Mining User Navigation Patterns for Personalizing Topic Directories

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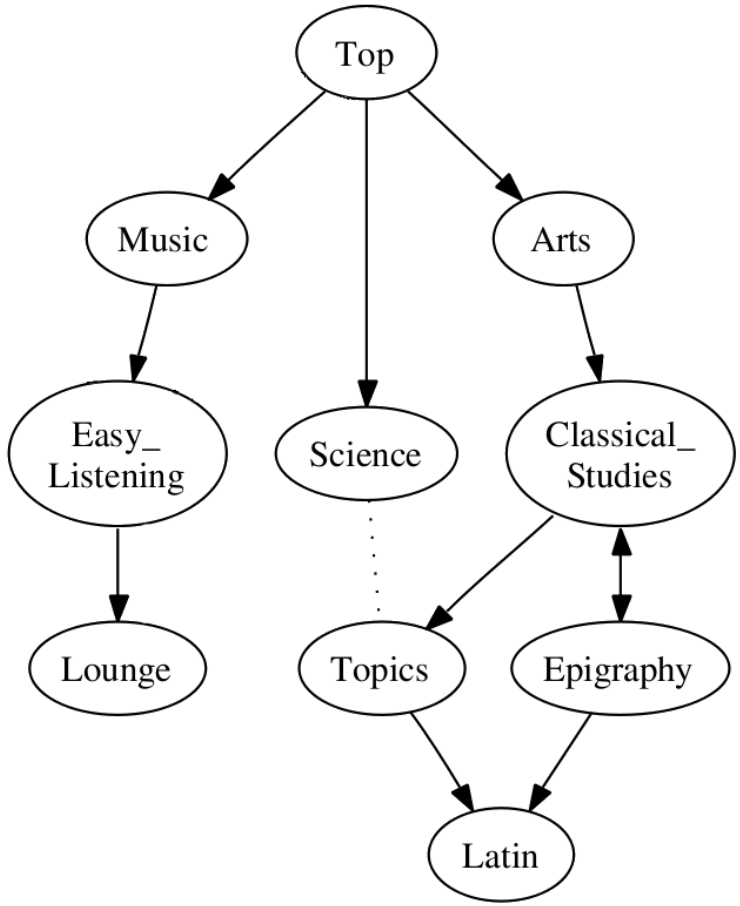
Outline

Introduction

- Topic directories, popular means of organizing web resources
  - Hierarchical organization of thematic categories
- As search "tools"
  - Narrowing search from broad topics to specific ones, e.g. `Arts` to `Classical_Studies`
  - Support keyword search



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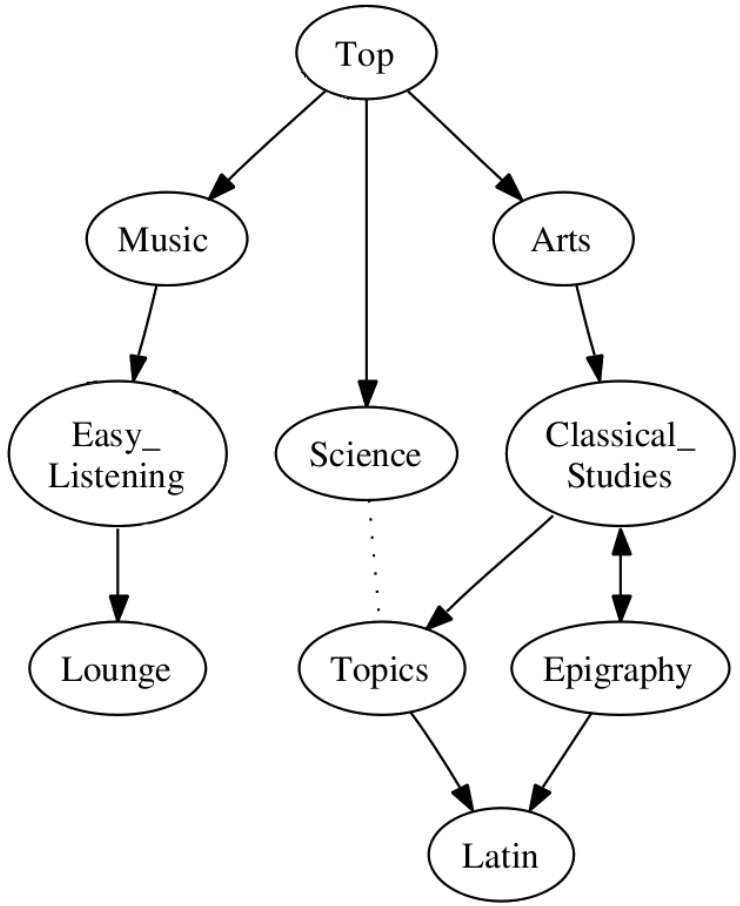
  - Heterogeneity of user communities



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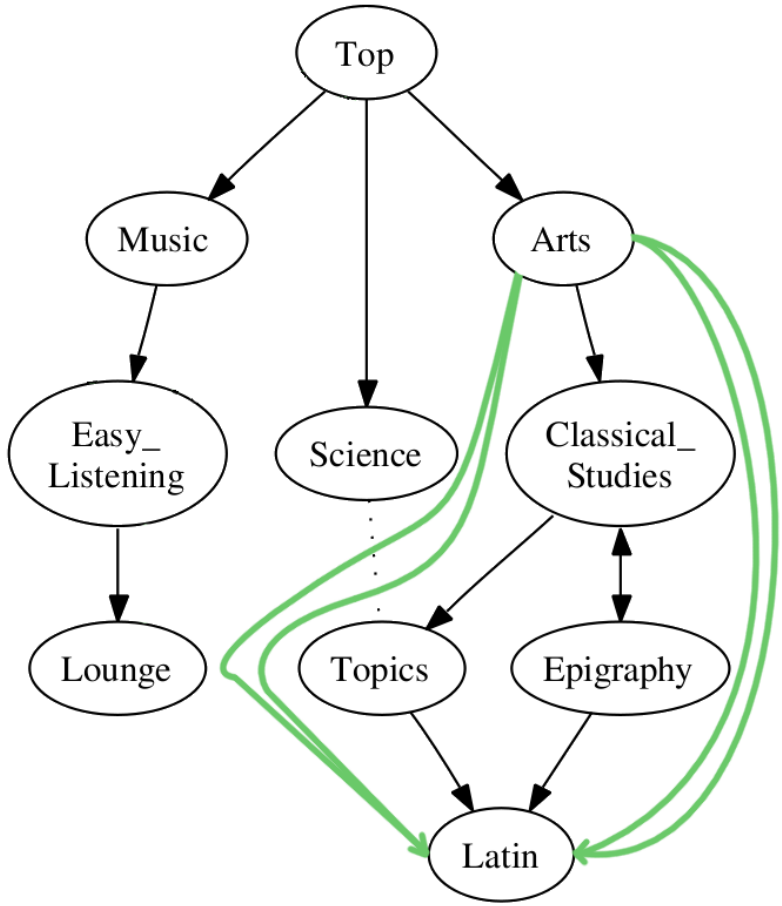

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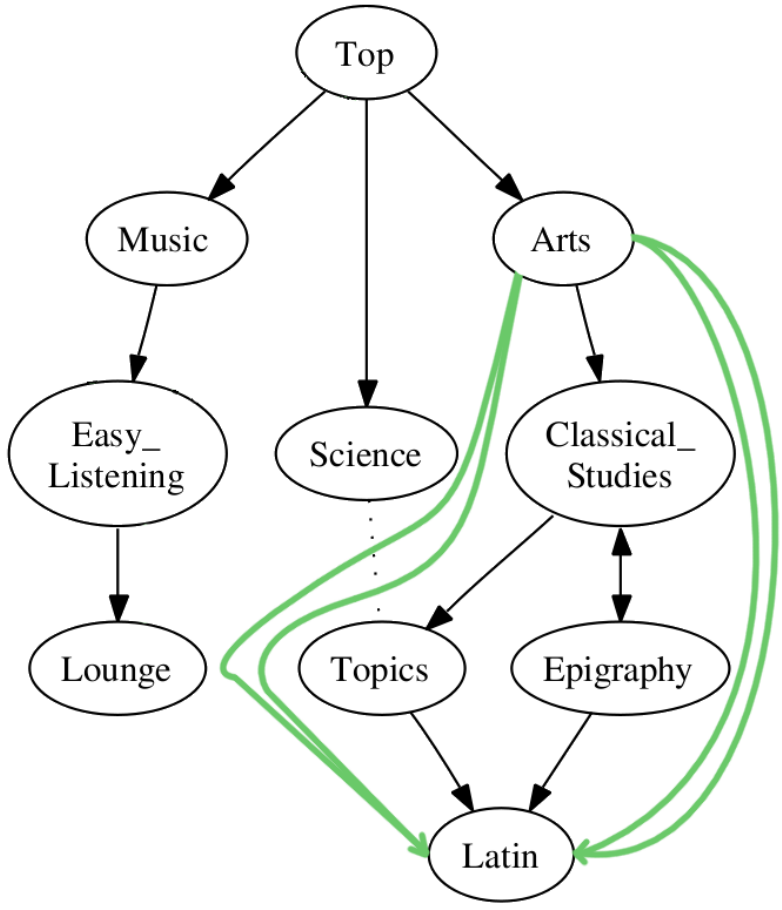

- Provide direct link from `Arts` to `Latin` for users interested in `Latin`

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- Methods to personalize topic directories
  - Provide topic directory views
  - Views are based on users navigation history - behaviour

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    - Offline (static shortcuts) - presented to groups of users with similar navigation behaviour
    - Online (dynamic shortcuts) - presented to each individual user
  - Shortcuts help users to easily reach topics tailored to their needs, while bypass others
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    - e.g., identifying interest groups, users with certain type of behaviour, etc. (see later slides)
- Experimental evaluation of both mining and personalization tasks

Outline

Modelling topic directories

Topic directory

- Hierarchical organization of thematic categories
- Categories contain resources, i.e. links to other pages
- Subcategories narrow content of broad categories
- Related categories contain similar resources
- Directory graph

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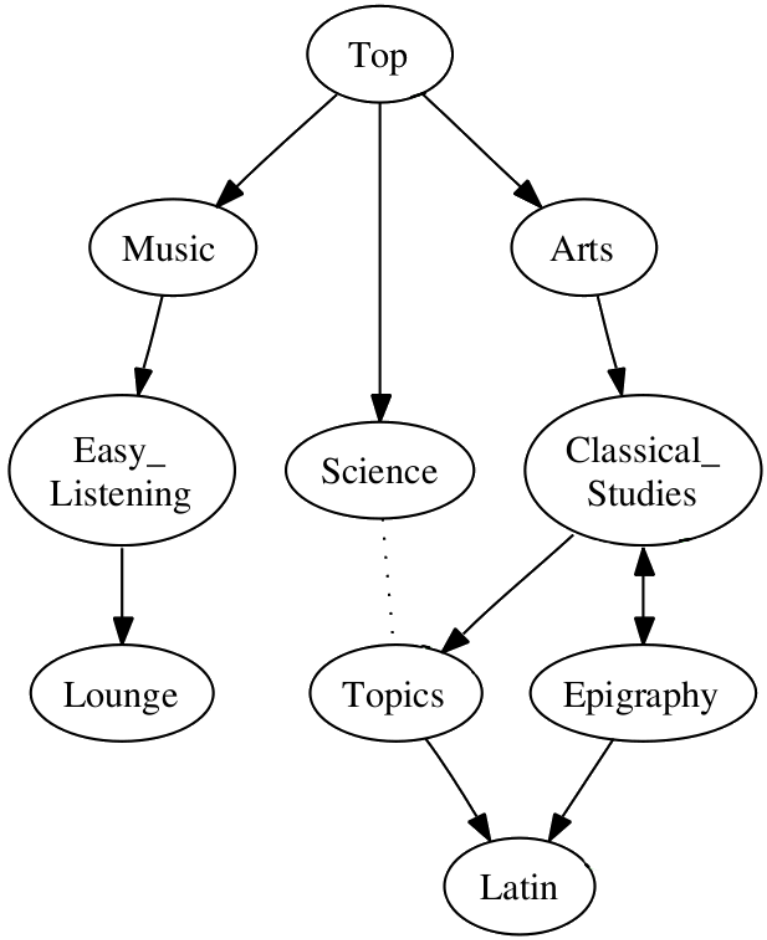

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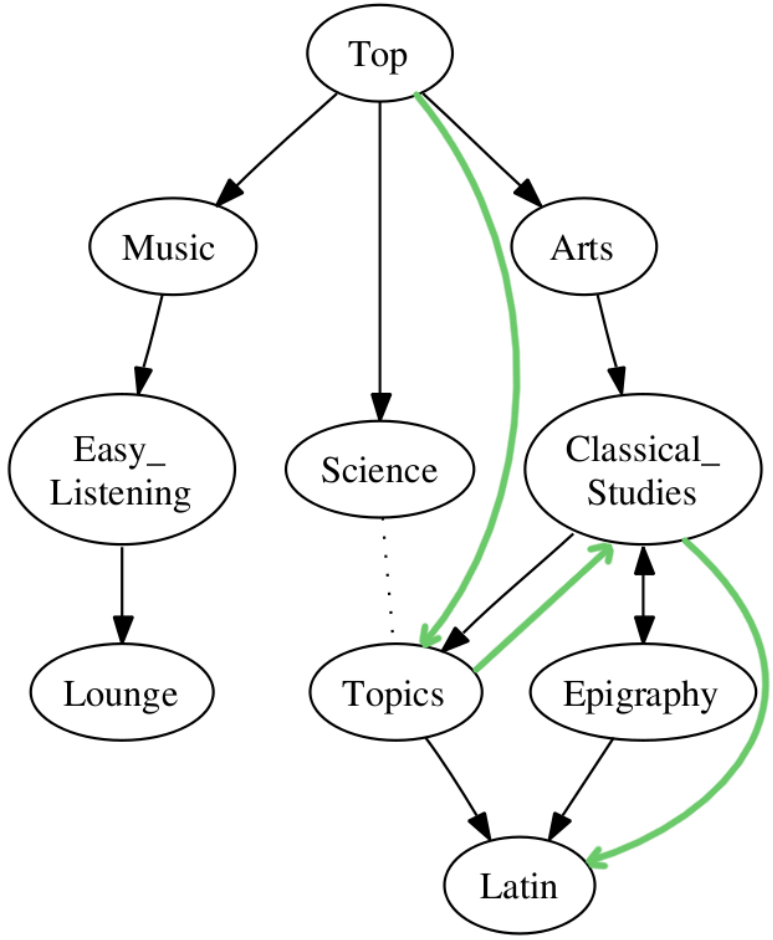
Navigation pattern

- Sequence of categories during session
- Navigation behaviour of users for reaching more than one topic
- Multiple occurrences of same categories, i.e. back and forth

Example

{Top,Arts,Classical_Studies,Topics,
Classical_Studies,Epigraphy,Latin}



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  - "Back and forth" to same categories
- Mining (L-)popular categories & sequential navigation (L-)subpatterns
  - Popular categories, i.e., frequently visited
  - (L-)popular categories, i.e., contain frequently selected resources
  - Sequential navigation (L-)subpatterns, i.e., frequent sequences of (L-)popular categories

Identifying interest groups

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  - Searching for similar information in a similar way

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- Interest groups construction
  - Exploit K-means clustering algorithm
  - Navigation patterns similarity
    - Ratio of the number of common categories (all their occurrences) to the total number of distinct categories
    - Example: navigation patterns
      $P_1 = \{$`Top,Arts,Classical_studies,Epigraphy,Latin,Epigraphy,Latin`$\}$ and
      $P_2 = \{$`Top,Arts,Classical_studies,Rome,Latin`$\}$
      4 common categories: `Top` ($\times 2$), `Arts` ($\times 2$), `Classical_Studies` ($\times 2$), `Latin` ($\times 3$)
      $S = 9/12 = 0.75$

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      4 common categories: `Top` ($\times 2$), `Arts` ($\times 2$), `Classical_Studies` ($\times 2$), `Latin` ($\times 3$)
      $S = 9/12 = 0.75$
  - Interest group = users whose navigation patterns in the same cluster
  - Each navigation pattern belongs to one cluster
  - User may belong to more than one interest groups

Identifying interest groups (cont'd)

Example

navigation patterns
{Top,Arts,Photography,Arts,Music,Dance}
{Top,Arts,Photography,Arts,Music,DJs}
{Top,Health,Medicine,Informatics,Journals_and_Publications}
{Top,Arts,Dance,Tango}
{Top,Computers,Information_Technology,Conferences}
{Top,Computers,Computer_Science,Publications,Bibliographies}

Construct 4 interest groups (clusters)

1. {Top,Arts,Photography,Arts,Music,Arts,Dance} and {Top,Arts,Dance,Tango}
2. {Top,Arts,Photography,Arts,Music,DJs}
3. {Top,Health,Medicine,Informatics,Journals_and_Publications}
4. {Top,Computers,Information_Technology,Conferences} and {Top,Computers,Computer_Science,Publications,Bibliographies}

Identifying indecisive users

Indecisive user

- Many "back and forth" visits to same categories
  - e.g. {`rock,80s,rock,80s,rock,60s,rock,60s`}
- This is due to:
  - Not knowing exactly what to search for in advance
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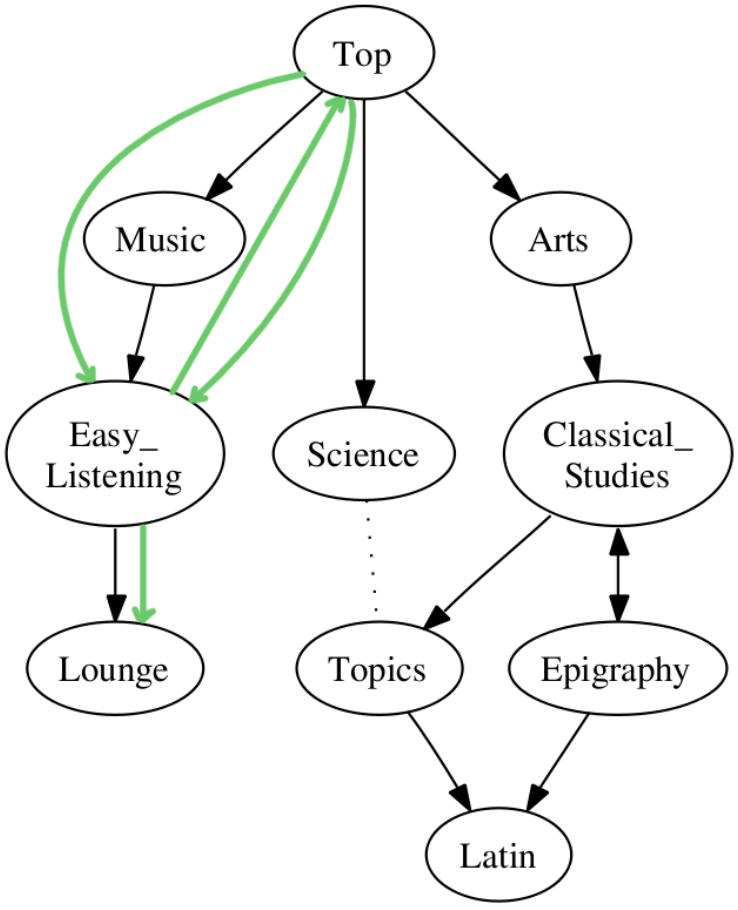
B&F actions/chains

- Record B&F actions/chains to detect indecisive users
- For each navigation pattern check:
  - If exists sequence of categories $\{N_1, N_2, ..., N_k\}$ appearing twice
  - If between two occurrences, exists backwards action $\{N_{k-1}, ..., N_2\}$
  - B&F action $= \{N_1, N_2, ..., N_k\}$
  - B&F chain $= \{N_1, N_2, ..., N_k, N_{k-1}, ..., N_2, N_1, N_2, ..., N_k\}$

Identifying indecisive users (cont'd)



- Navigation pattern:
  {Top,Music,Easy_Listening,Music,Top,Music,Easy_Listening,Lounge}

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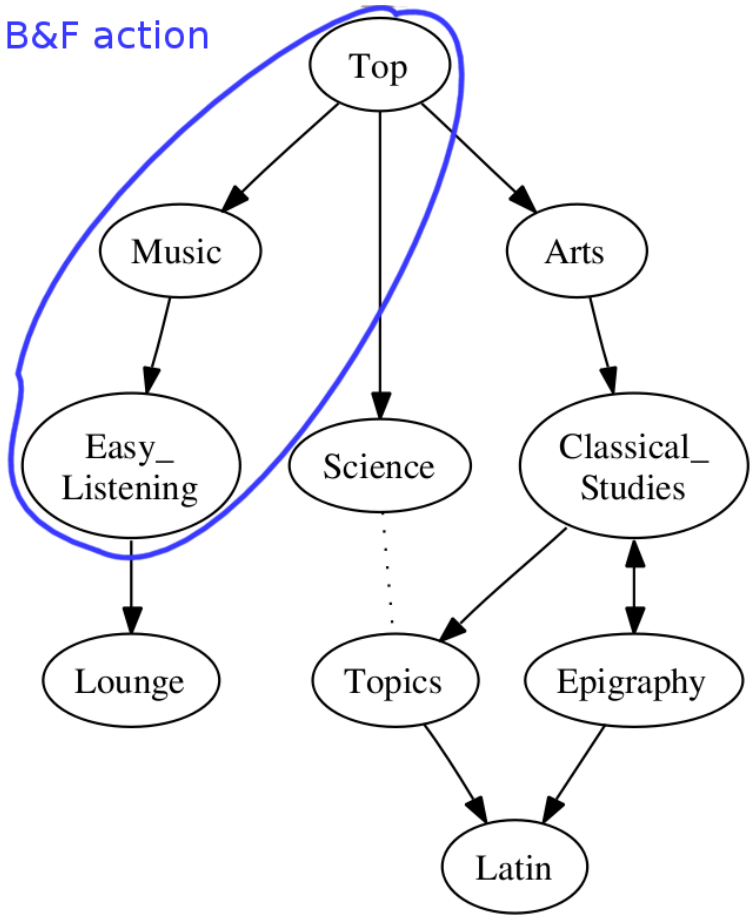

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  {Top,Music,Easy_Listening,Music,Top,Music,Easy_Listening,Lounge}
- B&F chain: {Top,Music,Easy_Listening,Music,Top,Music,Easy_Listening}

Mining (L-)popular categories & sequential navigation (L-)subpatterns

Two types of popular categories

- Popular: topics of great interest (i.e., frequently visited)
- L-popular: contain popular (i.e., frequently selected) resources
- Note that L-popular categories are not necessarily popular and vice versa

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Identifying sequential navigation (L-)subpatterns

- Trie-based implementation [Bodon05] of Apriori [AS94] for mining frequent itemsequences
- Support: probability of visiting categories in the order specified in (L-)subpattern

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Overview of personalization tasks

- Creation of shortcuts $A \longrightarrow B$, i.e. direct link from A to B
  - Alternative ways of navigating directory
  - Help users to easily reach topics tailored to their needs, while bypass others
  - Directed edge from A to B in the directory graph
- Two ways of creating shortcuts

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  - Online
    - Based on identifying frequent sequential navigation (L-)subpatterns
    - Consider not only navigation patterns of "user's" interest groups
    - But also last categories visited in current user session
    - For each user, create dynamic shortcuts in real time
    - Present dynamic shortcuts to each individual user

Offline - Personalization based on frequent B&F chains

Shortcut creation

- Frequent B&F chains indicate difficulties for users in browsing
- This is due to:
  - Not knowing exactly what to search for in advance
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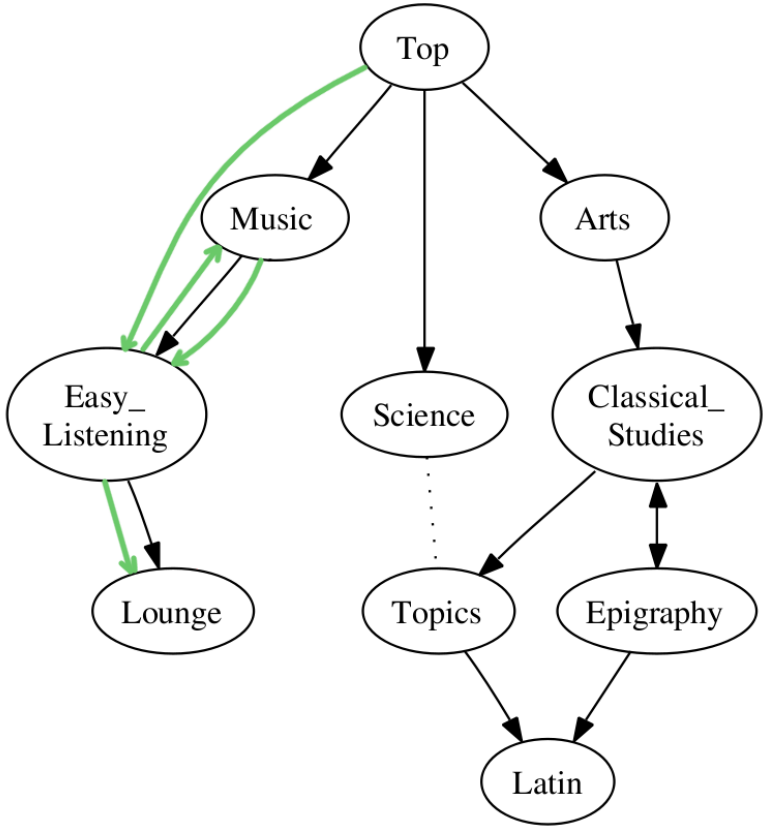
Example

- Navigation pattern: {Top,Music,Easy_Listening, Music,Easy_Listening,Lounge}



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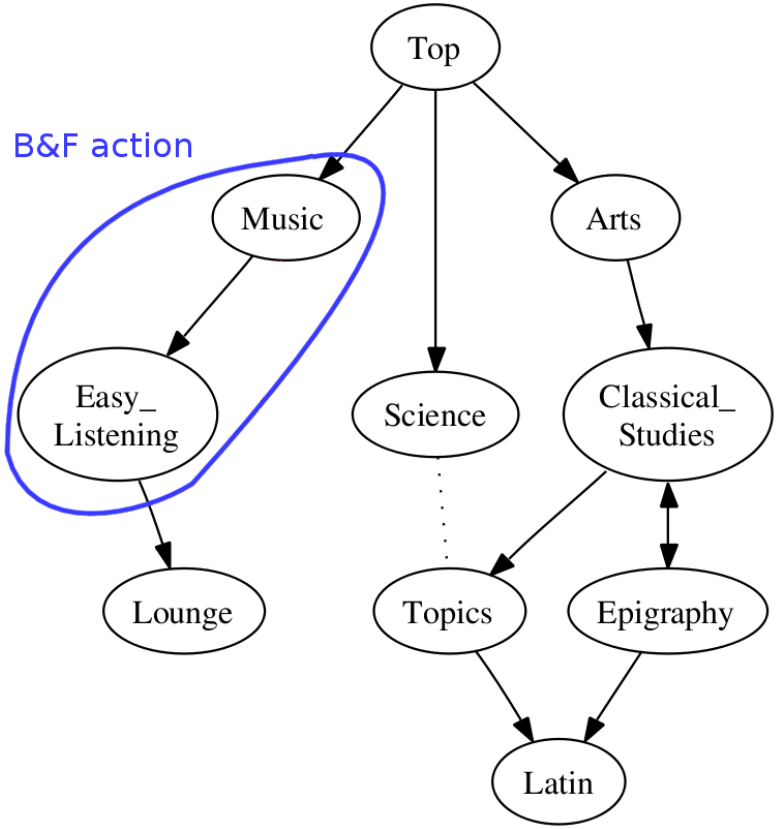

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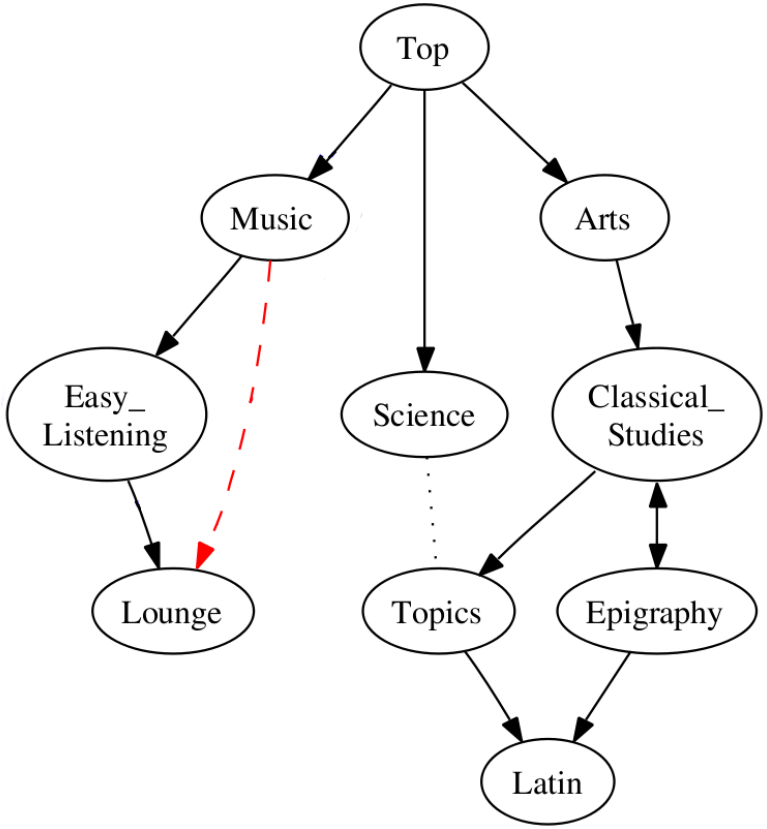
Example

- Assume B&F chain: {`Music`,`Easy_Listening`,`Music`, `Easy_Listening`} is frequent
- Create shortcut `Music`⟶`Lounge`



Offline - Personalization based on frequent sequential navigation (L-)subpatterns

Shortcut creation

- Frequent sequential navigation (L-)subpatterns indicate popular transitions between (L-)popular categories
- Provide direct access to popular topics and resources
- For each interest group and a given support threshold
  - Identify 2-sequential navigation (L-)subpatterns $\{\mathtt{X},\mathtt{Y}\}$
  - Create shortcut $\mathtt{X} \longrightarrow \mathtt{Y}$

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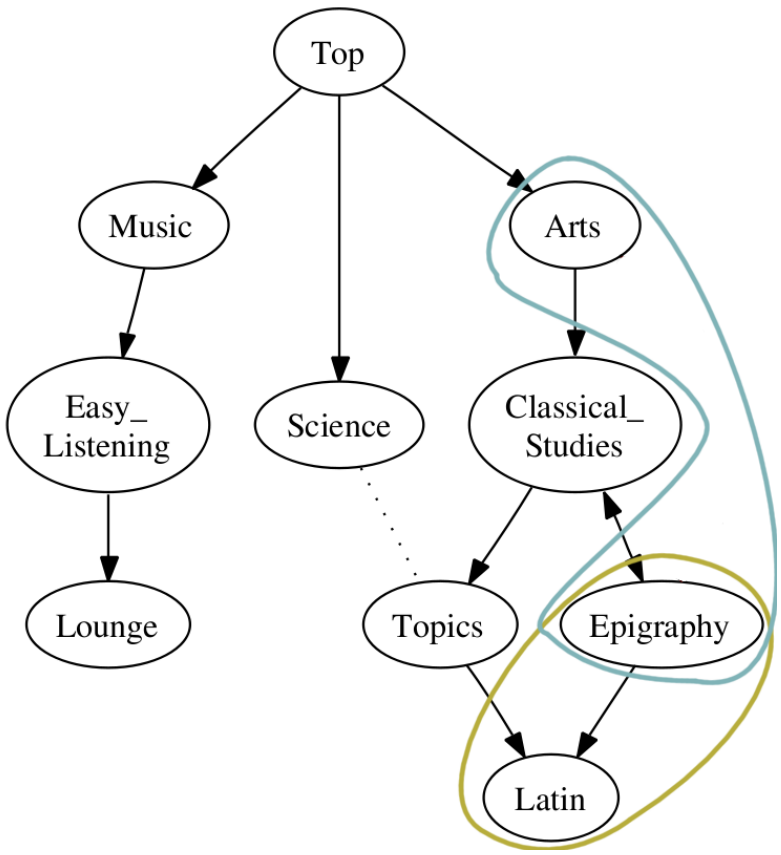

Example

- Frequent subpatterns: {Arts,Epigraphy} and {Epigraphy,Latin}
- Candidate shortcuts Arts⟶Epigraphy, Epigraphy⟶Latin

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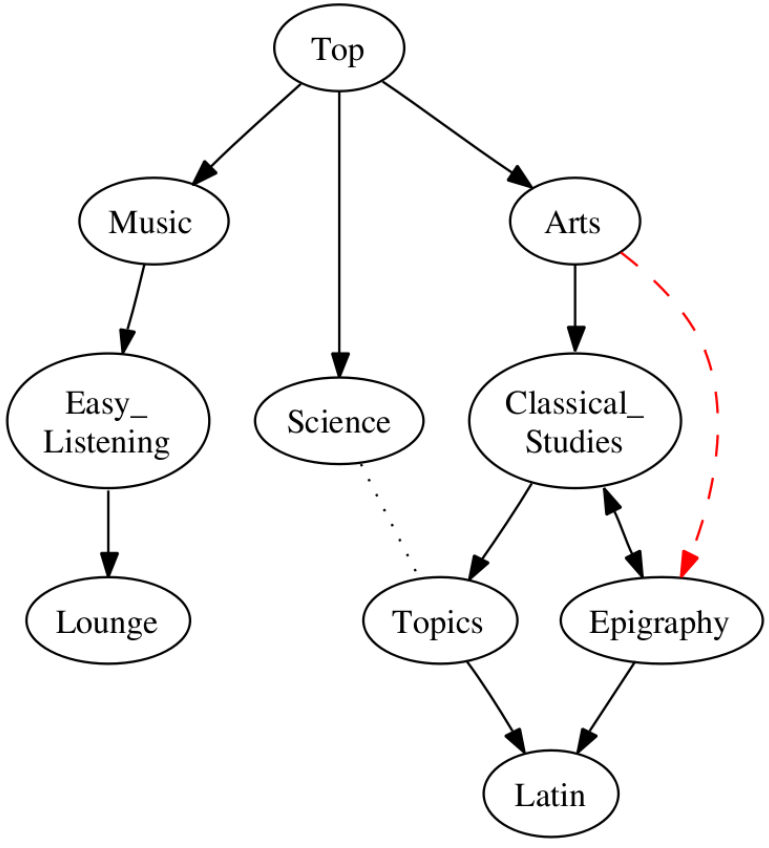


Example

- Frequent subpatterns: {Arts,Epigraphy} and {Epigraphy,Latin}
- Create shortcut Arts⟶Epigraphy

Online - Personalization based on frequent sequential navigation (L-)subpatterns

Active navigation window

- Retain two windows for each "user's" interest group
- Contains last $|w|$ (L-)popular categories visited

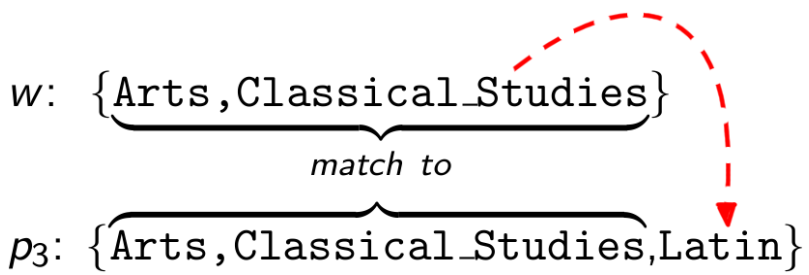
Shortcut creation

- Based on [MDL+02], but extended with multiple windows, interest groups
- For each interest group identify and store offline frequent sequential navigation (L-)subpatterns of size $|w| + 1$
- Match window with stored sequential navigation (L-)subpatterns
- For each matched frequent sequential navigation (L-)subpattern
  - `A` = last category of window
  - `B` = last category of (L-)subpattern
  - Create shortcut `A`$\longrightarrow$`B`, if its confidence is over given threshold
  - Confidence: conditional probability that user visits `B` provided that already visited all categories of window

Online - Personalization based on frequent sequential navigation (L-)subpatterns (cont'd)

Example

- Frequent sequential navigation subpatterns:
  p_1=$\{$`Arts`,`Classical_Studies`$\}$, support $\sigma(p_1) = 0.8$
  p_2=$\{$`Classical_Studies`,`Latin`$\}$, support $\sigma(p_2) = 0.7$
  p_3=$\{$`Arts`,`Classical_Studies`,`Latin`$\}$, support $\sigma(p_3) = 0.6$
- Assume $|w| = 2$, $w = \{$`Arts`,`Classical_Studies`$\}$
- Match w only to p_3 ($|p_3| = |w| + 1$, i.e., length acceptable)



- Shortcut `Classical_Studies`$\rightarrow$`Latin`
- $\alpha($`Classical_Studies`$\rightarrow$`Latin`$) = \frac{\sigma(p_3)}{\sigma(w)} = \frac{0.6}{0.8} = 0.75$

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Evaluation method

Mining tasks - Precision and recall of interest groups

- 12 users
- 4 topics: video games, William Shakespeare, basketball, food and cooking
- 10 interest groups (clusters) created
- Interest groups precision and recall

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Offline personalization - Hit ration of static shortcuts

- Creation of static shortcuts
- Second period of user browsing
- Shortcut `A`$\longrightarrow$`B` hit ratio: number of times used to total times users moved from A to B

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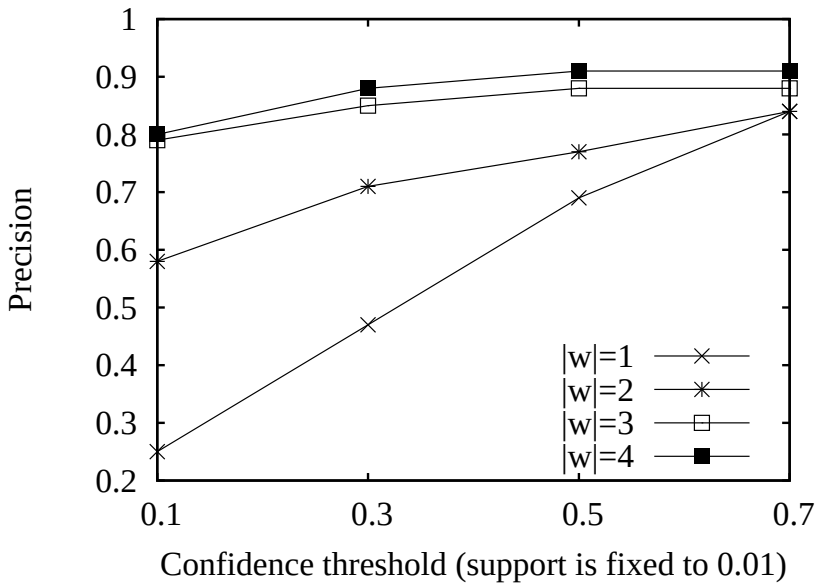
Online personalization - Precision of dynamic shortcuts

- Depth-first crawling at `Poetry`, `World_Literature` and `Drama` subtrees of `Top/Arts/Literature`
- Break navigation patterns
  - 70% generating dynamic shortcuts, 30% evaluation
- Shortcut `A`$\longrightarrow$`B` precision: number of categories *B* contained in 30% to total number of shortcuts

Online personalization - Precision of dynamic shortcuts (cont'd)

- Precision goes up as $|w|$ increases
  - Larger window provides a more representative part of user navigation behaviour
- Precision goes up as confidence threshold increases
  - Increased confidence for A⟶B means high probability that B in 30% part of navigation patterns
- Precision goes up as support threshold increases



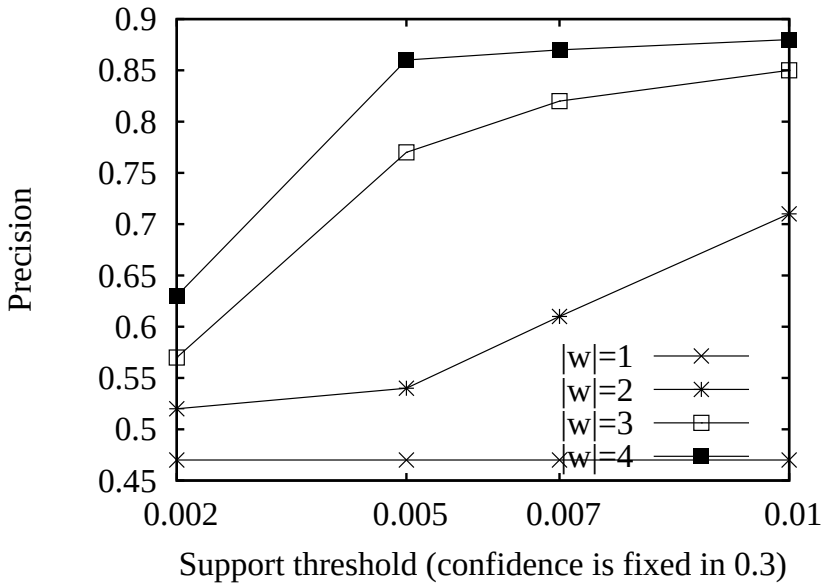


Figure: Precision of the personalization task varying the confidence/support threshold for several values of $|w|$.

Conclusion - Future work

Conclusion

- Methodology for personalizing topic directories according to users navigation behaviour
  - Set of mining tasks: interest groups, indecisive user behaviour, frequent navigation (L-)subpatterns
  - Set of personalization tasks: shortcuts creation
- Experiments for evaluating mining and personalization tasks

Future work

- Enhance personalization tasks
  - User-driven profiles
  - Semantically rich topic directories, e.g. *IS_A*, *PART_OF* relationships
- Extend evaluation of online personalization - study real user navigation patterns

Thank you

http://casablanca.dblab.ece.ntua.gr/p-miner

Related work

- Discovering sequences of visits
  - Datamining techniques
  - Probabilistic models
  - Most of them, do not perform personalization
  - The rest, do not distinguish between different users and groups of users
- Personalization in Digital Libraries and Web portals
  - The structure of these Web sites is similar to topic directories
  - Based on explicit user input
    - Provide simplified search functionalities and alerts
  - Based on implicit user input
    - They identify the preferences of each individual user
- Collaborative filtering-based methods
  - Also identify users with common interests and behaviour
  - Model user profiles as vectors
  - On the contrary, we use clustering to create interest groups
  - Also exploit sequential pattern mining to generate recommendations

System architecture