Reasoning about interaction protocols for web service composition

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Protocolli descritti mediante scambio di messaggi.

Teoria delle azioni per esprimere azioni comunicative atomiche e composte (protocolli).

Composizione: dati n servizi, costruire dei **piani** per interagire con i servizi rispettando un insieme di vincoli.

Due strumenti per ragionare su protocolli:

- DyLOG
- DLTL: logica dinamica + temporale linear-time.

DyLOG: overview [ICTCS 2003, AI*IA, 2003]

- A language for programming agents, based on a *modal approach* for reasoning about actions and change in *a logic programming setting*
- The behavior of an agent ag_i is described by a domain description DD^{agi} which consists of:
  - Π
    1. a set of primitive actions: preconditions and effects
    2. a set of sensing actions: interaction with the word
    3. a set of complex actions defined by means of prolog-like procedures
  - + S_0 a description of the initial situation (a set of initial beliefs)
  - + $CKit^{agi}$ a communication kit
- mentalistic approach

DyLOG Overview

- For each action a^{agi} atomic or complex ⟶ a modal operator $[a^{agi}]$
  $[a^{agi}]\alpha$ means that α holds after every execution of action a by agent agi

K

$[a^{agi}]\alpha$
$< a^{agi} > \alpha$

S4

$\Box\,\alpha$

K

$Done(a^{agi})T$

Always

$\Box\,\alpha \supset [a^{agi}]\alpha$

Awareness

$Done(a^{agi})\alpha \supset B^{agi}Done(a^{agi})\alpha$

- epistemic operator B^{agi}: The mental state includes beliefs and nested beliefs of rank 2 ($B^{agi}B^{agj}\ I$) of type KD45 for representing *what the other agents believe* and *for reasoning on how they can be affected by communicative actions*

KD + 45

$B^{agi}\alpha$

$M^{agi}\alpha \equiv \neg B^{agi}\neg\alpha$

- complex actions operators from the dynamic logic:
  - sequencing: ";"
  - non-det choice: "U"
  - test: "?"

The communication kit: Ckit

- *Integrating a communication theory in the general agent theory*:

$$DD^{agi} = (\Pi, Ckit^{agi}, S_0)$$

Π_C

a set of simple action laws to define the agent *speech acts* (inform, query, request, …)

Π_{CP}

a set of procedure axioms to specify the agent *conversation policies (i.e. internal representation of protocols)*

Π_{Sget}

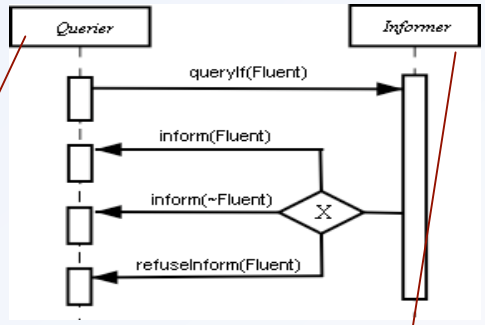
a set of sensing axioms to represent *messages from other agents*

speech acts and conversation policies are, as well, represented as primitive actions, sensing actions and procedure definitions of a DyLOG agent theory

CKit: conversation protocols

- Individual speech acts are used in the context of *predefined conversation protocols*, that specify communication patterns [Pitt & Madami 2000]

- Agents have a *subjective perception* of communication with the others (see also [Endriss et al., IJCAI'03]) → an agent represents a protocol as one of *its* (conversation) policies



Agent
Unified
Modelling
Language
sequence
diagram

$$\langle \text{yes\_no\_query}_Q(Self, Other, Fluent)\rangle\varphi \subset \langle \text{queryIf}(Self, Other, Fluent);\ \text{get\_answer}(Self, Other, Fluent)\rangle\varphi$$

$$[\text{get\_answer}(Self, Other, Fluent)]\varphi \equiv [\text{inform}(Other, Self, Fluent) \cup \text{inform}(Other, Self, \neg Fluent) \cup \text{refuseInform}(Other, Self, Fluent)]\varphi$$

$$\langle \text{yes\_no\_query}_I(Self, Other, Fluent)\rangle\varphi \subset \langle \text{get\_start}(Self, Other, Fluent);\ \mathcal{B}^{Self} Fluent?; \text{inform}(Self, Other, Fluent)\rangle\varphi$$

$$\langle \text{yes\_no\_query}_I(Self, Other, Fluent)\rangle\varphi \subset \langle \text{get\_start}(Self, Other, Fluent);\ \mathcal{B}^{Self} \neg Fluent?; \text{inform}(Self, Other, \neg Fluent)\rangle\varphi$$

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$$[\text{get\_start}(Self, Other, Fluent)]\varphi \equiv [\text{queryIf}(Other, Self, Fluent)]\varphi$$

DyLOG: overview

- Given a domain description, we can reason about it by means of existential queries

$$<p_1><p_2> \ldots <p_n>Fs$$

  - *Temporal projection*, when p_k's are all atomic actions
  - *Procedural planning*, when p_k's are both atomic and complex actions: “Is there an execution trace of p_1, ..., p_n (a plan) leading to a state where *Fs* holds?"

- *Notice that*: as a difference with classical planning, the procedure definitions constraint the search space
- *Linear plan:* it contains assumptions on the sensing outcome
- *Conditional plan*: for each sensing action it contains as many branches as possible action outcomes
- Correct plans

Reasoning about conversations

- Given a domain description, we can reason about it by means of *existential queries*:

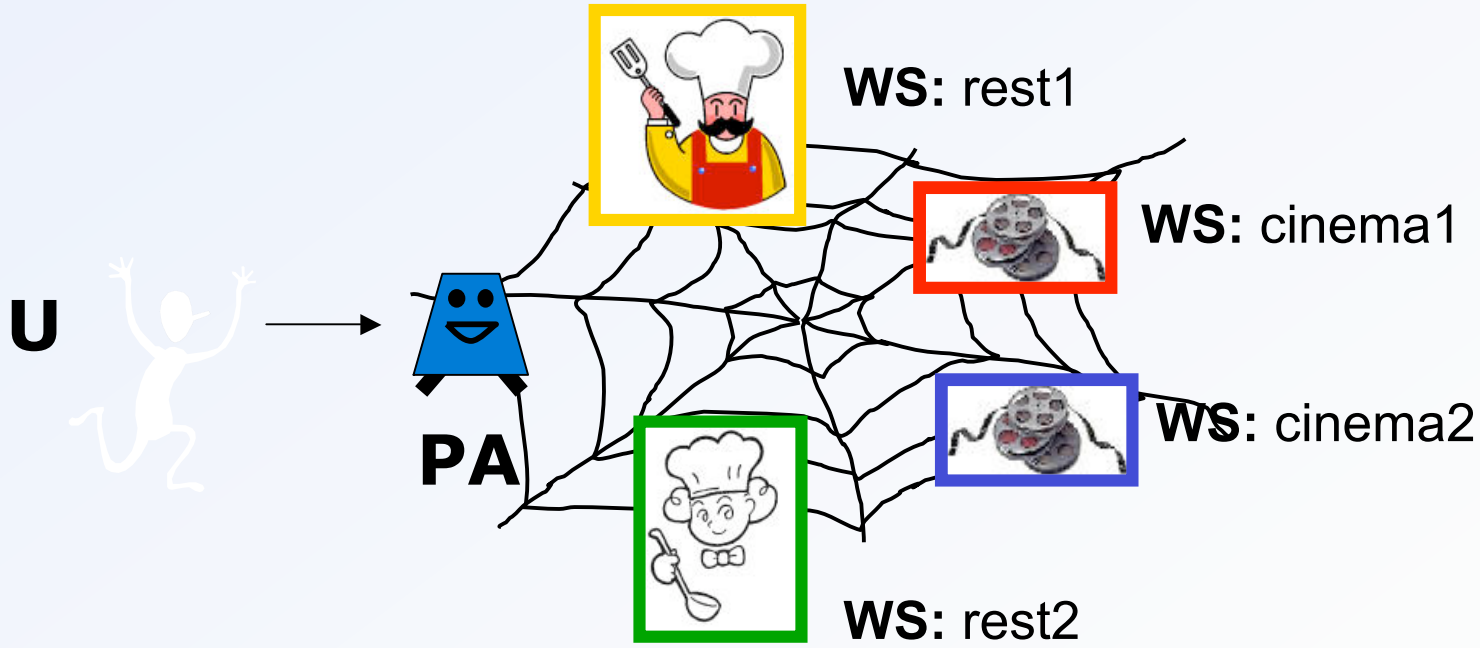
$?\ \langle p_m \rangle Fs$

Is there an execution of pm (a plan) leading to a state where Fs holds?

  - p_m is an interaction protocol
  - We look for a conversation, which is an instance of the protocol described by p_m, after which the condition *Fs* holds
  - We treat *get message* actions as *sensing actions*, whose outcome cannot be known at planning time.
- Goal directed proof procedure, based on negation as failure (dealing with persistency) [ICTCS 2003]

A semantic web scenario

The agent PA is requested to organize day out:



- The user wants **to eat out**
- Watch a certain **movie**
- Benefit of a promotion on the cinema ticket
- And to avoid the use of credit card

Composition of WS: example 1/4

- Among initial beliefs:

$$\mathcal{B}^{pa}\, service(restaurant, restaurant1, reserv\_rest\_1_C)$$
$$\mathcal{B}^{pa}\, service(restaurant, restaurant2, reserv\_rest\_2_C)$$
$$\mathcal{B}^{pa}\, service(cinema, cinema1, reserv\_cinema\_1_C)$$
$$\mathcal{B}^{pa}\, service(cinema, cinema2, reserv\_cinema\_2_C)$$

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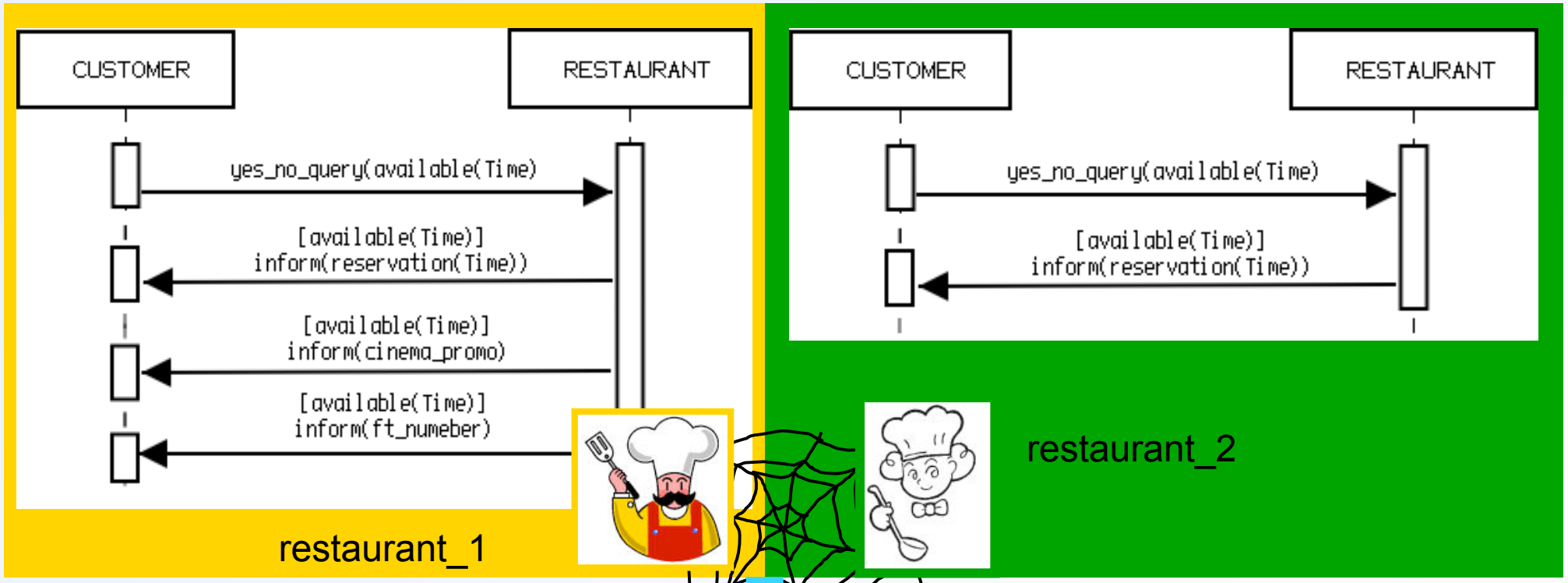
  - + ...U's credit card number
  - U's desire not to use it in the current transaction
  - No ticket for nausicaa has been booked yet
  - Hypothesis on the WS mental state (e.g. cinema1 does not know U's credit card number)

Interaction Protocols of WS: example 2/4



$$\langle \text{reserv\_rest\_1}_C(Self, WebS, Time)\rangle\varphi \subset \langle \text{yes\_no\_query}_Q(Self, WebS, available(Time))\ ;\ \mathcal{B}^{Self}\, available(Time)?\ ;\ \text{get\_info}(Self, WebS, reservation(Time))\ ;\ \text{get\_info}(Self, WebS, cinema\_promo)\ ;\ \text{get\_info}(Self, WebS, ft\_number)\rangle\varphi$$

$$\langle \text{reserv\_rest\_2}_C(Self, WebS, Time)\rangle\varphi \subset \langle \text{yes\_no\_query}_Q(Self, WebS, available(Time))\ ;\ \mathcal{B}^{Self}\, available(Time)?\ ;\ \text{get\_info}(Self, WebS, reservation(Time))\rangle\varphi$$

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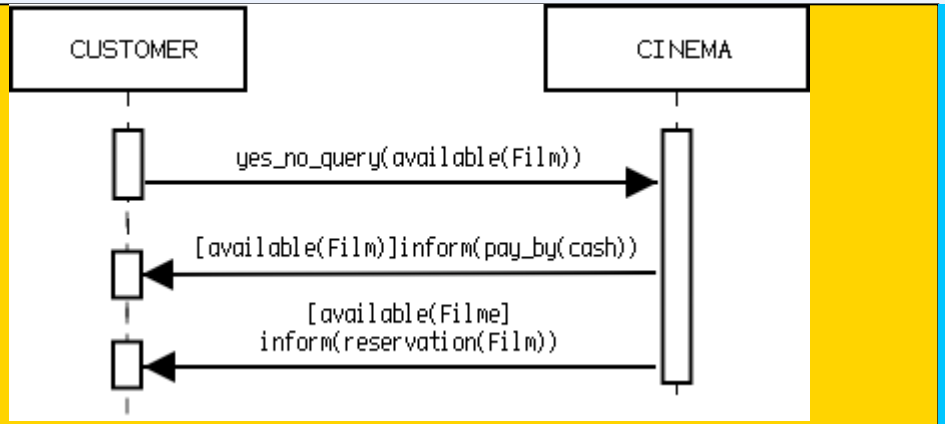
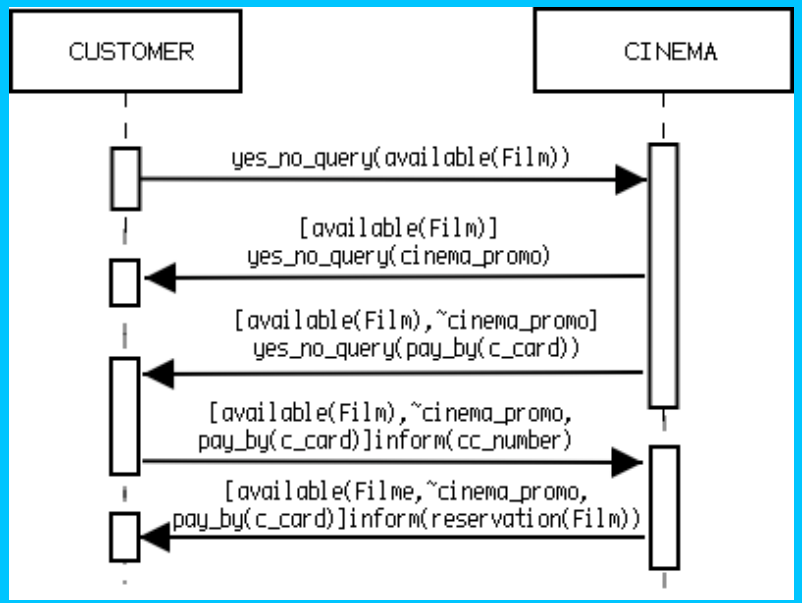
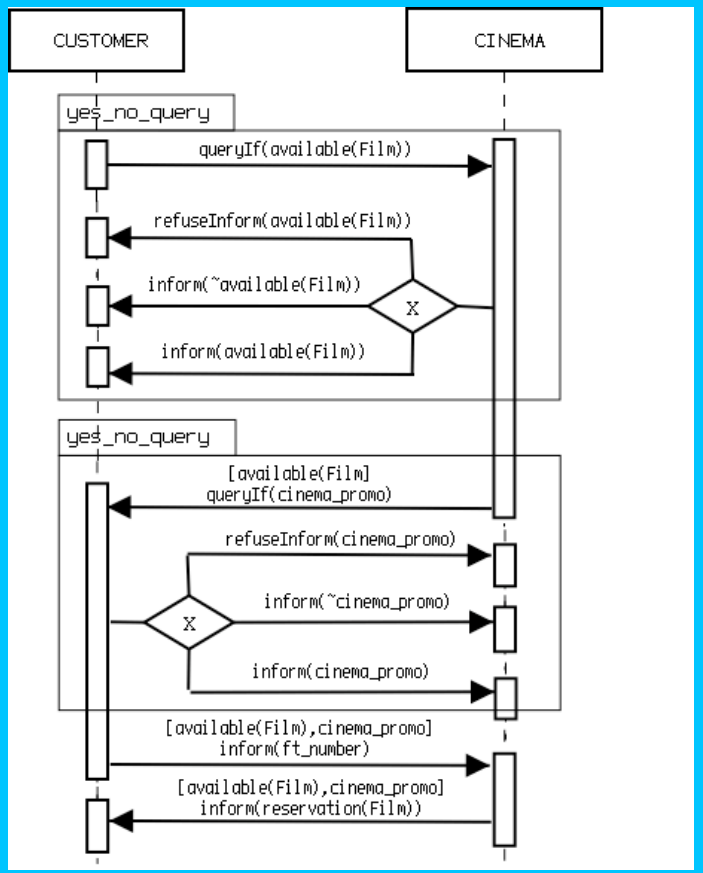
Interaction Protocols of WS: example 3/4



cinema_2





cinema_1

Composition of WS: example 4/4

- Combine services...

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$$\langle comp\_services([\,])\rangle\varphi \supset true$$
$$\langle comp\_services([[TypeService, Name, Data]|Services])\rangle\varphi \supset$$
$$\langle \mathcal{B}^{pa} service(TypeService, Name, Protocol)\ ;$$
$$Protocol(pa, Name, Data)\ ;$$
$$comp\_services(Services)\rangle\varphi$$

compose-by-sequencing

- Query

$$\langle comp\_services([[restaurant, R, dinner], [cinema, C, nausicaa]])\rangle$$
$$(\mathcal{B}^{pa} cinema\_promo \wedge \mathcal{B}^{pa} reservation(dinner) \wedge$$
$$\mathcal{B}^{pa} reservation(nausicaa) \wedge \mathcal{B}^{pa} \neg \mathcal{B}^{C} cc\_number \wedge \mathcal{B}^{pa} \mathcal{B}^{C} ft\_number)$$

- The answer is a linear plan...

there is no other execution trace of comp_services that satisfies the goal

$$\text{queryIf}(pa, restaurant1, available(dinner))\ ;$$
$$\text{inform}(restaurant1, pa, available(dinner))\ ;$$
$$\text{inform}(restaurant1, pa, reservation(dinner))\ ;$$
$$\text{inform}(restaurant1, pa, cinema\_promo)\ ;$$
$$\text{inform}(restaurant1, pa, ft\_number)\ ;$$
$$\text{queryIf}(pa, cinema1, available(nausicaa))\ ;$$
$$\text{inform}(cinema1, pa, available(nausicaa))\ ;$$
$$\text{queryIf}(cinema1, pa, cinema\_promo)\ ;$$
$$\text{inform}(pa, cinema1, cinema\_promo)\ ;$$
$$\text{inform}(pa, cinema1, ft\_number)\ ;$$
$$\text{inform}(cinema1, pa, reservation(nausicaa))$$