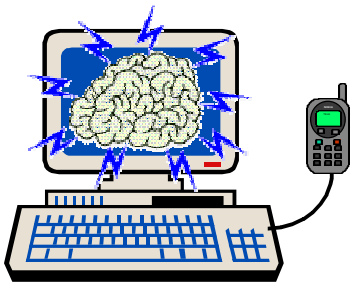
Intelligent Agents
in a
Wireless Environment



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Themes of This Presentation

- What is the Monads project?
- Why are we interested in intelligent agents?
- How could we use intelligent agents?
- Overview of the research on intelligent agents
- The approach chosen by Monads
- What problems brings the wireless environment?
- Concluding remarks

Monads in a Nutshell

- Targeted to nomadic users
  - Mobile computers (laptop, PDA)
  - Wireless communication (GSM, GPRS, WLAN)
- Intelligent and mobile agents
- Based on Mowgli
- Goal is to make the life of nomadic users easier
  - Make existing applications work smoother
  - Make new useful applications
- Supported by Nokia, Sonera, and Tekes

The Wireless Environment

- Slow and expensive network connection
- Suddenly changing conditions
- Terminals may have very limited resources
  - low processing capacity
  - little main memory, small/missing hard disk
  - small display, possibly non-graphical
- Terminal and User mobility
  - Quality of the connection may change while moving
  - User's behavior and needs may depend on the location

Examples: Web Browsing

- Quality of images on web pages is automatically reduced when the connection becomes poor.
  - shrink, reduce number of colors, ignore
- The user keeps on browsing even the connection was lost. How is this possible?
  - The system has correctly predicted onto which web pages the user will go next, and prefetched those web pages.
- The system finds web pages related to the current or future location of the user.

Examples: E-mail and Newsgroups

- E-mails/news are ordered according to user's interests
  - send important messages first
  - ignore unwanted messages
  - send only first few lines of large messages
  - do not send large attachments automatically
- E-mail/news specific compression
  - use previous messages to get better compression rate
- Automatically establish a connection *from* fixed network when a very important message arrives.

Examples: Tourist Helper

- Reserve a room from the nearest/cheapest/best hotel and tell how to get there.
- I want to go from here to location *X*. Which bus should I take?
- Find the nearest restaurant that has user's favorite food on today's menu.
  - predict when the user will be hungry and do the search beforehand
- Notify the user about interesting exhibitions on his/her way.

Required Intelligence

- Adaptation to
  - changing conditions of the network connection and other resources (power, processor load)
  - user's behavior and needs
    - Behavior may depend on time and location
    - The user may have several "roles" (work/freetime)
- The benefit from adaptation depends on how early it was done.
  - Too late adaptation may make things even worse!
  - Optimally we *predict* changes and adapt *beforehand*

Required Intelligence (slide 2)

- Filtering/pre-processing of data to be sent over wireless link
- Prioritizing/scheduling of processes and data packages
  - emergency mode
- Prefetching
  - e-mails / web pages / news / files / classes
- Search for information related to current location

Key Features

- Predict
  - Changes on the link quality
    - What is the expected throughput at time T?
  - Future location of the terminal
  - User's actions
- Learn
  - Characteristics of network connections
  - *Behavior Patterns* ("habits") of the user
    - especially *Movement Patterns*
  - User's interests (e.g. how he/she classifies e-mails)

More Requirements

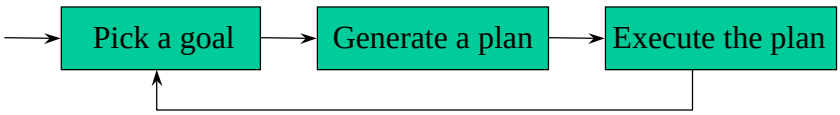
- Use predicted values to make intelligent decisions
- Conflicts must be avoided or resolved
  - Agents may disagree on use of resources
- System must react quickly to sudden changes in the environment
- Learning must be fast
  - User must be able to *teach* the system
- Building of new intelligent agents must be easy!

Research on Intelligent Agents

- Unfortunately, intelligent agents can not be bought from an agent shop
- Several approaches to intelligent agents:
  - Classical rule-based agents
  - Reactive agents
  - Hybrid agents
  - Distributed Artificial Intelligence
  - Learning agents

Classical Intelligent Agents

- Symbolic representation of the world:
  - Agent's knowledge about its environment
    - beliefs, desires, intentions
  - Rules that apply in the world
  - Goals of the agent
- "Intelligence" comes from symbolic reasoning
- A planning agent:



Problems with Symbolic Reasoning

- How to translate the world into an accurate and adequate symbolic description?
  - Closed world assumption
  - Who defines the rules?
  - Translation may take too much time
- Reasoning may take too much time
  - Late results may be useless
  - Slow reactions to changes in the environment
- Does not scale to real-world scenarios

Reactive Agents

- Intelligence is a product of *interaction* between an agent and its environment
- No symbolic representation or reasoning
- An agent is a collection of task accomplishing *behaviors*
- Each behavior continually maps perceptual input to action output
- Overall behavior is determined by interactions between behaviors

Problems with Reactive Agents

- Reactive systems are typically “handcrafted”
  - Development takes a lot of time
  - Impossible to build large systems?
  - Can be used only for its original purpose
- Hard to teach
  - The user can not easily affect to the behavior of the system.

Hybrid Agent Architectures

- Mix the good ideas of previous approaches
- An agent consists of several subsystems
  - Subsystems that develop plans and make decisions using symbolic reasoning
  - Reactive subsystems that are able to react quickly to events without complex reasoning
- Controlling system is needed

Distributed Artificial Intelligence

- Sometimes the problem is so complex that it is better to break it down into subproblems
- Distributed Problem Solving (DPS)
  - Divide a problem to several agents
  - Control the solving process
  - Collect and combine the results
- Multiagent Systems (MAS)
  - Agents may have different goals
  - Typically heterogeneous agents
  - Controlling is needed to avoid chaos

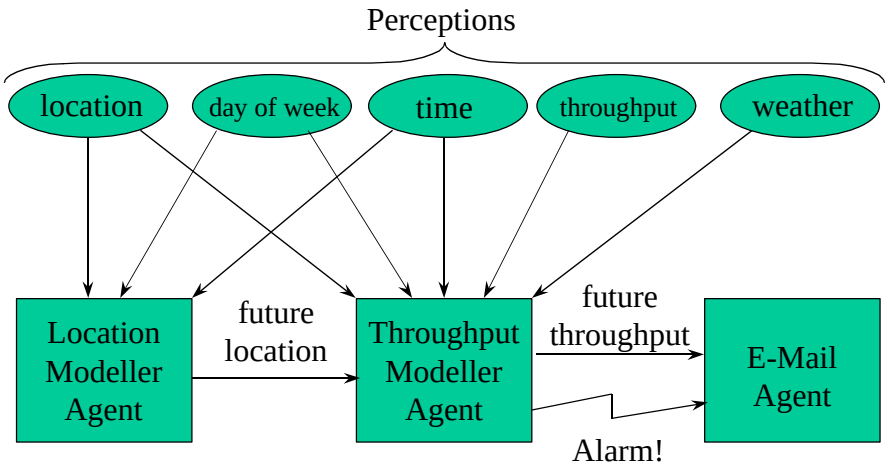
Learning Agents

- There is no intelligence without learning
- My definition of an intelligent agent:
  - An agent is intelligent if it does something *useful*, but the programmer of the agent can not explain *why*.
    - Otherwise the agent is just following some rules given by the programmer.
- Several good learning algorithms exist
  - We just have to apply them to right purposes!
- Use of learning components might solve some problems of previous approaches

Intelligent Agents in Monads

- Mixture of previous approaches
  - A reactive multiagent system including rule-based and learning agents.
- Small and simple agents that can solve only few problems, but do it well
- Agents use other agents to perform their tasks
- System support for learning
  - Use of learning components is made easy
  - Knowledge sharing between learning components

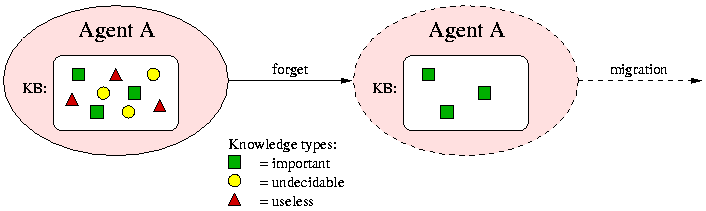
Example: E-mail agent



Mobile Intelligent Agents

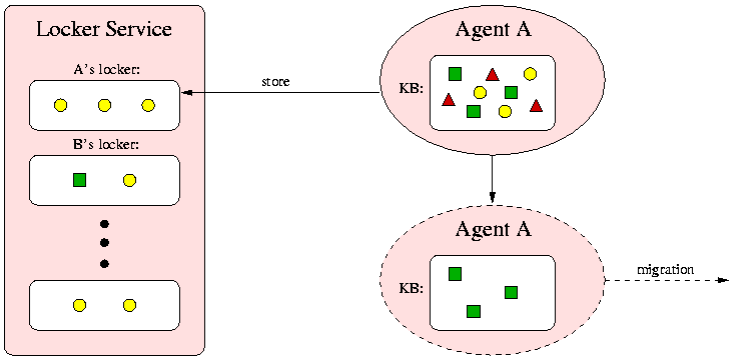
- Mobile agents can move between agent servers
- Good reasons to move an intelligent agent:
  - Move to a more powerful machine to do computationally heavy tasks like learning
  - Move intelligence to where it is needed
  - Move before connection is lost to keep on working
- An intelligent agent may be too big to be sent over wireless link
  - Forget unnecessary knowledge
  - Leave some of the knowledge to the starting point

Forgetting knowledge

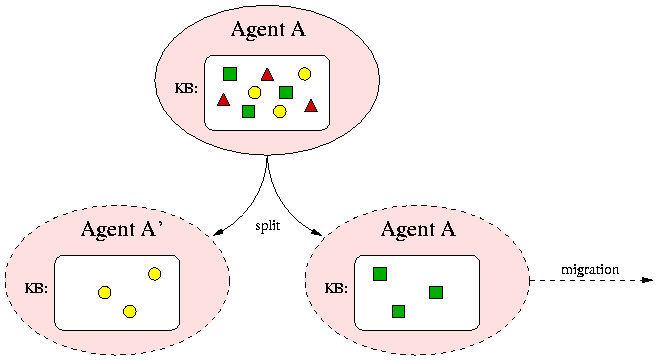


"I forgot to make a back-up copy of my brain, so everything I learned last semester was lost."

Knowledge Locker Service



Splitting Agents



Knowledge Sharing

- Learning requires a lot of data
- Several agents may be trying to learn the same thing
  - Each agent has its own local data
  - None of the agents have enough data
  - Too much data to be shared over wireless link
- Knowledge sharing in Monads
  - Central model repository
  - Agents test and compare models built by others
  - Make better models by combining existing ones

Concluding Remarks

- Intelligent agents have many uses in wireless environments
  - Intelligent adaptation
  - In some cases, intelligence is the only choice!
- Learning is needed
  - Probably also knowledge sharing
- Mobile intelligence with mobile agents
- Monads project will use intelligent and learning agents for adaptation to wireless links
  - a prototype will be ready in the beginning of year 2000