CoCoME: Component-Interaction Automata Approach

The CoIn Team

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Group introduction

Affiliation:

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Members:

- Profs: Ivana Černá, Luboš Brim, Jiří Sochor
- Studs: Barbora Zimmerova, Pavlína Vařeková, Nikola Beneš

Experience:

- ParaDiSe Laboratory (1999)
  automated verification of large-scale systems
  verification tool DiVinE
- CoIn Team (2005)
  communication behaviour in component-based systems

Component Model

Focus of our modelling approach

- Behavioural view
- Interaction among components

The purpose of the model

- Formal verification of component interaction

Framework represented by

- Component-interaction automata language
- For detailed modelling of communication behaviour in CBSs
- Very general → can be used with various component models

Component-interaction automata language

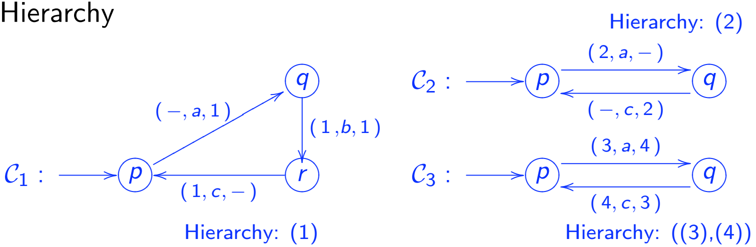
Component-Interaction automata language
(or CI automata for short)

- Automata-based language
  finite state model, infinite executions/traces
- Three types of actions (*input*, *output* and *internal*)
  no additional semantics – interfaces/services/events/etc.
- Captures important interaction information
  participants of communication, hierarchy of components
- Flexible composition
  can be parametrized by architectural assembly, communication strategy
- General to meet various component models
  by fixing the composition operator and semantics of actions

Definition of a CI automaton

A component-Interaction automaton

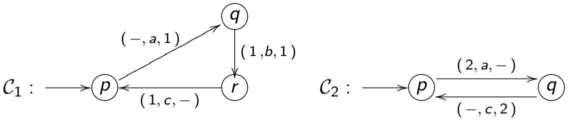
- States (initial)
- Labeled transitions
- Labels (structured - component names, actions)
  - input, output and internal
- Hierarchy



Composition of CI automata

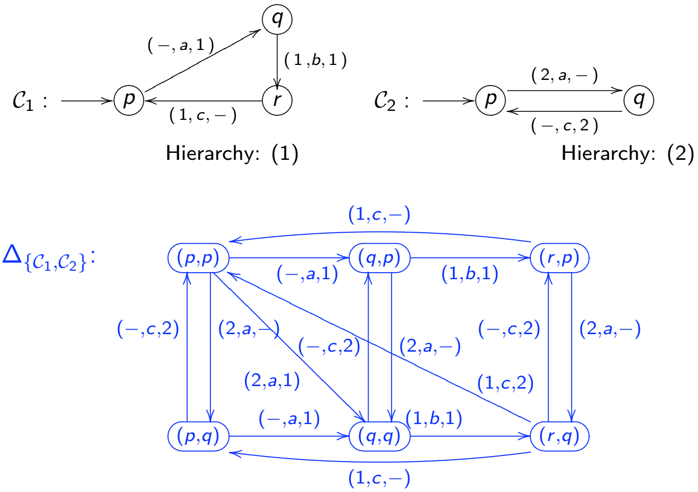
A parameterizable **composition operator** $\otimes_T$ determines a composite automaton $\otimes_T \mathcal{S}$ as

- a product of automata from the set $\mathcal{S}$
  $\rightarrow$ **complete transition space** $\Delta_{\mathcal{S}}$
- where the transitions outside T are removed
  $\rightarrow$ T can reflect various **communicational strategies**
- composed hierarchically $\otimes_T \{ \mathcal{C}_1 , \mathcal{C}_2 = \otimes_{T'} \{ \mathcal{C}_4, \mathcal{C}_5, \mathcal{C}_6 \} , \mathcal{C}_3 = \otimes_{T''} \{ \mathcal{C}_7 \} \}$
  $\rightarrow$ the transition space determined by the expression,
  not computed explicitly!

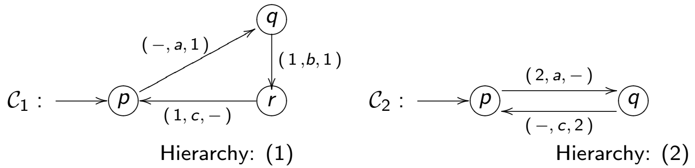


Hierarchy: (1) Hierarchy: (2)

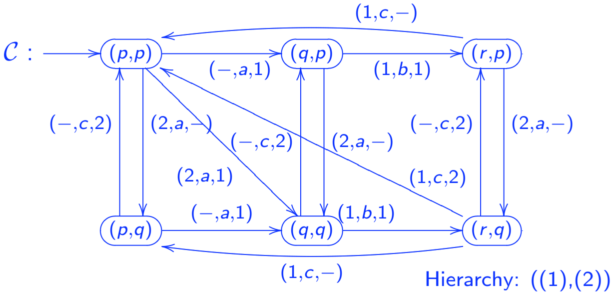
Composition – complete transition space



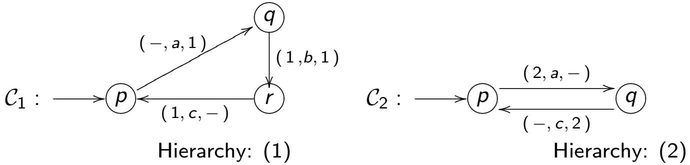
Composition – cube-like composition



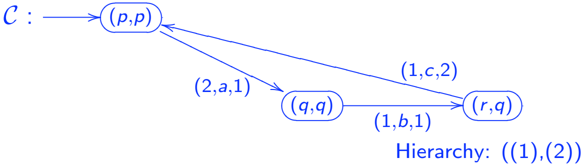
$\mathcal{C} = \otimes_T\{\mathcal{C}_1, \mathcal{C}_2\}$ where $T = \Delta_{\{\mathcal{C}_1,\mathcal{C}_2\}}$



Composition – handshake-like composition



$\mathcal{C} = \otimes_T \{\mathcal{C}_1, \mathcal{C}_2\}$ where $T = \{(s, x, s') \mid x \in \{(2, a, 1), (1, b, 1), (1, c, 2)\}\}$



Modelling technique 1/2

Input

- Specification of behaviour of primitive components
  - Java implementation
- Static structure of the system
  - hierarchy of components, interfaces and bindings in between
  - derived from component diagrams and Java implementation

Output

- CI automaton representing the whole system

Modelling technique 2/2

Modelling process

- Identify primitive components and their services
- Model primitive components as automata
  - An automaton for a service
  - An automaton for a primitive component via composition of the services
- Model composite components as automata
  - Fix the composition operator
  - An automaton for a composite component
- Proceed to formal analysis and verification

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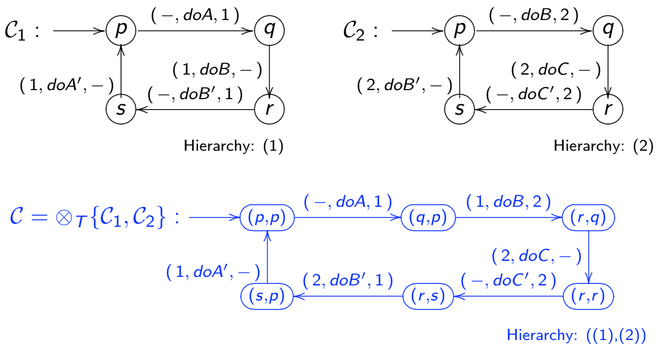
An automaton for a service

Each service, say `doIt()`, assigned a tuple of actions

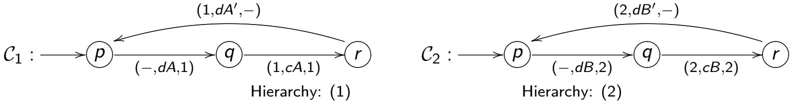
- call of the method – `doIt`
- return from the method – `doIt'`

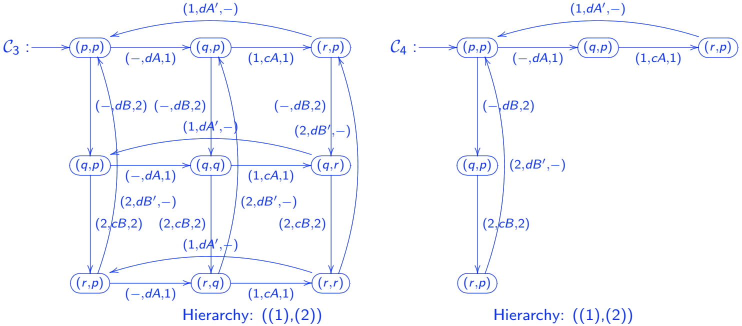
and modelled as a loop



An automaton for a primitive (basic) component

- Composition of automata for services using the star-like $\mathcal{C}_4$ and the cube-like $\mathcal{C}_3$ composition





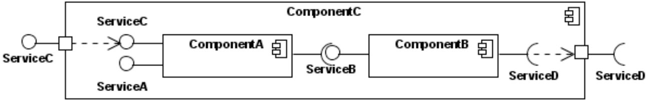
An automaton for a composite component

- Composition of automata for components using the handshake-like or the assembly-like composition

Assembly-like composition

- T given explicitly as a set of transitions with labels representing interaction allowed by bindings among components

Example:

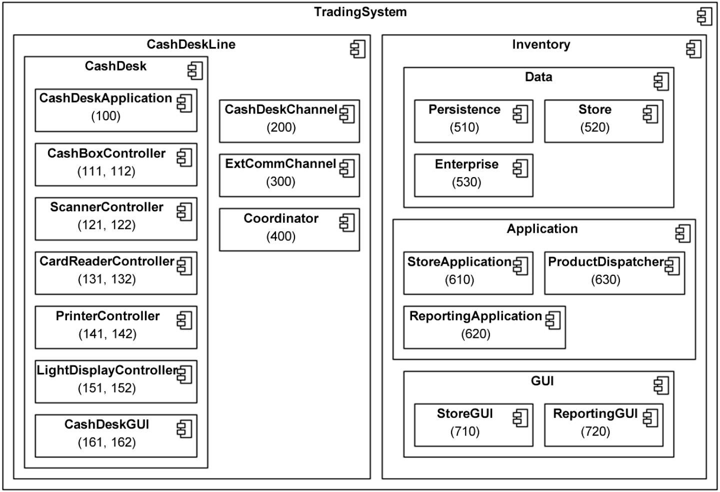


$\mathcal{L}_A = \{(-, sA, 1), (1, sA', -), (-, sC, 1), (1, sC', -), (1, sB, -), (-, sB', 1), (1, intA, 1)\}$
$\mathcal{L}_B = \{(-, sB, 2), (2, sB', -), (2, sD, -), (-, sD', 2), (2, intB, 2)\}$
$\mathcal{F} = \{(1, intA, 1), (2, intB, 2), (1, sB, 2), (2, sB', 1), (-, sC, 1), (1, sC', -), (2, sD, -), (-, sD', 2)\}$

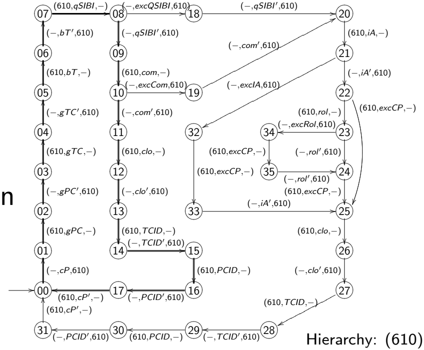
$\mathcal{C}_C = \otimes_T \{\mathcal{C}_A, \mathcal{C}_B\}$ where $T = \{(q, x, q') \mid x \in \mathcal{F}\}$

Modelling overview

- The whole *Trading System* modelled in a fine detail



Selected issues 1/2



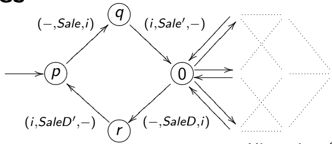
Hierarchy: (610)

Exception handling

- try, catch, finally blocks
- throw, delegate an exception

Creation and destruction of instances

- initial activation part

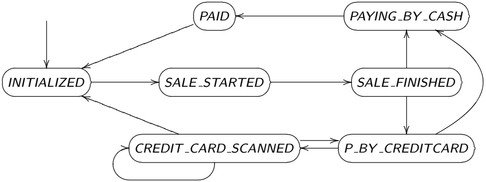


Hierarchy: (i)

Selected issues 2/2

Internal state of a component

- additional automaton representing the internal state
- answers questions `if (currState.equals(PAYING_BY_CASH))` and reacts to commands `currState = PAID;`



Asynchronous messaging

- publish-subscribe communicational model
- realized via event channels

Analysis

Input for the analysis

- Model of the system as a CI automaton
- Labelled transition system (LTS) in fact

Analytical methods

- Variety of methods available for LTSs
- Verification of temporal properties with Model Checking
- DiVinE tool for verification of large-scale systems
- Application
  - In design phase to predict properties of a new system
  - Analysis and verification of existing system
  - During modelling to detect modelling errors

Temporal-logic properties

Logic for expressing properties CI-LTL

- Extended version of LTL, operators next $\mathcal{X}$ and until $\mathcal{U}$
- Both state and action-based
- Properties about
  - component interaction that is proceeding $\mathcal{P}$
  - possible interaction that is enabled $\mathcal{E}$

Verification

- DiVinE tool
  - distributed and on-the-fly model checking and reachability analysis
- Verification run on a cluster of 20 computers
- Presented properties verified in terms of seconds or minutes

Example of properties

- If the *StoreApplication (610)* starts a transaction with the *Persistence (511)*, it correctly closes the transaction before it is able to start another one.

$$\mathcal{G}\ (\mathcal{P}(610, \text{beginTransaction}, 511) \Rightarrow \mathcal{X}\ (\neg\, \mathcal{E}(610, \text{beginTransaction}, 511)\ \mathcal{U}\ \mathcal{P}(610, \text{close}, 511)))$$

- It cannot happen that the *StoreApplication (610)* is ready to call `queryStockItemById()` but never can do so because its counterpart is never ready to receive the call.

$$\mathcal{G}\ (\mathcal{E}(610, \text{queryStockItemById}, -) \Rightarrow \mathcal{F}\, \mathcal{E}(610, \text{queryStockItemById}, 521))$$

1. Introduction
2. Component Model
   - Component-interaction automata
3. Modelling the CoCoME
   - Modelling technique
   - Modelling overview
   - Selected issues
4. Analysis
   - Temporal-logic properties
   - Use cases and test cases
5. Conclusion

Use cases

Application

- To check the model against the use case scenarios
- To find a path in the model that realizes the scenario
- To refine the scenario according to the path

All use cases confirmed using DiVinE

Use Case		States	Transitions	Confirmed after generating
UC 1: ProcessSale	(i)	401	1.488	18 of 384 states
	(ii)	10.600.010	63.819.991	85 of 3.965.100 states
	(iii)	4.975.487	29.648.100	1.658.496 of 3.317.012 states
UC 3: OrderProducts		181	211	487 of 876 states
UC 5: ShowStockReports		57	64	63 of 94 states
UC 7: ChangePrice		82	94	49 of 114 states

(i) UC 1: ProcessSale: CashPayment: btnStartNewSale
(ii) UC 1: ProcessSale: CashPayment: btnClose
(iii) UC 1: ProcessSale: CardPayment: btnEnterPIN

Test cases

Application

- To evaluate the test scenarios on the model

Informal scenarios

- Check for existence of a good behaviour
- Formulate a CI-LTL formula
- Verify in a negative way

Formal scenarios

- Check if all behaviours are good in some sense
- Formulate a CI-LTL formula and verify
- Consider only fair runs

Summary and lessons learned

Summary

- Application of Component-interaction automata to CoCoME
  – mapping of actions, composition operators, modelling process
- Solutions to various modelling issues
- Detailed automatic verification

Lessons learned

- The modelling language
  + high modelling capability
  – requires a lot of effort → current works on modelling support
- The verification techniques
  + verification of very large models
  + fully automatic

Thank you

Thank you for your attention