Computational Analysis of Interacting Web services: a Logical Approach

Philippe Balbiani and Fahima Cheikh

LILaC

Irit

Outline of the talk

- Model for web services
- Web services composition
- Composition problem decidability

Introduction

- Services oriented computing
- What is a Web service ?

Information system

- Structure of the form IF=(Obj,Att,Val,f)

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f	a1	a2
o1	{v1,v2}	{}
o2	{v1}	{v3}

Val={v1,v2,v3,v4,v5}

Example

- Information system for manufactured goods.

f	name	price	color
o1	{sweater}	{40}	{blue, white}
o2	{skirt}	{80}	{black, white}

Val={sweater, skirt, dress, 40, 80, blue, white, black, red }

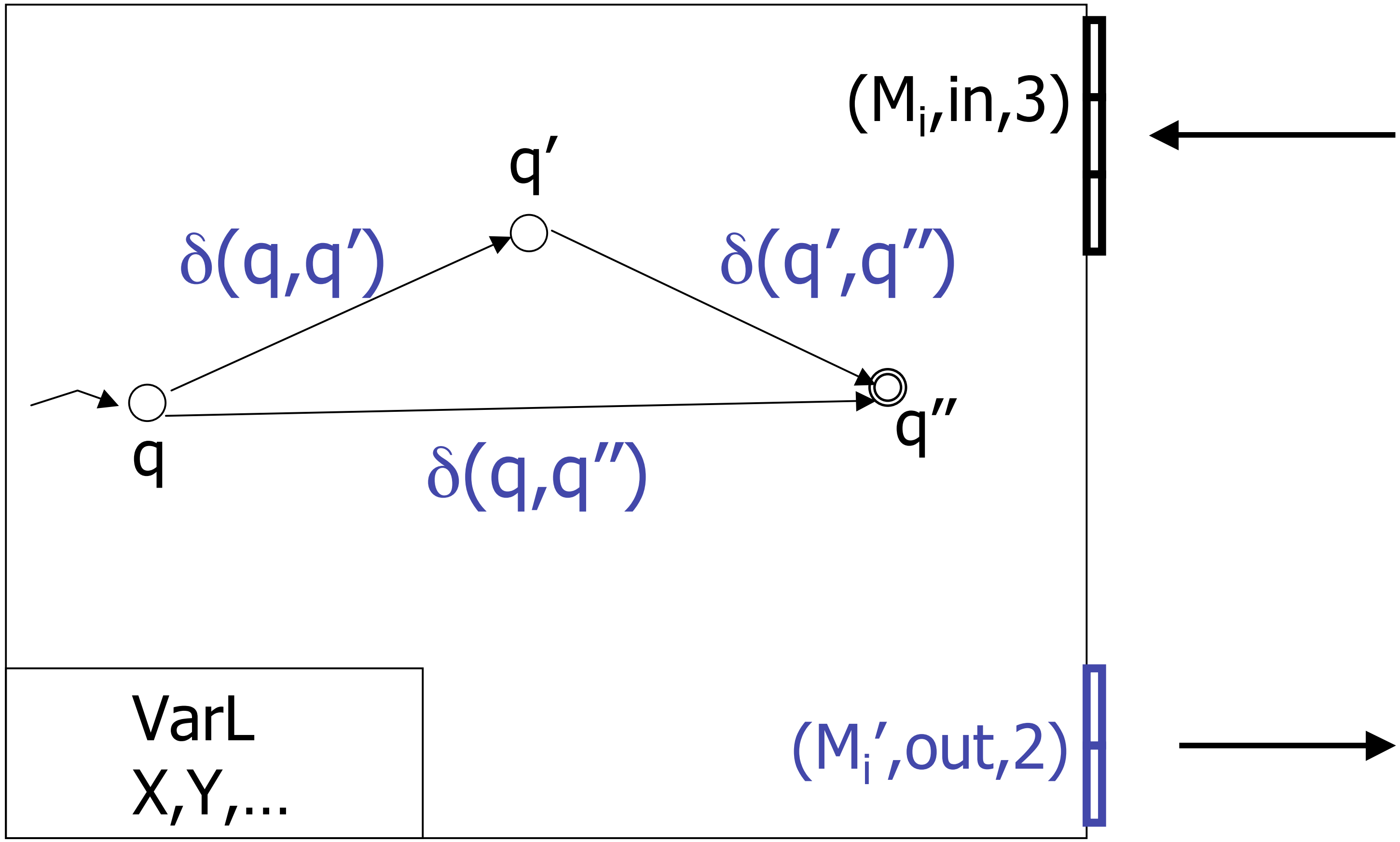
Web service

- Web service is defined w.r.t. to an information system

- It is a structure of the form $S=(Q,I,F,VarL,P,\delta)$

- Q: finite set of states
- I: set of initial states
- F: set of final states
- VarL: finite set of local variables
- P: finite set of ports
- δ: transition function

Web service



Web service S_i

Web service

- Transition function

  $\delta(q,q') = \{(C, \alpha) \mid C$ is a condition, α is a sequence of primitive operations$\}$

- Condition

$$C := T \mid (\theta_1 = \theta_2) \mid (\theta \in f(z,a)) \mid \neg C \mid (C_1 \wedge C_2) \mid \exists z\, C$$

θ : local variable or a value in Val

z : variable ranging over Obj

a : attribute in Att

Web service

- primitive operations

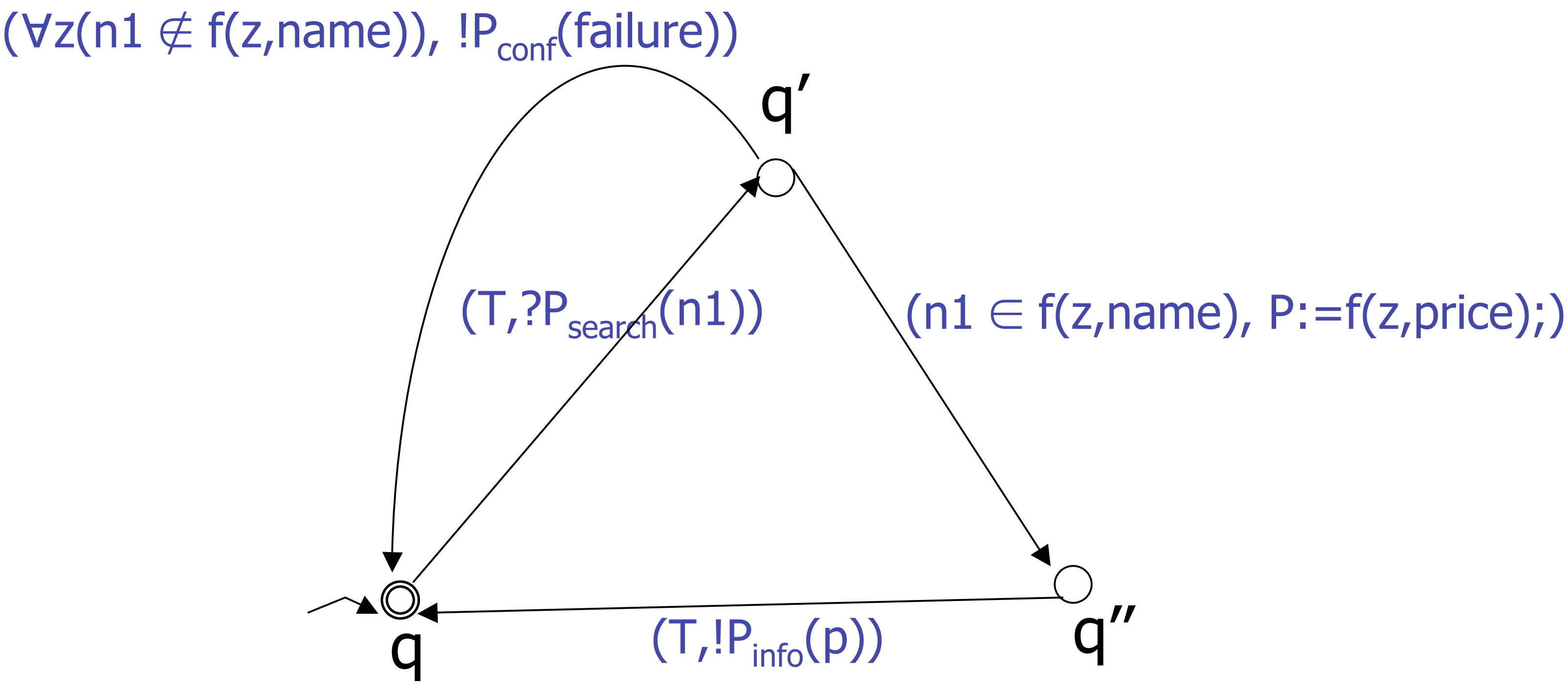
- create object Z
- destroy object z
- add θ to f(z,a)
- delete θ from f(z,a)

IF update

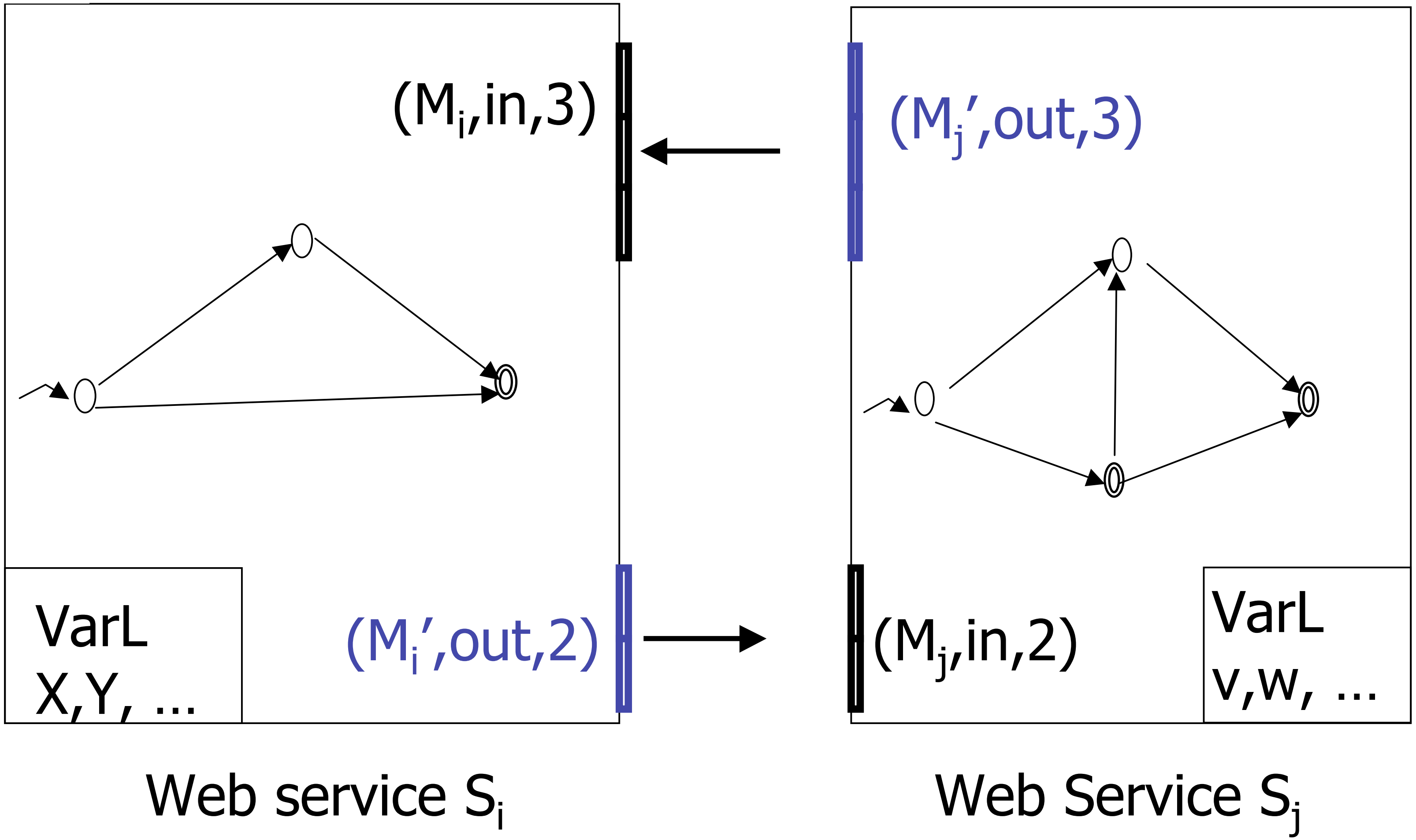
- x:= θ — allocate a value

- ?M(θ1,…, θn) — receive a message
- !M′(θ1,…, θm) — send a message

Example


(∀z(n1 ∉ f(z,name)), !P_conf(failure))
q′
(T,?P_search(n1))
(n1 ∈ f(z,name), P:=f(z,price);)
q
(T,!P_info(p))
q″

Web service



(M_i,in,3)
(M_j',out,3)
VarL
X,Y, ...
(M_i',out,2)
(M_j,in,2)
VarL
v,w, ...
Web service S_i
Web Service S_j

Link

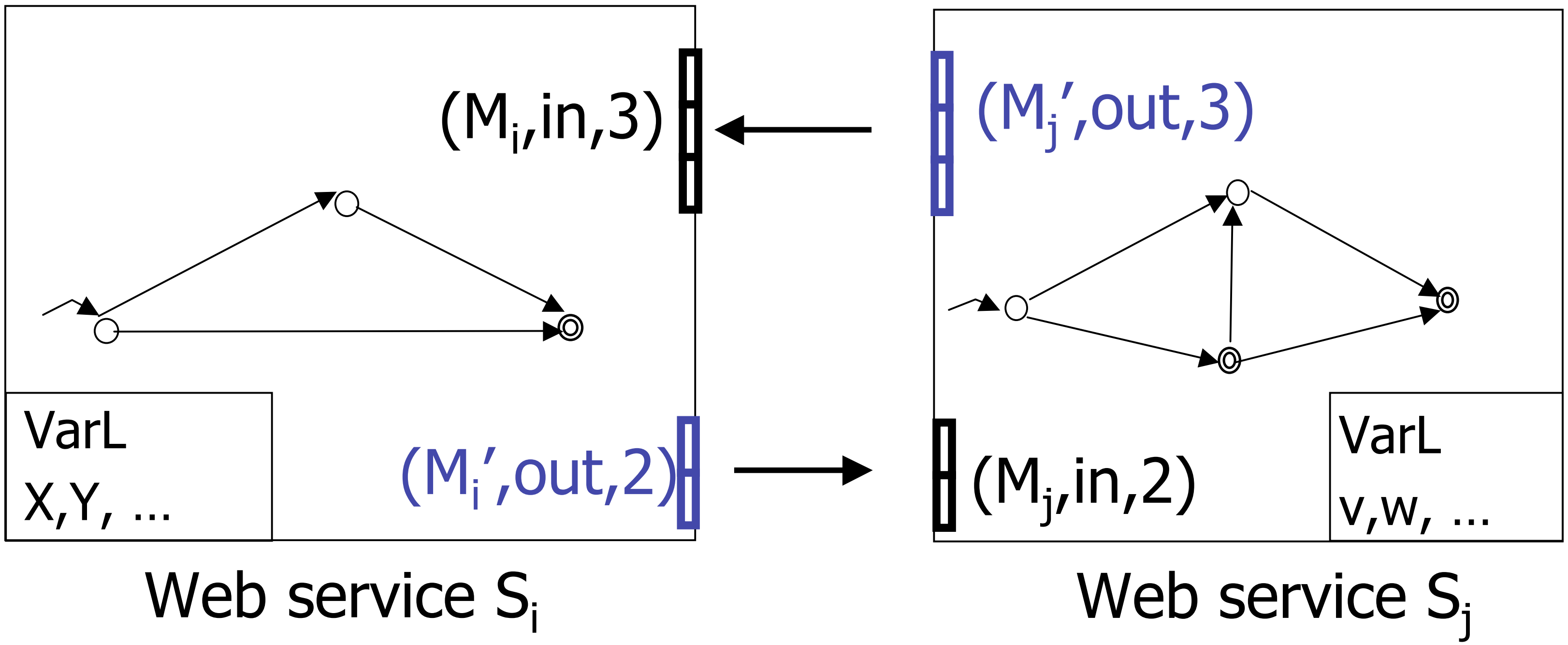
- $C=\{S_0,\ldots,S_n\}$ set of services
- P_i, $i \in \{0,\ldots,n\}$ set of S_i ports
- A C-link L is a binary relation on $P_0 \cup P_1 \cup \ldots \cup P_n$
- L is defined such that:

  - if (M,d,m) L (M',d',m') then d=in, d'=out, m=m'

  - if (M,d,m) L (M',d',m') and (M,d,m) L (M'',d'',m'') then M'=M''

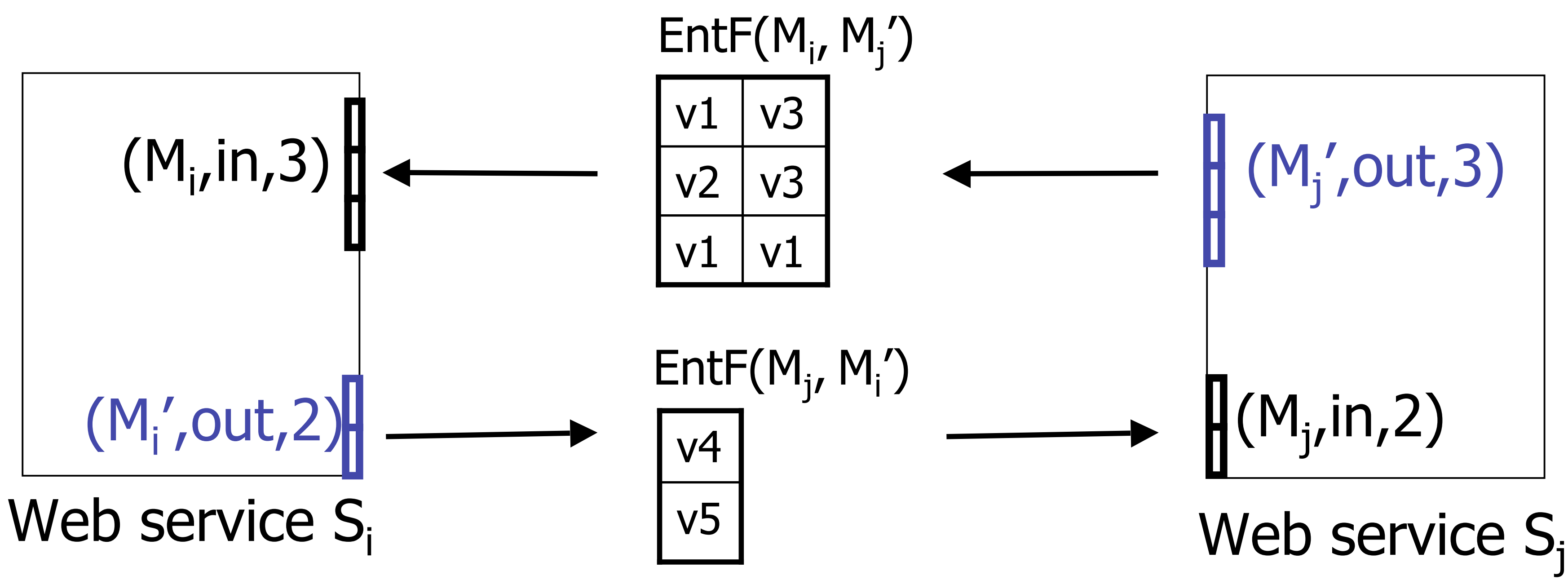
  - if (M,d,m) L (M'',d'',m'') and (M',d',m') L (M'',d'',m'') then M=M'

Example



- $L=\{(M_i,M_j'),(M_j,M_i')\}$

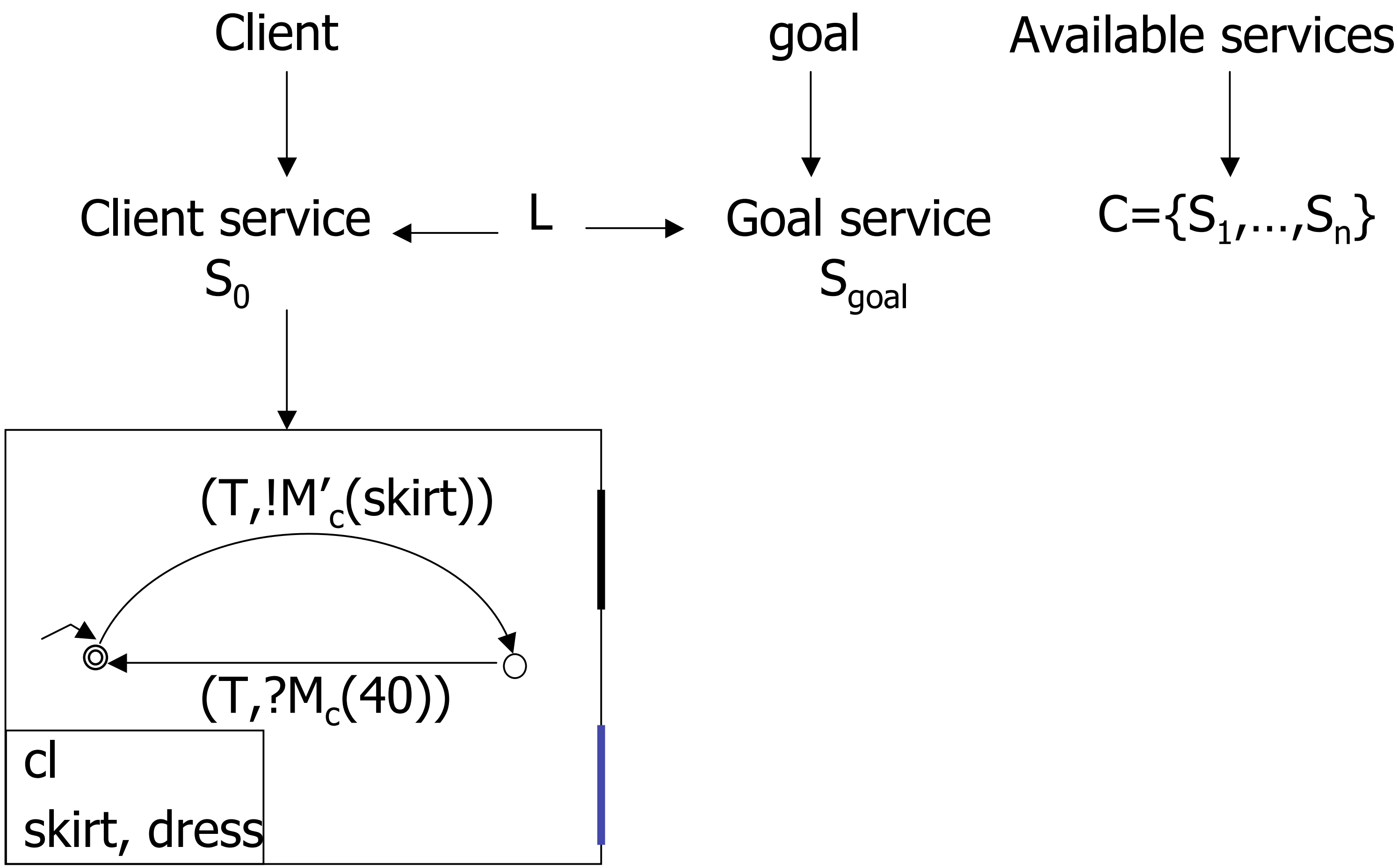
Queue



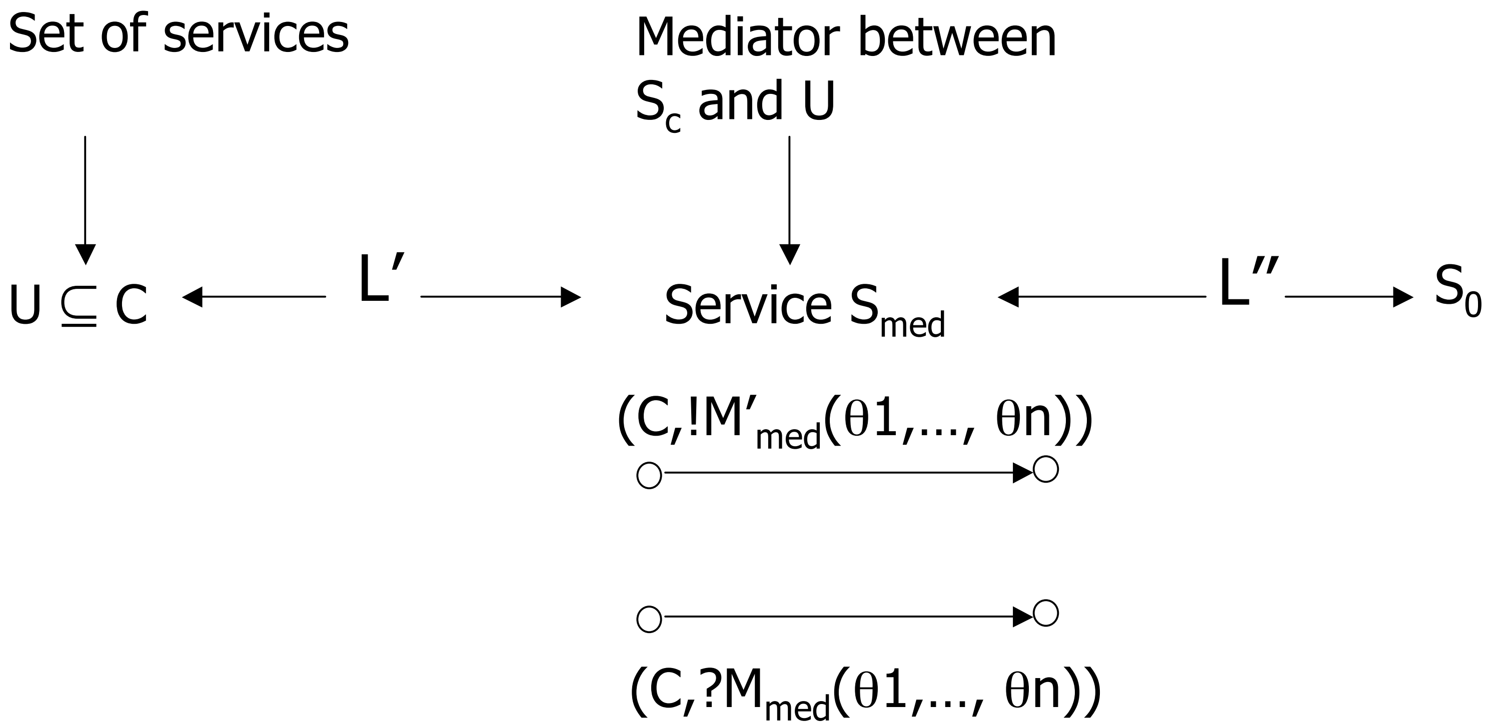
EntF(Mi, Mj')
v1 v3
v2 v3
v1 v1
(Mi,in,3)
(Mj',out,3)
EntF(Mj, Mi')
v4
v5
(Mi',out,2)
(Mj,in,2)
Web service Si
Web service Sj

What is the composition problem?

Input


Client
goal
Available services
Client service
S_0
L
Goal service
S_{goal}
$C=\{S_1,\ldots,S_n\}$
$(T,!M'_c(skirt))$
$(T,?M_c(40))$
cl
skirt, dress

Output



- The behavior of $\{S_0, S_{med}, U\}$ is equivalent to that of $\{S_0, S_{goal}\}$

Nodes

- A node, in a tree for $C=\{S_0,\ldots,S_n\}$ and a C-link L, is a structure of the form

  $\Delta=(IF, q_0,\ldots, q_n, int_0,\ldots,int_n, EntF, cl)$

  - IF: information system

  - q_i: state of S_i

  - int_i: $VarL_i \rightarrow Val$

  - EntF: $(M,M') \in L \rightarrow EntF(M,M')$

  - cl: finite set of values

Edges

$(IF, q_0,\ldots,q_i,\ldots, q_n,int_0,\ldots int_i,\ldots,int_n,EntF,cl)$

α

$(IF', q_0,\ldots,q'_i,\ldots, q_n,int_0 ,\ldots int'_i,\ldots, int_n,EntF,cl)$

$(IF, q_0,\ldots,q_i,\ldots, q_n,int_0,\ldots int_i,\ldots,int_n,EntF,cl)$

$?M(\theta 1,\ldots, \theta m)$

$EntF(M,M')\neq\emptyset$

$(M,M') \in L$

$(IF, q_0,\ldots,q'_i,\ldots, q_n,int_0 ,\ldots int'_i,\ldots, int_n,EntF',cl)$

Equivalence between trees

- Two trees T and T' are embedding equivalent if T is included in T'

- Two trees T and T' are weakly equivalent if T and T' are similar

Composition problem

- Input: client service S_0, goal service S_{goal}, link L for S_0 and S_{goal}, and finite set $C=\{S_1,\ldots,S_n\}$

- Output: determines if there exists a subset U of C, a mediator service S_{med}, a link L' for S_{med} and S_0 and, a link L" for S_{med} and U such that:

∀ IF tree(S_0, S_{goal}, L, IF) is embedding (resp. weakly) equivalent to tree (S_0 , S_{med}, L',U, L", IF)

Decidability

- Theorem 1

The embedding composition problem is undecidable

Proof. We reduce the uniform halting problem of Minsky machines to the embedding composition problem

Decidability

- Theorem 2

The weakly composition problem is undecidable

Proof. We reduce the 0-halting problem of Minsky machines to the weakly composition problem

Decidability

Some restrictions:

- There is no condition in the transitions
- Queues' length is limited to at most 1 message
- Service mediator has at most k states and b ports

Decidability

- Theorem 3

The weakly composition problem is decidable, when restrictions above are considered

Proof. 1- The number of all possible U, S_{med} L′ and L″ is bounded and countable

2- L(T) and L(T′) are rational

Conclusion

- Composition problem decidability
- Services and safety policies
- Services and cryptographic protocols