Plan Recognition

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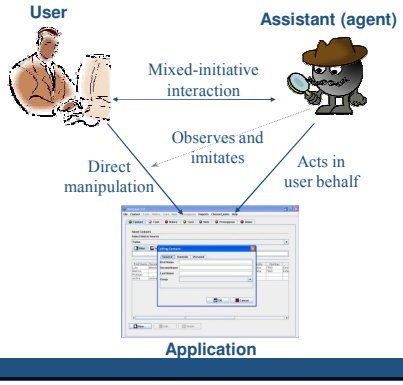
Agenda

- **Problem Overview**
  - Interface Agents
  - Plan Recognition
- **Probabilistic approach**
  - Monitoring user actions
  - Model of the application
  - Model of user intentions
- **Example**
- **Summary**

Interface Agents

- **Assist users in a personalized manner**
- **Learn interests, preferences and needs of the user**
- **Should consider the status of the user's attention and the uncertainty about the user's goals**
  - ability to recognize or predict opportune moments for gaining the user's attention

Interface Agents



Interface Agents

- **Two ways of detecting the user's intention**
  - Asking the user
    - Is a direct way of accessing to his/her intentions
    - We run the risk of disturbing him/her
    - Slows down the interaction
    - Interrupts the user's line of thought
  - Inferring from context
    - Information obtained from user's interaction with the application is on a low level compared to the user's intention

Plan Recognition - Objective

- **Aims at identifying the goal (or intention) of a subject based on the actions he performs in an environment**

Plan Recognition - Objective

- **Aims at identifying the goal (or intention) of the user based on the tasks he performs in a software application**

Some definitions…

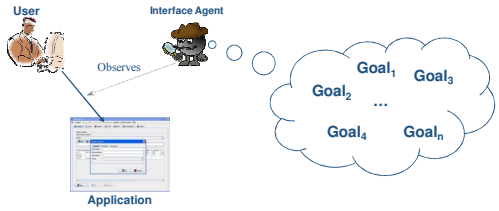
- **Action**
  - Event performed by the user in the GUI of the application.
  - Ex.: Mouse click, key typed, etc
- **Task**
  - Piece of work that the user can perform in the application
  - Ex.: Send an email, add a contact to the address book, enter the topic of a meeting
- **Intention / goal**
  - The desire of the user to do something in the application.
  - Ex.: Arrange a meeting with my friends, Register the birthday of a contact
- **Plan**
  - The set of tasks the user performs to achieve his intention

Plan Recognition – Inputs and outputs

- **Inputs:**
  - a set of goals the agent expects the user to carry out in the domain,
  - a set of plans describing the way in which the user can reach each goal,
  - an action observed by the agent.
- **Output:**
  - foretelling the user's goal, and determining how the observed action contributes to reach it

Plan Recognition – Basic Idea

- **narrow the number of possible goals the agent believes the user is pursuing by observing the actions the user performs.**



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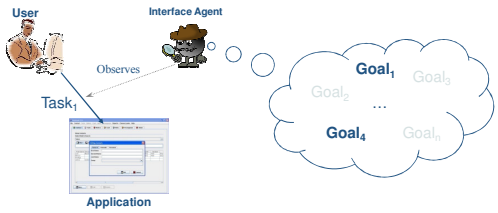


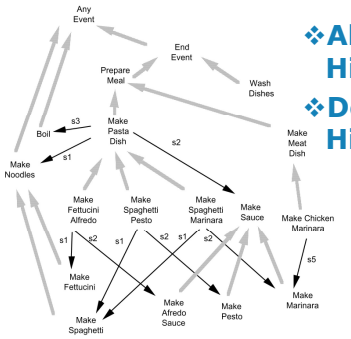
Plan Recognition for Interface Agents

- **We have to consider several issues:**
  - The uncertainty related to the moment in which the user starts a new plan
  - Overloaded tasks
  - Noisy tasks
  - Interruptions and plan abandonment
  - Multiple interleaved goals
  - Multiple plans
  - Adaptation to the user

Approaches to Plan Recognition

- **Consistency**
  - Determine which of an input set of goals is consistent with the observed tasks
  - A goal G is consistent with a task sequence T if T might have been executed in service of G
- **Probabilistic**
  - Select as a candidate intention that with the higher probability in light of the evidence at each moment

Plan library for a Consistency approach

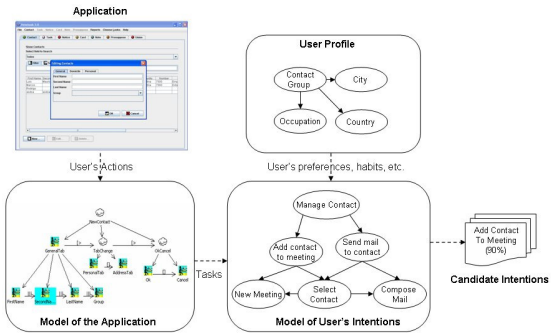


- **Abstraction Hierarchy**
- **Decomposition Hierarchy**

Probabilistic approach

- **Model for the detection of the user's intentions**
  - Used by an interface agent as the context in which the user is moving through
    - Assist the user in the context of his intention
    - Finding appropriate moments to initiate an interaction with the user
  - Three basic steps
    - Observe the user's interaction with the application
    - Known the task the user is performing in the application
    - Infer the user's intention
      - Adapted to each particular user

Probabilistic approach - Overview

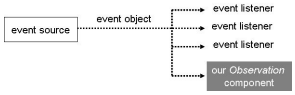


Monitoring user actions

- **We should not modify the application in order to detect user actions**
  - Dependent on the programming language
  - JAVA
  - Example

Monitoring user actions

- **Any number of objects can register as listeners on an event source**



Model of the application

- **Task Model**
  - Representation used to specify the tasks that the user can perform in the application.
  - Hierarchical structure
  - Temporal restrictions between tasks
  - ConcurTaskTrees
    - Rich set of operators
    - Task model simulator

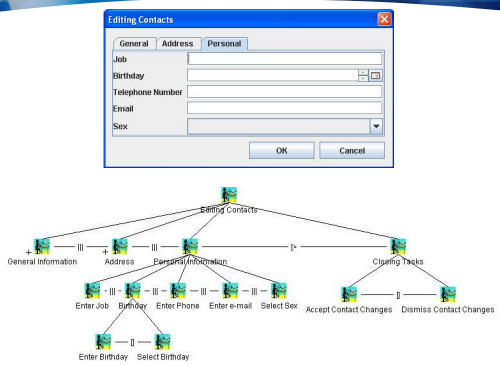
ConcurTaskTrees

- **Binary operators**
  - Choice: T1 [] T2
  - Order Independence: T1 |=| T2
  - Concurrency: T1 ||| T2
  - Concurrency with information exchange: T1 |[]| T2
  - Deactivation: T1 [> T2
  - Suspend / Resume: T1 |> T2
  - Enabling: T1 >> T2
  - Enabling with information exchange: T1 []>> T2
- **Unary operators**
  - Optional: [T1]
  - Iterative: T1*

ConcurTaskTrees

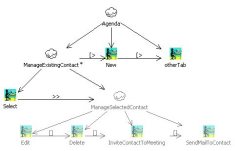
- **Categories of tasks**
  - Define the allocation of their performance
    - User Task
    - Application Task
    - Interaction Task
    - Abstract Task
- **Types of tasks**
  - Groups tasks according to their semantics
  - Each category has it owns types
    - For example, for interaction tasks: Selection, Control and editing

Model of the application



Model of the application

- **Operators allow the agent to know which tasks are *expected***
- **Task model simulator**
  - After each action performed by the user, the agent set the corresponding task as *performed* in the task model
  - According to the operators, the expected task list is updated



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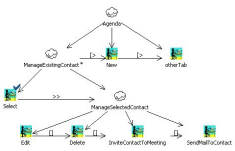


Model of user intentions

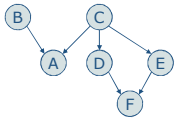
- **An interface agent should be able to detect higher level goals of the user**
  - Enhance and personalize the interaction with the user
  - Adapt its behavior to the user's needs
- **Model of user intentions**
  - General information about the intentions users can pursue in the application
  - Specific information about the habits and preferences of a particular user

Model of user intentions

- **Intention Graph**
  - models the intentions the user can pursue in the domain
  - represents the influence that a set of tasks has in the confidence the agent will have in any intention that the user could be pursuing.
  - materialized by a Bayesian Network
    - Knowledge representation capable of capturing and modeling dynamically the uncertainty of user-application interactions

Bayesian networks

- **Probabilistic knowledge representation used to model uncertain information**
  - DAG structure
    - Nodes → random variables
      - Mutually exclusive set of states
    - Arcs → causal relations
  - Strength of relations are encoded in conditional probability tables (CPT)



Bayes Theorem

- **Bayes' rule tells us how to update our belief about a hypothesis Vi in the light of new evidence Vj.**

$$p(Vi/Vj) = \frac{p(Vj/Vi)\,p(Vi)}{p(Vj)}$$

- **p(Vi|Vj) is calculated by multiplying our prior belief p(Vi) by the likelihood p(Vj|Vi) that Vj will occur if Vi is true**
- ***Evidence*: collection of findings on some variables**

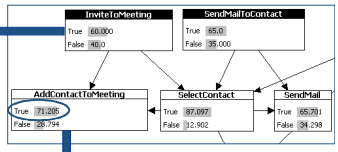
Intention Graph

- **Intention Graph G=<V,A,P,F,T>**
  - A set of variables V, where each variable can be of the type:
    - Task: a variable representing a task of the application
    - Goal: a variable representing a goal the user can pursue while using the application
    - Context: a variable representing attributes or properties of tasks in the application
  - A set of directed edges A between variables
  - Each variable has a finite set of mutually exclusive states
  - The variables together with the directed edges form a directed acyclic graph (DAG).
  - To each variable v in V with parents $v_1,\ldots,v_n$, there is attached the potential table P_v encoding $p(v|v_1,\ldots,v_n)$
  - A fading function F for evidence introduced in the network
  - A set of T traceable nodes, which is a subset of the nodes in V

Intention Graph

P(InviteToMeeting)=0.6

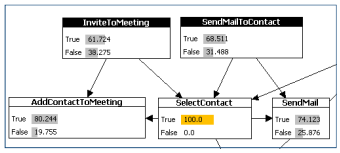
Confidence Level



P(AddContactToMeeting/SelectContact, InviteToMeeting) = 0.99
P(AddContactToMeeting/SelectContact, ¬InviteToMeeting) = 0.2
P(AddContactToMeeting/¬SelectContact, InviteToMeeting) = 0.5
P(AddContactToMeeting/¬SelectContact, ¬InviteToMeeting) = 0.01

Overloaded Tasks and Multiple Interleaved Goals

- **Overloaded task: a task that the user can perform to achieve multiple goals**



Agentes Inteligentes Plan Recognition

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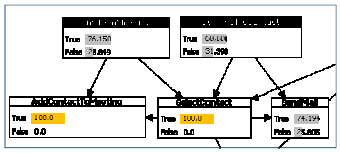

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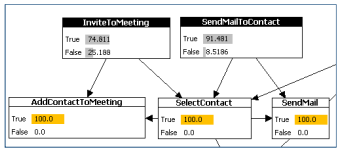

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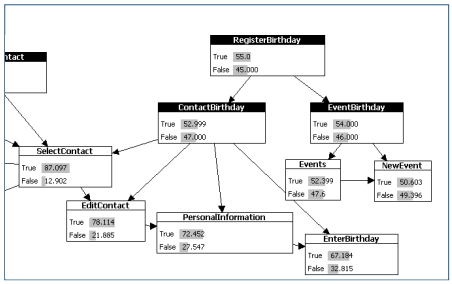
Multiple plans



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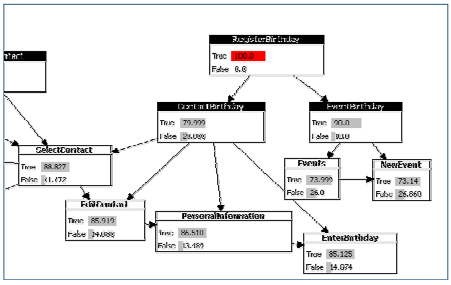

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Noisy Tasks and changes in the user's goal

- **Fading function**
  - Gradually forget past observations
  - Ex.: decrement evidence by a constant factor
- **Soft evidence**
  - Use a probabilistic distribution to set evidence in Bayesian Networks

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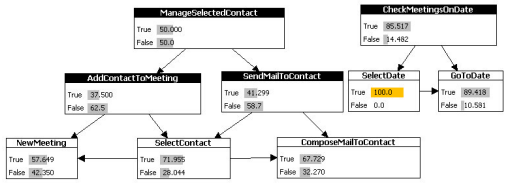
Noisy Tasks and changes in the user's goal



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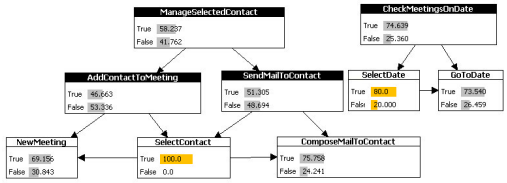

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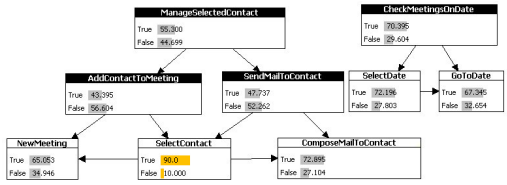


Personalization: Learning from the user

- **Adapt the process to a particular user of the application**
  - Adaptation of probabilities
  - Learning new relations

Adaptation of probabilities

- **Adapt the CPTs established by the designer to a particular user**
- **User Feedback declaring his intention**
- **Fractional updating** [Jensen2001]
  - Statistical approach
  - Experience count

$$p(N = k \mid conf) = \frac{n_k + y_k.z}{count_{old} + z}$$

Adaptation of probabilities

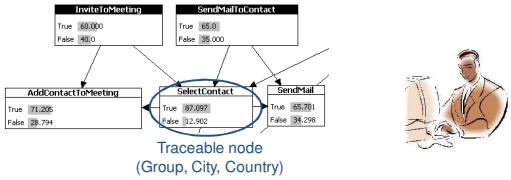
- **N=node**
- **k= state**
- **conf = pa(N) configuration**
- **z = probability of conf**
- **n_k = count of N being in state k**
- **y_k = probability of query N being in state k**
- **$count_{old}$ = previous count of experiences for n being in state k**

$$p(N = k \mid conf) = \frac{n_k + y_k.z}{count_{old} + z}$$

Learning new relations

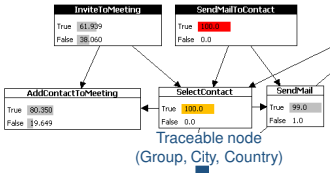
- **Use the attributes of the tasks performed by the user to build an interaction history**
- **Traceable node: a task node of the Intention Graph in which we want to register the values taken by such attributes**
- **Find new relations between these attributes and the nodes in the Intention Graph**
  - Batch learning and Parametric learning for Bayesian Networks.

Learning new relations



Traceable node
(Group, City, Country)

Learning new relations

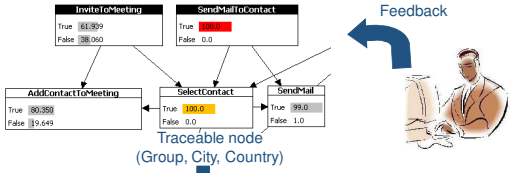


Feedback

Traceable node
(Group, City, Country)

```
Friends, Tandil, Argentina, False, True
Work, BsAs, Argentina, True, False
...
```


Learning new relations



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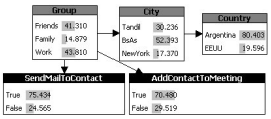
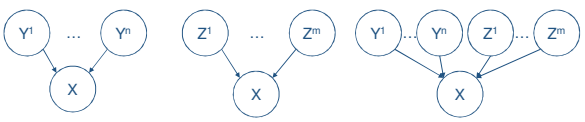
Batch learning
+ Parametric learning



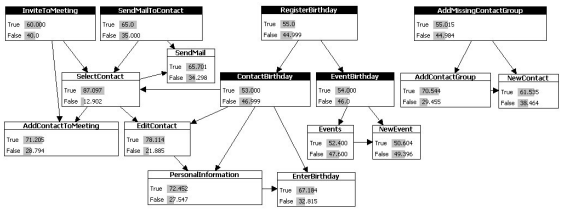
Learning new relations

- **Merging the learnt network into the Intention Graph**



$$p(X_j \mid Y_{1_{j1}},...,Y_{n_{jn}},Z_{1_{j1}},...,Z_{m_{jm}}) = p(X_j \mid Y_{1_{j1}},...,Y_{n_{jn}}).\prod + p(X_j \mid Z_{1_{j1}},...,Z_{m_{jm}}).(1-\prod)$$

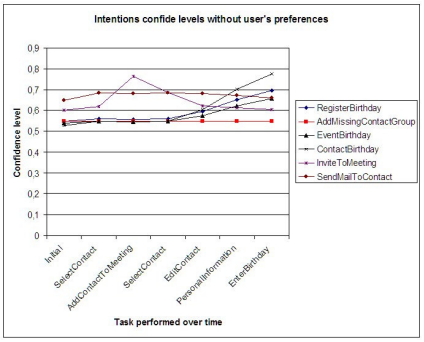
Example 1



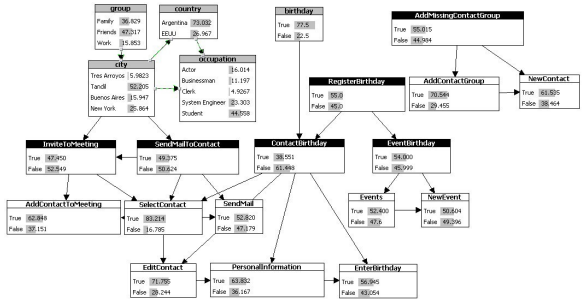
1. SelectContact
2. AddContactToMeeting
3. SelectContact
4. EditContact
5. PersonalInformation
6. EnterBirthday

1. Organize a meeting with John Smith
2. Register Mary's Birthday

Example 1



Example 2



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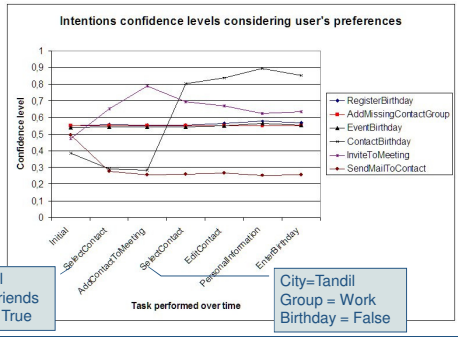

City=Tandil
Group = Friends
Birthday = True

City=Tandil
Group = Work
Birthday = False

Summary

- **Inferring the goal of the user from observations of his actions**
  - A problem of inference under conditions of uncertainty.
- **Non-probabilistic approaches can not decide to what degree the evidence supports any particular goal hypothesis.**
  - important issue to consider so that the agent could be able to rank different possible explanations supported by the set of performed actions.
- **We presented a probabilistic approach able to**
  - deal with some common problems of plan recognition
  - adapt to a particular user of the software application

Questions

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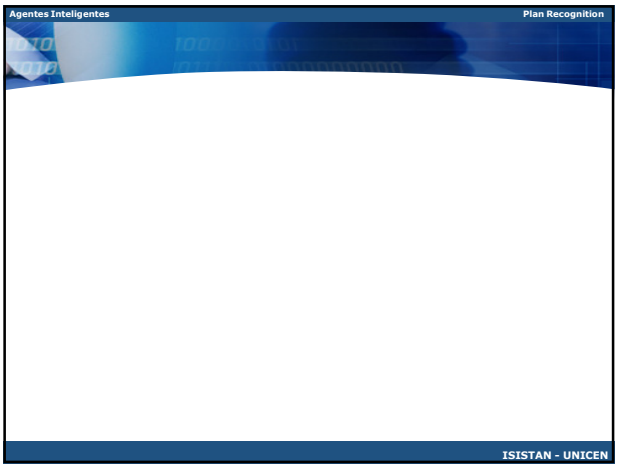
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