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Reusing and Adapting Components using atomic and non-atomic Strong Synchronisations

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Motivation

Component-based development aims at :

- Reusing existing components.
- Facilitating the construction of very complex and huge applications.
- Reducing cost and time.
- Improving system maintainability and flexibility.

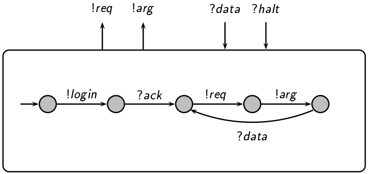
Motivation

Component Interface

- The specification of the offered or required services (operations)

Component Protocol

- Specify the ordering constraints on the exchange of messages



Components Interoperability

- The typical approach to make interoperation of heterogeneous software components possible consists of using adapters.
- An adapter is used as a component that can be plugged between the heterogeneous components,

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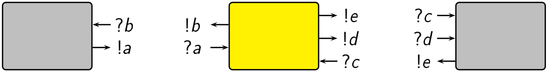

Outline

Overview

Interface Automata

Mapping Rules for Incompatible Components

Description of the adapter construction

Conclusion

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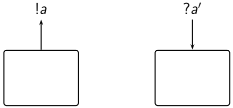
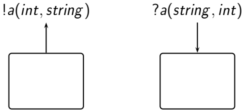
A classification of possible interface mismatches

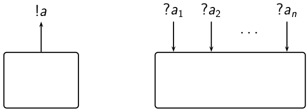
- Different names,



- Different types,

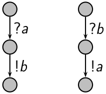


- Different structure,

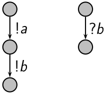


A classification of possible protocol mismatches

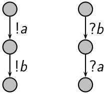
- Deadlock,



- Message missing,



- Message ordering,



Related Works

Automated generation of adapters

- Assume no interface mismatch [BP07] or matching rules given by the developer ([CMM10])
- Propose automatic building of an adaptation process for BPEL processes whose interaction may lock ([BP07])

Semi-automated adaptation

- Identification and resolution of mismatches at interface-level by using :
  - Web Ontology Language OWL and inference rules ([AA$^+$03])
  - XML schema ([MNBM$^+$07])
- Identification of mismatches at protocol-level ([MNBM$^+$07])
  - Automatic management of unspecified reception.
  - Semi-automatic management of deadlock interactions and help for contract construction.

Interface Automata

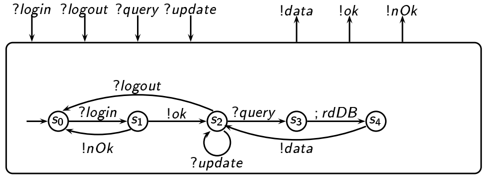
Definition

An interface automaton $A = \langle S_A, S_A^{init}, \Sigma_A, \tau_A \rangle$ *where :*

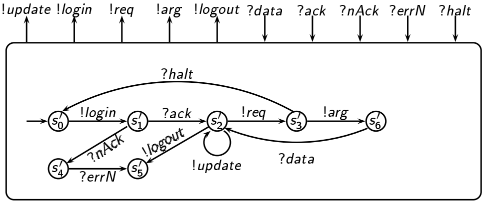
1. S_A *is a finite set of states,*
2. $S_A^{init} \subseteq S_A$ *is a set of initial states. If* $S_A^{init} = \emptyset$ *then* A *is empty,*
3. $\Sigma_A = \Sigma_A^O \cup \Sigma_A^I \cup \Sigma_A^H$ *a disjoint union of output, input and internal actions,*
4. $\tau_A \subseteq S_A \times \Sigma_A \times S_A$.

Interface Automata (Example)

Example



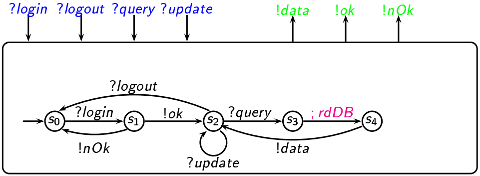
(a) Server



(b) Client

Interface Automata (Example)

Example



(a) Server

- $\Sigma^{O}_{Server} = \{ok, nOk, data\}$
- $\Sigma^{I}_{Server} = \{login, logout, query, update\}$
- $\Sigma^{H}_{Server} = \{rdDB\}$

Composition of interface automata

Let A_1 and A_2 two interface automata :

- An input action of one may coincide with a corresponding output action of the other. Such an action is called a shared action.
- We define the set $\Sigma_{shr(A_1,A_2)} = \{a \mid \delta a \in \Sigma_{A_1} \wedge \overline{\delta} a \in \Sigma_{A_2}\}$, e.g. set $\Sigma_{shr(Client,Server)} = \{login, logout, update, data\}$.
- Actions are disjoint, except shared input and output ones.
- The two automata will synchronize on shared actions, and asynchronously interleave all other actions.

Definition

Two interface automata A_1 and A_2 are composable iff

$$(\Sigma^H_{A_1} \cap \Sigma_{A_2} = \emptyset) \wedge (\Sigma^H_{A_2} \cap \Sigma_{A_1} = \emptyset) \wedge (\Sigma^I_{A_1} \cap \Sigma^I_{A_2} = \emptyset) \wedge (\Sigma^O_{A_1} \cap \Sigma^O_{A_2} = \emptyset)$$

Synchronous product of interface automata

Definition

If A_1 and A_2 are composable interface automata, their product $A_1 \otimes A_2$ is the interface automaton defined by :

1. $S_{A_1 \otimes A_2} = S_{A_1} \times S_{A_2}$,
2. $S^{int}_{A_1 \otimes A_2} = S^{int}_{A_1} \times S^{int}_{A_2}$,
3. $\Sigma^H_{A_1 \otimes A_2} = (\Sigma^H_{A_2} \cup \Sigma^H_{A_1}) \cup \Sigma_{shr(A_1,A_2)}$,
4. $\Sigma^I_{A_1 \otimes A_2} = (\Sigma^I_{A_1} \cup \Sigma^I_{A_2}) \setminus \Sigma_{shr(A_1,A_2)}$,
5. $\Sigma^O_{A_1 \otimes A_2} = (\Sigma^O_{A_1} \cup \Sigma^O_{A_2}) \setminus \Sigma_{shr(A_1,A_2)}$,
6. $\tau_{A_1 \otimes A_2} = \{(v,u), a, (v',u) \mid (v,a,v') \in \tau_{A_1} \wedge a \notin \Sigma_{shr(A_1,A_2)} \wedge u \in S_{A_2}\}$
   $\cup \{(v,u), a, (v,u') \mid (u,a,u') \in \tau_{A_2} \wedge a \notin \Sigma_{shr(A_1,A_2)} \wedge v \in S_{A_1}\}$
   $\cup \{(v,u), a, (v',u') \mid (v,a,v') \in \tau_{A_1} \wedge (u,a,u') \in \tau_{A_2} \wedge a \in \Sigma_{shr(A_1,A_2)}\}$.

Incompatible interface automata

- In the product $A_1 \otimes A_2$, one of the automata may produce an output action that is not accepted by the other. A state of $A_1 \otimes A_2$ where this occurs is called an illegal state.
- When $A_1 \otimes A_2$ contains illegal states, A_1 and A_2 can't be composed in the pessimistic approach.
- In the optimistic approach A_1 and A_2 can be composed provided that there is an adequate environment which avoids illegal states.

Incompatible interface automata

Mismatch situations between component interfaces may be caused by :

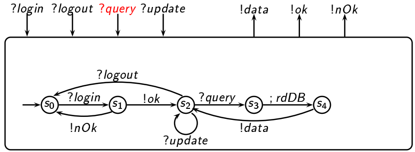
- message (services) names that do not correspond,
- an ordering of messages (services) which is not compatible,
- some messages in one component that have no counterpart (one-to-zero),
- some messages match with several messages in another component (one-to-many)

All these cases of behavioural mismatch can be worked out by using **Adapters**, to convert the exchanged information causing mismatches.

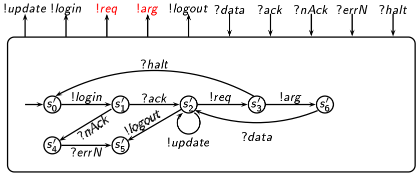
mapping rules are used to adapt exchanged action names between the components.

Mapping Rules for Incompatible Components

Consider again the components of example 1.



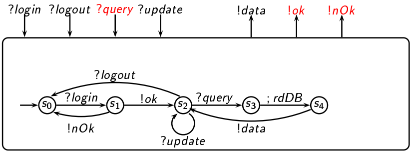
(a) Server



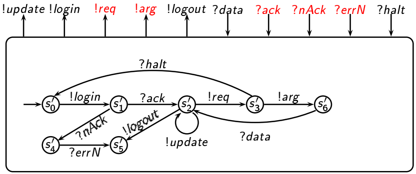
(b) Client

- In *Server* a read request is viewed into one part (?*query*), whereas it is structured as two parts (!*req*, !*arg*) in *Client*.
- A mapping rule is necessarily to map {!*req*, !*arg*} to {?*query*}.

Mapping Rules for Incompatible Components



(a) Server



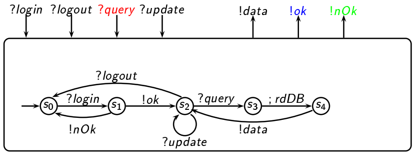
(b) Client

The sets of mapping rules between *Client* and *Server* are defined as follows :

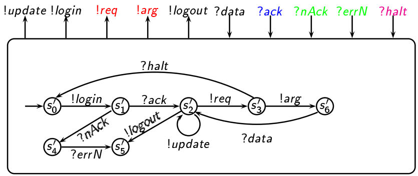
- $\Phi_{(Client,Server)} =$

  $\{ (\{ ?\mathrm{nAck}, ?\mathrm{errN} \}, \{ !\mathrm{nOk} \}), (\{ ?\mathrm{ack} \}, \{ !\mathrm{ok} \}), (\{ !\mathrm{req}, !\mathrm{arg} \}, \{ ?\mathrm{query} \})\}$

Mapping Rules for Incompatible Components



(a) Server



(b) Client

- Shared actions : $\Sigma_{shr(Client,Server)} = \{login, logout, update, data\}$.
- Mismatch actions : $\Sigma_{\Phi(Client,Server)} = \{!req, !arg, ?query, ?ack, !ok, ?nAck, !nOk, ?errN\}$
- Synchronization actions : $\Sigma_{syn(Client,Server)} = \Sigma_{shr(Client,Server)} \cup \Sigma_{\Phi(Client,Server)}$

Mapping Rules for Incompatible Components

- A mapping rule establishes correspondence between some actions of A_1 and A_2.
- Each mapping rule of A_1 and A_2 associates an action of A_1 with more actions of A_2 (one-for-more) or vice versa (more-for-one).

Definition

A mapping rule of two composable interface automata A_1 *and* A_2 *is a couple* (L_1, L_2) $\in (2^{\Sigma_{A_1}^{ext}} \times 2^{\Sigma_{A_2}^{ext}})$ *such that* $(L_1 \cup L_2) \cap \Sigma_{shr(A_1,A_2)} = \emptyset$ *and if* $|L_1| > 1$ *(resp.* $|L_2| > 1$*) then* $|L_2| = 1$ *(resp.* $|L_1| = 1$*).*

Description of the adapter construction

- The adapter is a mediator between A_1 and A_2 and aims at converting mismatch actions
- This adapter is mainly based on the set $\Phi(A_1, A_2)$.
- The adapter receives the output mismatch actions from one automaton and sends the corresponding input actions to the other.

Description of the adapter construction

- When it is plugged between A_1 and A_2 , a possible step in one automaton :
  - an internal step,
  - A communication step with the environment,
  - A shared action communication (atomic synchronisation) with the other automaton,
  - A mismatch action communication (non-atomic synchronisation) towards the other automaton, transiting by the adapter
- Whatever its kind, almost one synchronisation between the automata can be on. Therefore, a non-atomic synchronisation occurrence freezes temporally any other synchronisation between them.

Description of the adapter construction

- The protocol behaviour of the Adapter is represented by an interface automaton
- A state of the Adapter is a tuple $s =< s_1, s_2, R, O, I >$ such that :
    - s_1 and s_2 are states of A_1 and A_2, respectively.
    - R, O, I are used for non-atomic synchronisation implementation requirements
    - During the construction of the adapter R is set either to a matching rule α or to `null` :
    - Whenever $R = \alpha$, O contains the output actions already encountered, I contains the input action expected in the following states.
    - When $R =$ `null`, O and I are empty.

Description of the adapter construction

Definition

Let two composable automata A_1, A_2 and a non-empty set of mapping $\Phi(A_1, A_2)$, an adapter of A_1 and A_2 according to $\Phi(A_1, A_2)$ is an interface automaton defined by :

$$\Sigma^I_{Ad} = \{a \in \Sigma^O_{A_1} \cup \Sigma^O_{A_2} | a \in \Sigma_\Phi(A_1, A_2)\},$$

$$\Sigma^O_{Ad} = \{a \in \Sigma^I_{A_1} \cup \Sigma^I_{A_2} | a \in \Sigma_\Phi(A_1, A_2)\},$$

$$\Sigma^H_{Ad} = \{\epsilon\},$$

$$S_{A_d} = S_{A_1} \times S_{A_2} \times (\Phi(A_1, A_2) \cup \{null\}) \times 2^{\Sigma^I_{Ad}} \times 2^{\Sigma^O_{Ad}},$$

$$S^{int}_{Ad} = S^{int}_{A_1} \times S^{int}_{A_2} \times \{null\} \times \emptyset \times \emptyset,$$

Description of the adapter construction

The set τ_{Ad} are defined as follows :

1. **If** $s_1 \xrightarrow{\delta a} s'_1 \in \tau_{A_1} \wedge a \in \Sigma_{A_1} \setminus \Sigma_{syn(A_1,A_2)}$
   then $(s_1, s_2, R, O, I) \xrightarrow{\epsilon} (s'_1, s_2, R, O, I) \in \tau_{Ad}$.

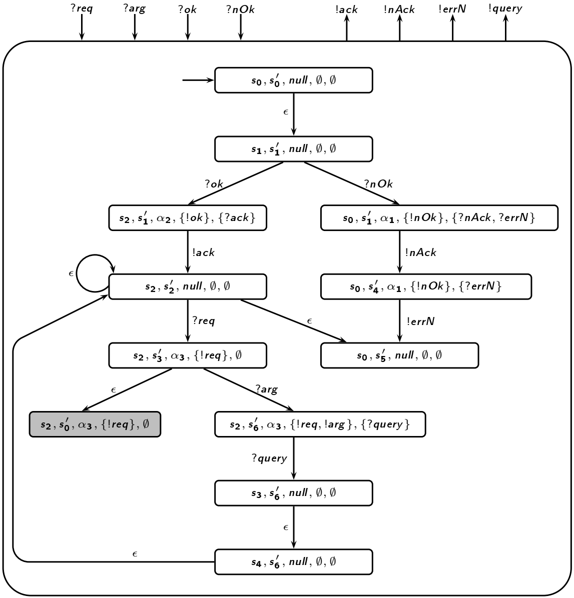
2. **If** $s_1 \xrightarrow{\delta a} s'_1 \in \tau_{A_1} \wedge s_2 \xrightarrow{\overline{\delta} a} s'_2 \in \tau_{A_2} \wedge\ R = null \wedge a \in \Sigma_{shr}(A_1, A_2)$
   then $(s_1, s_2, R, O, I) \xrightarrow{\epsilon} (s'_1, s'_2, R, O, I) \in \tau_{Ad}$.

3. **If** $s_1 \xrightarrow{!a} s'_1 \in \tau_{A_1} \wedge \exists \alpha \in \Phi(A_1, A_2)$ s.t. $a \in \Pi_1(\alpha) \wedge a \notin O \wedge (R = null \vee R = \alpha)$
   then
   - $R' \leftarrow \alpha$, $O' \leftarrow O \cup \{a\}$,
   - **If** $O' = \Pi_1(\alpha)$ **then** $I' = \Pi_2(\alpha)$ **else** $I' = I$.
   - $(s_1, s_2, R, O, I) \xrightarrow{?a} (s'_1, s_2, R', O', I') \in \tau_{Ad}$

4. **If** $s_1 \xrightarrow{?a} s'_1 \in \tau_{A_1} \wedge \exists \alpha \in \Phi(A_1, A_2)$ s.t. $a \in \Pi_1(\alpha) \wedge a \in I \wedge R = \alpha$
   then
   - $I' \leftarrow I \setminus \{a\}$,
   - **If** $I' = \emptyset$ **then** $O' \leftarrow \emptyset$, $R' \leftarrow null$ **else** $R' \leftarrow \alpha$
   - $(s_1, s_2, R, O, I) \xrightarrow{!a} (s'_1, s_2, R', O', I') \in \tau_{Ad}$

5. Adapt points 1, 3 and 4 for the automaton A_2.

Description of the adapter construction



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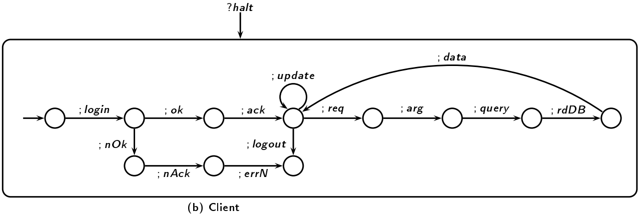

Figure : *Client* ⊗ *Adapter* ⊗ *Server*

Adapter properties

By construction, the following properties hold :

1. (*No Mixing*)
   $\forall a \in \Sigma_{shr(A_1,A_2)}$, $\forall\ s = \langle s_1, s_2, R, O, I\rangle$ a state of *Ad*,
   $\exists s_1 \xrightarrow{\delta a} s_1' \in \tau_{A_1}$ and $\exists s_2 \xrightarrow{\overline{\delta} a} s_2' \in \tau_{A_2} \Rightarrow R = null,\ O = \emptyset$ and $I = \emptyset$.
2. (*Coherence*)
   $\forall\ \sigma$ a sequence of *Ad* such that each of its state has its third field non *null*, except the states of the extremities, the following points hold :
   - The intermediate states of σ are attached to a same rule, say α.
   - Each action of α appears once and only once in σ ; the output actions of α (i.e. which are necessarily input actions of *Ad*) appear before its input ones.
   - ϵ actions may appear in σ. They come from actions which are not synchronisation between A_1 and A_2.
3. (*Illegal state*)
   Any *terminal* state $s = \langle s_1, s_2, R, O, I\rangle$ of *Ad* such that O or I are not empty indicates a **failure** of a non-atomic synchronization.

Conclusion

- we presented simple and clear automata construction for software adaptation based on mapping rules.
- we opted for a *strong* synchronisation semantic, synchronisations between same components can not be interfered.

Future works :

- Developing tools to assist designers to generate adapters.
- extend component interfaces to take into account adaptation of components with temporal constraints and verification of temporal properties.

Merci.

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