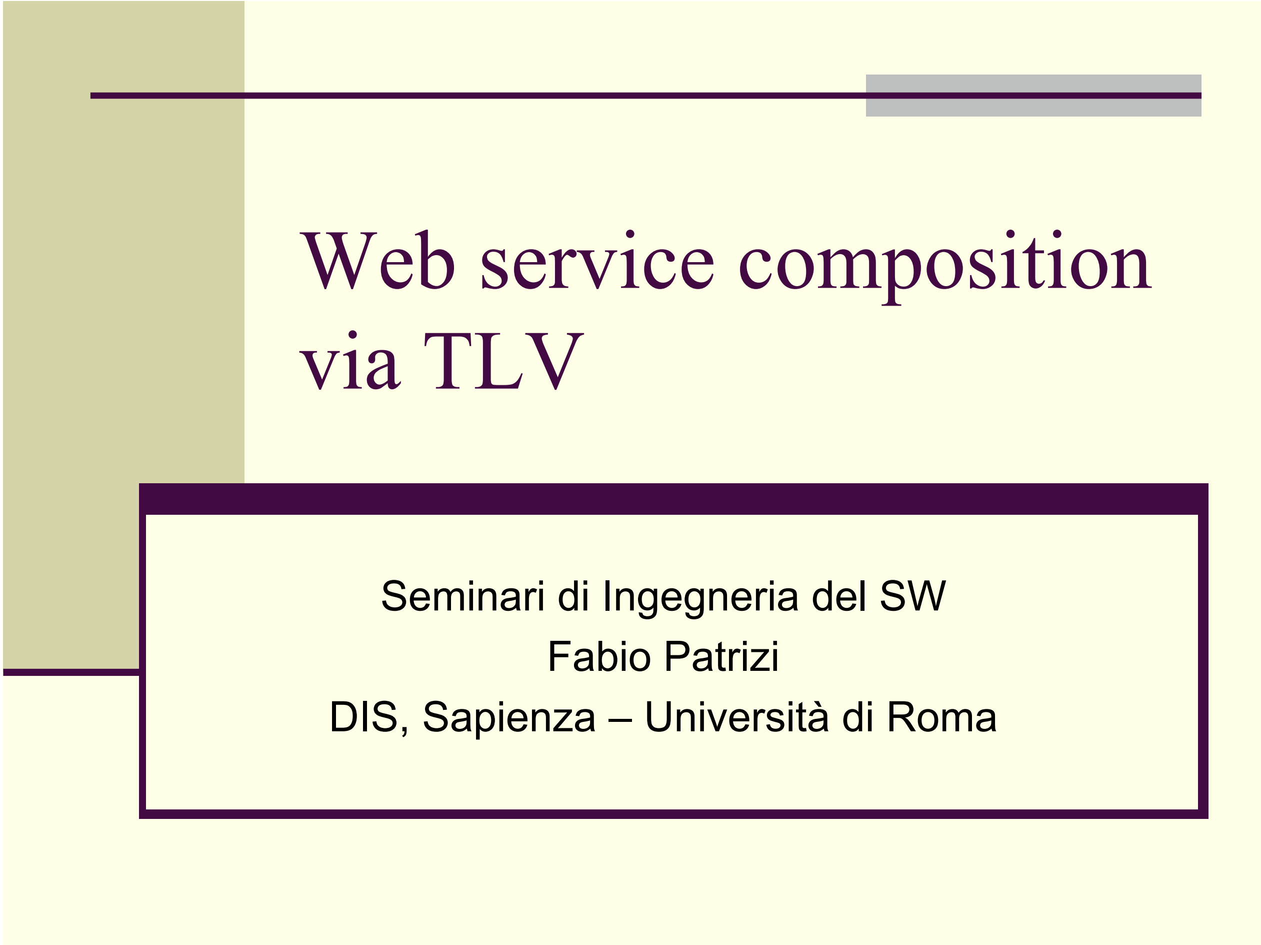

Web service composition via TLV

Seminari di Ingegneria del SW
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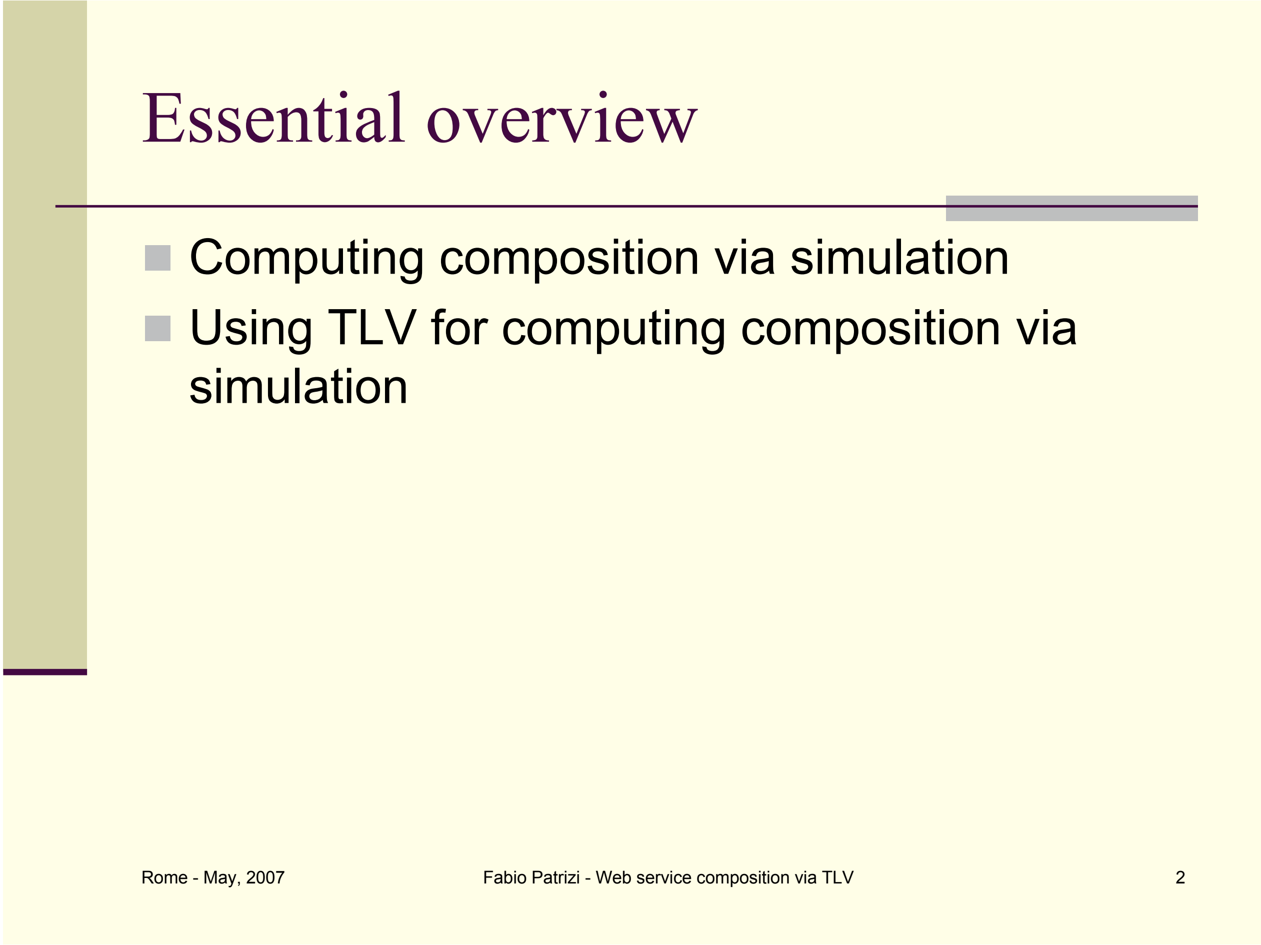
DIS, Sapienza – Università di Roma



Essential overview

- Computing composition via simulation
- Using TLV for computing composition via simulation

The Problem

Given:

- a community of available services

$$\mathcal{C} = \{S_{1},\dots,S_{n}\};$$

- a target service

$$T;$$

Find a *composition* (or *orchestrator*) s.t.

$$\mathcal{C} \text{ mimicks } T$$

The Problem (cont.)

We model services as transition systems:

Finding a composition

Strategies for computing compositions:

- Reducion to PDL
- Simulation-based ←

Simulation Relation

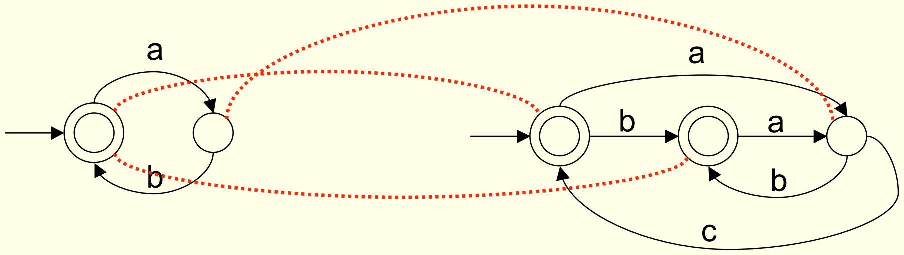
Intuition:

a service S can simulate T if it can reproduce T’s behavior over time.

Simulation Relation (cont.)

Simulation Relation (cont.)

T: :



Can $\mathcal{C}$ simulate T?

YES!

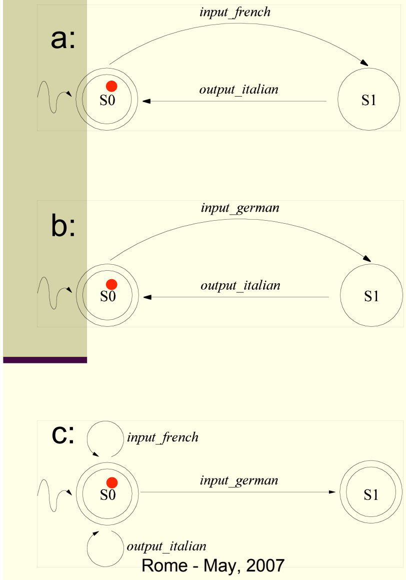
Computing composition via simulation

Idea:

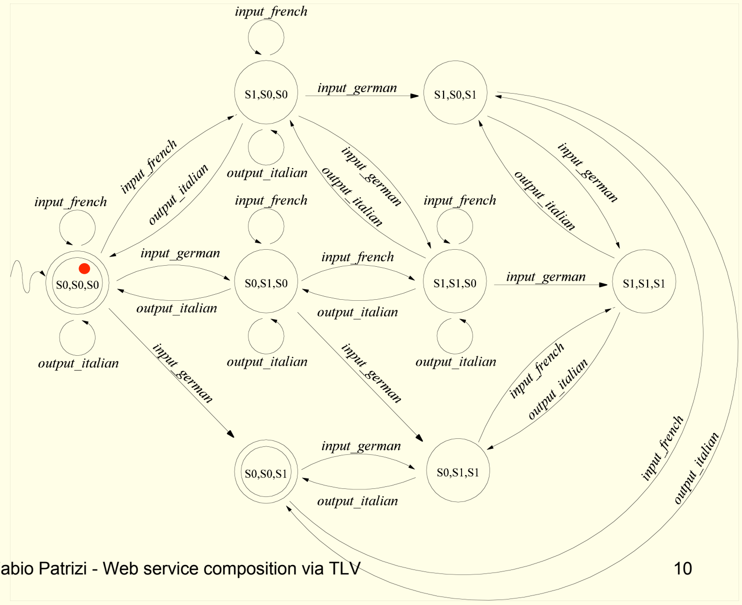
A service community can be seen as the (possibly N-DET) *asynchronous product* of available services…

Computing composition via simulation (cont.)

Available services



Community TS



Computing composition via simulation (cont.)

Idea:

Theorem:

A composition exists if and only if $\mathcal{C}$ simulates T

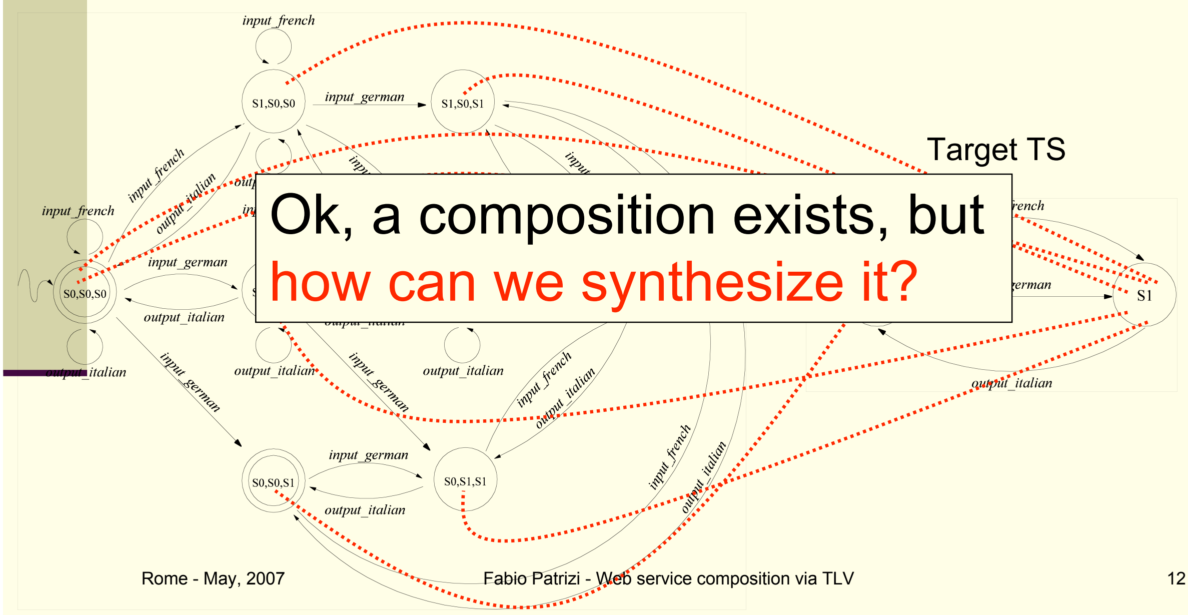
… thus, the problem becomes:

“Can the community TS $\mathcal{C}$ simulate target service T?”

Computing composition via simulation (cont.)

Community TS

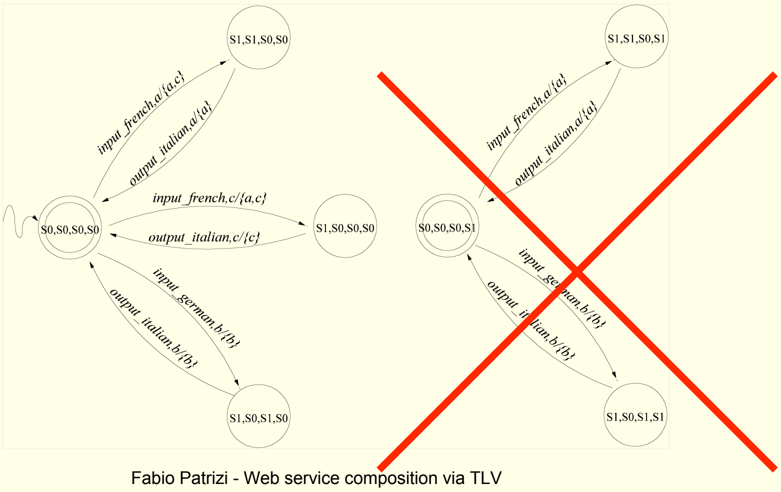
Target TS



Ok, a composition exists, but how can we synthesize it?

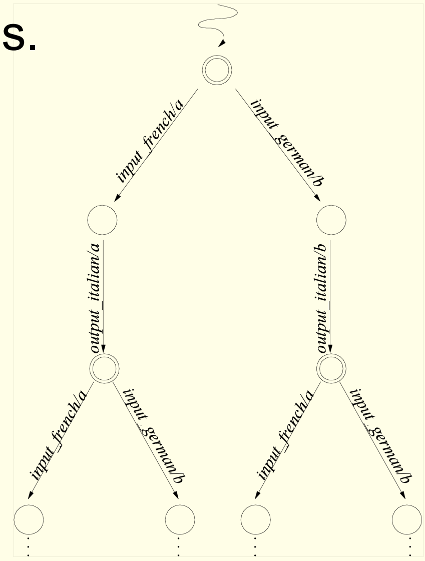
Computing composition via simulation (cont.)

- From the maximal simulation, we can easily derive an *orchestrator generator, e.g.:*



Computing composition via simulation (cont.)

From OG, one can select services to perform client actions.



Comments

- *Full observability* is crucial for OG to work properly. In fact, in order to propose services for action execution, state of each available service *needs* to be known.
- This technique is well-suited for deterministic target and available services.
- Interesting extension: dealing with nondeterministic (devilish) available services (a slightly different notion of simulation is needed).

Such points are object of current/future work.

Computing composition via simulation (cont.)

Summing up:

- Compute community TS $\mathcal{C}$;
- Compute the maximal simulation of T by $\mathcal{C}$;
-
  - If simulation exists, compute OG;
  - else return “unrealizable”;
- Exploit OG for available service selection, even in a *just-in-time* fashion.

Essential overview (2)

- Computing composition via simulation
  - Any questions?
- Using TLV for computing composition via simulation

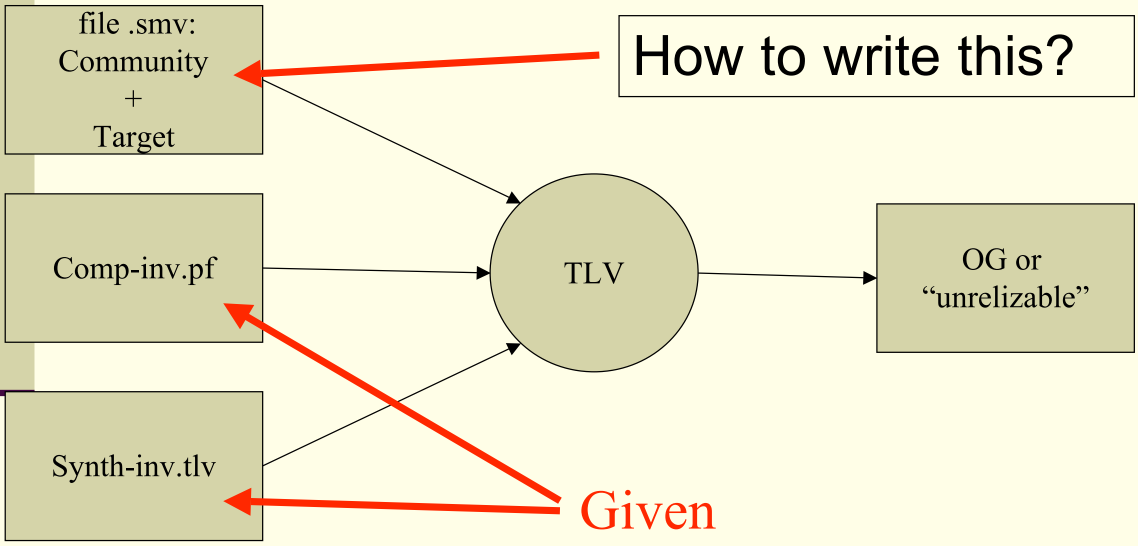
Composing services via TLV

The environment TLV (Temporal Logic Verifier) [Pnueli and Shahar, 1996] is a useful tool that can be used to

automatically compute the orchestrator generator,

given a problem instance.

Composing services via TLV (cont.)



file .smv:
Community
+
Target

How to write this?

Comp-inv.pf

TLV

OG or
“unrelizable”

Synth-inv.tlv

Given

Composing services via TLV (cont.)

We provide TLV a file written in (a flavour of) SMV, a language for specifying TSs.

- SMV specifications are tipically composed of *modules, properly interconnected;*
- Intuitively, a module is a *sort of TS* which may share variables with other modules;
- A module may contain several submodules, properly synchronized;
- Module main is mandatory and contains all relevant modules, properly interconnected and synchronized.

Composing services via TLV (cont.)

A name dule:

parameter(s)

initialization

internal variable(s)

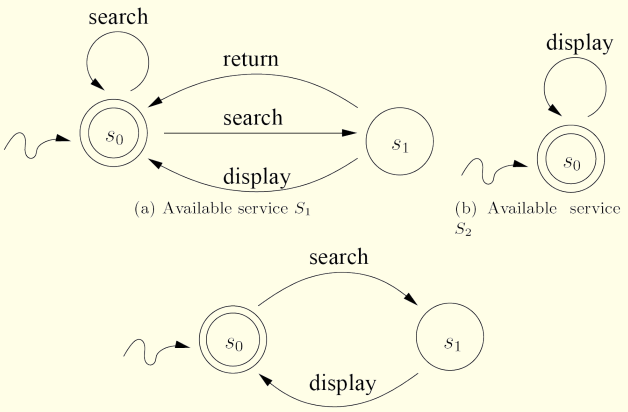
transition relation

```
MODULE mT1(act)
VAR
  loc : 0..1;
ASSIGN
  init(loc) := 0;
  init(act) := nil;
  next(loc) :=
          case
                 loc = 0 & act = search  : 1;
                 loc = 1 & act = display : 0;
                 TRUE                    : loc;
          esac;
  next(act) :=
          case
                 act = nil               : {search};
                 loc = 0 & act = search  : {display};
                 loc = 1 & act = display : {search};
                 TRUE                    : {act};
          esac;
DEFINE
      final := (loc = 0);
```

boolean expression

Composing services via TLV (cont.)

We introduce SMV formalization by means of the following example, proceeding top-down:



(a) Available service S_1

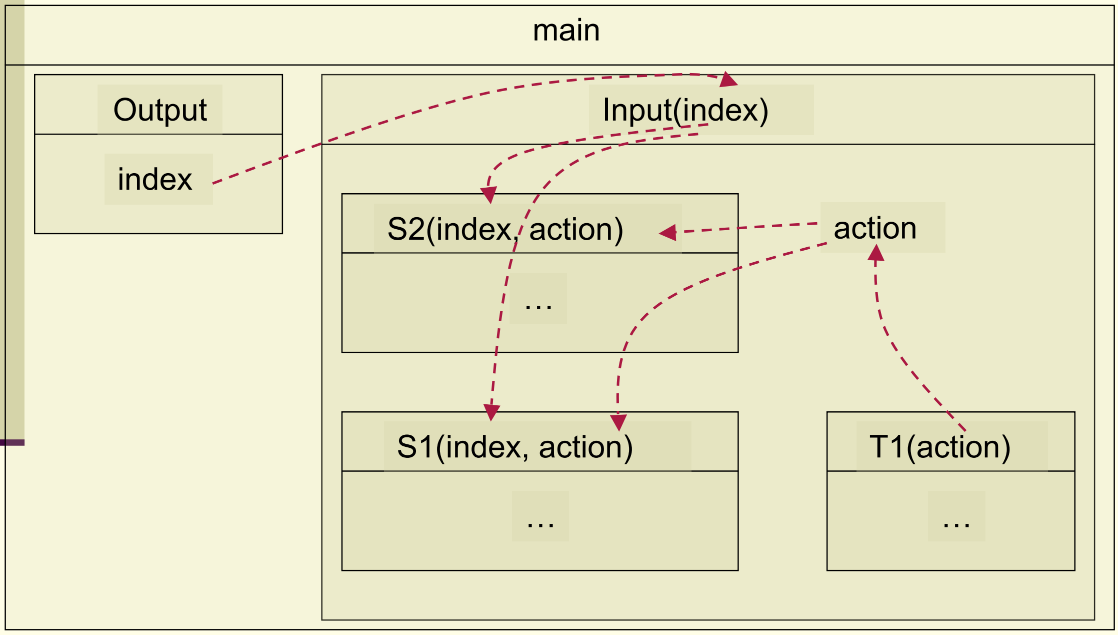
(b) Available service S_2

(c) Target service T_1

Composing services via TLV (cont.)

- The application is structured as follows:
  - 1 module main
  - 1 module Output, representing OG service selection
  - 1 module Input, representing the (synchronous) interaction community-target
  - 1 module mT1 representing the target service
  - 1 module mSi per available service

Module interconnections



main

Output

index

Input(index)

S2(index, action)

…

action

S1(index, action)

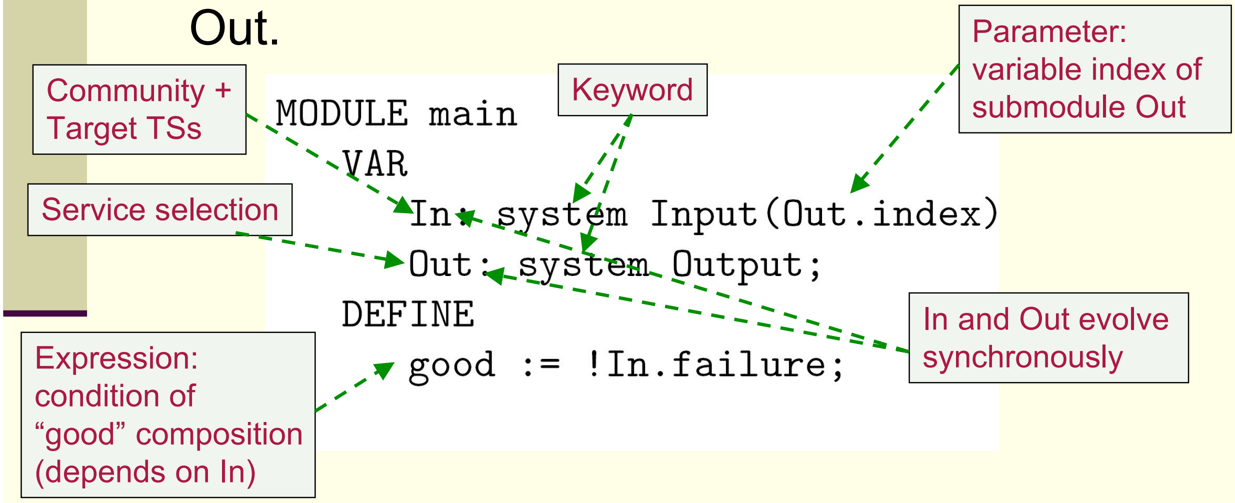
…

T1(action)

…

The module main

- Instance independent
- Includes synchronous submodules In and Out.

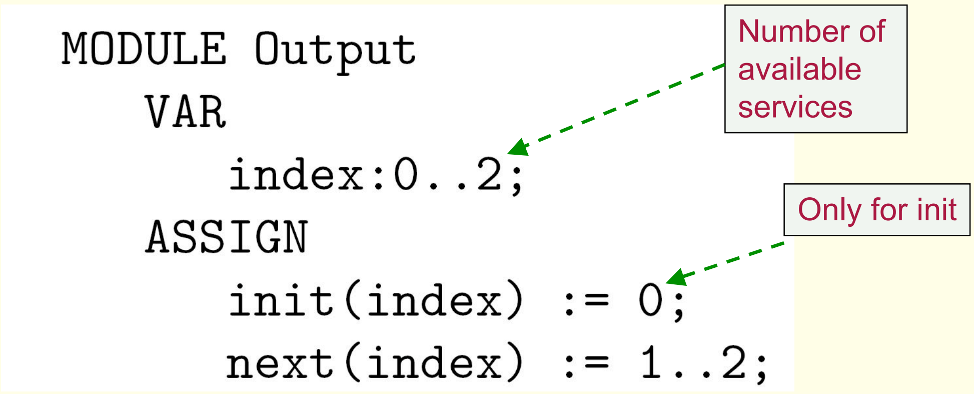


```
MODULE main
  VAR
    In: system Input(Out.index)
    Out: system Output;
  DEFINE
    good := !In.failure;
```

Community + Target TSs
Keyword
Parameter: variable index of submodule Out
Service selection
In and Out evolve synchronously
Expression: condition of “good” composition (depends on In)

The module Output

- Depends on number of available services. In this case: 2



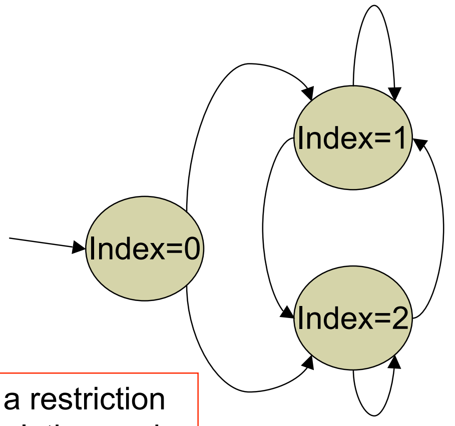
```
MODULE Output
  VAR
    index:0..2;
  ASSIGN
    init(index) := 0;
    next(index) := 1..2;
```

The module Output (cont.)

```
MODULE Output
    VAR
        index:0..2;
    ASSIGN
        init(index) := 0;
        next(index) := 1..2;
```

```
MODULE main
   VAR
      In: system Input(Out.index)
      Out: system Output;
   DEFINE
      good := !In.failure;
```

Synchronized



The goal is computing a restriction on Output's transition relation such that good is satisfied. RECALL that In is affected by Out through parameter Out.index

The module Input

Action alphabet + special action nil (used for init)

Target service

Available service 1

Available service 2

```
MODULE Input(index)
VAR
   action : {nil,search,display,return};
   T1 : mT1(action);
   S1 : mS1(index,action);
  S2 : mS2(index,action);
DEFINE
  failure := (S1.failure | S2.failure) |
             !(T1.final -> (S1.final & S2.final));
```

Fail if:

- S1 or S2 (… or SN) fail, OR
- T1 can be in a final state when S1 or S2 (… or SN) are not.

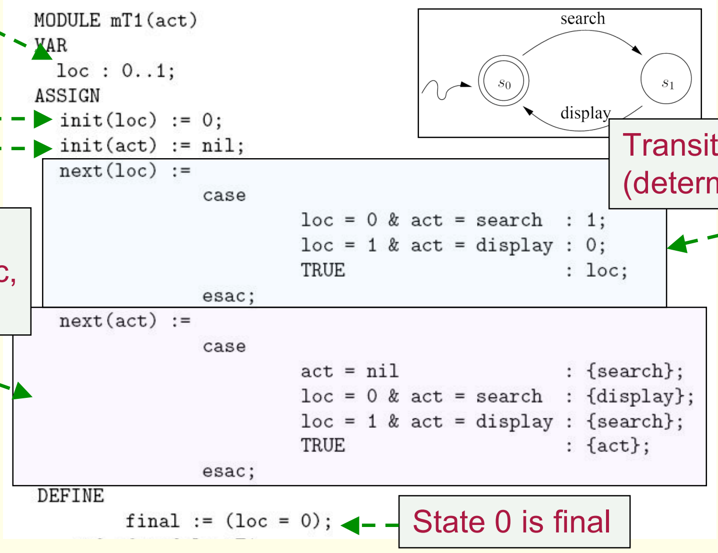
The target module mT1

- Think of mT1 as an action producer

TS States

Init

Output relation (non-deterministic, in general)

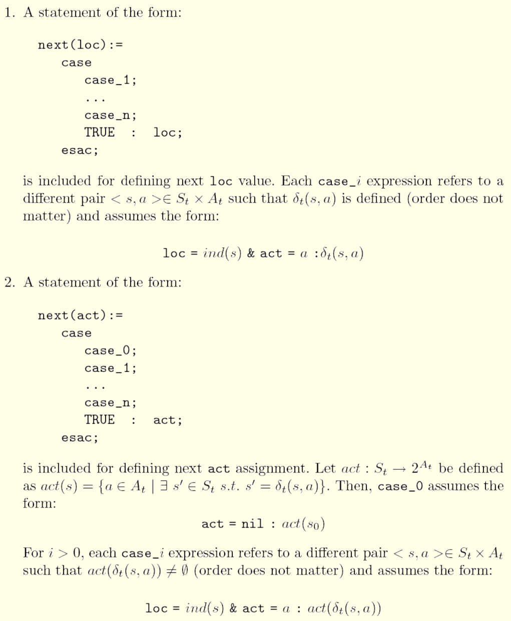


```
MODULE mT1(act)
VAR
  loc : 0..1;
ASSIGN
   init(loc) := 0;
   init(act) := nil;
   next(loc) :=
               case
                       loc = 0 & act = search  : 1;
                       loc = 1 & act = display : 0;
                       TRUE                    : loc;
               esac;
   next(act) :=
               case
                       act = nil               : {search};
                       loc = 0 & act = search  : {display};
                       loc = 1 & act = display : {search};
                       TRUE                    : {act};
               esac;
DEFINE
        final := (loc = 0);
```

Transition function (deterministic, in general)

State 0 is final

The target module mT1 (cont.)



1. A statement of the form:

```
next(loc):=
   case
      case_1;
      ...
      case_n;
      TRUE  :  loc;
   esac;
```

is included for defining next `loc` value. Each `case_`i expression refers to a different pair $< s, a >\in S_t \times A_t$ such that $\delta_t(s, a)$ is defined (order does not matter) and assumes the form:

$$\texttt{loc = } ind(s) \texttt{ \& act = } a \ :\delta_t(s, a)$$

2. A statement of the form:

```
next(act):=
   case
      case_0;
      case_1;
      ...
      case_n;
      TRUE  :  act;
   esac;
```

is included for defining next `act` assignment. Let $act : S_t \rightarrow 2^{A_t}$ be defined as $act(s) = \{a \in A_t \mid \exists\ s' \in S_t\ s.t.\ s' = \delta_t(s, a)\}$. Then, `case_0` assumes the form:

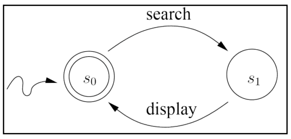
$$\texttt{act = nil} \ :\ act(s_0)$$

For $i > 0$, each `case_`i expression refers to a different pair $< s, a >\in S_t \times A_t$ such that $act(\delta_t(s, a)) \neq \emptyset$ (order does not matter) and assumes the form:

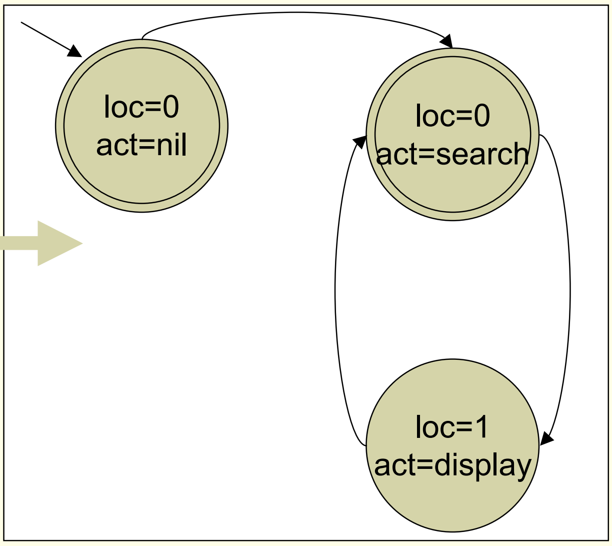
$$\texttt{loc = } ind(s) \texttt{ \& act = } a \ :\ act(\delta_t(s, a))$$

The target module mT1 (cont.)

```
MODULE mT1(act)
VAR
  loc : 0..1;
ASSIGN
  init(loc) := 0;
  init(act) := nil;
  next(loc) :=
             case
                      loc = 0 & act = search  : 1;
                      loc = 1 & act = display : 0;
                      TRUE                    : loc;
             esac;
  next(act) :=
             case
                      act = nil               : {search};
                      loc = 0 & act = search  : {display};
                      loc = 1 & act = display : {search};
                      TRUE                    : {act};
             esac;
DEFINE
       final := (loc = 0);
```



```
MODULE Input(index)
VAR
  action  : {nil,search,display,return};
  T1 : mT1(action);
  S1 : mS1(index,action);
 S2 : mS2(index,action);
DEFINE
 failure := (S1.failure | S2.failure) |
            !(T1.final -> (S1.final & S2.final));
```



The available service module mS1

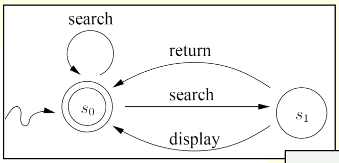
externally controlled (input parameters)

If service is not selected… … remain still!

service selection

Check whether assigned action is actually executable. Directly derived from transition relation.

```
MODULE mS1(index,action)
    VAR
       loc : 0..1;
    ASSIGN
       init(loc) := 0;
       next(loc) :=
          case
             index != 1                               : loc;
             loc=0 & action in {search}              : {0,1};
             loc=1 & action in {display,return}      : {0};
             TRUE                                     : loc;
          esac;
    DEFINE
       failure :=
          index = 1 &
          !(
             (loc = 0 & action in {search})|
             (loc = 1 & action in {display, return})
          );
       final := (loc = 0);
```



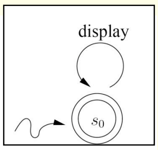
Transition relation (ND, in general)

Sets, instead of elements.

next(action) missing!

The available service module mS2

```
MODULE mS2(index,action)
  DEFINE
    failure :=
      index = 2 & !(action in {display});
      final := TRUE;
```



Stateless system: neither states nor transition relation needed

Putting things together

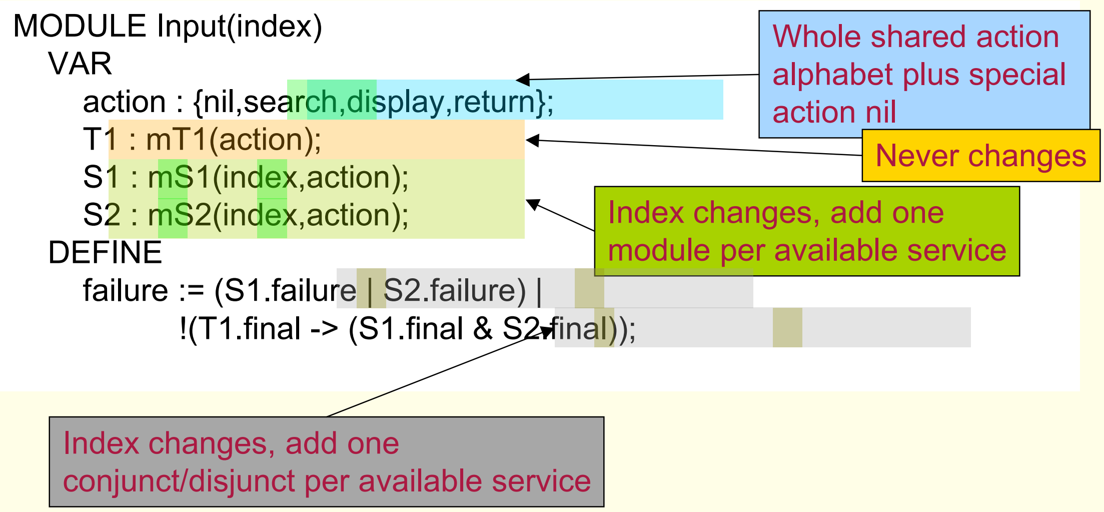
```
MODULE main
   VAR
      In: system Input(Out.index);
      Out: system Output;
   DEFINE
      good := !In.failure;
```

Never changes

```
MODULE Output
   VAR
      index:0..2;
   ASSIGN
      init(index) := 0;
      next(index) := 1..2;
```

Number of available services

Putting things together (cont.)



```
MODULE Input(index)
   VAR
      action : {nil,search,display,return};
      T1 : mT1(action);
      S1 : mS1(index,action);
      S2 : mS2(index,action);
   DEFINE
      failure := (S1.failure | S2.failure) |
              !(T1.final -> (S1.final & S2.final));
```

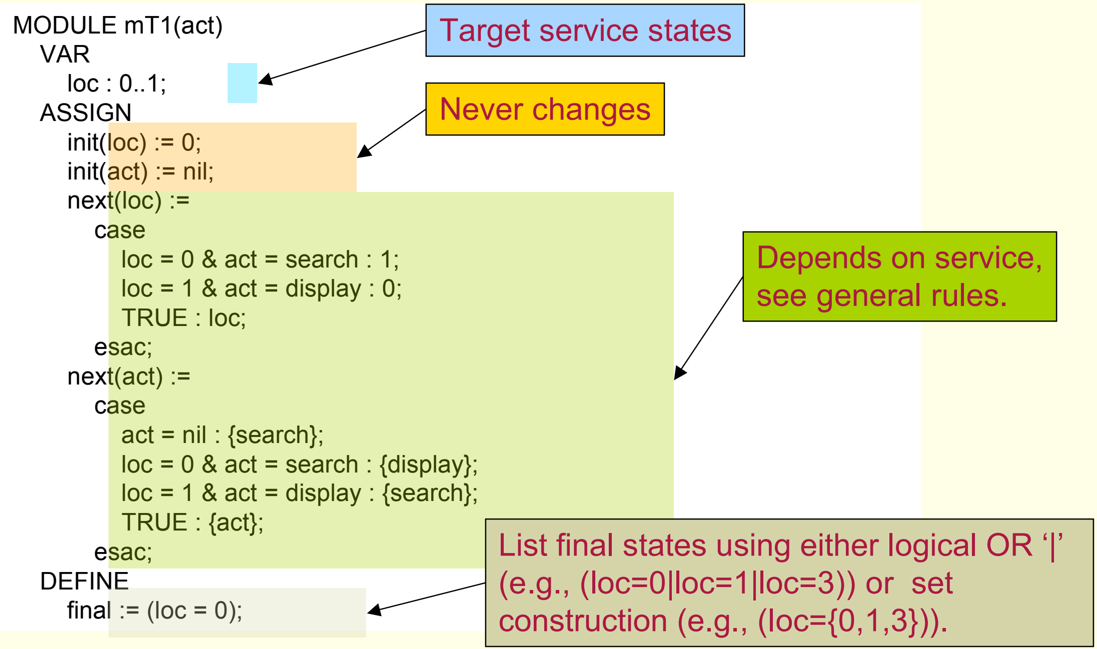
Whole shared action alphabet plus special action nil

Never changes

Index changes, add one module per available service

Index changes, add one conjunct/disjunct per available service

Putting things together (cont.)



```
MODULE mT1(act)
   VAR
      loc : 0..1;
   ASSIGN
      init(loc) := 0;
      init(act) := nil;
      next(loc) :=
         case
            loc = 0 & act = search : 1;
            loc = 1 & act = display : 0;
            TRUE : loc;
         esac;
      next(act) :=
         case
            act = nil : {search};
            loc = 0 & act = search : {display};
            loc = 1 & act = display : {search};
            TRUE : {act};
         esac;
   DEFINE
      final := (loc = 0);
```

Target service states

Never changes

Depends on service, see general rules.

List final states using either logical OR ‘|’ (e.g., (loc=0|loc=1|loc=3)) or set construction (e.g., (loc={0,1,3})).

Putting things together (cont.)

```
MODULE mS1(index,action)
   VAR
      loc : 0..1;
   ASSIGN
      init(loc) := 0;
      next(loc) :=
         case
            index != 1 : loc;
            loc=0 & action in {search} : {0,1};
            loc=1 & action in {display,return} : {0};
            TRUE : loc;
         esac;
      DEFINE
         failure :=
            index = 1 &

                     0 & action in {search} )|
                     1 & action in {display, return})
            );
            final := (loc = 0);
```

Available service states

Never changes

Depends on service, see general rules.

Index changes. Same as module name

Putting things together (cont.)

```
MODULE mS2(index,action)
   DEFINE
      failure :=
         index = 2 & !(action in {display});
      final := TRUE;
```

Running the specification

Running TLV with our specification as input…

State 1
In.action = nil, In.T1.loc = 0, In.S1.loc = 0, Out.index = 0,

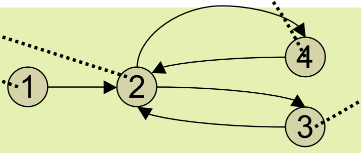
State 2
In.action = search, In.T1.loc = 0, In.S1.loc = 0, Out.index = 1,

State 3
In.action = display,In.T1.loc = 1, In.S1.loc = 0, Out.index = 2,

State 4
In.action = display,In.T1.loc = 1, In.S1.loc = 1, Out.index = 1,

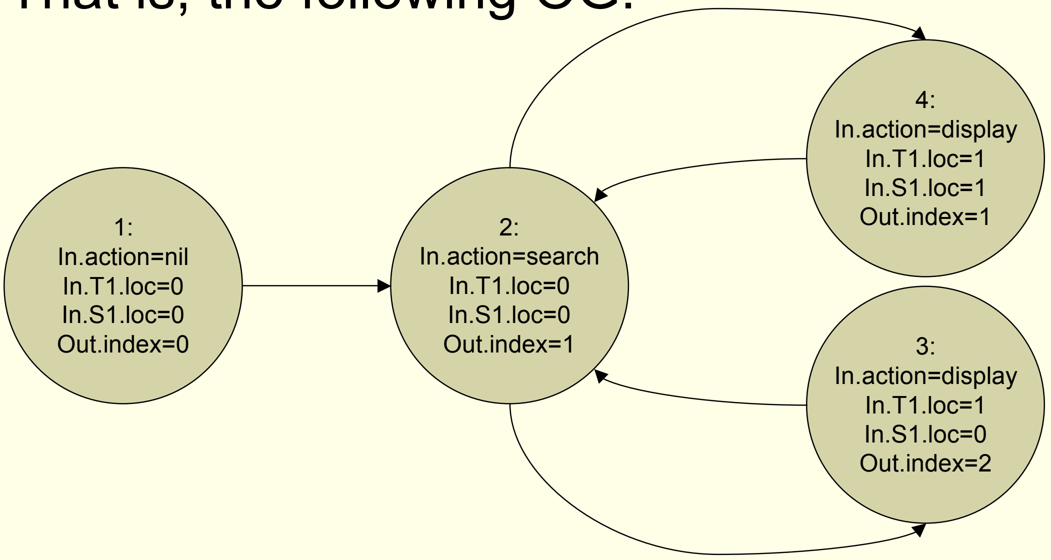
Automaton Transitions

From 1 to 2
From 2 to 3 4
From 3 to 2
From 4 to 2



Running the specification (cont.)

That is, the following OG:


1:
In.action=nil
In.T1.loc=0
In.S1.loc=0
Out.index=0
2:
In.action=search
In.T1.loc=0
In.S1.loc=0
Out.index=1
4:
In.action=display
In.T1.loc=1
In.S1.loc=1
Out.index=1
3:
In.action=display
In.T1.loc=1
In.S1.loc=0
Out.index=2