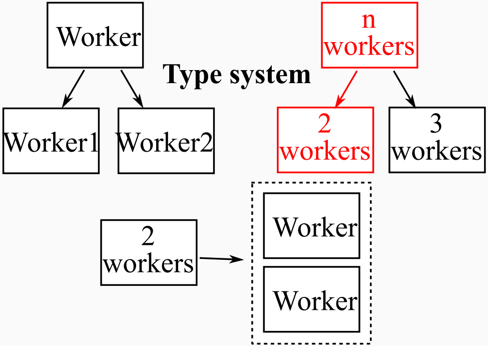

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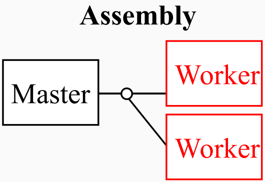

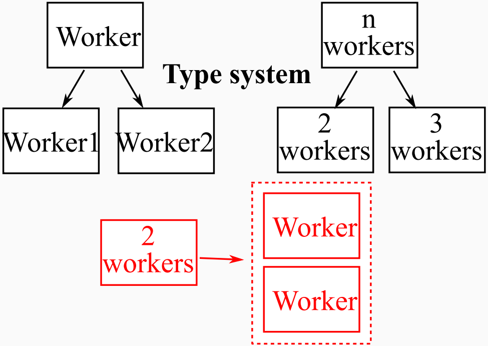

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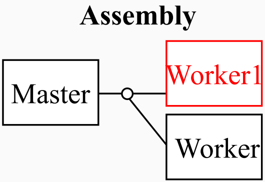
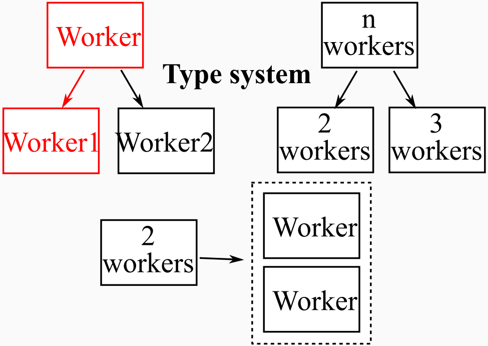


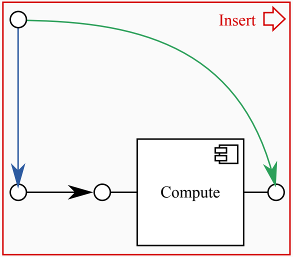


Formal Work

SpecMOD: a general specialization calculus

- type system definition
- assembly definition
- specialization operations as rewriting rules
- parametric type systems encoding

Encoding Example



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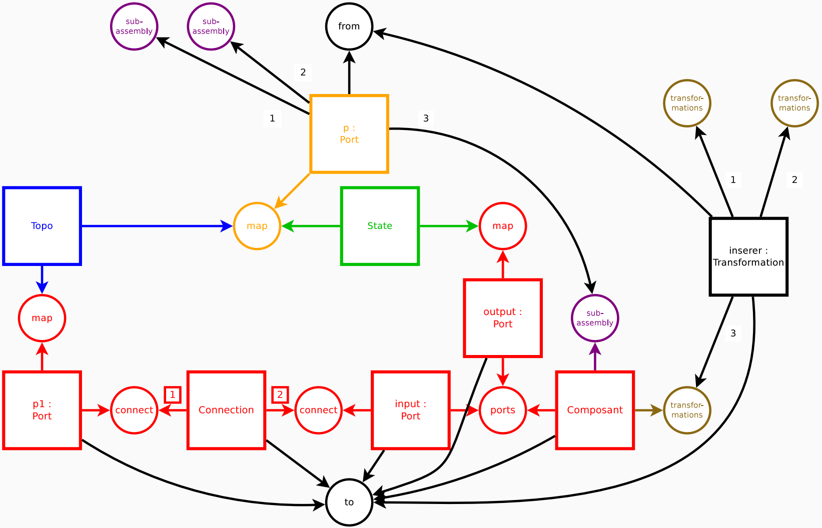
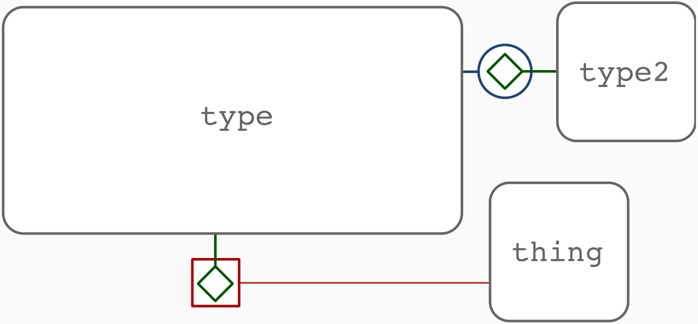


Work with Chardet Maverick

Hierarchy

Components implemented by component assemblies called composite components



Structure

- bigraphs?

Challenges

- transformation expression

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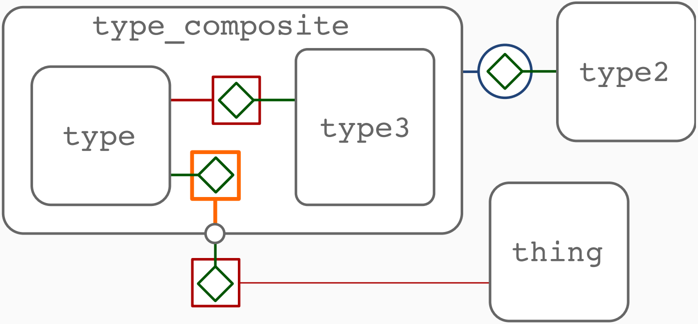

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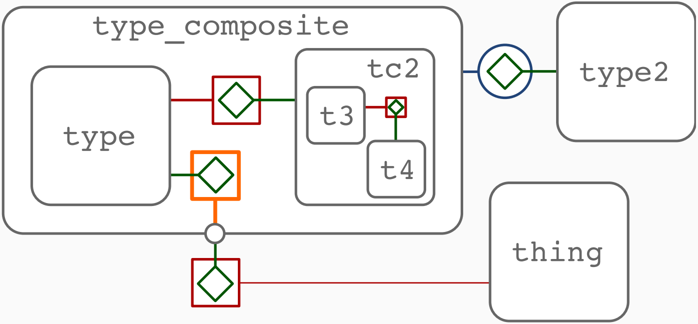

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Plan

Conclusion

Discrete structures themes:

- specialized graph-like structures
  - multi-sorted graphs
  - list edges
  - hierarchy
- graph transformations
- graph specialization through rewriting

Problems and perspectives

- proofs with transformations
- locking / deadlock detection
- encoding / decoding complex structures