A MultiAgent System providing Situation-aware Services in a Smart Environment

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Smart Support to Users

- **Smart Environment**
  - Acquire and apply knowledge about the situation to adapt behavior to its inhabitants in order to improve their experience in the environment.

Smart Environment Services

? How ?

Fully Automated
Keep users intervention at minimum

Semi Automated

Not Automated
Give complete control to users

Smart Services

Supporting people in daily activities by adapting the fruition of services of a Smart Home Environment to their goals.

- **Smart Services**: integrated, interoperable and personalized services accessible through interfaces available on several devices, in the optic of ubiquitous and pervasive computing.
- **Agent-based system** for reasoning on the user and the context and activating smart services.
- **Balance** between the **system proactivity** and the **user control** over services
- **Interactive execution** of the smart service workflow

↳ Learning the User Model

The Proposed Approach: MAS + Services

Sensor Agents (SA)

- provide information about context parameters and features (temperature, light level, humidity,...) at a higher abstraction level than sensor data
  - Transform signals and numeric data into a symbolic representation that is closer to the human way of reasoning about context.

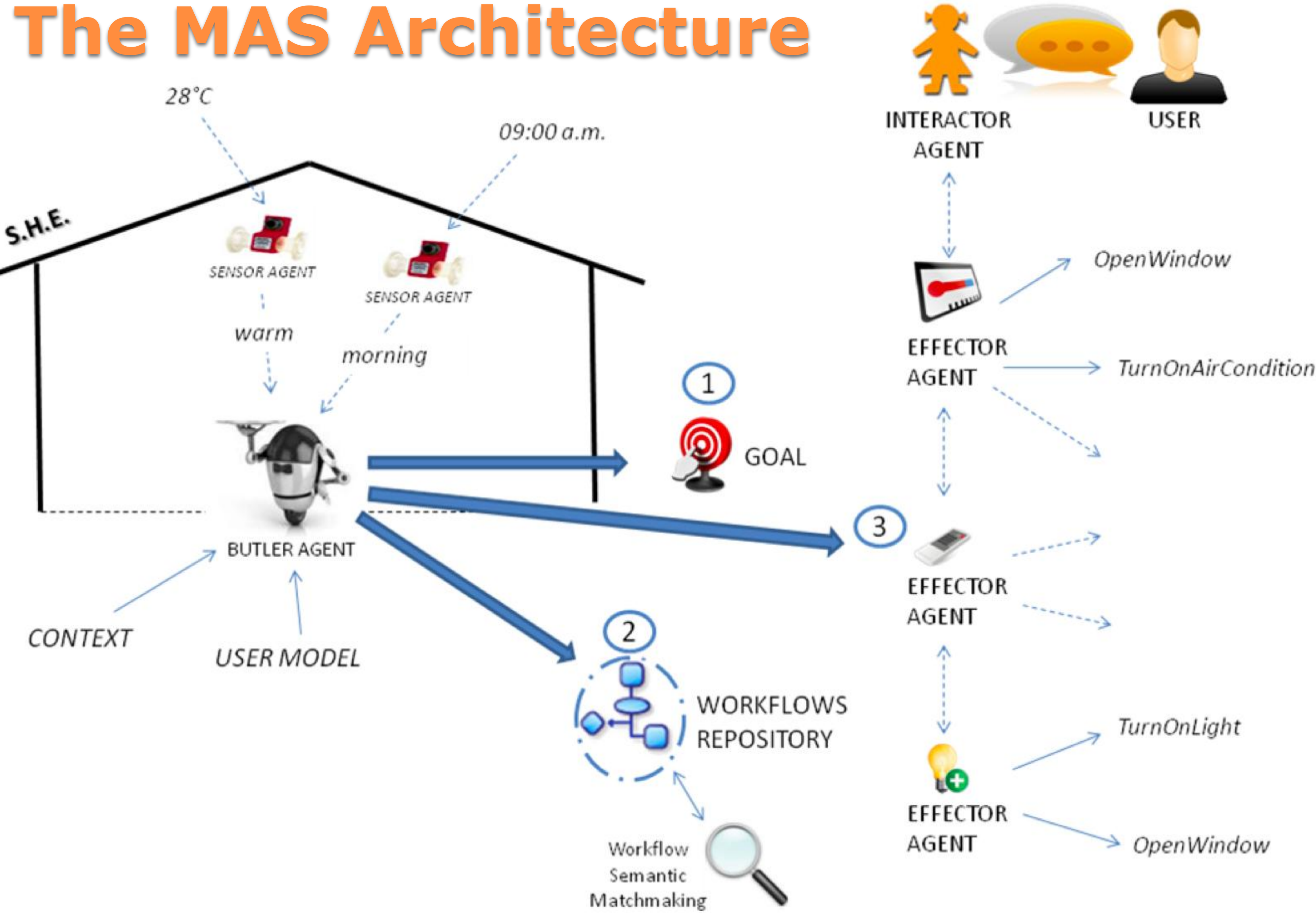
Butler Agent (BA)

- flexibly coordinates and adaptively provides smart services in dynamically changing contexts
  - Behavior based on a combination of intelligent reasoning, machine learning, service-oriented computing and semantic technologies for
  - Reasoning on the user’s goals and devises the smart service to satisfy them.

The Proposed Approach: MAS + Services

- **Effector (EA)** and **Interactor (IA)** agents
  - Reason on the opportunity of performing an action in the current context to find the best solution to satisfy a basic goal
    - EA: Decisions about actions that have impact on device behaviors
    - IA: communicative action with the user
- **Housekeeper Agent (HA)**
  - Acts as a facilitator
    - Knows all the agents that are active in the house and the goal they are able to fulfill

The MAS Architecture



Logic Setting

- First-Order Logic
  - Powerful representation (relationships)
    - Complex situations
    - Compliant to Reasoning KB
  - Multi-Strategy Reasoning
    - Induction: learning/refining the model (ILP)
    - Deduction: draw implicit information hidden in data
    - Abduction: deals with incomplete knowledge
    - Abstraction: removes superfluous details
- InTheLEx

(Esposito, F., Fanizzi, N., Ferilli, S., Basile, T.M.A. and Di Mauro, N. Multistrategy Operators for Relational Learning and Their Cooperation. Fundamenta Informaticae Journal, 69(4):389-409, IOS Press, Amsterdam, 2006.)

The Agent's Architecture

All agents share the same architecture

Different agents

- Work on different portions of domain knowledge
- May require different effort
- Pose different problems

The agents' behaviors:

- Reasoning uses the agent's knowledge to perform inferences
- Learning exploits possible feedback on the agent's decisions to improve that knowledge

Scenario

It's *evening* and John, a 73 y.o. man, is at home *alone*.

He has a *cold* and *fever*.

He is a bit *sad* and *bored* since he cannot go dowtown and drink something with his friend, like he does *every evening*.

John is sitting on the bench in his living room *in front of the TV*. He has got a smatphone able to interact with house services.

The living room is equipped:

- with *sensors*, which can catch sound/noise in the air, time, temperature, status of the window (open/close) and of the radio and TV (on/off), and the current activity of the user, and
- with *effectors*, acting and controlling windows, radio and TV and also
- the *execution* of *digital services* that may be visualized on communication devices, as for instance the TV.

Sensor Agents

Sensor Agents control sensors -> abstract context features

sound/noise in the air,
time, temperature,
status of the window (open/close)
radio and TV (on/off),
current activity of the user

Induction Learning

Events recorded in the past:

temperature	28	16	8	20	32	18	37	26	22	19	29	23	12	25	4
action	C	H	H	-	C	H	C	C	-	-	C	-	H	-	H

the user turns on heating (i.e., he is cold) whenever the temperature is below 19 degrees, and turns on cooling (i.e., he is warm) whenever the temperature is above 25 degrees:

cold(X,Y) :- temperature(X,T),T<19,user(Y), present(X,Y), john(Y).
warm(X,Y):- temperature(X,T),T>25,user(Y),present(X,Y), john(Y).

Sensor Agents

Sensor Agents control sensors -> reason on context

Low-level Deduction

Observation at time t0:

morning(t0), closedWindow(t0), present(t0,j), john(j), user(j), temperature(t0,14), has_fever(j), sad(j).

Using rule

cold(X,Y) :- temperature(X,T), T<19, user(Y), present(X,Y), john(Y).

The following deduction is performed

cold(t0,john)

ButlerAgent:from Situations to Goals

Observation of a specific situation

Deduction

model

Set of possible **goals** to be fulfilled

time t0:

morning(t0),
closedWindow(t0),
present(t0,j),
john(j),
user(j),
cold(t0,j),
has_fever(j),
sad(j).

improveHealth(X) :- present(X,Y), user(Y),has_fever(Y).

improveHealth(X) :- present(X,Y), user(Y), has_headache(Y), cold(X,Y).

improveHealth(X) :- present(X,Y), user(Y), has_flu(Y).

improveMind(X) :- present(X,Y), user(Y), sad(Y).

improveMind(X) :- present(X,Y), user(Y), bored(Y).

X = t0, Y = john

improveHealth(X)

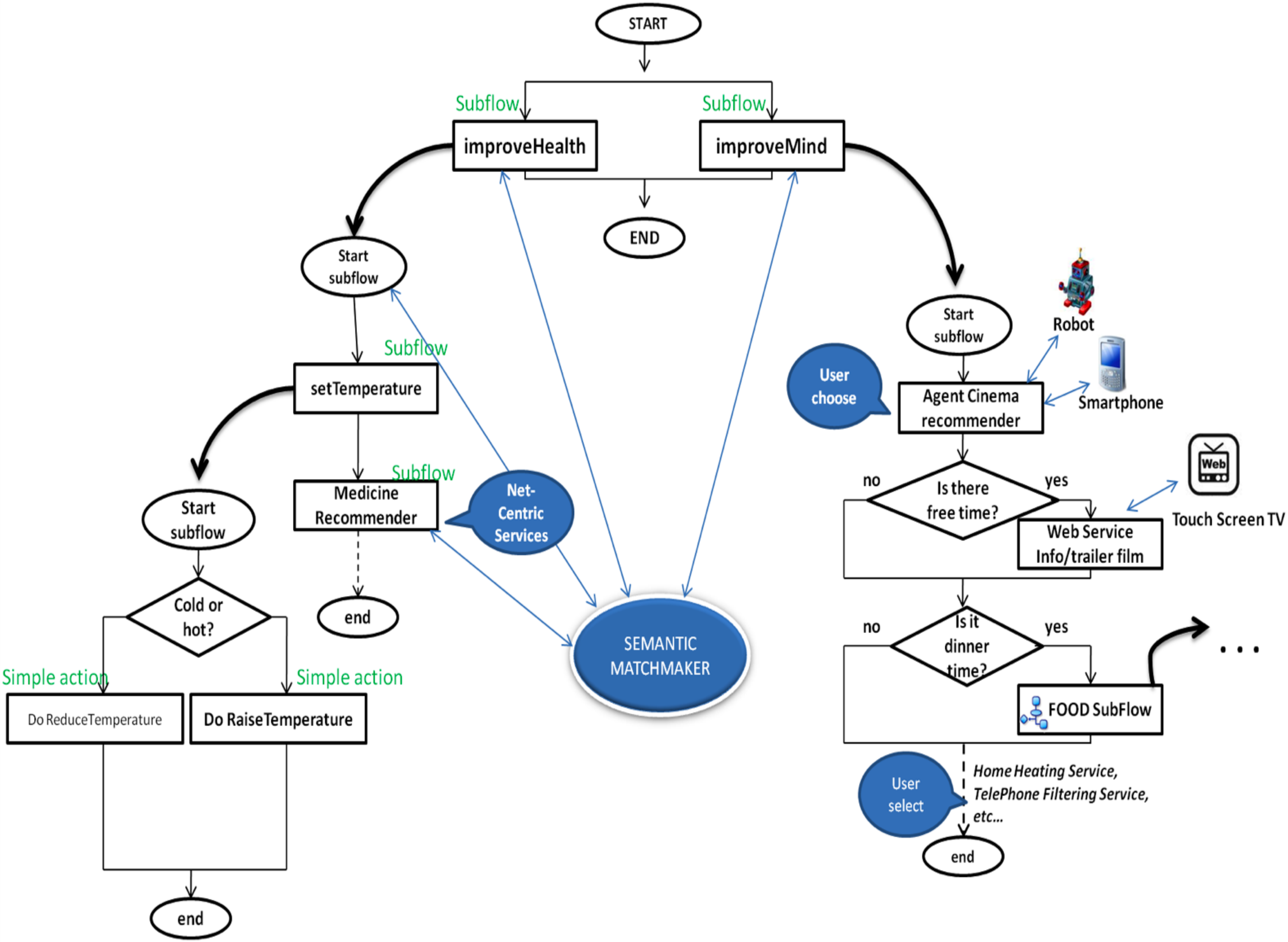
improveMind(X)

X = t0, Y = john

From Goals to Workflows (1)

- Triggered Goals >> workflow selection by semantic matchmaking between the description of goals and the semantic profiles of all workflows in the knowledge base of the system.
- Possible results:
  - **0 WF** no semantic matching between the goal and any of the available workflows;
  - **1 WF** semantically matching the goal;
  - **n WFs** that are semantically consistent with the goal. Ranking of all selected workflows according to semantic similarity.

- Semantic matchmaking is also used within the workflow, to find both the best subflows (corresponding to subgoals) and services.


START
Subflow
Subflow
improveHealth
improveMind
END
Start subflow
Subflow
setTemperature
Subflow
Medicine Recommender
end
Net-Centric Services
SEMANTIC MATCHMAKER
Start subflow
Cold or hot?
Simple action
Simple action
Do ReduceTemperature
Do RaiseTemperature
end
Start subflow
Robot
Smartphone
User choose
Agent Cinema recommender
no
yes
Is there free time?
Web Service Info/trailer film
Web
Touch Screen TV
no
yes
Is it dinner time?
FOOD SubFlow
...
User select
Home Heating Service,
TelePhone Filtering Service,
etc...
end

Scenario Example (1)

the main workflow includes two goals

Selection of two corresponding SubFlows:

improveHealth and **improveMind**

Both include simple actions

can be directly executed

and subgoals

must be satisfied

Scenario Example (2)

- In the ImproveHealth
- SetTemperature
  - Satisfied by applying again the matching process to find a suitable workflow
    - the Reasoning layer processes the information collected by the temperature sensors in order to understand whether to raise or reduce the environment temperature
    - doReduceTemperature(X) :- present(X,Y), user(Y), warm(X,Y).
    - doRaiseTemperature(X) :- present(X,Y), user(Y), cold(X,Y).
    - doCloseWindow(X) :- present(X,Y), user(Y), ¬didOpenWindow(X,Y), openWindow(X).

- Predefined and static adaptation models:
  - Pros: user always in control of the execution of services
  - Cons: user must change system's settings in order to reflect changes in the user profile. Frustrating or annoying task for the user.

BA **learns** from user's implicit and explicit **feedback** to **refine** the **user model**

Butler Agent Learning Behavior … keep knowing the user

Effector Agents

Effector Agents have a direct impact on several device behaviors and/or net-centric services affecting the same environment parameter (e.g. temperature, light, ...).

In order to find the best solution to satisfy the user needs, these agents reason about different possible solutions to attain the same elementary goal in the current context.

For instance, deciding how to control the temperature devices (e.g. how widely the window must be opened or which is the temperature to set in turning on the air conditioning).

Interactor Agents

- Satisfy the goal of interacting with the user by executing communicative actions through different interaction modalities.
- There are several communicative goals that IAs may carry out:
  - ***Information Seeking***: interaction with the user to get hints on how to attain a simple goal and, based on this, possibly learn new preferences in order to continuously and dynamically improve adaptation.
  - ***Information Providing***: provision of information to the user when he requests explanations about the smart home appliances behaviour or about the system decision.
  - ***Remind***: reminding “something” to the user; i.e. to take the medicine.

Interactor Agents

- **John** is sitting in front of the **TV** and he is **bored**,
- the BA selects the workflow satisfying the triggered **ImproveMind** goal.
- According to the context the **WathcTV** subflow will be selected through the semantic matchmaking process.
- the BA starts the execution of the workflow and, as a first service, it **recommends** to John a set of **movies** that could be of his interest.
- this interactive task is delegated to the **Interactor Agent** associated to the **Smartphone**, since it is the device that John can access immediately.

Interactor Agents

- John may accept or refuse the proposed service. Let's suppose that John accepts.
- Then, since it is almost dinner time, the smart service **recommends** his favourite take-away **food**, sushi.
- John may accept or use another of the available services for that situation.

Interactor Agents

- Another example - the subflow ‘Medicine Recommender’

- Let’s suppose that the user has got a headache. There is a social intelligent robot in the house (scenario developed in the NICA project).

- Robot: ‘Hi John, how are you doing?’
- John: ‘I have got a flu, I think I need some medicine’
- Robot: ‘Do you have fever or is just a cold?
- John: ‘I don’t feel like having fever, I rather have some headache and sore throat’
- Robot: ‘Well, in this situation your doctor suggested you to take a pill of paracetamol that is ok for headache too. If you don’t feel better we will call the doctor’.

Understanding the User Goals

Building the initial Knowledge

- A diary for collecting data about situated user actions and their relation with possible user needs and goals.
- **Study**: 40 subjects, aged between 20 and 65, equal distributed in gender, different roles in the family, living in a house with typical devices.
- Subjects were asked to describe:
  - their goals,
  - actions to execute for achieving goals,
  - relevant contextual factors,
  - devices to be used for the interaction.
- Initial dataset of about 945 entries -> the input of a reasoning modules of the system.

Example of Diary Entry

- 26 y.o. man living alone

GOAL	WHAT - actions	Where	Device	When	With Who	Relevant Factors
1. Watch a movie with my girlfriend	Look for interesting movies on the TV guide. Ask my girlfriend what she prefers. Choose a movie. Order by phone a pizza four seasons from "Angelo" to be delivered at home by 21:00.	At home. On the bench in front of TV.	TV	Saturday 20:00	Maria, my girlfriend	Outside is raining and cold.
2. Receive Relevant Information	Look for interesting news. Select news. Get Meteo Information. Get Traffic situation.	In the bathroom. On my smartphone	Mirror	Mon-Fry Around 8:00	-	-
3. Get Remind Missing Food	Look in the fridge. Write on the shopping list the missing items. Get remind about shopping list by 13:00	In the kitchen. In my car.	Smartphone/ In-car system	Today	-	-

Experiments

- C@sa National Project

- In the Lab -> OK

- In a real SHE -> PROBLEMS
  - Trust – AAL scenario and Maternity scenario
  - Lack of Control
- -> ACCEPTANCE
  - Reduction of energy costs
  - A very simple version has been integrated in a domotic system produced by a local company with the only aim of reducing energy costs.

Conclusions

- First Step in developing a MAS aiming at handling the situation aware adaptation of a SHE behavior.
- The main peculiarity of the proposed architecture lies in the fact that all agents in the MAS are a specialization of an abstract class endowed with both reasoning and learning behavior.
- Reasoning, in turn, can exploit any combination of abstraction, deduction and abduction according to the role of the agent in the MAS.
- Learning uses a fully incremental technique based on a first-order logic representation and can exploit induction to build/update the theories used by the various inference strategies on which reasoning is based.
- Besides user preferences we are also able to learn user daily routines as well as workflow (plans of activities – WoMan).

Future Work

Interactor Agents – development of interaction models and integration with existing devices.

How to reason correctly on users' reactions to the proposed flow of activities in order to adopt the optimal behavior of the Smart Home Environment.

e.g. the user gives a negative feedback because there is:

a change in the situation that has not been detected or taken into account,

a mistake in controlling the effectors to achieve a simple goal,

a mistake in interpreting the user's goals or in selecting or composing the workflow.

Each of these cases determines which agent in the MAS has made a wrong decision and is to be involved in theory refinement.