User Modeling and Personalization
2: User Modeling - Introduction

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Outline I

Introduction

User model contents
   Explicit and implicit models
   Differences in lifetime and scope

User modeling process

Obtaining user data
   Direct input from the user
   Observing the user
   Relevant user data

Knowledge inference

User model representation
   User data and metadata
   User model structure

Outline II

Understanding the user

Tools such as Google Analytics show general trends:

- ▶ number of visits and users
- ▶ where do users come from, which systems do they use
- ▶ popular pages and keywords

User modeling is about getting to know the *individual* user.

User Model and the Process of User Modeling

User Model

A User Model is a data structure that characterizes a user U at a certain moment in time.

In other words, at a certain point of time t the User Model contains a snapshot of the characteristics of the user U, as collected, inferred and stored by the system S.

The user characteristics in the User Model may be explicitly provided by the users themselves (e.g. preferences, hobbies); alternatively, they can be inferred from the (raw) user data of U (will be explained later).

The interpretation of the user characteristics depends on how these characteristics have been provided:

- If the user provided the characteristics himself, the corresponding elements in the User Model are simply the system's *representations* of these characteristics,

- If the characteristics have been inferred from raw data, the corresponding user model elements are *estimates* from the system S.

What information can be represented in a user model?

Traditionally, the following user characteristics are taken into account:

- ▶ *Demographic information*: simple demographics can be used for a rough initial fine-tuning of the interface (e.g. localization)
- ▶ *User goals and user tasks*: used to satisfy user needs as effectively, and efficiently as possible
- ▶ *User background knowledge*: which concepts a user is already familiar with, and which need additional explanation.

- ▶ *User interests*: used for determining the information, services or products that users are most likely to appreciate.
- ▶ *User skills and capabilities*: the user's familiarity with the system and practical knowledge on how to interact with the system.
- ▶ *User traits*: personality factors, cognitive factors, and learning styles.
- ▶ *User mood*: happy, stressed, relaxed, tense, afraid, motivated, bored, engaged, frustrated, . . .

Some information is easier to obtain or to infer than other information (do a reality-check yourself).

Explicit user models

Adaptive hypermedia systems aim to adapt the interface to better fit the user's knowledge, skills, interests and goals.

As a consequence, the inference techniques and representations used might be called *mentalistic*:

- ▶ the user model explicitly represents the relevant aspects of the user as closely as possible
- ▶ the model is built from human-like inferences.

Advantage: the process is intuitive and the models are interpretable and reproducible

Disadvantage: it is known to have limitations in scalability and extendability

Implicit user models

As an alternative approach, statistical models and machine learning technique have become popular, in particular in the context of the Web.

- ▶ implicit, statistical approaches are more flexible and better suitable for dealing with huge quantities of data
- ▶ implicit user models are built from raw user data, which is the input for the adaptation mechanisms

Example: The Amazon online store recommends items of interest based on (among others)

- ▶ items that you bought, searched or browsed in the past
- ▶ items that you recently visited
- ▶ items that similar users bought, searched or browsed (similar means: there is an overlap between items visited by you and them)

But Amazon does not know:

- ▶ whether you look for items for yourself or for your mother-in-law
- ▶ whether you are window shopping, shopping for work, or for private reasons
- ▶ whether you already have these items

Still, these methods work quite well (and users can tell Amazon when assumptions are wrong).

Differences in lifetime and scope

Depending on the type of user model and the function it fulfills.
Possible variations:

- *short-term user models* that are valid for a specific session or task
- *long-term user models* that store knowledge, interests, demographics etc.
- *individual user models* store information about a single user
- *group models* represent groups of users (e.g. a class of learners)

User Modeling

User Modeling

User Modeling is the process of creating and updating a user model, by deriving user characteristics from user data - which is either data that is explicitly provided by the user or data that stems from indirect events and observations.
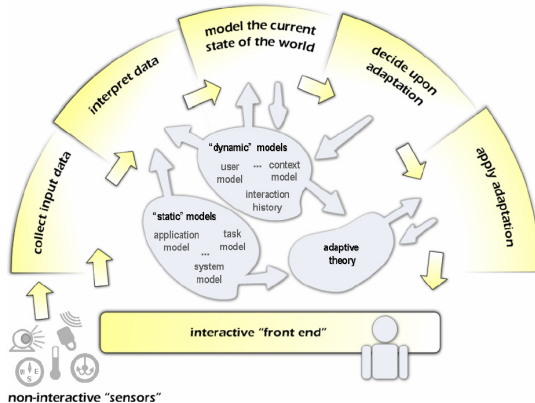
Methods of user modeling

Three tasks can be separated in the user modeling process:

- ▶ acquisition of user data
- ▶ inference of knowledge from the data
- ▶ representation of the user model

Some critical notes on user modeling:

- ▶ When is a system allowed to update user characteristics, and in which situations?
- ▶ Not all observations can be translated to user characteristics with 100% confidence

The adaptation process: a process-oriented view

Alexandros Paramythis, Stephan Weibelzahl, Judith Masthoff. Layered evaluation of interactive adaptive systems: framework and formative methods. User Model. User-Adapt. Interact. 20(5): 383-453 (2010)
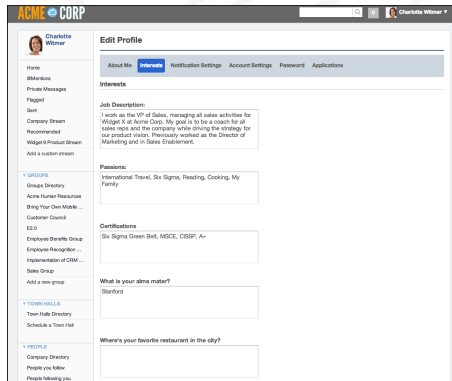
Acquisition of user data

User Data

User data consists of events and observations on the user's interaction with the system that can either directly be used for adaptation purposes, or need to be resolved to user characteristics.

Direct input from the user

User input (a user profile) is often gathered upon the first use of a system using forms or questionnaires. User input is also commonly gathered while the user interacts with the system.

Another option is that the user gives *relevance feedback*. In recommendation systems such as Movielens, feedback is an essential part of the system, as the recommendation process mainly relies on user ratings and reviews of movies.
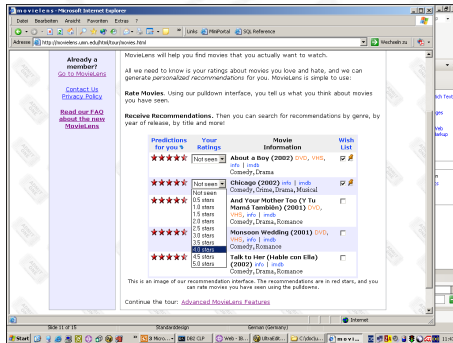
Another alternative: users make adaptations themselves by ordering lists, enabling or disabling options, dragging interface elements or by any other specific interaction with the system.

Observing the user

In many cases users just want to start working on their tasks without first reading manuals, following an introductory tour or filling out forms.

Many adaptive systems attempt to infer knowledge directly by unobtrusively monitoring the user interactions with the system.

Which user data can be of relevance

Personal data, demographics

- ▶ Name, address, age, birthday, email address, gender, phone number, credit card information, . . .
- ▶ Education, profession, . . .

  Can be used for a rough initial fine-tuning of the interface

Contacts and friends

- ▶ Friends' personal data, groups and group membership, chatlogs, . . .

Social Media

- ▶ User Ids or User Names for social media (e.g. Skype, Twitter, Facebook, LinkedIn, Xing)
- ▶ Login data (direct or via a token) for accessing the contents of the social media profiles
- ▶ Privacy controls (which data may be retrieved and used)

Device Information

- System specs, display resolution, network speed and bandwidth, software and tools

Location

- Position, direction, speed, vehicle, . . .

Browsing-History & Bookmarks

- ► Bookmark Folder
- ► History
- ► Search history
- ► Ratings of pages, sites and other objects

Learning actions

- ► Visited pages
- ► Test scores
- ► Number of test attempts
- ► Time spent learning
- ► . . .

And much more

Inference of knowledge from the data

Inference of knowledge

Knowledge inference is the process of interpreting events and observations on a user U, making use of conditions, rules or other forms of reasoning, and the storage of the inferred knowledge in the user model.

Many interactions contain meaning in themselves, such as page visits, bookmarking or saving actions, queries issued by the user and items inspected or bought from an e-commerce Web site.
Other interactions need to be combined or interpreted in order to become meaningful, such as key strokes, mouse clicks and eye gaze behavior.
The assumption for knowledge inference is that user interaction with a system is predictable to a certain extent.
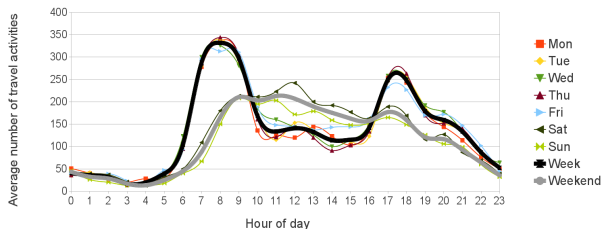
General approaches

In general, three approaches can be identified:

- ▶ detecting patterns in user behavior
  Useful when the aim of the adaptive system is to respond to recurrent behavior or to infer items that may be of the user's interest.

- ▶ matching user behavior with the behavior of other users
  Useful when a user behaves in a similar way to other users and is typically used for making recommendations involving items not seen before.

- ▶ classifying users or hypermedia content based on user behavior
  Common applications include stereotyping and the modeling of user interests.

Example from last week

A document D_j is assumed to be learned by a user, if it has been visited,

> $\forall\ U_i\ \forall\ D_j$
> $obs(D_j,\ U_i,\ Visited) \implies p\_obs(D_j,\ U_i,\ Learned).$

or if a document D_k, for which D_j is a prerequisite, has been visited:

> $\forall\ U_i\ \forall\ D_j$
> $(\ \exists\ D_k\ preq(D_k,\ D_j)\ \wedge\ obs(D_k,\ U_i,\ Visited)\ )$
> $\implies p\_obs(D_j,\ U_i,\ Learned).$

Many more techniques will be dealt with in the next lecture, as well as in upcoming lectures on web (usage) mining and recommender systems.

Representation of the user model

User Model

A User Model is a data structure that characterizes a user U at a certain moment in time.

What data formats can be used for representing user data?

Similar to the user profile, you can use **virtually any format,** for example

- ▶ Attribute-Value Pairs
- ▶ Probability Intervals
- ▶ Booleans
- ▶ Fuzzy Intervals
- ▶ Lists or Bags, possibly including weights
- ▶ Rules
- ▶ Heuristics
- ▶ References to external objects
- ▶ . . .

In addition: Metadata that can be used for deducting where the origin of the data, the age of the data, contexts in which they are valid, systems that can use the data, etcetera

Basic structure of a statement about a user

A statement in a user model should contain at least the first three statements of the main part (subject-predicate-object). Metadata is optional, but recommended. The more complete, the more useful.

Main Part

- ▶ *Subject*: whom or what is this statement about (the user)
- ▶ *Predicate*: the (user) characteristic represented in the statement (e.g. Interest)
- ▶ *Object*: what is the target or object of this characteristic
- ▶ *Level*: Qualification/level (if applicable)
- ▶ *Origin*: The statement in its original form (if applicable)

Meta Part

- ▶ *ID*: Globally unique
- ▶ *Creator*: Entity that created the statement
- ▶ *Created*: Time of creation/submission of statement
- ▶ *Access*: Data for any kind of access control mechanism
- ▶ *Temporal*: Constraints on temporal validity of statement
- ▶ *Spatial*: In which contexts is the statement valid
- ▶ *Evidence*: Refers to or embodies formal evidence
- ▶ *Rating*:Level of trust

An example statement

"Peter is interested in Sweden"

gc = http://www.grapple-project.org/grapple-core/
foaf = http://xmlns.com/foaf/0.1/

gc.Statement (
gc:id gc:statement-peter-2009-01-01-3234190;
gc:user http://www.peter.de/foaf.rdf#me;
gc:predicate foaf:interest;
gc:object http://en.wikipedia.org/wiki/Sweden;
)

(Metadata omitted for simplicity)

Structure of the user model

Knowledge on the user may be represented in many different formats.

Flat model

The most basic model is a simple collection of variables and associated values. These variables can represent a variety of independent user characteristics, such as the user's demographics, the liking of certain interface elements and knowledge on certain topics. These variables may be combined at will for adaptation decisions in the form of basic rules.

An example rule might indicate that if a user's age is lower than eighteen and the user is female a selection of news items interesting to young females should be made. Due to the flatness of the model, it is hard to make more complex deductions.

Hierarchical model

Allows some aspects of the user model to be regarded as higher level and more general than others. In contrast to the flat model, hierarchical structures represent user characteristics and relations between these user characteristics.

A common hierarchical structure is a tree or a directed acyclic graph. The hierarchies are typically hand-crafted based on the domain knowledge of the designer.

Stereotypes

People often make assumptions of other people, often based on fairly simple observations - or *triggers*. The assumptions tend to work fairly well in every-day life and can be *overridden* when shown otherwise. Stereotyping is particularly useful when a solid amount of statistical data of user groups is available.
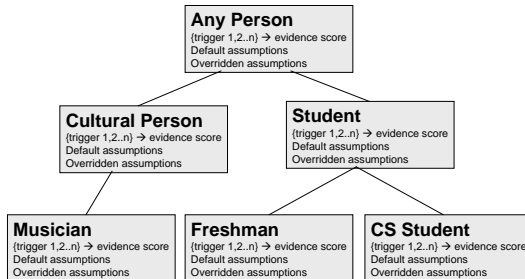
Domain Overlay

This user model can be regarded as an overlay of the domain structure. For each item in the domain overlay model, certain attributes can be set representing the user's knowledge of, interest in or any other relation between the user and the item.
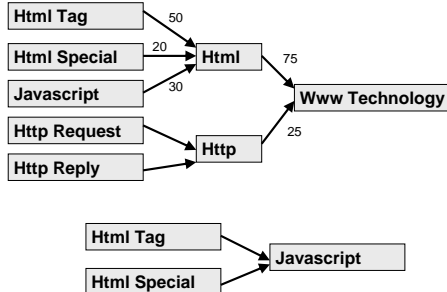
Logic-Based

A more sophisticated yet more complicated approach is the use of logic-based representation and reasoning. Rules are represented in logical languages like First Order Logic (FOL) .

Special predicates and modal logic operators can be used for expressing the difference between observations and inferred assumptions and uncertainty of inferences.

Dedicated logic programming languages such as Prolog can be used for reasoning.

In more detail: Stereotypes

Stereotype

A stereotype is a popular belief about specific social groups or types of individuals. Stereotypes are standardized and simplified conceptions of groups based on some prior assumptions.

Example stereotypes

- Beginner, Intermediate, Expert
- Kid, Youngster, Adult, Senior
- Freshman, Senior Student, Active Student, Cultural Student, Nerd

Triggers for assigning someone to a specific stereotype include age, gender, clothing, behavior, body-language, . . .

Stereotype User Model

A stereotype user model consists of one or more *stereotypes*, one or more *triggers* for activating these stereotypes, and *user data* that is used as input for these triggers.

Stereotype user models are particularly useful for quickly inferring the kind of user that a system is dealing with, and for providing adaptations specific to this kind of user.

Example: In a Web forum, users with less than 20 posts are considered 'novices', users with 20-500 posts are considered 'intermediate users', users with more than 500 posts are 'power users'.

▶ posts from novices are subject to moderation
▶ power users are granted more space for personal messages

A classic stereotype model: "Grundy"

One of the groundbreaking stereotype user models has been created by E. Rich, reported in the article "User Modeling via Stereotypes" (Cognitive Science 3, 329-354 (1979)).

Motivation 1
In a library, a person looks for some books on China. What will the librarian recommend?

- Is the person a *small child* who saw a TV show about China and wants to learn about this exotic country?
- Or a *high school student* working on a paper?
- Perhaps a *prospective tourist*?
- A scholar interested in *Eastern philosophy*?
- Someone who can *read Chinese*?

Most likely the librarian will make an educated guess, based on the person's appearance:

- age, style of clothing, accent, choice of words, ...

This initial guess might be confirmed or refuted by observations.

- ▶ It is assumed that a European cannot read Chinese, unless said otherwise
- ▶ Children are generally not (yet) interested in Eastern philosophy, but there are exceptions
- ▶ . . . .

The educated guess, a *stereotype* can be refined with follow-up questions.

Based on the (guessed) stereotype, the librarian will make a selection of books.

Motivation 2:

"The phone rings in the information division of a large pharmaceutical firm. The caller wants information about a drug the company makes. What sort of information should be provided? That depends. Is the caller

- ▶ a doctor?
- ▶ a patient?
- ▶ an FDA representative?

To provide the right information, the person answering the phone needs to know some facts about the caller."

E. Rich developed the system "Grundy", a virtual librarian that aims to propose interesting literature to the user. The following dialogue takes place:

PLEASE TYPE IN YOUR NAME
"John Greene"
YOU HAVEN'T USED THIS SYSTEM BEFORE, HAVE YOU?
"no"

The system can now activate two stereotypes.

- ▶ ANY-PERSON: the default stereotype, with average values for all dimensions
- ▶ MAN: most likely, 'John' is a male name

Both stereotypes are very generic and predictions are most likely poor.

Therefore, the system will try its first task designed to tell it as much as possible about the user.

OK
I'D LIKE TO KNOW WHAT SORT OF PERSON YOU THINK
YOU ARE. PLEASE TYPE IN A FEW SINGLE WORDS THAT
YOU THINK CHARACTERIZE THE MOST IMPORTANT
ASPECTS OF YOURSELF
"unconventional open direct honest humorous persistent
adventurous"
I DON'T KNOW THE WORD UNCONVENTIONAL
I DON'T KNOW THE WORD OPEN
I DON'T KNOW THE WORD DIRECT
WOULD YOU LIKE TO TRY SOME MORE WORDS?

Since it didn't get the complete picture of the user was trying to convey, it gives him another chance.

"yes"
OK GO AHEAD
"relaxed jewish friendly playful thoughtful eccentric"

At this point, Grundy believes it knows quite a lot about John.

- ▶ Because he is male, it believes he has:
  - ▶ a fairly high tolerance for violence and suffering,
  - ▶ preference for thrill, suspense, fast plots,
  - ▶ a negative interest in romance
- ▶ Because of stereotypes evokes by "humorous", "friendly", and "playful" it thinks he's quite optimistic.
- ▶ It thinks he's interested in conflicts such as art-vs-science, exploration, God, and what it means to be a human.
- ▶ It thinks he has particular sympathy for such strengths as kindness, courage, honesty, and perceptiveness.

HAVE YOU EVER READ EARTH ANGELS BY SUSAN CAHILL?
"no"

▶ The systems picks this choice of one of the facets of John
  that has both a non-middle-of-the-road value and a fairly high
  rating.

▶ Then it rates all the books suggested by the facet by
  comparing them to John along all dimensions.

▶ It got this suggestion from the belief that he is politically
  liberal (which it believes from "Jewish").

Grundy selects, from the things it knows about the book, those
things that it thinks will make John like it.

YOU MIGHT LIKE IT.
IT IS ABOUT A GIRL WHO GOES TO CATHOLIC
ELEMENTARY SCHOOL, HIGH SCHOOL, AND COLLEGE,
THEN GOES ON TO BECOME A NUN, BUT FINALLY BACKS
OUT A FEW DAYS BEFORE FINAL VOWS.
[...]
IT IS POLITICALLY LIBERAL. IT HAS A BIT OF ROMANCE. IT
HAS A MEDIUM-FAST MOVING PLOT.

DOES THAT SOUND GOOD?
"no"

Grundy needs to find out where it went wrong. It knows the reasons it thought John would like the book.

▶ It asks about them to see which if any of them is incorrect.

The order in which it asks about them is determined by *an priori rating* of how likely that reason is to be the problem and the current rating of the relates characteristics of John.

▶ It asks about things it is least sure of first.

WAS IT BECAUSE OF THE DEPTH OF THE CHARACTER
DEVELOPMENT?(EITHER TOO MUCH OR NOT ENOUGH)
"no"
WAS IT BECAUSE OF THE AMOUNT OF ROMANCE?
(EITHER TOO MUCH OR NOT ENOUGH)
"no"
WHERE YOU BOTHERED BY THE POLITICAL POSITION
ESPOUSED BY THE BOOK?
"no"
AREN'T YOU INTERESTED IN THE RELATIONSHIP OF MAN
TO GOD?
"no"
DO YOU WANT SOME MORE SUGGESTIONS?
"yes"

HAVE YOU EVER READ ZEN ANOTHER ART OF
MOTORCYCLE MAINTENANCE BY ROBERT PIRSIG?
It selected this based on the personality characteristic "living in a
separate world", which it got from "eccentric". It also matches on
several other dimensions, such as an interest in the conflict of
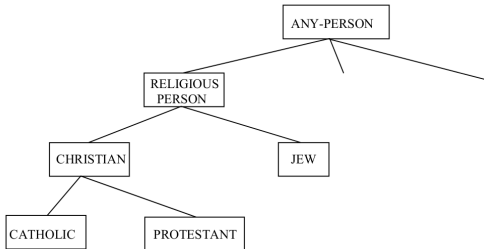art-vs-science.

"yes"
DO YOU LIKE IT?
"yes"

Stereotypes

Stereotypes are manually defined and stored in a directed acyclic graph.

Two sample stereotypes

FACET	VALUE	RATING
Activated-by	*Athletic-w-trig*	
GenI	*ANY-PERSON*	
Motivations		
Excite	3	600
Interests		
Sports	4	800
Thrill	5	700
Tolerate-violence	4	600
Romance	-5	500
Education	-2	500
Tolerate-suffering	4	600
Strengths		
Physical-strength	4	900
Perseverance	3	600

SPORTS-PERSON

Activated-by	*Feminist-w-trig*	
GenI	*ANY-PERSON*	
Genres		
Woman	3	700
Politics	*liberal*	700
Sex-open	5	900
Piety	-5	800
Political-causes		
Women	5	1000
Conflicts		
Sex-roles	4	900
Upbringing	3	800
Tolerate-sex	5	700
Strengths		
Perseverance	3	600
Independence	3	600
Triggers	Fem-woman-trig	

FEMINIST

Each stereotype consists of:

- ▶ *Attributes* (facets): characteristics commonly associated with this stereotype
- ▶ *Values*: the score (-5 . . . +5) of the average stereotypical person on the attribute
- ▶ *Rating*: degree of certainty (correlation) that the assumption holds

The sports-person stereotype highly values thrill, tolerates violence and suffering and is not romantic at all.

Note that this paper stems from the 1970s.

Triggers

NO-TV-TRIG		(Besides asking for characteristic words, the other thing Grundy can do to find out about users is to ask them about TV. This trigger is activated if the user says he does not watch TV.)
FACET	*VALUE*	
Stereotype	NON- TV-PERSON	(this stereotype suggests that a person is likely to be educated and serious)
Rating	800	(maybe this person is not really a non-TV person. Maybe he just can't afford to buy one.)
SCI-ED-TRIG		(This trigger is associated with the SCIENTIST stereotype and will be activated whenever the SCIENTIST stereotype is activated.)
FACET	*VALUE*	
Stereotype	EDUCATED-PERSON	
Rating	900	
Reasons	SCIENTIST	

A trigger is an object or event associated with a particular situation: a response to an answer or some other action.
Each trigger consists of the stereotype it activates plus:

▶ *Attributes* (facets): characteristics or events that activate the trigger

▶ *Values*: the score (-5 ... +5) that the facet should have for activating the trigger

▶ *Rating*: degree of certainty (correlation) that the trigger is valid

User Models

FACET	VALUE	RATING	JUSTIFICATIONS
Gender	female	1000	Inference-female name
			WOMAN
Nationality	USA	100	ANY-PERSON
Education	5	900	INTELLECTUAL
Seriousness	5	800	INTELLECTUAL
Piety	-3	423	WOMAN
			FEMINIST
			INTELLECTUAL
Politics	Liberal	910	FEMINIST
			INTELLECTUAL
Tolerate-sex	5	700	FEMINIST
Tolerate-violence	-5	597	WOMAN
Tolerate-suffering	-5	597	WOMAN
Sex-open	5	960	FEMINIST
			INTELLECTUAL
Personalities	4	646	WOMAN
Opt-pes	0	100	ANY-PERSON
Plot-intr	0	100	ANY-PERSON
Plot-speed	-2	475	EDUCATED-PERSON
Suspense	0	100	ANY-PERSON
Thrill	-4	839	WOMAN
			INTELLECTUAL

Each stereotype user model is a combination of attributes and their corresponding values that belong to the activated stereotypes and consists of:

- ▶ *Attributes* (facets): user characteristics derived from the activated stereotypes
- ▶ *Values*: the score associated with the characteristics (weighted average from stereotypes)
- ▶ *Rating*: degree of certainty (correlation) that the facet holds (stereotypes with similar values reinforce one another)
- ▶ *Justification*: the stereotypes that contributed to this attribute

Exploitation of stereotypes

The goal of Grundy is to *recommend books*. The (rather simple) recommendation algorithm is:

1. Build a set of facets with a high rating that is not middle-of-the-road
   (the user's *salient characteristics*)
2. Randomly select one of these facets and select books that score high on this facet
3. Compare the facets of each selected book with the facets in the user model.
   Pick the best match.
4. Use the facets again, this time to provide the user with *explanations* why this book was selected.