Combining Fuzzy Logic and Semantic Web to Enable Situation-Awareness in Service Recommendation

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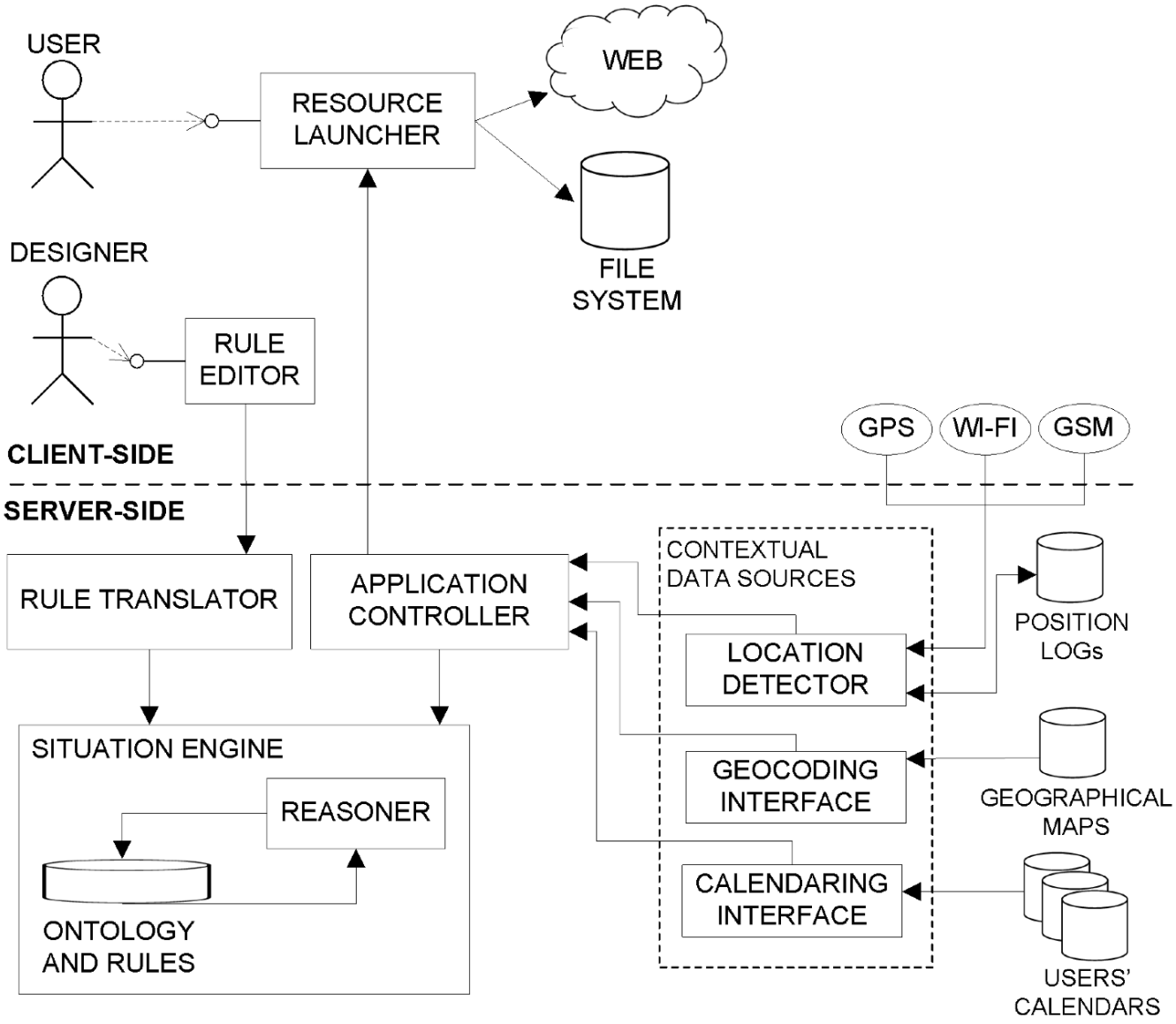
Contribution

- Situation-aware framework for personalised resource recommendation on mobile device
- How do we do it?
  - User situation is inferred
  - Task descriptions allow connecting a situation to specific tasks
  - Specific tasks are related to specific resources to be recommended
    - Resources are tailored by proper contextual information, selected according to the identified user task

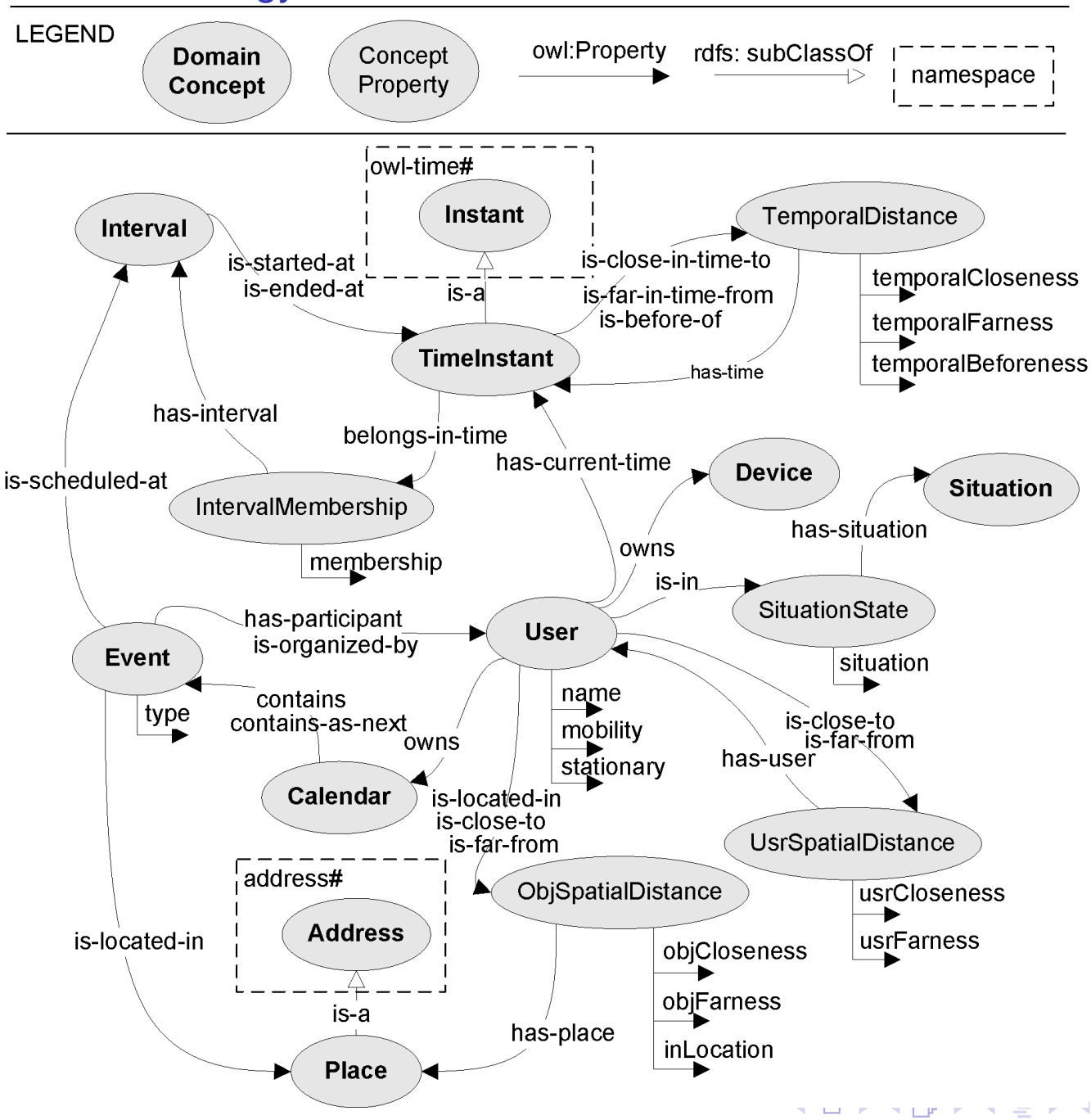
Ingredients

- Languages to describe background knowledge, situations, tasks and resources to be recommended
  - Semantic Web Ontology Language OWL (W3C standard)
  - Semantic Web Rule Language SWRL (W3C standard)
- Additionally, fuzzyness is added to describe the inherent vagueness in situation identification
  - E.g, “User is close to a place”

The pictures



The Upper Situation Ontology



Rule Example

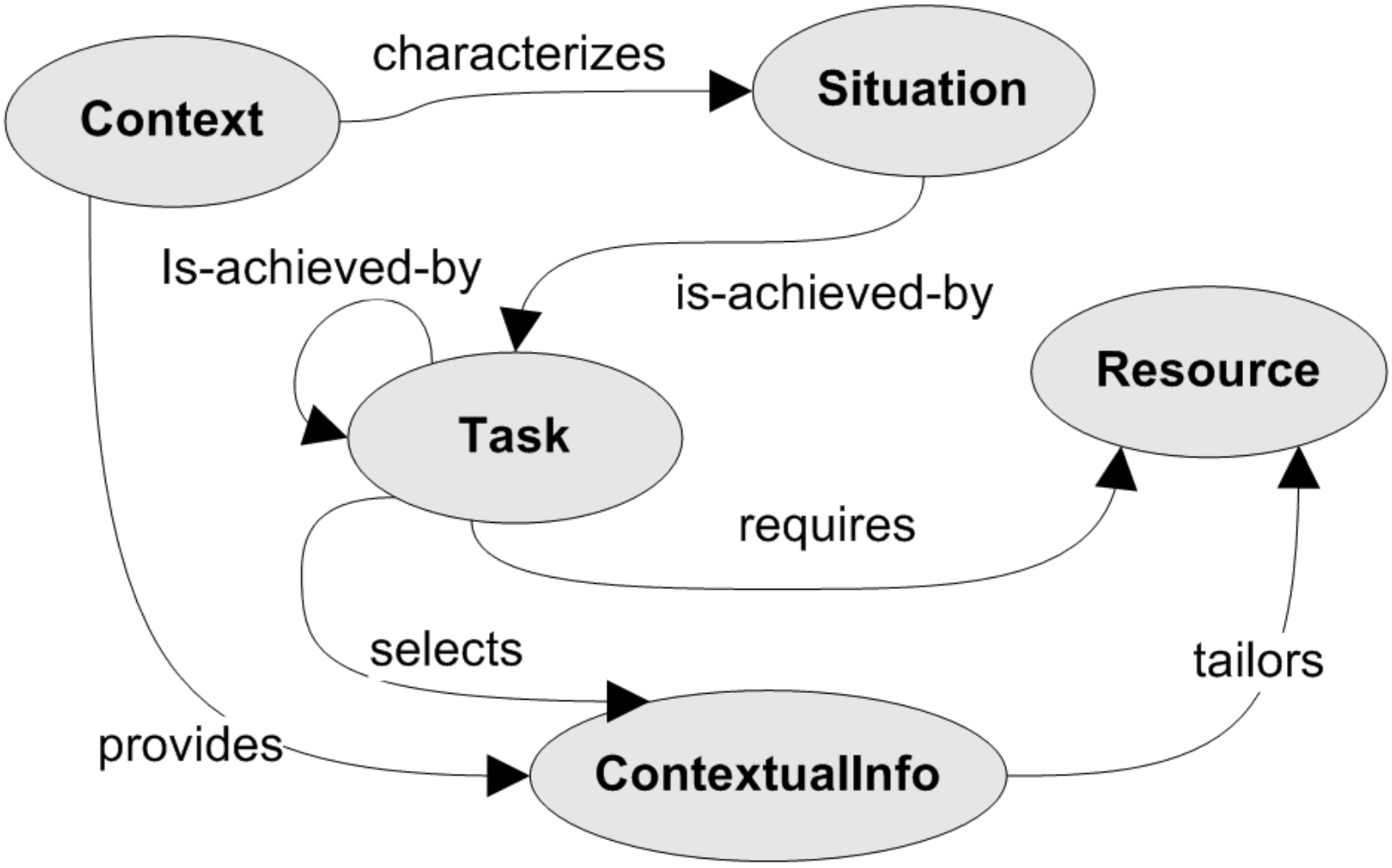
```
owns(?user1, ?aCalendar)
^ contains-as-next(?aCalendar, ?nextEvent)
^ is-scheduled-at(?nextEvent, ?anInterval)
^ is-started-at(?anInterval, ?aTime)
^ mobility(?user1, ?user1mobility)
^ has-current-time(?user1, ?user1Time)
^ is-before-of(?user1Time, ?temporalDistance)
^ has-time(?temporalDistance, ?aTime)
^ type(?nextEvent, "business")
^ Pre-Meeting-on-Movement(?aSituation)
⟹ is-in-a-situation(?user1,?aSituation)
```

(a)

IF *user1* **IS A PARTICIPANT** *to the scheduled event*
AND *user1* ***IS*** *moving*
AND *user1Time* ***IS BEFORE*** *the scheduled event start-time*
AND *event* **HAS TYPE** *business*
THEN *user1* ***IS IN A SITUATION OF*** *pre-meeting-on-movement*

(b)

The Upper Task Ontology



A Simple Integration of Fuzzy Logic into SWRL

- General Fuzzy Rules

$$R(\mathbf{x})[s] \quad \leftarrow \quad R_1(\mathbf{z}_1)[s_1], \ldots, R_l(\mathbf{z}_l)[s_l], s = f(s_1, \ldots, s_l)$$

if all $R_i(\mathbf{z}_i)$ *hold to degree* s_i*, then* $R(\mathbf{x})$ *holds to degree* $s = f(s_1, \ldots, s_l)$

Example

$$
\begin{aligned}
\mathrm{is-in-a-situation}(?\mathrm{user1}, ?\mathrm{aSituation})[s] \quad \leftarrow \quad & \mathrm{owns}(?\mathrm{user1}, ?\mathrm{aCalendar}), \\
& \mathrm{contains-as-next}(?\mathrm{aCalendar}, ?\mathrm{nextEvent}), \\
& \mathrm{is-located-in}(?\mathrm{nextEvent}, ?\mathrm{aPlace}), \\
& \mathrm{is-scheduled-at}(?\mathrm{nextEvent}, ?\mathrm{anInterval}), \\
& \mathrm{is-started-at}(?\mathrm{anInterval}, ?\mathrm{aTime}), \\
& \mathrm{mobility}(?\mathrm{user1}, \text{`moving'})[s1], \\
& \mathrm{has-current-time}(?\mathrm{user1}, ?\mathrm{userTime}), \\
& \mathrm{is-before-of}(?\mathrm{userTime}, ?\mathrm{aTime})[s2], \\
& \mathrm{type}(?\mathrm{nextEvent}, \text{`business'}), \\
& \mathrm{Pre-Meeting-on-Movement}(?\mathrm{aSituation}), \\
& s = \min(s1, s2)
\end{aligned}
$$

Converting Fuzzy SWRL to SWRL rules

- For the sake of a simple implementation ...
- Assume no cyclic dependencies among rules
- Replace

$$\begin{array}{rcl} R(\mathbf{x})[s] & \leftarrow & \phi_1(\mathbf{x}, \mathbf{y}_1)[\mathbf{s}_1] \\ R(\mathbf{x})[s] & \leftarrow & \phi_2(\mathbf{x}, \mathbf{y}_2)[\mathbf{s}_2] \\ \vdots & \vdots & \vdots \\ R(\mathbf{x})[s] & \leftarrow & \phi_n(\mathbf{x}, \mathbf{y}_n)[\mathbf{s}_n] \end{array}$$

with

$$\begin{array}{rcl} R_1(\mathbf{x})[s] & \leftarrow & \phi_1(\mathbf{x}, \mathbf{y}_1)[\mathbf{s}_1] \\ R_2(\mathbf{x})[s] & \leftarrow & \phi_2(\mathbf{x}, \mathbf{y}_2)[\mathbf{s}_2] \\ \vdots & \vdots & \vdots \\ R_n(\mathbf{x})[s] & \leftarrow & \phi_n(\mathbf{x}, \mathbf{y}_n)[\mathbf{s}_n] \\ R(\mathbf{x})[s] & \leftarrow & R_1(\mathbf{x})[s_1], \ldots, R_n(\mathbf{x})[s_n], s = g(s_1, \ldots, s_n) \end{array}$$

- R_i new symbols
- g specifies how to combine the scores of rules
- E.g., $g(s_1, \ldots, s_n) = \max(s_1, \ldots, s_n)$

Converting Fuzzy SWRL to SWRL rules (cont.)

- An expression $R(\mathbf{z})[s]$ is replaced with the predicate $R(\mathbf{z}, s)$. For instance,

$$\text{is}-\text{before}-\text{of}(?\text{userTime}, ?\text{aTime})[\text{s2}]$$

becomes

$$\text{is}-\text{before}-\text{of}(?\text{userTime}, ?\text{aTime}, \text{s2})\ .$$

- As our crisp rule language supports arithmetic built-in predicates, there is a way to express a rule

$$P_f(s_1, \ldots, s_l, s) \leftarrow \text{built-in}(s = f(s_1, \ldots, s_l))$$

which defines a predicate $P_f(s_1, \ldots, s_l, s)$ such that $s = f(s_1, \ldots, s_l)$, using the built-in arithmetic operations of the rule language

- Now, we replace each rule

$$R(\mathbf{x})[s] \leftarrow R_1(\mathbf{z}_1)[s_1], \ldots, R_l(\mathbf{z}_l)[s_l], s = f(s_1, \ldots, s_l)$$

with the crisp rule

$$R(\mathbf{x}, s) \leftarrow R_1(\mathbf{z}_1, s_1), \ldots, R_l(\mathbf{z}_l, s_l), P_f(s_1, \ldots, s_l, s)$$

Example

$$\text{min}(s1, s2, s3) \leftarrow \text{built-in}(s3 = \text{min}(s1, s2))$$

$$\begin{aligned}
\text{is_in_a_situation}(?\text{user1}, ?\text{aSituation}, s) \leftarrow\ & \text{owns}(?\text{user1}, ?\text{aCalendar}),\\
& \text{contains_as_next}(?\text{aCalendar}, ?\text{nextEvent}),\\
& \text{is_located_in}(?\text{nextEvent}, ?\text{aPlace}),\\
& \text{is_scheduled_at}(?\text{nextEvent}, ?\text{anInterval}),\\
& \text{is_started_at}(?\text{anInterval}, ?\text{aTime}),\\
& \text{mobility}(?\text{user1}, \text{`moving'}, s1),\\
& \text{has_current_time}(?\text{user1}, ?\text{userTime}),\\
& \text{is_before_of}(?\text{userTime}, ?\text{aTime}, s2),\\
& \text{type}(?\text{nextEvent}, \text{`business'}),\\
& \text{Pre_Meeting_on_Movement}(?\text{aSituation}),\\
& \text{min}(s1, s2, s)
\end{aligned}$$

- However, SWRL is a rule language supporting unary and binary predicates only . . .
- Not a particular problem, as we may rely on a well-known procedure, called reification
- Example: for

$$is-before-of(?userTime, ?aTime, s2)$$

we create a new class

$$is-before-ofRelation(?aTimeReification)$$

with two additional properties

$$is-before-ofValue(?aTimeReification, ?aTime)$$
$$is-before-ofDegree(?aTimeReification, s2)$$

and, thus, $is-before-of(?userTime, ?aTime, s2)$ will be replaced with

$$is-before-of(?userTime, ?aTimeReification),$$
$$is-before-ofValue(?aTimeReification, ?aTime),$$
$$is-before-ofDegree(?aTimeReification, s2)\ .$$

Conclusions

- We have presented a situation-aware framework for personalised resource recommendation on mobile devices
- It is based on Semantic Web technology (OWL + SWRL), extended with Fuzzy Logic features
- Tested on two use cases
  - pharmaceutical consultant in typical business situations
    - situations of interest are: (i) *Meeting-Planning*, (ii) *Pre-Meeting*, (iii) *Ongoing-Meeting*, (iv) *Post-Meeting*, (v) *Hospital-Conference*, (vi) *Call-for-Tenders*, and (vii) *Meal*
  - off-site student, who performs a daily travel to go to university and return
    - situations of interest are: (i) *Pre-University-Day*, (ii) *Preparing-for-Transportations*, (iii) *Traveling*, (iv) *Studying*, (v) *Attending-Courses*, and (vi) *Meal*
- In both use cases, domain-specific ontology has been added to the upper ontology and the fuzzy linguistic variables have been tuned properly
- A set of 13 rules has been designed for the above cases
- the system has been tested by considering the events concerning one overall working week of two different consultants and three different students, with 53 and 82 different test events
- A weakness of the system: the design of the linguistic variables is domain-specific and does not take into account actual differences among users.
- We are currently working on improving the possibility of adaptation of the system to the specific user