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Modeling of Architectural Reconfiguration Case Study: Automated Teller Machine

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Outline

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- Related Work
- Basic Concepts
  - Bigraphical Reactive System (BRS)
  - Architecture Analysis and Design Language (AADL)
- Approach
- Case study: ATM System
- Conclusion & Future Work

Introduction

- Rapidly growing complexity of software systems.
- Software Architecture, a key approach to decrease complexity.
- Architecture Description Languages, a representation in terms of components, connectors and configuration.
- ADLs facilitate the high-quality development of software systems.
- Only few ADLs are provided with some hold for the dynamic behavior.

Introduction

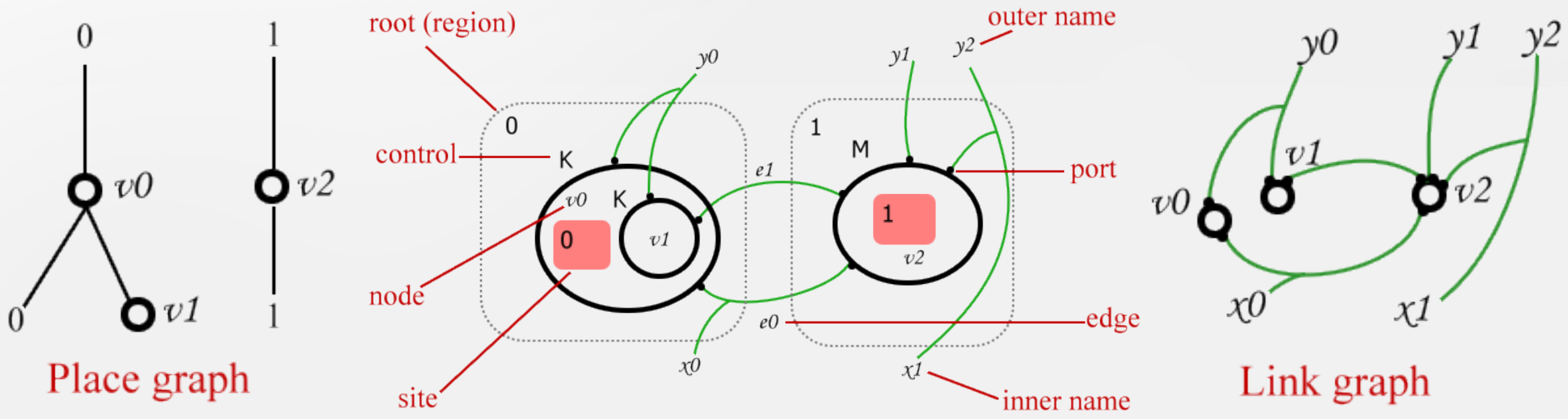
- AADL, an international standard to model both structural and behavioral aspects of SA.
- The lack of a concrete formal model to define AADL semantics.
- An extended BRS-based approach to formalize the dynamic architectural reconfiguration.

Related Work

- R. Allen, R. Douence, and D. Garlan, *"Specifying and analyzing dynamic software architectures"*
  - Clear separation between individual components behavior and software architectural dynamics.
- L. Baresi, and R. Heckel, *"Tutorial introduction to graph transformation: A Software Engineering Perspective"*
  - Class diagram to represent a software architecture.
- Z. Chang, X. Mao, and Z. Qi, "*Towards a formal model for reconfigurable software architectures by bigraphs*"
  - Graph transformation to only define structural reconfiguration.

Basic Concepts : BRS

- Bigraphical Reactive System is a graphical model.
- Emphases both locality and connectivity of distributed systems.



- Bigraph consists of two graphs :
  - ❑ Place graph: physical location of nodes.
  - ❑ Link graph : interaction between these nodes.

Basic Concepts : BRS

- Formally a bigraph takes the form:

$G=(V, E, ctrl, G^{P}, G^{L}) : I \to J$

- V is a finite set of nodes.
- E is a finite set of edges.
- $ctrl = V \to K$ is a control map.

Signature

- $G^{P} = (V, ctrl, prnt) : m \to n$ is the place graph
  - $prnt : m \uplus V \to V \uplus n$ is the acyclic parent map.
  - m is a finite ordinal number which represents sites.
  - n is a finite ordinal number which represents regions.

Basic Concepts : BRS

- Formally a bigraph takes the form:

$G=(V, E, ctrl, G^{P}, G^{L}) : I \to J$

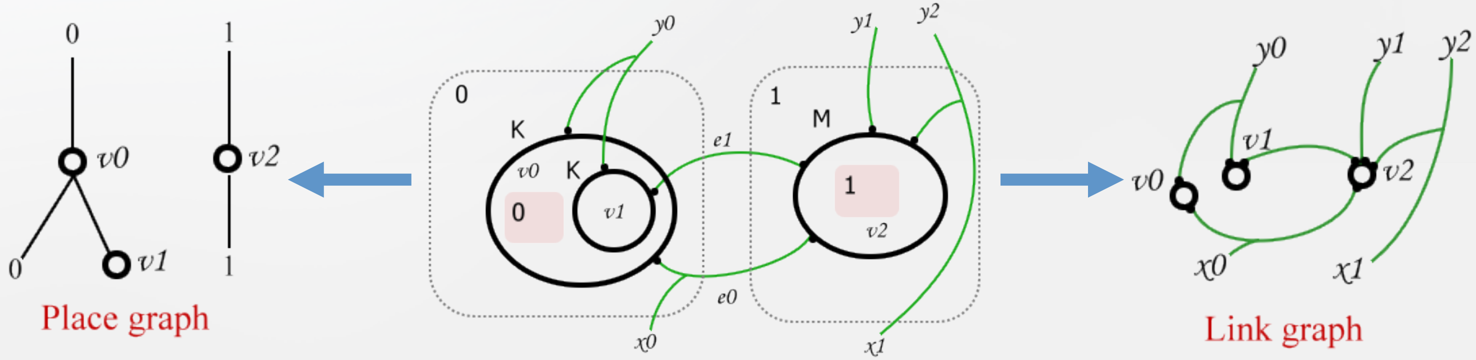
- $G^{L} = (V, E, ctrl, link) : X \to Y$ is the link graph
    - $link : X \uplus P \to E \uplus Y$ is the link map.
    - X represents the inner names.
    - Y represents the outer names.
    - P is a set of ports.

- $I = \langle m, X \rangle$ represents the inner face.
- $J = \langle n, Y \rangle$ represents the outer face.

Basic Concepts : BRS

Example :

$G{\uparrow}P : 2 \to 2$ $\quad G : (2, \{x0, x1\}) \to (2, \{y0, y1, y2\})$ $\quad G{\uparrow}L : \{x0, x1\} \to \{y0, y1, y2\}$



Place graph

Link graph

- $V = \{v0, v1, v2\}$
- $E = \{e0, e1\}$
- $K = \{v0{:}2, v1{:}2, v2{:}4\}$
- $prnt = \{v0{:}\emptyset, v1{:}v0, v2{:}\emptyset\}$
- $I = (2, \{x0, x1\})$
- $J = (2, \{y0, y1, y2\})$

Basic Concepts : BRS

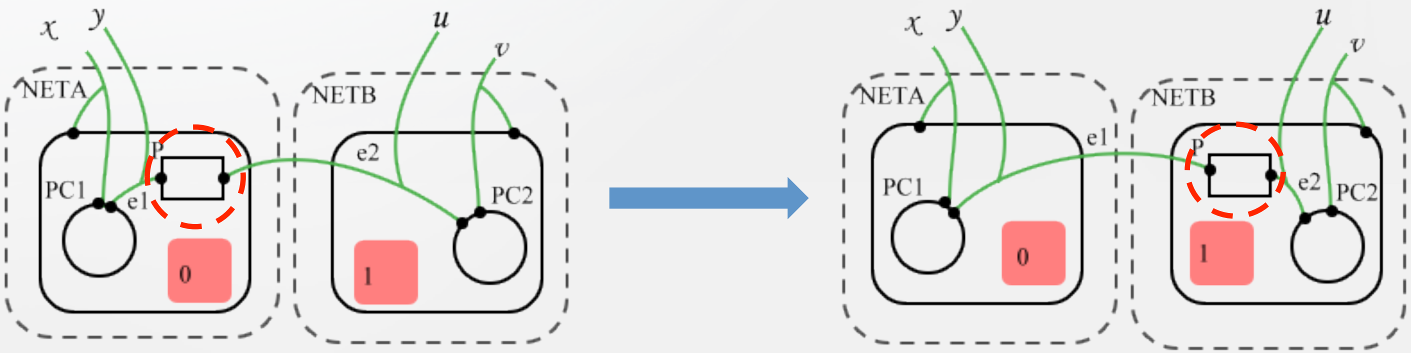
- BRS consists of a category of bigraphs and a set of reaction rules.

- Reaction rules define the dynamics of bigraphs :
  - Nesting
  - Linkage

- A reaction rule (R, R', η) consists of a redex $(R{:}m \to J)$ which may be transformed to a reactum $(R' : m' \to J)$ to rewrite the bigraph where η: $m' \to m$ is map of ordinals.

Basic Concepts : BRS

Example :



- Redex : R:2→(2, {x,y,u,v})
- Reactum : R' :2→(2, {x,y,u,v})
- Map : η:{ 2→2 }
- Transformation : locality reconfiguration

Basic Concepts : AADL

- Architecture Analysis and Design Language is an international standard.

- Represents a real-time embedded system as a component-based architecture.

  - Software : data, process, thread, thread group and subprogram.
  - Platform : processor, memory, device and bus.
  - Composite : system.

- Models the interaction of the software components and their target platforms.

- Represents operational modes to describe the dynamic behavior of systems.

Approach

- BRS, a suitable platform to formalize the installation activity of AADL systems.
- Formal mapping based on correspondences between AADL and bigraph elements.

AADL elements	Bigraphical semantic
System: S	Bigraph/Region: $S = (V_S, E_S, ctrl_S, G_S^P, G_S^L): I_S \rightarrow J_S$
Component: C	Node $C \in V_S$
Port/Role: P	Port/Inner-name or Outer-name: $P \in I_S \cup J_S$
Interaction Port-Role: L	Hyper-edges: $L \in E_S$
Hierarchy	Imbrication of Nodes and Sites: $prnt_S : m_S \cup V_S \rightarrow V_S \cup n_S$
Binding properties	Composition: $S_S \circ S_H$ where S_S and S_H are bigraphs modeling respectively both software and hardware parts of S.

Approach

- Enrich the proposed mapping rules set between AADL and bigraph concepts :

  ✓ Extend the control function to deal with all possible modes.
  ✓ Exploit the bigraphs reaction rules.

- Dynamic runtime formalization :

AADL elements	Bigraphical semantic
Configuration S_m	Bigraph: $S_m = (V_S, E_S^m, ctrl^m, G_S^P, G_S^L)$
Mode transitions	Reaction rule: $\mathcal{R}=(R_m, R_{m'}, \eta)$

Approach

- A bigraph $\mathcal{S}_m$ over a signature $\mathcal{K}^m$ is given by:

$\mathcal{S}_m = (V_S, E_S^m, ctrl^m, G_S^P, G_S^L)$ where:

- $m \in \mathcal{M}$ represents a current operational mode.
- $\mathcal{M}$ is a finite set of modes.
- $\mathcal{K}^m = \mathcal{K} \cup \mathcal{M}$ is an extended signature.
- $K(C) = (arity(C), m)$ is an extended control function.
- $ctrl^m : V_S \rightarrow \mathcal{K}^m$ is a new control map assigning to each node C a control $K \in \mathcal{K}^m$

Approach

- $T:(C, m)\rightarrow(C, m')$ is a mode transition of a component C between m and m'.

- Formally $T:\mathcal{R}=(R{\downarrow}m\,, R{\downarrow}m'\upharpoonleft'\,, \eta)$ is a parametric reaction rule where:

  - ❑ $R{\downarrow}m$ is a redex bigraph of a component C in a mode m.
  - ❑ $R'{\downarrow}m'$ is a reactum bigraph of a component C in a new mode m'.
  - ❑ η is a map of ordinals.

Case Study: ATM System

- Automated Teller Machine (ATM) is a computerized machine.
- Provides bank costumers with an alternative access to financial transactions.
- An ATM machine consists of :
  - Card reader
  - Keypad
  - Processor
  - Modem
  - Monitor
  - Printer
  - Cash dispenser

Case Study: ATM System

- ATM system is an embedded real-time system which provides banking services :
  - Withdraw cash
  - Make deposits
  - Transfer funds
  - Balance checking

- Basically, an AADL description of ATM System is a collection of interconnected software and hardware components.

Case Study: ATM System

Automated Teller Machine

system ATM_System
end ATM_System;

Software components

customer : process Customer.impl;
session : process Session.impl;
account : process Account.impl;
ATM_Service : process ATM_Service.impl;

Execution platform components

CPU : processor ATM_Processor.impl;
ATM_Memory : memory ATM_Memory.impl;
ATM_Keypad : device ATM_Keypad;
ATM_Screen : device ATM_Screen;
ATM_Printer : device ATM_Printer;
ATM_Modem : device ATM_Modem;
Card_Reader : device Card_Reader;
Cash_Dispenser : device Cash_Dispenser;
ATM_Bus : bus ATM_Bus;

Connections

cnx1: data **port** ATM_Modem.status_data ->
ATM_Service.ATM_Status;
cnx2: event data **port** customer.Card_Number_out ->
session.Card_Number_in;

Installation

Actual_Processor_**Binding** => reference CPU applies to customer;
Actual_Memory_**Binding** => reference ATM_Memory applies to account;

Operational modes

modes
IN_SERVICE : initial mode;
OUT_OF_SERVICE : mode;

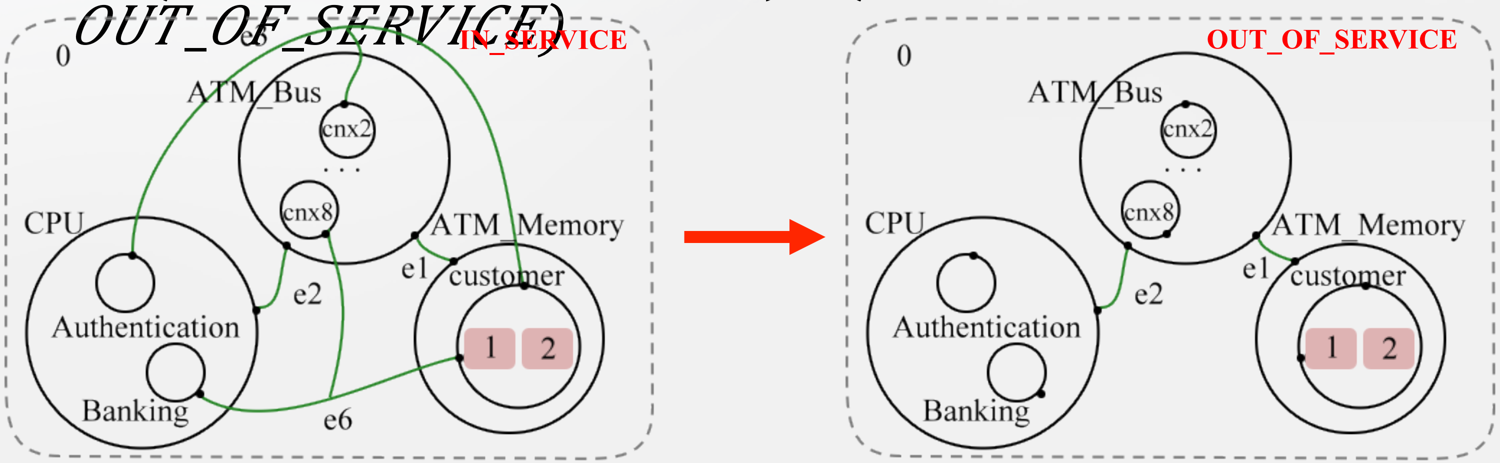
-- Mode transitions

IN_SERVICE -[ATM_Service.**OFFLINE**]-> OUT_OF_SERVICE;
OUT_OF_SERVICE -[ATM_service.**ONLINE**]-> IN_SERVICE;

Case Study: ATM System

- Exploitation of the extended BRS-based approach :

- Mode transition :
  - T : (customer, IN_SERVICE)→(customer, OUT_OF_SERVICE)



- Reaction rule :
  - $\mathcal{R}=(R{\downarrow}IN\_SERVICE\ , R{\downarrow}OUT\_OF\_SERVICE{\uparrow}'\ , \eta)$ where:
  - $R{\downarrow}IN\_SERVICE\ : 2 \rightarrow \langle 1, \emptyset \rangle$
  - $R'{\downarrow}OUT\_OF\_SERVICE\ : 2 \rightarrow \langle 1, \emptyset \rangle$
  - $\eta : 2 \rightarrow 2$

Case Study: ATM System

- Signature:

$\mathcal{K} \upharpoonright m\ (customer)$={(2, $IN\_SERVICE$), (0, $OUT\_OF\_SERVICE$)}

- $\mathcal{M}$={$IN\_SERVICE$, $OUT\_OF\_SERVICE$} is the set of operational modes.
- $K(customer)$=(2, $IN\_SERVICE$)
  - $arity(customer) = \mathbf{2}$
  - m=$IN\_SERVICE$
- $K(customer)$=(0, $OUT\_OF\_SERVICE$)
  - $arity(customer)$= $\mathbf{0}$

Linkage transformation

connectivity reconfiguration

Conclusion & Future Work

- AADL and the absence of a concrete formal model in its standard.
- A new extended BRS-based approach to model the dynamic architectural reconfiguration.
    - ❑ High-level modeling of software architecture.
- Our ongoing research focuses on handling BRS to adopt the context-aware information.

Questi ons?