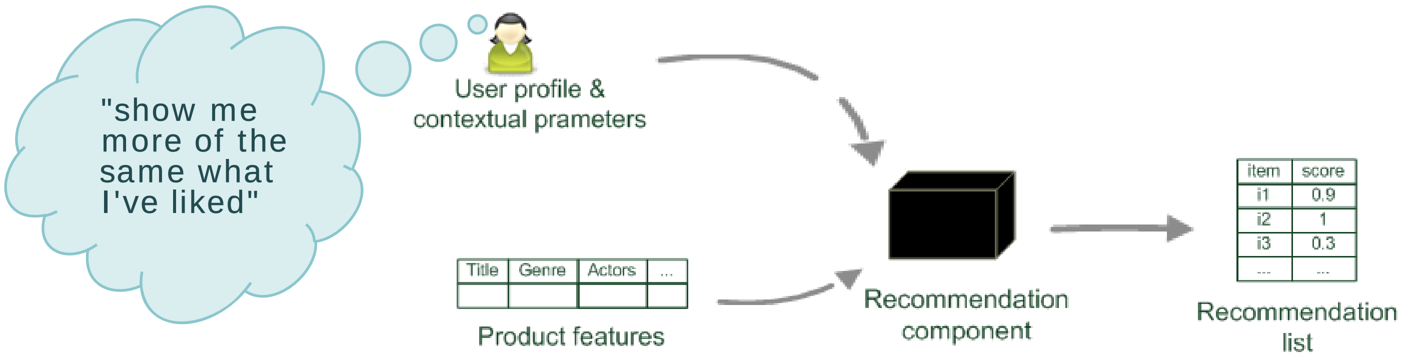
Content-based recommendation

Content-based recommendation

- **While CF – methods do not require any information about the items,**
  - it might be reasonable to exploit such information; and
  - recommend fantasy novels to people who liked fantasy novels in the past
- **What do we need:**
  - some information about the available items such as the genre ("content")
  - some sort of *user profile* describing what the user likes (the preferences)
- **The task:**
  - learn user preferences
  - locate/recommend items that are "similar" to the user preferences



What is the "content"?

- **Most CB-recommendation techniques were applied to recommending text documents.**
  - Like web pages or newsgroup messages for example.
- **Content of items can also be represented as text documents.**
  - With textual descriptions of their basic characteristics.
  - Structured: Each item is described by the same set of attributes

Title	Genre	Author	Type	Price	Keywords
The Night of the Gun	Memoir	David Carr	Paperback	29.90	Press and journalism, drug addiction, personal memoirs, New York
The Lace Reader	Fiction, Mystery	Brunonia Barry	Hardcover	49.90	American contemporary fiction, detective, historical
Into the Fire	Romance, Suspense	Suzanne Brockmann	Hardcover	45.90	American fiction, murder, neo-Nazism

  - Unstructured: free-text description.

Content representation and item similarities

- **Item representation**

Title	Genre	Author	Type	Price	Keywords
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- **User profile**

Title	Genre	Author	Type	Price	Keywords
...	Fiction	Brunonia, Barry, Ken Follett	Paperback	25.65	Detective, murder, New York

$keywords(b_j)$ describes Book b_j with a set of keywords

- **Simple approach**
  - Compute the similarity of an unseen item with the user profile based on the keyword overlap (e.g. using the Dice coefficient)

$$\frac{2 \times |keywords(b_i) \cap keywords(b_j)|}{|keywords(b_i)| + |keywords(b_j)|}$$

  - Or use and combine multiple metrics

Term-Frequency - Inverse Document Frequency ($TF - IDF$)

- **Simple keyword representation has its problems**
  - in particular when automatically extracted as
    - not every word has similar importance
    - longer documents have a higher chance to have an overlap with the user profile
- **Standard measure: TF-IDF**
  - Encodes text documents in multi-dimensional Euclidian space
    - weighted term vector
  - TF: Measures, how often a term appears (density in a document)
    - assuming that important terms appear more often
    - normalization has to be done in order to take document length into account
  - IDF: Aims to reduce the weight of terms that appear in all documents

TF-IDF II

- **Given a keyword i and a document j**
- $TF(i,j)$
  - term frequency of keyword i in document j
- $IDF(i)$
  - inverse document frequency calculated as $\boldsymbol{IDF(i) = log\frac{N}{n(i)}}$
    - N : number of all recommendable documents
    - $n(i)$: number of documents from N in which keyword i appears
- $TF - IDF$
  - is calculated as: $\boldsymbol{TF\text{-}IDF(i,j) = TF(i,j) * IDF(i)}$

Example TF-IDF representation

- **Term frequency:**
  - Each document is a $\boxed{\text{count vector}}$ in $\mathbb{N}^{|v|}$

	Antony and Cleopatra	Julius Caesar	The Tempest	Hamlet	Othello	Macbeth
Antony	157	73	0	0	0	0
Brutus	4	157	0	1	0	0
Caesar	232	227	0	2	1	1
Calpurnia	0	10	0	0	0	0
Cleopatra	57	0	0	0	0	0
mercy	1.51	0	3	5	5	1
worser	1.37	0	1	1	1	0

Vector v with dimension $|v| = 7$

Example taken from http://informationretrieval.org

Example TF-IDF representation

- **Combined TF-IDF weights**
  - Each document is now represented by a real-valued vector of $TF\text{-}IDF$ weights $\in \mathbb{R}^{|v|}$

	Antony and Cleopatra	Julius Caesar	The Tempest	Hamlet	Othello	Macbeth
Antony	157	73	0	0	0	0
Brutus	4					
Caesar	232					
Calpurnia	0					
Cleopatra	57					
mercy	1.5					
worser	1.3					

	Antony and Cleopatra	Julius Caesar	The Tempest	Hamlet	Othello	Macbeth
Antony	5.25	3.18	0	0	0	0.35
Brutus	1.21	6.1	0	1	0	0
Caesar	8.59	2.54	0	1.51	0.25	0
Calpurnia	0	1.54	0	0	0	0
Cleopatra	2.85	0	0	0	0	0
mercy	1.51	0	1.9	0.12	5.25	0.88
worser	1.37	0	0.11	4.15	0.25	1.95

Example taken from http://informationretrieval.org

Improving the vector space model

- **Vectors are usually long and sparse**
- **remove stop words**
  - They will appear in nearly all documents.
  - e.g. "a", "the", "on", …
- **use stemming**
  - Aims to replace variants of words by their common stem
  - e.g. "went" $\Longrightarrow$ "go", "stemming" $\Longrightarrow$ "stem", …
- **size cut-offs**
  - only use top n most representative words to remove "noise" from data
  - e.g. use top 100 words

Improving the vector space model II

- **Use lexical knowledge, use more elaborate methods for feature selection**
  - Remove words that are not relevant in the domain
- **Detection of phrases as terms**
  - More descriptive for a text than single words
  - e.g. "United Nations"
- **Limitations**
  - semantic meaning remains unknown
  - example: usage of a word in a negative context
    - "there is nothing on the menu that a vegetarian would like.."
    - The word "vegetarian" will receive a higher weight then desired

⇨ an unintended match with a user interested in vegetarian restaurants

Cosine similarity

- **Usual similarity metric to compare vectors: Cosine similarity (angle)**
  - Cosine similarity is calculated based on the angle between the vectors
    - $sim(\vec{a}, \vec{b}) = \frac{\vec{a} \cdot \vec{b}}{|\vec{a}| * |\vec{b}|}$
- **Adjusted cosine similarity**
  - take average user ratings into account ($\bar{r}_u$), transform the original ratings
  - U: set of users who have rated both items a and b
  - $sim(\vec{a}, \vec{b}) = \frac{\sum_{u \in U}(r_{u,a} - \bar{r}_u)(r_{u,b} - \bar{r}_u)}{\sqrt{\sum_{u \in U}(r_{u,a} - \bar{r}_u)^2} \sqrt{\sum_{u \in U}(r_{u,b} - \bar{r}_u)^2}}$

Recommending items

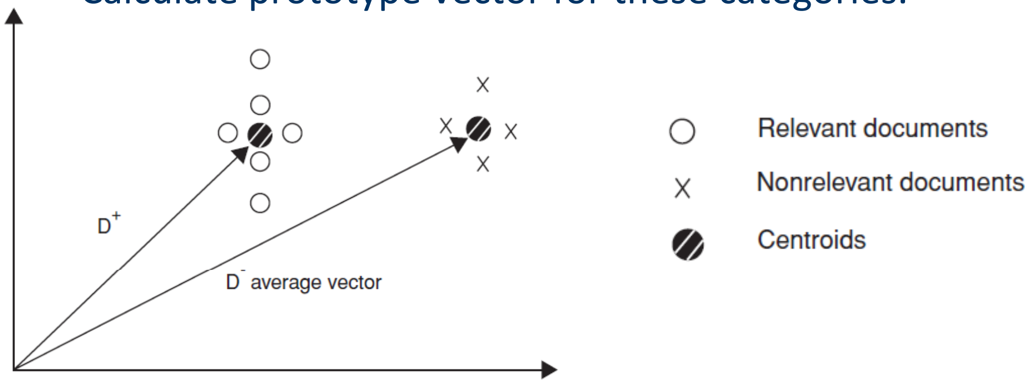
- **Simple method: nearest neighbors**
  - Given a set of documents D already rated by the user (like/dislike)
    - Either explicitly via user interface
    - Or implicitly by monitoring user's behavior
  - Find the n nearest neighbors of an not-yet-seen item i in D
    - Use similarity measures (like cosine similarity) to capture similarity of two documents
  - Take these neighbors to predict a rating for i
    - e.g. $k = 5$ most similar items to i.
4 of k items were liked by current user ⇨ item i will also be liked by this user
  - Variations:
    - Varying neighborhood size k
    - lower/upper similarity thresholds to prevent system from recommending items the user already has seen
  - Good to model short-term interests / follow-up stories
  - Used in combination with method to model long-term preferences

Recommending items

- Retrieval quality depends on individual capability to formulate queries with right keywords.
- **Query-based retrieval: Rocchio's method**
  - The SMART System: Users are allowed to rate (relevant/irrelevant) retrieved documents (feedback)
  - The system then learns a prototype of relevant/irrelevant documents
  - Queries are then automatically extended with additional terms/weight of relevant documents

Rocchio details

- **Document collections D^+ (liked) and D^- (disliked)**
  - Calculate prototype vector for these categories.



- **Computing modified query Q_{i+1} from current query Q_i with:**

$$Q_{i+1} = \alpha * Q_i + \beta\left(\frac{1}{|D^+|}\sum_{d^+\in D^+} d^+\right) - \gamma\left(\frac{1}{|D^-|}\sum_{d^-\in D^-} d^-\right)$$

- **α, β, γ used to fine-tune the feedback**
  - α weight for original query
  - β weight for positive feedback
  - γ weight for negative feedback

- **Often only positive feedback is used**
  - More valuable than negative feedback

Practical challenges of Rocchio's method

- **Certain number of item ratings needed to build reasonable user model**
  - Can be automated by trying to capture user ratings implicitly (click on document)
  - Pseudorelevance Feedback: Assume that the first n documents match the query best. The set D^{-} is not used until explicit negative feedback exists.
- **User interaction required during retrieval phase**
  - Interactive query refinement opens new opportunities for gathering information and
  - Helps user to learn which vocabulary should be used to receive the information he needs

Probabilistic methods

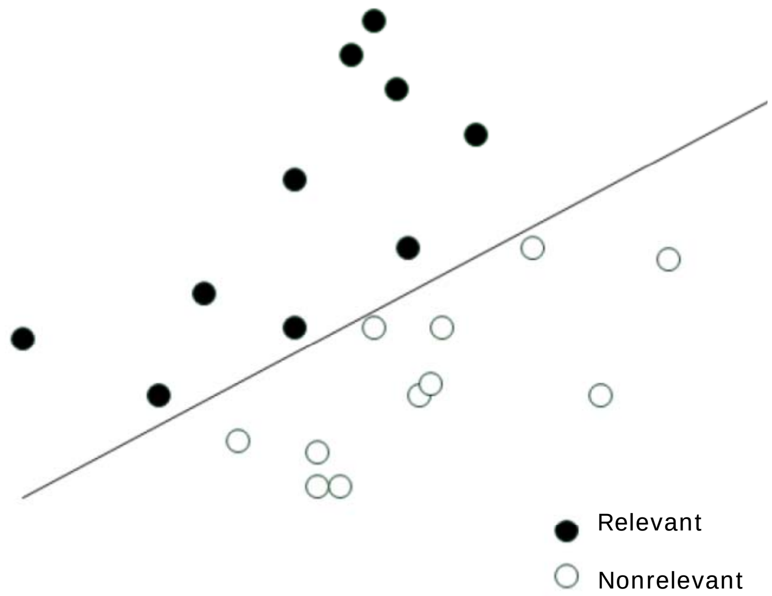
- **Recommendation as classical text classification problem**
  - long history of using probabilistic methods
- **Simple approach:**
  - 2 classes: hot/cold
  - simple Boolean document representation
  - calculate probability that document is hot/cold based on Bayes theorem

Doc-ID	recommender	intelligent	learning	school	Label
1	1	1	1	0	1
2	0	0	1	1	0
3	1	1	0	0	1
4	1	0	1	1	1
5	0	0	0	1	0
6	1	1	0	0	?

$$\begin{aligned} P(X|Label = 1) \\ &= P(recommender = 1|Label = 1) \\ &\times P(intelligent = 1|Label = 1) \\ &\times P(learning = 0|Label = 1) \\ &\times P(school = 0|Label = 1) \\ &= {}^{3}/_{3} \times {}^{2}/_{3} \times {}^{1}/_{3} \times {}^{2}/_{3} \approx 0.149 \end{aligned}$$

Linear classifiers

- **Most learning methods aim to find coefficients of a linear model**
- **A simplified classifier with only two dimensions can be represented by a line**
- **The line has the form $w_1x_1 + w_2x_2 = b$**
  - x_1 and x_2 correspond to the vector representation of a document (using e.g. TF-IDF weights)
  - w_1, w_2 and b are parameters to be learned
  - Classification of a document based on checking
    $$w_1x_1 + w_2x_2 > b$$
- **In n-dimensional space the classification function is $\vec{w}^T\vec{x} = b$**



- **Other linear classifiers:**
  - Naive Bayes classifier, Rocchio method, Windrow-Hoff algorithm, Support vector machines

Improvements

- **Side note: Conditional independence of events does in fact not hold**
  – "New York", "Hong Kong"
  – Still, good accuracy can be achieved
- **Boolean representation simplistic**
  – positional independence assumed
  – keyword counts lost
- **More elaborate probabilistic methods**
  – e.g., estimate probability of term v occurring in a document of class C by relative frequency of v in all documents of the class
- **Other linear classification algorithms (machine learning) can be used**
  – Support Vector Machines, ..
- **Use other information retrieval methods (used by search engines..)**

Explicit decision models

- **Decision tree for recommendation problems**
  - inner nodes labeled with item features (keywords)
  - used to partition the test examples
    - **existence or non existence of a keyword**
  - in basic setting only two classes appear at leaf nodes
    - **interesting or not interesting**
  - decision tree can automatically be constructed from training data
  - works best with small number of features
  - use meta features like author name, genre, ... instead of TF-IDF representation.

Explicit decision models II

- **Rule induction**
  - built on RIPPER algorithm
  - good performance compared with other classification methods
    - **eloborate postpruning techniques of RIPPER**
    - **extension for e-mail classification**
      - **takes document structure into account**
- **main advantages of these decision models:**
  - inferred decision rules serve as basis for generating explanations for recommendation
  - existing domain knowledge can be incorporated in models

On feature selection

- **process of choosing a subset of available terms**
- **different strategies exist for deciding which features to use**
  - feature selection based on domain knowledge and lexical information from WordNet (Pazzani and Billsus 1997)
  - frequency-based feature selection to remove words appearing "too rare" or "too often" (Chakrabarti 2002)
- **Not appropriate for larger text corpora**
  - Better to
    - evaluate value of individual features (keywords) independently and
    - construct a ranked list of "good" keywords.
- **Typical measure for determining utility of keywords: e.g. X^2, mutual information measure or Fisher's discrimination index**

Limitations of content-based recommendation methods

- **Keywords alone may not be sufficient to judge quality/relevance of a document or web page**
  - up-to-date-ness, usability, aesthetics, writing style
  - content may also be limited / too short
  - content may not be automatically extractable (multimedia)
- **Ramp-up phase required**
  - Some training data is still required
  - Web 2.0: Use other sources to learn the user preferences
- **Overspecialization**
  - Algorithms tend to propose "more of the same"
  - Or: too similar news items

Discussion & summary

- In contrast to collaborative approaches, content-based techniques do not require user community in order to work
- Presented approaches aim to learn a model of user's interest preferences based on explicit or implicit feedback
  - Deriving implicit feedback from user behavior can be problematic
- Evaluations show that a good recommendation accuracy can be achieved with help of machine learning techniques
  - These techniques do not require a user community
- Danger exists that recommendation lists contain too many similar items
  - All learning techniques require a certain amount of training data
  - Some learning methods tend to overfit the training data
- Pure content-based systems are rarely found in commercial environments

Literature

- **[Michael Pazzani and Daniel Billsus 1997]** Learning and revising user profiles: The identification of interesting web sites, Machine Learning **27** (1997), no. 3, 313-331.
- **[Soumen Chakrabarti 2002]** Mining the web: Discovering knowledge from hyper-text data, Science & Technology Books, 2002.