User Modelling for Multi User Environments

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- New uses for User Modeling: adaptive rewards

Stone age and Antiquity

1970

Middle-ages and Present

2000

1990
Types of UM architectures for MUE

**Centralized (UM Servers)**
- Recommender systems
- Expert Finding systems

**Decentralized**
- Multi-agent systems
- Ubiquitous Computing
- Online Communities

**WHAT ARCHITECTURES?**
**UM Servers: Main Advantages**

- Information maintained centrally or at a virtually central location can be used by many (distributed) applications; also information inferred by one application can be used by another application at the same time for a different purpose.
- Information is stored in a non-redundant manner in centralized user modelling, which more readily supports consistency and coherence of the user information.
- User modelling servers allow the application of methods and tools for security, identification, authentication, and access control.
- Information about user groups can be obtained more easily, as well as group user information can be added to the user models.

**Disadvantages**

- A centralized point of failure
  - May crack under high load of requests
  - Provides a tempting target for hacking and stealing user data
- Requires a standard representation of user data
  - All subscribing applications have to adhere to standard representation / shared ontology
  - Many applications use just a fraction of the data that they can be served
- User data is out of the context in which it was harvested
  - Can be interpreted in an incorrect / harmful way in a different context; generalization not straightforward

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**Backed by a database**

- Efficient
- Secure
- Scalable
- Standard technology

**Hosted at one place**

- Legal responsibility - regulated by privacy legislation
- Allows collecting data about large user population
  - Data-mining
  - Using demographic data for adaptation
  - “Cross-fertilization” – using user data across different subscriber applications
- Allows more complex inferences, consistency maintenance, more raw data available → better quality of deduced data

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**Centralized: UM Servers**

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Stereotypes and personalized stereotypes:
- BGP-MS (Kobsa, 1990), UMT (Brainik & Tasso, 1994)
- First-order logic and stereotypes
  - Tagus (Paiva & Self, 1994), um (Kay, 1995), Personis (Kay, 2002)
- Vectors (profiles)
  - GroupLens (Breese et al., 1998, Herlocker, 1999)
- Directories (LDAP servers)
  - Standardized, security and authentication
- Usually, storage of user data was not considered important; typically read from secondary storage – file or db – at launch time or were part of the program code

Example: MovieLens – a system for recommending movies
- Users first rate a set of 20 movies given by the system
- System computes similarity between user ratings
- If two users have rated similarly a number of movies the system predicts that movies that were rated positively by one of the users, but not seen by the other one will be rated positively by the other user too.
- It recommends these movies to the other user

Amazon recommendations – people who have bought similar things in the past are more likely to continue buying similar things.

Advantages:
- Easier to get user data (clicks, buys, ratings)
- Solid mathematical basis – Pearson correlation

The goal is to predict the score of empty cells for the active user, the user currently requesting recommendations.

Once scores have been predicted, a straightforward approach is to recommend the Top-N items that have the highest scores.
CF - basics

- Variety of recommendation strategies.
- Collaborative filtering algorithms are divided into two categories:
  - memory-based - uses statistical methods to derive predictions from like-minded users;
  - model-based - builds models of user ratings through machine learning algorithms (e.g. Bayesian networks)

Memory-based CF algorithms

- If the active user \( c \) has not rated item \( s \), but the recommender system can find similar or correlated users \( c' \) (i.e. a set of neighbours \( \hat{C} \)) who have, then a rating score can be predicted using:

  \[
  \hat{r}_{c,s} = \bar{r}_c + k \sum_{c' \in \hat{C}} \text{sim}(c, c') \times (r_{c',s} - \bar{r}_{c'})
  \]

- Where \( \text{sim}(c, c') \) is the Pearson correlation coefficient (next slide)
- \( k = 1 / \sum_{c' \in \hat{C}} \text{sim}(c,c') \) is a normalizing coefficient

Similarity between 2 users

\[
\text{sim}(c, c') = \frac{\sum_{s \in S_{c,c'}} (r_{c,s} - \bar{r}_c)(r_{c',s} - \bar{r}_{c'})}{\sqrt{\sum_{s \in S_{c,c'}} (r_{c,s} - \bar{r}_c)^2 \sum_{s \in S_{c,c'}} (r_{c',s} - \bar{r}_{c'})^2}}
\]

- Users tend to use ratings scales differently.
  - For example, on 5-scale rating, the active user may seldom rate 1 or 5 while a neighbour only rates 1 and 5.
- Therefore, the average rating of the active user and current neighbour (\( \bar{r}_c \) and \( \bar{r}_{c'} \), respectively) are used to smooth out this inconsistency.
- \( S_{c,c'} \) is the set of items both users have rated in common.

Limitations

- The lack of ratings presents well-known challenges: if rating information does not exist, then predictions will be inaccurate or undefined
  - new users must rate some number of items before recommendations can be made,
  - new items must receive ratings before being recommended to users
- The computational complexity of memory-based algorithms requires offline calculations (e.g. at night when resource demand is low), and they do not scale well under millions of items and users

Expert Finding

- Example: the PHelpS system (Prison Help System)
  - The system discovers the area of expertise/knowledge of each user (prison guard/employee) by monitoring how many times they completed certain tasks
  - User model – a overlay of a domain task model, together with information about location, time-zone, telephone, language (En/Fr)
  - When a user asks for help with a certain task (filling out a form), the system finds a suitable user (location, time zone, language) who has completed this task a number of times before and shows her phone number.

- Many such systems since 1986…

Modeling the expertise of experts
- Latent Semantic Analysis of documents, e.g. e-mails (www.lasif.com), newsgroup postings,
- Analysis of web-browsing patterns (systems called Memoir, Expert Browser),
- Social network analysis from emails, paper co-authorships etc.

Matchmaking
- Keyword matching
- Similarity matching (e.g. correlation like in CF, or vector-space based methods)
- Domain-model enhanced (with concept- or task-relationships that imply knowing sub-concepts or tasks)

Multi-Agent Expert Finder System

- Each user represented by an agent who keeps the UM of the user
- Resources and applications are also represented by agents with application models (AM)
- User model is private, user can interact with the agent and change the UM as she wants to be perceived by others
- Agent connects with other agents and searches for good matches for the user’s need
- Agent society, agent economy…
Goal-driven social agents

- Agents are autonomous and rational
- Types of Agent Goals:
  - intrinsic: maximize utility, save state, maintain resource repository, evaluate goal importance
  - extrinsic: adopted from user, from other users
- Intra-Agent Process:
  - Monitor the environment
  - Calculate goal importance
  - Calculate and maximize utility (Utility function → agent “character”)
  - Retrieve plans for goal achievement / plan
  - Execute plans
  - Delegate goals
- Inter-Agents Process:
  - Agents can communicate
  - Agents can not achieve their goals alone → need to collaborate: delegate goals, provide services, share resources, and to compete for resources
  - Agents offer excess resources or services in exchange for money
  - Agents negotiate to resolve conflicts
  - Agents make models of other agents

Possible implementations

- Physically distributed on Different machines (P2P)
- Physically centralized - All agents reside on the same server
  - Why?!
    - to minimize communication costs
  - Yet, logically decentralized!
    - preserved autonomy of each agent - can have its own UM representation
Agent Negotiation

- Agents negotiate on behalf of their users depending on
  - the importance of a request
  - the importance of own goals
  - the importance of saving or earning money
  - the importance and sign of the relationship

- Each agent computes a utility function
  - one for the utility of getting help
  - one for the utility of providing help
  - price affects utility; quality affects price
  - agents have limited knowledge about each other

- Decision theoretic approach
- Negotiation protocol

UM challenge

What User Models in such a decentralized environment?

- User models AND Application models
- Agents modelling other agents in negotiation
- User model as a repository of user resources:
  - knowledge
  - social competence
  - time, money and relationships with other users
- Distributed, domain/task specific diagnostic applications
- User information that is context dependent?

Ubiquitous Environments and UM

- Smart appliances have appeared on the market that maintain use characteristics and adapt their functionality

  Examples:
  - Refrigerators keep track of user preferences and stored food and order out-of-stock items via the internet
  - Mobile phones preload pages that are assumed relevant
  - DVD recorders record programs deemed interesting for the viewer based on her viewer patterns
  - Museum guides that adapt presentation and tours
  - Car-radios and navigation systems …

- User data fragments everywhere:
  - Variety of user features modeled, representations, adaptation techniques (what is adapted, how).
Decentralized UM

- Every application / agent stores user data locally in its own representation format
  - data is lose to the context of its harvesting and use
- Applications communicate and share user data
  - only on a “need to know” basis
  - for particular purpose
- User modeling
  - Searching, retrieving and integrating fragmented user information from diverse sources at the time when it is needed for a particular purpose.
  - “to model” (verb) is a process, not a data-structure!!

Centralized vs. Decentralized UM

- Centralized
  - collecting at one place as much information as possible
  - about many users,
  - to make sure it is correct and consistent,
  - so that it can be used for many purposes.
- Decentralized
  - user information fragmented among many applications
  - each application models one or more users
  - inherently inconsistent (in different contexts, applications autonomous and by different designers)
  - fragments are retrieved and combined just in time for one specific purpose only

Purposes for modeling

- A “Purpose” is like a recipe – a procedural knowledge representation construct
  - Retrieval – which are the relevant sources to get user data from
  - Interpretation – mapping information to own representation / context
  - Integration – reasoning based on the user data and possibly generating new user data
  - Adaptation – using the user data to make a decision about adaptation of interface or functionality.
- Example: Selecting new graduate students
  - Retrieve data from transcripts, letters of reference (not from his mom)
  - Interpret the marks: 6 in Bulgaria corresponds to 1 in Germany, to 92-95% in Canada
  - Integrate the interpreted data from all sources, for all considered students
  - Adaptation – generate a ranked list
**Purposes**

- Procedural, decentralized
- Computed just-in-time on demand
- A purpose defines the context and the processing (both user modeling and adaptation) to be done in that context
- Purposes can be designed as clichés and re-used in different situations
- Purpose libraries for designers of adaptive autonomous interconnected applications

**Purposes**

- **Collaborative Recommenders**
- **Expert Finding**
- **Decentralized UM**

**Purposes**

- **Decentralized UM**
- **Purpose-based UM**
- **Policies in OC**

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**Purpose Hierarchies**

- **Specialization**

**Purpose**

- **Finding an expert agent**
- **Matching user type and advertisements**
- **Checking most used expert agent**
- **Checking trust in expert agents by similar investors**
- **Do subPurpose by taking into account user types**

**Purpose-base UM**

- **Policies in OC**

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**Online Communities**

Many communities exist

Few collaborate and share users yet, but in the future they will. Users will be travelling seamlessly across online communities, as they travel from city to city in the real worlds.

Do they have to be strangers when they go to a new place?

How to share user data across?

Authentication (login data)

Profile (interests, status, friends, resources?)
## User Models in OC

- Fragments stored by logically and physically distributed nodes
- How to collaborate and share data, without giving up the autonomy
- How to update and synchronize models of users who are members of many communities

**Example:**
- European Countries have agreed to a standard format and security features of their national passports and have implemented standard policies for sharing data to facilitate travel within the EU (Schengen)

## Policies in OC

- UM in OC are based on policies describing the role, status, and rights of each user
- Roles, status, imply rights and adaptation of the functionality and interface of the OC to the user.
- Examples:
  - "New users can not delete links" = If user_participation_C1 < threshold disable "delete link" functionality.
  - "Users from community C2 are not treated as new users". If user_participation_C2 <> 0, user_participation_C1 = user_participation_c2
- The purpose-based approach can be implemented through policies
  - Transparent
  - Editable by users in certain roles (moderators)

## Comtella Framework for OCs

- Every user can create a community → "owner"
- Communities can be hosted at different websites (Comtella nodes)
- Every owner defines the policies for rewarding participation (e.g. bronze, silver, gold status), the privileges with each status level, the roles that users can take (e.g. guest, member, moderator) and the rights associated with the role.
- Policies are like decision making procedures that use UM data to generate new UM data or to make an adaptation decision – enabling or disabling a particular interface feature.
- UM data can be from any community in the NW

## Policies in Comtella: user editable UM processes

- UM models created by different policies in different communities
- Policies used in different communities created by different community owners

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## Comparison

<table>
<thead>
<tr>
<th>Centralized UM</th>
<th>Decentralized UM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed schema (user features)</td>
<td>No fixed representation schema - diverse user features</td>
</tr>
<tr>
<td>De-contextualized</td>
<td>In context</td>
</tr>
<tr>
<td>Same update mechanisms</td>
<td>Purpose-defined update mechanisms</td>
</tr>
<tr>
<td>Maintaining consistency is a goal</td>
<td>No attempt to maintain consistency</td>
</tr>
<tr>
<td>Designed</td>
<td>Participative</td>
</tr>
</tbody>
</table>

**Expert Finding**

**Decentralized UM**

- Purpose-based UM
- Policies in OC

**Collaborative Recommenders**

- Designed update mechanisms
- No attempt to maintain consistency
- Participative

**UM Servers**

- De-contextualized
- Same update mechanisms
- Maintaining consistency is a goal
- Designed

**Purpose-based UM**

- Purpose-defined update mechanisms
- No attempt to maintain consistency
- Participative