From Orchestration to Choreography: Memoryless and Distributed Orchestrators

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FLACOS, September 2009

Outline

1. Motivation
2. Memoryless orchestrators
3. Distributing memoryless orchestrators
4. Conclusion

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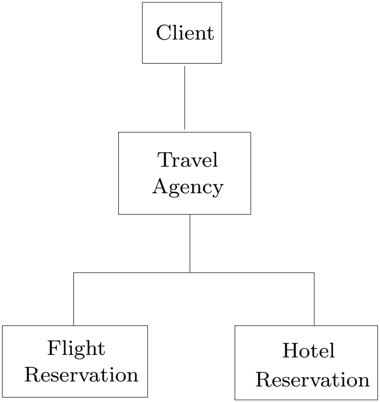
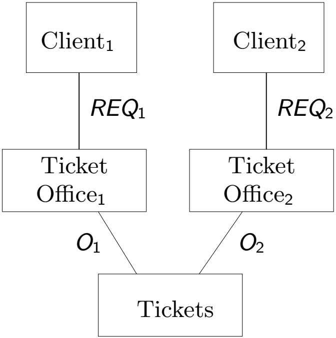
Rich interaction in Web services



n-ary rendez-vous



global priority

Orchestrators

- A contract describes how a client or a service is expected to behave.
- Syntax: $\sigma ::= 0 \mid \alpha.\,\sigma \mid \sigma + \sigma \mid \sigma \oplus \sigma \mid \texttt{rec}\, x.\,\sigma \mid x$
- A service ρ is compliant with a client σ iff $\sigma \parallel \rho$ has no deadlock.
- An orchestrator “helps” making a service compliant to a client.

Our approach

- Focus on a particular class: memoryless orchestrators (MO).
- MO can be represented as BIP connectors and priorities.
- MO can more easily be distributed.

Contracts in a fragment of CCS

Syntax

$$\sigma ::= 0 \mid \alpha.\, \sigma \mid \sigma + \sigma \mid \sigma \oplus \sigma \mid \texttt{rec}\, x.\, \sigma \mid x$$

Semantics

$$\alpha.\, \sigma \xrightarrow{\alpha} \sigma \qquad \sigma \oplus \rho \xrightarrow{\tau} \sigma \qquad \texttt{rec}\, x.\, \sigma \xrightarrow{\tau} \sigma\{{}^{\texttt{rec}\, x.\, \sigma}/_{x}\}$$

$$\frac{\sigma \xrightarrow{\tau} \sigma'}{\sigma + \rho \xrightarrow{\tau} \sigma' + \rho} \qquad \frac{\sigma \xrightarrow{\alpha} \sigma'}{\sigma + \rho \xrightarrow{\alpha} \sigma'}$$

Toy examples

A simple example that works with priorities.

Client : $\bar{a}.\, c.\, e + \bar{b}.\, d.\, e$

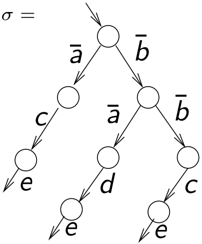
Service : $a.\, \bar{d} + b.\, \bar{d}$

A simple example that does not work with priorities.

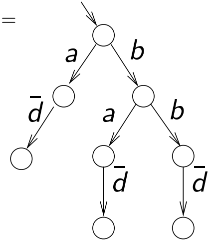
Client : $\bar{a}.\, c.\, e + \bar{b}.\, \bar{b}.\, c.\, e + \bar{b}.\, \bar{a}.\, d.\, e$

Service : $a.\, \bar{d} + b.\, b.\, \bar{d} + b.\, a.\, \bar{d}$

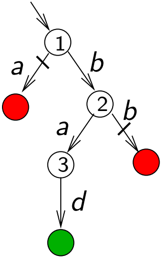
$\sigma =$



$\rho =$



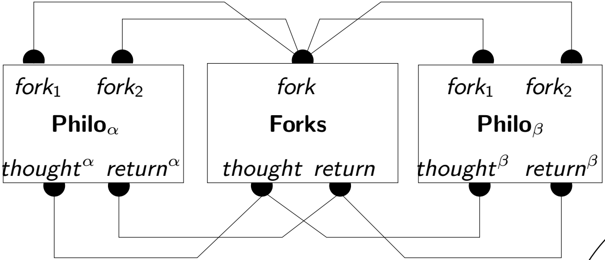
$\sigma \parallel \rho =$

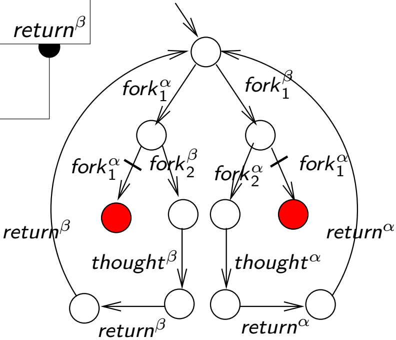


An example: the dining philosophers

Forks $= \mathtt{rec}\, x.\overline{fork}.\overline{fork}.thought.return.return.x$

Philo $= \mathtt{rec}\, x.fork_1.fork_2.\overline{thought}.\overline{return}.\overline{return}.x$





$fork_1^\beta < fork_2^\alpha$
$fork_1^\alpha < fork_2^\beta$

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Description of the problem

- Components communicating via exchange of messages
- Global priority rules over interactions
- Restriction in this talk: only binary rendez-vous connectors

Properties expected

- Safety: in a given state, only specified interactions can be fired
- Progress: deadlock-freedom (no fairness)
- Efficiency: reduce the longest exchange of messages between two transitions

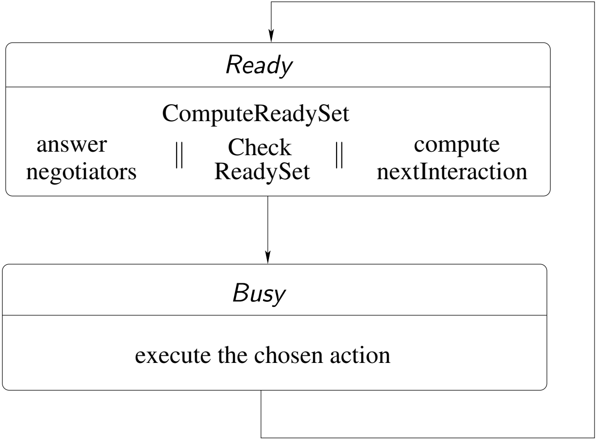
Principle of the algorithm

For a component K, an interaction is:

- possible $=$ possible for K
- ready $=$ possible for K and its counterpart
- enabled $=$ ready $+$ no ready interaction with higher priority

For each interaction α involved in a priority rule, a negotiator is chosen between the processes that participate in α.

Protocol overview



Ready

ComputeReadySet

answer negotiators || Check ReadySet || compute nextInteraction

Busy

execute the chosen action

Negotiate:

```
Require: $higherPrio(a) = \{i \mid a < i\}$
    Input: interaction $a$
    Output: $OK$ or $NOK$
toCheck ⟵ higherPrio(a)
$\forall b \in toCheck$ send $READY?(b)$
while $toCheck \neq \emptyset$ do
    if receive $READY!(b)$ then
        return $NOK$
    else if receive $NOTREADY!(b)$ then
        $toCheck \longleftarrow toCheck \setminus \{b\}$
    end if
end while
return $OK$
```

ComputeNextInteraction:

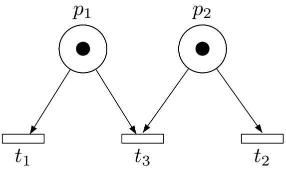
```
Require: $toNegotiate = \{i \mid negociator(i) = K\}$
    Input: set of interactions $readySet \neq \emptyset$
    Output: set of interactions $enabledSet$
Ready:
$localMax \longleftarrow readySet \backslash \{i \mid \exists j \in readySet\ s.t.\ i < j\}$
$enabledSet \longleftarrow \{i \in readySet \mid i \notin \pi\}$
for all $i \in localMax \cap toNegotiate$ do
    if $Negotiate(i) = OK$ then
        $enabledSet \longleftarrow enabledSet \cup \{i\}$
    end if
end for
if $enabledSet = \emptyset$ then
    goto Ready
else
    $enabledSetCompleted \longleftarrow true$
end if
```

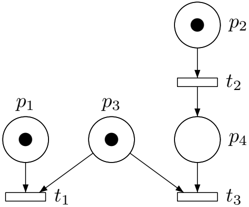
CheckReadySet:

```
Require: set of interactions $possibleSet$
    Output: interaction $i$
createNewThread ChooseNextInteraction($readySet$)
while not enabledSetCompleted do
    if receive $REFUSE(a)$ and $a \in enabledSet$ then
        kill ChooseNextInteraction
    end if
end while
choose interaction $i$ to fire among $enabledSet$
```

Safety

- t_1 and t_2 are independent when one may fire in parallel with the other.
- Otherwise t_1 and t_2 are said to be in structural conflict.
- Confusion arises if t_1 and t_2 may fire concurrently, but firing one modifies the set of transitions in actual conflict with the other.





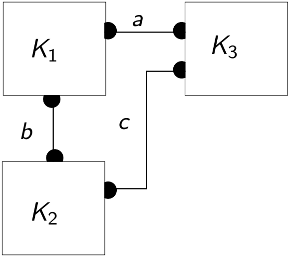
- A process can commit just one interaction at a time $\Longrightarrow$ interactions in conflict cannot be committed simultaneously.
- We do not handle confusion related to priorities.

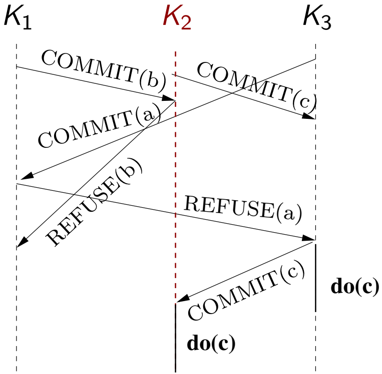
Progress

- No notion of fairness
- Avoid additional deadlocks due to negotiations
- Avoid deadlocks due to cycles: use cycle breakers

$K_1 = a + b \qquad K_3 = c + a$

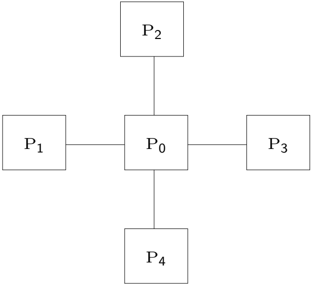
$K_2 = b + c$

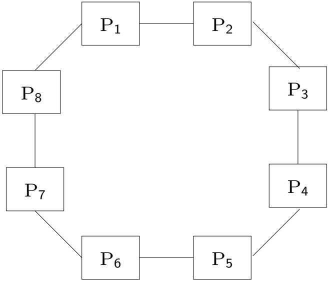




Efficiency: choice of the negociators

- Minimize the maximal number of components communicating to decide the enabledness of an interaction.
- Centralized topology $\implies$ as efficient as a central orchestrator
- Ring tobology $\implies$ at least as efficient than a central orchestrator





Conclusion and perspectives

Summary

- Memoryless orchestrators
- Concurrency and priorities can be inferred
- A distributed implementation

Future work

- Handle multiparty interactions
- Handle complex connectors: need for a new algorithm?
- Add knowledge to reduce the need for communication
- Combine this work with compositional verification
- Evaluate the approach on actual Web services