Interactive Exploration of Multi-Dimensional Information Spaces with Preference Support

PhD Presentation

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Ευρωπαϊκή Ένωση
Ευρωπαϊκό Κοινωνικό Ταμείο

ΕΠΙΧΕΙΡΗΣΙΑΚΟ ΠΡΟΓΡΑΜΜΑ
ΕΚΠΑΙΔΕΥΣΗ ΚΑΙ ΔΙΑ ΒΙΟΥ ΜΑΘΗΣΗ
επένδυση στην κοινωνία της γνώσης
ΥΠΟΥΡΓΕΙΟ ΠΑΙΔΕΙΑΣ & ΘΡΗΣΚΕΥΜΑΤΩΝ, ΠΟΛΙΤΙΣΜΟΥ & ΑΘΛΗΤΙΣΜΟΥ
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ΕΥΡΩΠΑΪΚΟ ΚΟΙΝΩΝΙΚΟ ΤΑΜΕΙΟ

Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης

In one slide

This thesis proposes a novel interaction model

- for **searching** and **exploring gradually information**
- enriched with a language for **expressing preferences**
- over **hierarchically organized** and **multi-valued attributes**
- that is **user friendly**

`Hippalus`

- Implementation of `Hippalus`, a system that supports the aforementioned framework

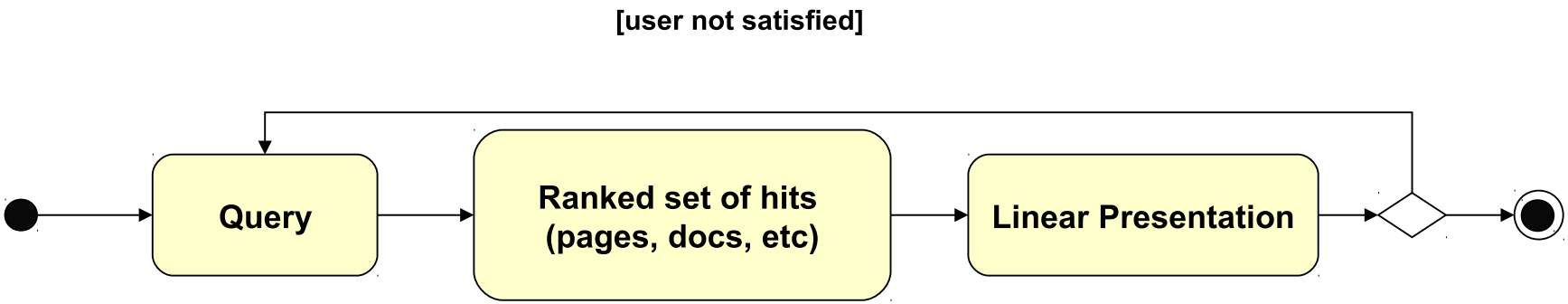
The conducted user studies, show that this interaction model helps the users

- **explore** the information space
- **easily express** their preferences over the **available choices** in a **gradual manner**
- **locate more easily/fast** the desired information

Motivation

- Most Search Systems (eg. Web Search Engines) return a **ranked-list of results**
  - Users have to explore the answer **linearly**
  - In practice users tend to look **only** at the first page of results
    → **Miss** useful hits
    → Difficult to find **useful hits** if the query contains ambiguous words
    → Difficult **to guess the right words for expanding** the query

Traditional Searching



Motivation

- Almost 60% of search tasks are of **exploratory** nature (Crawford, 2006)
  - As a result the user has to inspect more than one resources (hits) to be satisfied $\rightarrow$ which is typical in decision making (e.g. buy a car)
  - Exploratory tasks are **time consuming** and **session-based**
- Users rarely exploit the **available metadata**
  - e.g. Google Advanced Search or specific keywords (i.e. filetype:pdf)

Objective and Requirements

General objective of thesis

- offer users a **flexible** and **effective** method for accessing **large amounts of data**
- supporting **recall-oriented** information needs and **decision making** (i.e. preferences)

Requirements meeting the objective

- **Generality**
  - Capture a wide range of information spaces and user information needs
- **Expressiveness**
  - Interactively specify complex preference structures
- **Usability**
  - Users should be able to use and understand the interaction immediately

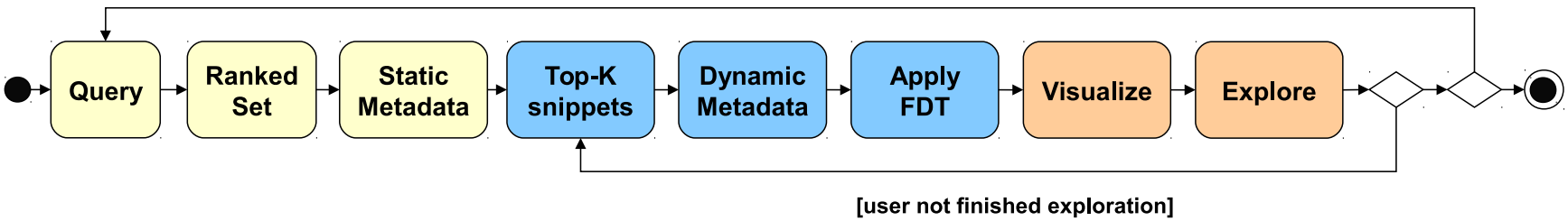
Approach

Faceted and Dynamic Taxonomies (FDT)

- is a **widely** used interaction scheme for **Exploratory Search**
- can be used over **structured** and **unstructured** information spaces
- supports **static** and **dynamically** mined metadata
- display data under different categorization schemes (**facets**) and categories (**terms**)

Exploratory Searching
With Static and Dynamic Metadata

(Papadakos et al 2012a)

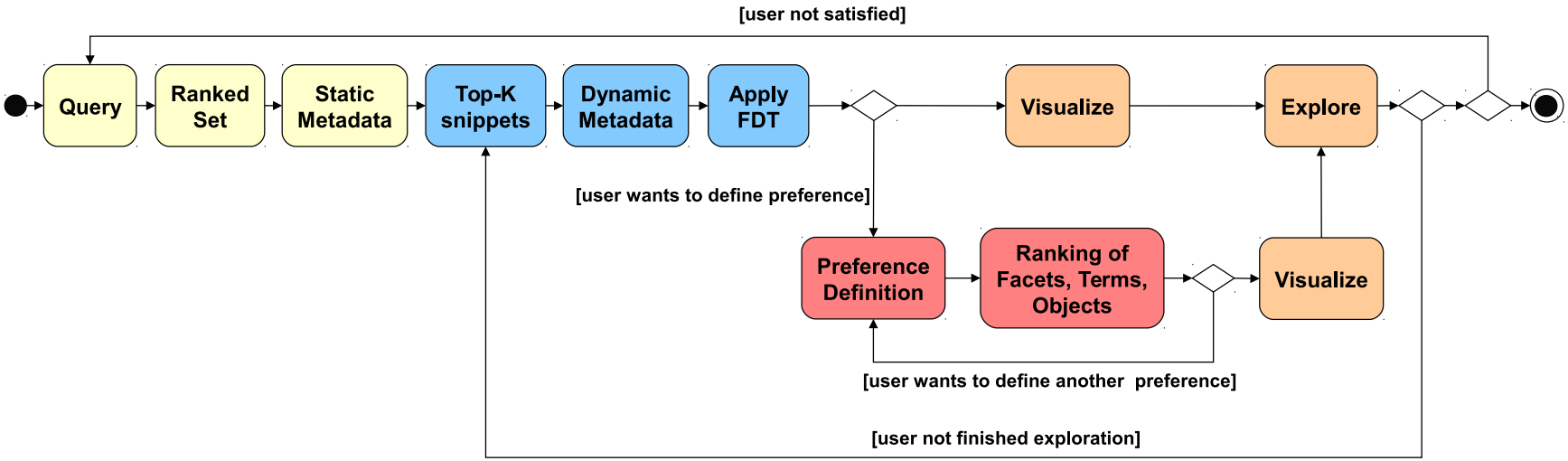


Approach

We propose the enrichment of the FDT with preference actions that:

- affect the ordering of **facets**, **terms**, **objects** (of the focus)
- support **hierarchically organized data**, automatically **resolving conflicts**
- support **multi-valued** attributes (commonly found in tags, etc.)
- offer **composition of preference actions**

Exploratory Preference Based Searching With Static and Dynamic Metadata



Research Questions

Questions

1. How can we **gradually** and **flexibly** specify **preferences** over information spaces that might be **hierarchically** organized, resolving when possible **conficts**, and might support **multi-valued** attributes, and which will be their **semantics**?
2. How can we tackle the **algorithmic** perspective so that the proposed interaction can be applied over **large information bases**?
3. How does the proposed interaction affect the **user effort** and other **metrics** during exploratory tasks?

Outline of the Presentation

BG & RW

Proposed Preference Framework

Hippalus

Evaluation

Conclusion & FW

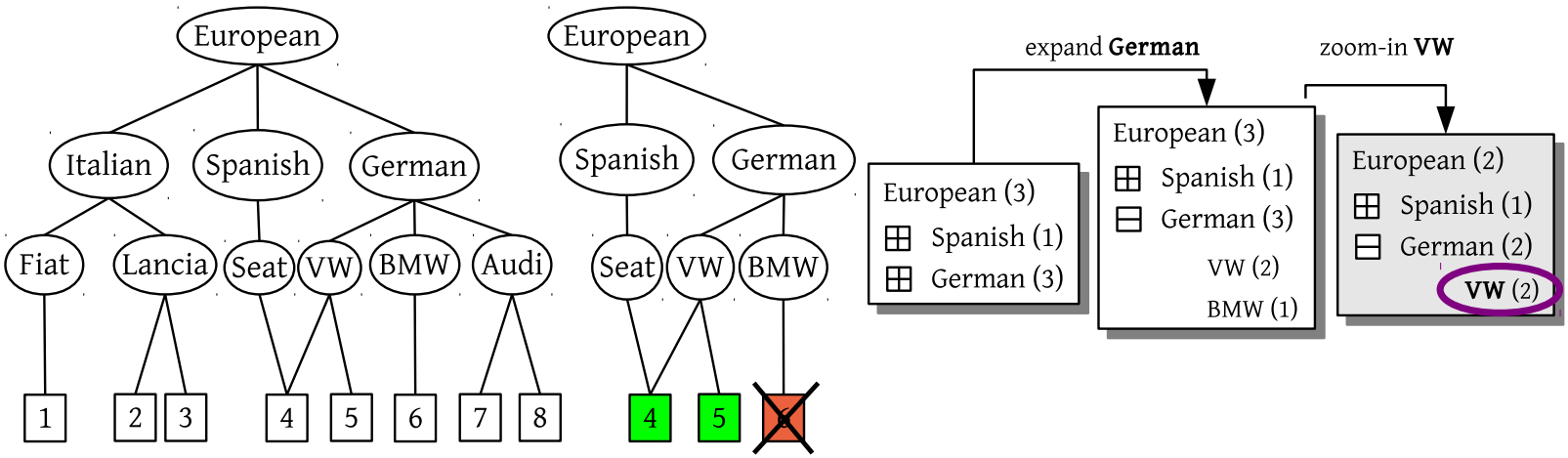
BG & RW

- Faceted and Dynamic Taxonomies
- Preferences in General
- Preferences in Databases
- Personalization in FDT

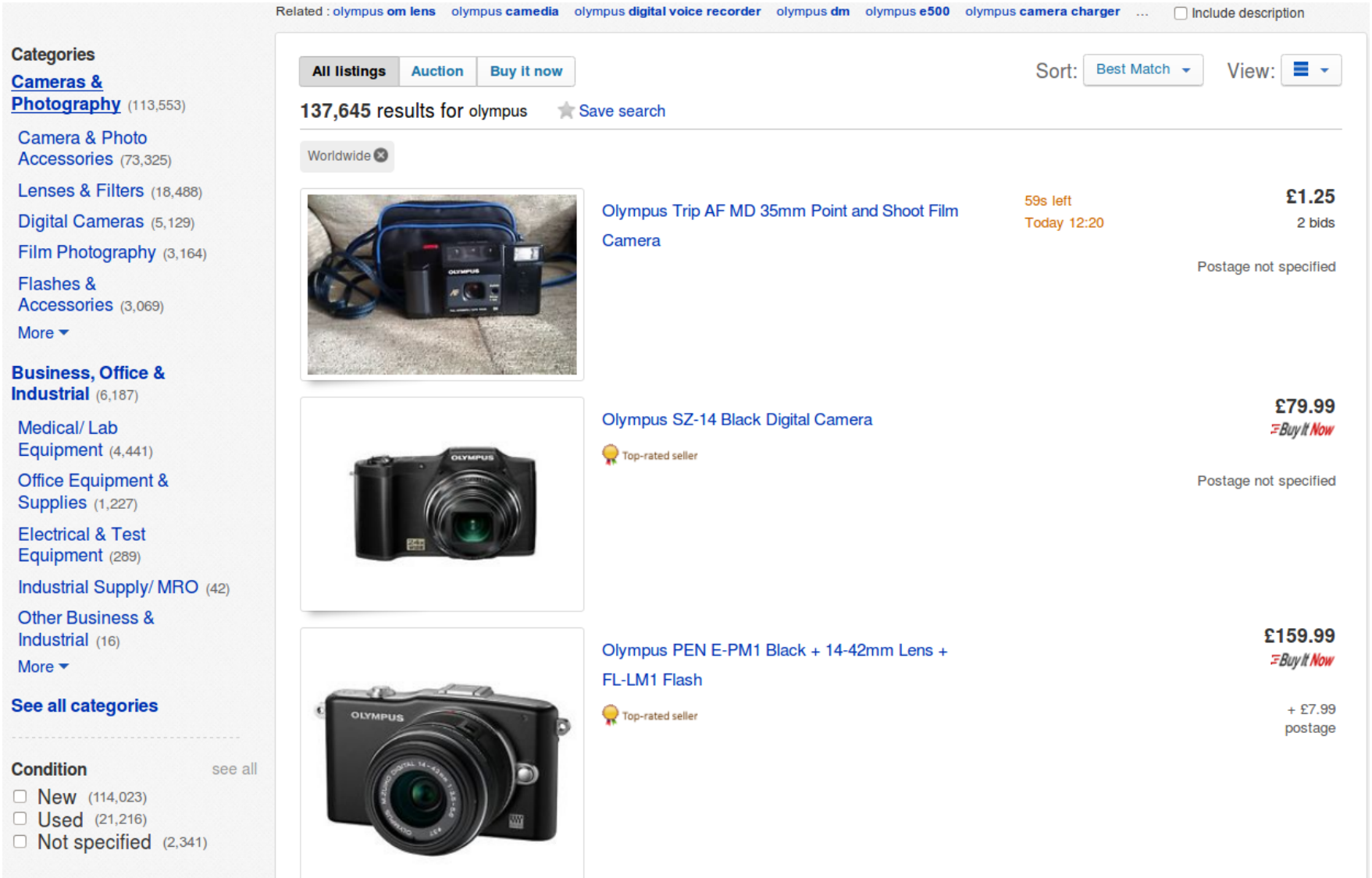
Faceted and Dynamic Taxonomies

Faceted and Dynamic Taxonomies (FDT) is currently a widely used interaction scheme that provides exploration services (Sacco and Tzitzikas, 2009)

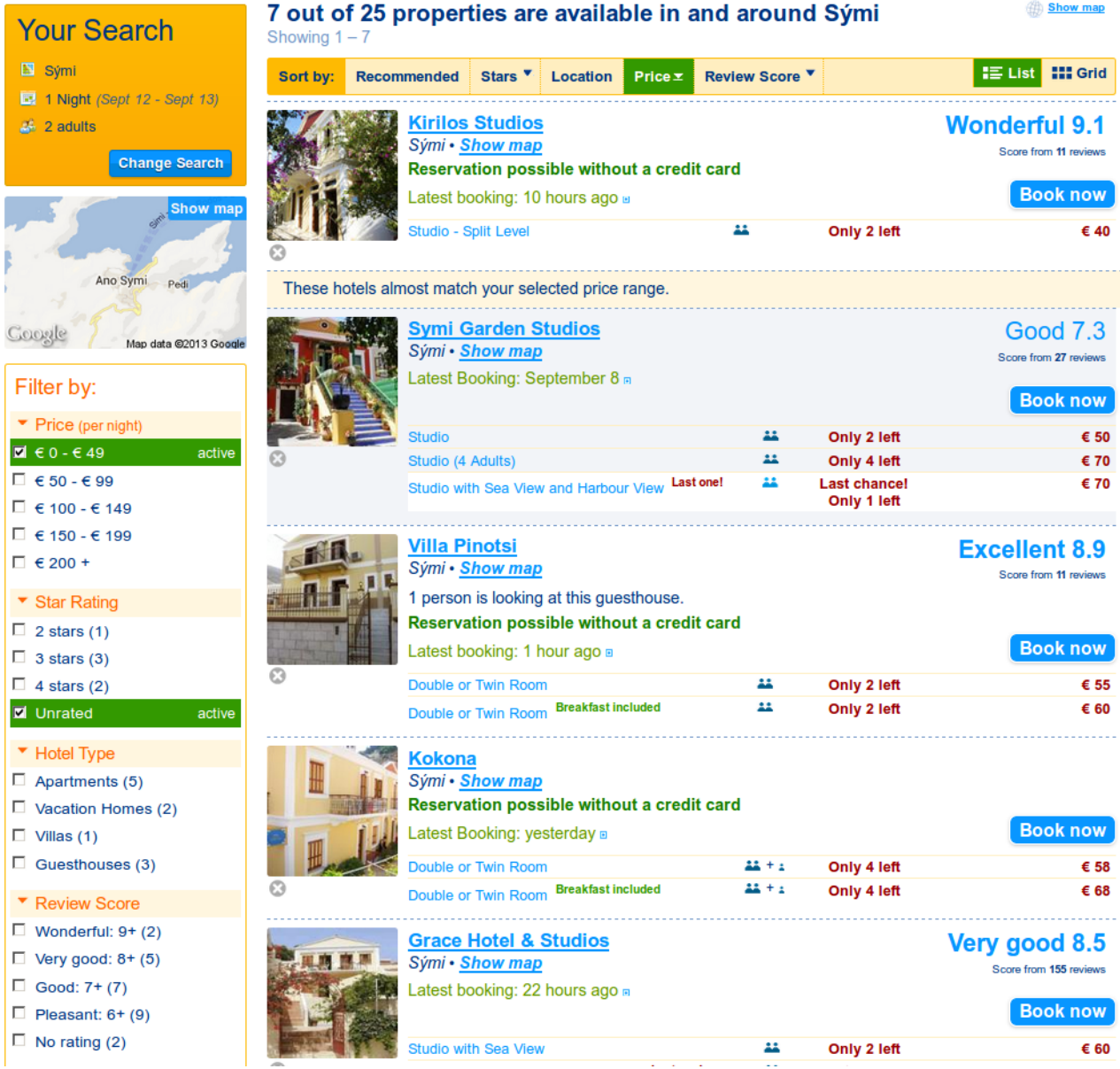
- They are used to **explore** and **browse** complex information bases in a **guided** and **gradual**, yet **unconstrained** way through a visual interface
- display of **current results** in multiple categorization schemes (**facets**)
- display categories (**terms**) leading to **non-empty results**
- display of the **count** of the indexed objects of each category
- the **focus** of the user can be extensionally defined (results of a query) or intentionally (a set of terms selected by the user)



Faceted and Dynamic Taxonomies → ebay



Faceted and Dynamic Taxonomies → Booking.com



Preferences in General

- FDT can be considered as hard constraints
- ... Preferences are not hard constraints, but **wishes**

General Limitations

- Users do not have **stable preferences** over time
- Preferences change according to **available choices**
- Without **knowing the available choices** expression of preferences
  - **difficult** and **time-consuming**
  - results to **incomplete** preferences

Preferences in Databases

- Preferences have been **studied** thoroughly in the **DB world** (Stefanidis et al., 2011)

Limitations

- Users have to formulate **complicated queries** or use **complex UIs**
- They must be **acquainted with the information space** and **available choices**
- Preferences are given in **one shot** (not **gradually**)
- Users cannot exploit **hierarchically organized** attribute values
- They only support **single-valued** attributes, (i.e. no **multi-valued** attributes)

Personalization in FDT

- Facets and terms **ordered lexicographically** or based on **# indexed objects**
- Personalization services over FDT have **started to come up**
- Automatically present the **most preferred** facets and terms based on:
  - **set cover ranking** (Dakka et al., 2005)
  - their **"interestingness"** (Dash et al., 2008)
  - **collaborative filtering** (Koren et al., 2008; Tvarožek et al., 2008)
  - **less effort approaches** (Roy et al., 2008; Kashyap et al., 2010)
  - **semantically enriching tweets** (Abel et al., 2011)
  - **intuitions** (small and uniform operations) (Wagner et al., 2011)
  - **logs** for modeling user behaviour (Pound et al., 2011)

Limitations

- The user **cannot explicitly** and **gradually rank** the facets, terms or objects
- Such approaches **do not exploit inherent properties of FDTs** like hierarchies

Proposed Preference Framework

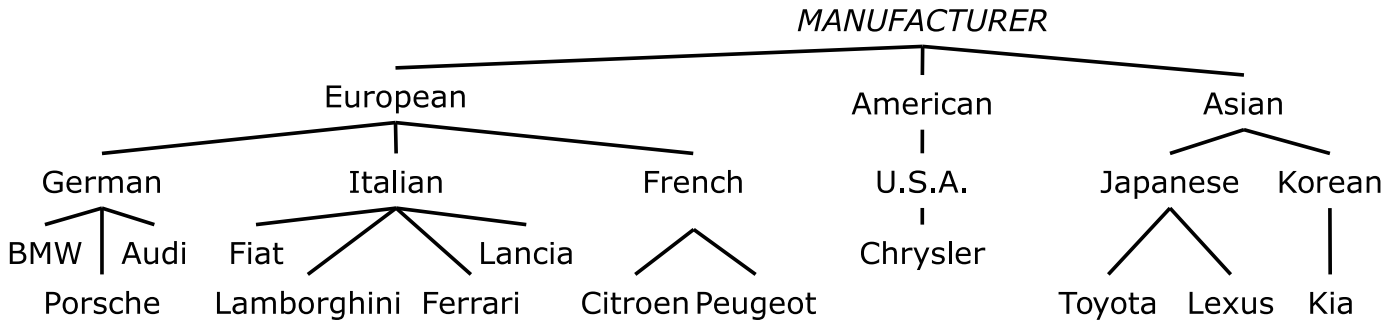
Information Space

- We consider data forming a **table**, with **single-valued (SV)** and **multi-valued (MV)** attributes, where attribute values can be organized hierarchically in **taxonomies**
- In the context of the unstructured world, attributes can be **extracted from**:
  - **static metadata** (e.g. filetype, date, etc.)
  - **dynamic metadata** (e.g. clustering, entity mining, etc.) Papadakos et al. (2012a)

Running Example

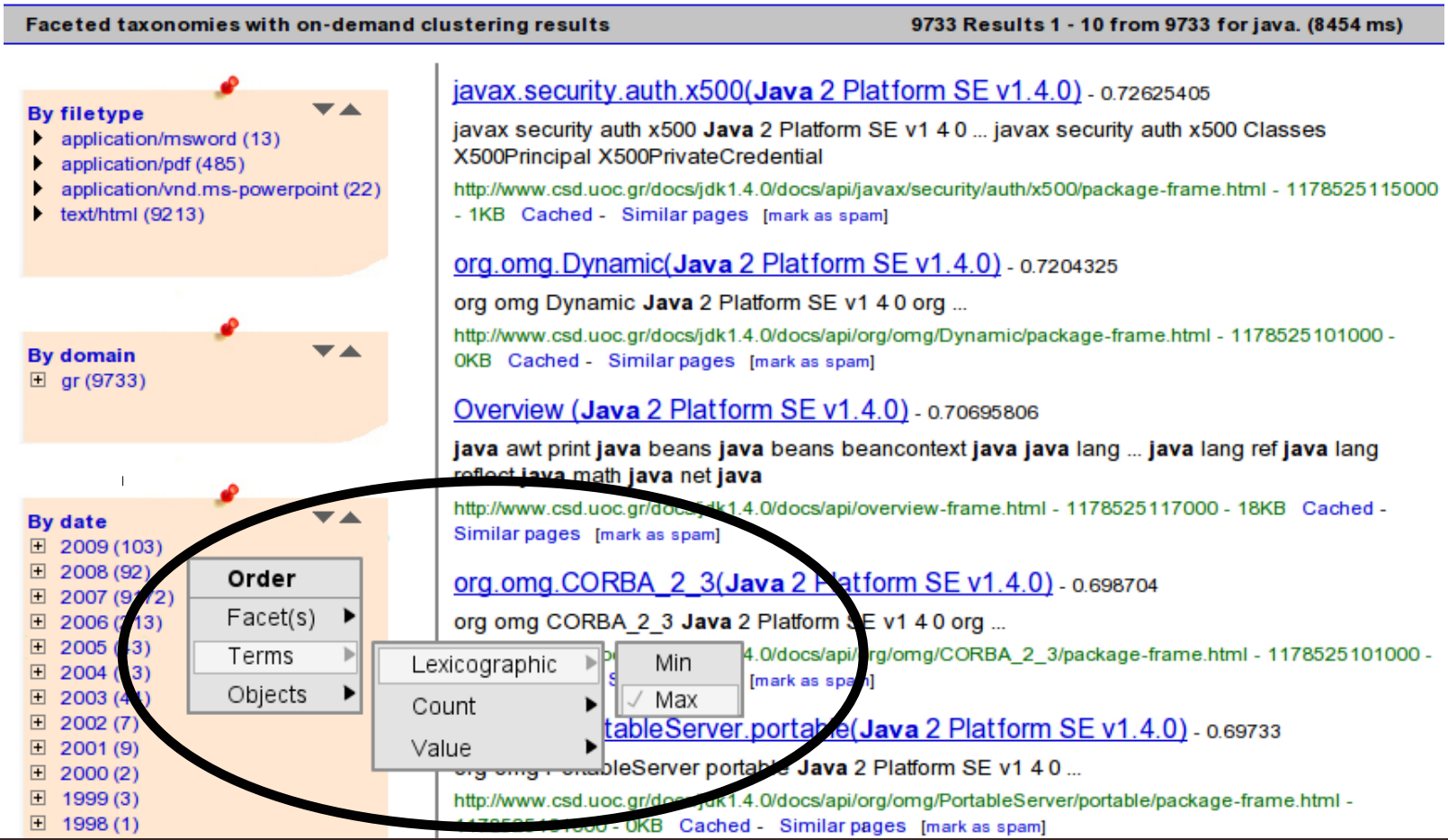
- `Car(Id, Manuf., Model, Category, Price, Power, Volume, Year, Fuel, Location, Access., Comment)`
- Hierarchically organized taxonomies like: `Manufacturer`, `Fuel` and `Location`
- Attribute `Accessories` is multi-valued

Id	Manufacturer	Model	Category	Price	Power	Volume	Year	Fuel	Location	Accessories	Comment
1	Porsche	Carrera 911	Cabrio	50000	350	3600	2005	Petrol	Cefalonia	{ABS,AT}	"Uncrashed, like new"
...	...	...	...	...	...	...	...	...	...	...	...



Language for Expressing Preferences

- Requirements:
  - **Easily enacted** through a GUI
  - Affecting **facets**, **terms** and **objects**
  - Expressive enough, to support **a number of preference actions** (i.e. relative preferences, composition)



Language: BNF Language Syntax

$$
\begin{array}{rcl}
\langle stmt \rangle & ::= & \langle scopeType \rangle \langle spec \rangle \\
\langle scopeType \rangle & ::= & \texttt{facets order :} \mid \texttt{terms order :} \mid \texttt{object order :} \\
\langle spec \rangle & ::= & \langle anchor \rangle \langle rankSpec \rangle \\
\langle anchor \rangle & ::= & \texttt{facet } \langle F_i \rangle \\
& \mid & \texttt{term } \langle t_j \rangle \\
& \mid & \texttt{object } \langle o_k \rangle \\
& \mid & \epsilon \qquad\qquad \text{// the empty string} \\
\langle rankSpec \rangle & ::= & \{\texttt{lexicographic} \mid \texttt{count} \mid \texttt{value} \mid \texttt{indexedBy}\} \ \{\texttt{min}|\texttt{max}\} \\
& \mid & \texttt{best} \mid \texttt{worst} \\
& \mid & \texttt{use scoreFunction } \langle score() \rangle \ \{\texttt{min}|\texttt{max}\}
\end{array}
$$

Examples

- `facets order: facet` *Manufacturer* `best`
- `object order: term` *Location.Cefalonia* `best`
- `object order: facet` *Relevance* `value max`

Language: Extending the language...

- To support *relative preferences* over facets and terms

$\langle stmt \rangle$ | `facets order :` `prefer` $\langle F_i \rangle$ `to` $\langle F_j \rangle$

$\langle stmt \rangle$ | `terms order :` `prefer` $\langle t_i \rangle$ `to` $\langle t_j \rangle$

$\langle stmt \rangle$ | `object order :` `prefer` $\langle t_i \rangle$ `to` $\langle t_j \rangle$

- Extending syntax to allow *complex expressions*, synthesizing two or more actions e.g. *Pareto, prioritized synthesis*

$\langle stmt \rangle$ | `objects order :` `Pareto` $\langle setOfFacets \rangle$

$\langle stmt \rangle$ | `objects order :` `ParetoOptimal` $\langle setOfFacets \rangle$

$\langle stmt \rangle$ | `objects order :` `Priority` $\langle orderedSetOfFacets \rangle$

$\langle stmt \rangle$ | `objects order :` `Combinational` $\langle bucketOrderedSetOfFacets \rangle$

Preference Semantics

- Let $\mathcal{B}$ be the set of preference statements the user has given
- Then $\mathcal{B}$ can be partitioned to $\mathbf{k+2}$ subsets (k is the number of facets)
  - $\mathcal{B}_{\mathbf{F}}$ holds the user actions for facets
  - $\mathcal{B}_{\mathbf{T_i}}$ holds the user actions for the terms of each facet F_i (k such subsets)
  - $\mathcal{B}_{\mathbf{Obj}}$ holds the user actions regarding the objects preferences
  - So $\mathcal{B} = \mathcal{B}_{\mathbf{F}} \cup (\bigcup_{\mathbf{i}} \mathcal{B}_{\mathbf{T_i}}) \cup \mathcal{B}_{\mathbf{Obj}}$
- A preference over a set of elements E can be expressed as a **binary relation** $(\mathbf{E}, \succ)$ over E
- Independently of the number of actions we have $\mathbf{k+2}$ preference relations
  - $\mathbf{1}$ over the facets: $(\{F_1, \ldots, F_k\}, \prec_F)$
  - $\mathbf{k}$ preferences relations defined over the terms T_i of each facet F_i (having the form $(T_i, \prec_i)$)
  - $\mathbf{1}$ preference relation for the objects $(A, \prec_{Obj})$

Definition (Valid Preference)

A preference relation R over a set of elements E is valid, *if it is acyclic.*

Definition (L Respects R)

We say that a linear or bucket order L over E respects *a preference relation R, if $R \subseteq L$.*

Cases

- Flat Single Valued (SV)
- Hierarchical non-Relative Single Valued
- Hierarchical Relative Single Valued
- Flat Multi Valued (MV)
- Hierarchical Relative Multi Valued

Case Flat SV: Input & Output

- Input:
  - Let $E = \{e_1, \ldots, e_n\}$ be a set of elements
  - Let B be the elements of E on which a **best** action has been defined
  - Let W be the elements of E on which a **worst** action has been defined
  - Let $R_{\succ}$ be binary relation holding the **relative** preferences (of the form $e_i \succ e_j$)
  - Let *Policy* determine the ordering of **inactive elements** (e.g. **minimal**, **maximal**)

- Output:
  - A bucket order L of E

Case Flat SV: Algorithm

Algorithm 1 `Apply`$(E, B, W, R_{\succ}, Policy)$

Input: the set of elements E, the set of best elements B, the set of worst elements W, a set of relative relationships $R_{\succ}$, and *Policy* for *inactive* elements

Output: a bucket order over E that respects R

1: $R_{bw} \leftarrow \{(b, w) \mid b \in B, w \in W\}$ // each best is preferred than each worst
2: $R \leftarrow R_{bw} \cup R_{\succ}$ //add relative prefs
3: $L \leftarrow$ `SourceRemoval`(R) //produce blocks with boundaries
4: $I \leftarrow E \setminus (B \cup W \cup dom(R_{\succ}))$ // I contains inactive elements
5: $L' \leftarrow$ `addInactiveElements`$(L, I, Policy)$
6: **return** L'

Algorithm 2 `SourceRemoval`(R), a topological sorting algorithm

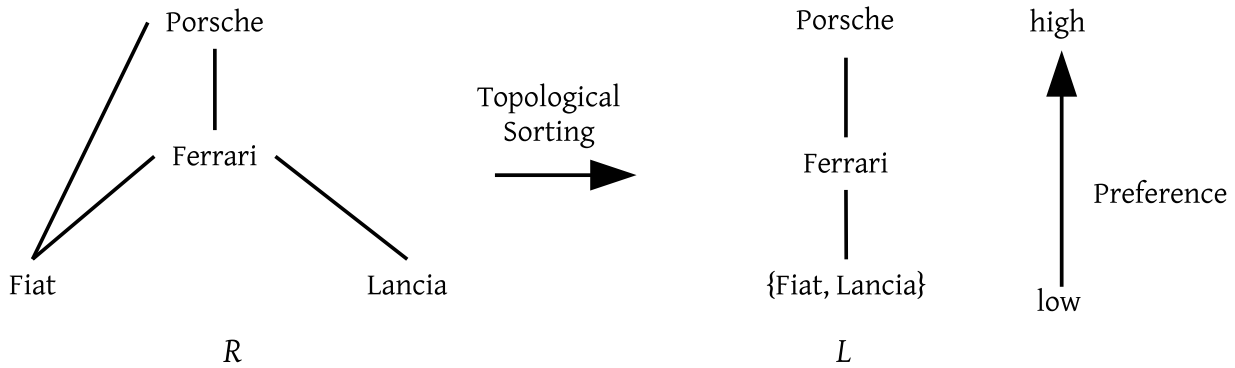
Input: a binary relation R over E

Output: a bucket order over E

1: $L \leftarrow \langle\rangle$
2: **repeat**
3: $\quad S \leftarrow maximal_{\succ}(R)$
4: $\quad R \leftarrow R \setminus \{(x, y) \in R \mid x \in S\}$ // Remove maximal
5: $\quad L \leftarrow L.append(S)$ // Append a bucket to L
6: **until** $S \neq \varnothing$
7: **return** L

Case Flat SV: Example

- let $B = \{Ferrari\}$ and $W = \{Fiat, Lancia\}$
- let $R_{\succ} = \{Porsche \succ Ferrari, Porsche \succ Fiat\}$



- After running topological sorting, $L = \langle Porsche, Ferrari, \{Fiat, Lancia\}\rangle$

Exploit Hierarchies

Question

- What if a user wants to say that all **German** manufactures are considered best, while all **Italian** as worst?

- Express a preference action **for each** available German and Italian manufacturer
  - `Best(BMW)`
  - `Best(Mercedes)`
  - `Worst(Fiat)`
  - `Worst(Lancia)`
  - etc.

- FDT **inherently** support **hierarchies**
- **Exploit hierarchically** organized taxonomies
  - through **preference inheritance**
  - **simplify user interaction** (less number of preference actions)

Case Hierarchical SV Non-Relative: Scope & Inheritance

- Let b be an action in $\mathcal{B}$, either **best** or **worst**
- We denote with $scope(b)$ the *scope* of the action b (ie. either the facets, terms, or objects that it affects)
- To capture **inheritance** we redefine the scope of inherited actions, as:

Definition (Scope and Inheritance)

Let b be an inherited action $b = \langle e, rs \rangle$ where e is its anchor and rs the other part of the action. The scope of b is defined as:

$$scope(b) = \cup_{e' \in N^*(e)} scope(\langle e', rs \rangle)$$

where $N^*(e)$ stands for e and the narrower elements of e, formally $N^*(e) = \{e\} \cup N^+(e) = \{e' \mid e' \leq e\}$.

Case Hierarchical SV Non-Relative: Dominance Rule

- Unfolding each $b \in \mathcal{B}$ based on its scope might lead to **cycles** (i.e. non valid preferences) e.g. `Worst(Italian), Best(Ferrari)`
- Automatically resolve such conflicts through **action refining**
- Define a **preorder relation** over $\mathcal{B}$, denoted by $(\mathcal{B}, \sqsubseteq)$ according to definition:

Definition (Refinement Checking)

We say that an action b is equally or more refined *than an action b', denoted by $b \sqsubseteq b'$, if $scope(b) \subseteq scope(b')$.*

- We can use $(\mathcal{B}, \sqsubseteq)$ to **resolve conflicts due to inheritance**, based on the following rule:

Definition (Scope-based Dominance Rule)

If $A \subseteq scope(b) \subseteq scope(b')$ then b' is dominated by *b on A, thus action b should determine the ordering of A.*

Hierarchical SV Non-Relative: Active Scope & Example

- Define the *active scope* of each action by **excluding** from its scope the scopes of its direct children with respect to $\sqsubseteq$

Definition (Active Scope)

If $C(b)$ denotes the direct children of b with respect to $\sqsubseteq$, then the active scope of b, *denoted by $aScope(b)$, is defined as: $aScope(b) = scope(b) \setminus (\bigcup_{b' \in C(b)} scope(b'))$*

- Assuming **term scoped** actions

action	scope	active scope
b_1: Best(Europe)	{European, German, Audi, BMW, Porsche, French, Citroen, Peugeot, ~~Italian~~, ~~Alfa Romeo~~, ~~Ferrari~~, ~~Fiat~~, ~~Lamborghini~~}	**{European, German, Audi, BMW, Porsche, French, Citroen, Peugeot}**
b_2: Worst(Italian)	{Italian, Alfa Romeo, ~~Ferrari~~, Fiat, Lamborghini}	**{Italian, Alfa Romeo, Fiat, Lamborghini}**
b_3: Best(Ferrari)	{Ferrari}	**{Ferrari}**

Hierarchical SV Non-Relative: Active Scope & Example

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- Assuming **term scoped** actions
- Assuming **object scoped** actions

Id	Manufacturer	...
P	Porsche	...
L	Lancia	...
A_1	Alfa Romeo	...
A_2	Alfa Romeo	...
F	Ferrari	...

action	scope	active scope
b_1: Best(Europe)	$\{P, L, A_1, A_2, F\}$	$\{P\}$
b_2: Worst(Italian)	$\{L, A_1, A_2, F\}$	$\{L, A_1, A_2\}$
b_3: Best(Ferrari)	$\{F\}$	$\{F\}$

Case Hierarchical SV Non-Relative: Algorithm

Algorithm 3 `PrefOrder`(E, $\mathcal{B}$, *Policy*)
Input: the set of elements E, the set of actions $\mathcal{B}$, and *Policy* for *inactive* elements
Output: a bucket order over E

1: /** *Part (1): Computation of* $(\mathcal{B}, \sqsubseteq)$ */
2: Compute the *scopes* of the actions in $\mathcal{B}$
3: Form $(\mathcal{B}, \sqsubseteq)$
4: /** *Part (2): Efficient Computation of Act. Scopes* */
5: Use $(\mathcal{B}, \sqsubseteq)$ to compute the *active scopes* of the actions in $\mathcal{B}$
6: Use the active scopes to expand the set $\mathcal{B}$ to a set $\mathcal{B}'$
7: /** *Part (3): Derivation of the final bucket order* */
8: $(B, W, R_{\succ}) \leftarrow$ Parse($\mathcal{B}'$, ActiveScope)
9: **return** Apply(E, B, W, $R_{\succ}$, *Policy*) // call to Alg. 1

Case Hierarchical SV Relative

Question

- What about relative preference actions over hierarchical organized single-valued attributes?

Case Hierarchical SV Relative: Scope & Expansion

- We have to redefine *scope* and *active scope*

Definition (Scope of Relative Preferences)

The scope of a preference relationship $e_i \succ e_j$*, denoted by* $scope(e_i \succ e_j)$*, is defined as:* $scope(e_i \succ e_j) = (N^*(e_i) \times N^*(e_j)) \cup (N^*(e_j) \times N^*(e_i))$.

Definition (Expansion of Relative Preferences)

The expansion of a preference relationship $e_i \succ e_j$*, denoted by* $expansion(e_i \succ e_j)$*, is defined as:* $expansion(e_i \succ e_j) = \{e_i' \succ e_j' \mid e_i' \in N^*(e_i), e_j' \in N^*(e_j)\}$

- $expansion(e_i \succ e_j)$ actually "unfolds" the preference relationship $e_i \succ e_j$ on the basis of the subsumption relationships
- The scope-based ordering of such actions is defined as before, i.e. $b \sqsubseteq b'$ iff $scope(b) \subseteq scope(b')$

Case Hierarchical SV Relative: Active Scope

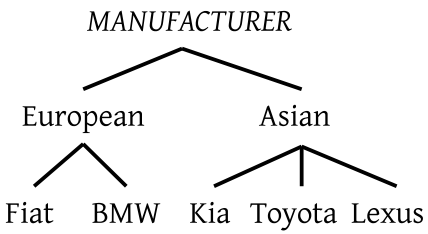
- We can define the *active scope* of each action by excluding from its expansion the scopes of its direct children, wrt to $\sqsubseteq$

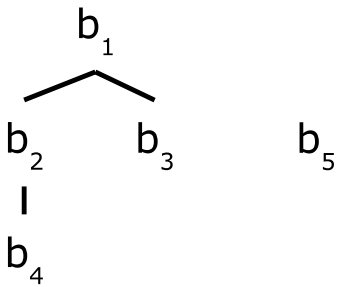
Definition (Active Scope)

The active scope of a preference relationship b, in the context of a set of preference actions $\mathcal{B}$ is defined as:
$AScope(b) = \{e_i \succ e_j \in expansion(b) \mid \nexists b' \in \mathcal{B}\ s.t.\ b' \sqsubseteq b,\ and\ \ (e_i, e_j) \in scope(b')\}$,
and this is equivalent to:
$AScope(b) = expansion(b) \setminus (\bigcup_{b' \sqsubseteq b} \{e_i \succ e_j \mid (e_i, e_j) \in scope(b')\})$

- We can use Alg. `PrefOrder` with *scope* and *active scope* as defined here

Case Hierarchical SV Relative: Example





Action	Expansion	Active scope
b_1 : *Asian* $\succ$ *European*	*Asian* $\succ$ *European*, ~~*Asian* $\succ$ *BMW*~~, *Asian* $\succ$ *Fiat*, ~~*Kia* $\succ$ *European*~~, ~~*Kia* $\succ$ *BMW*~~, ~~*Kia* $\succ$ *Fiat*~~, *Toyota* $\succ$ *European*, ~~*Toyota* $\succ$ *BMW*~~, *Toyota* $\succ$ *Fiat*, *Lexus* $\succ$ *European*, ~~*Lexus* $\succ$ *BMW*~~, *Lexus* $\succ$ *Fiat*	**Asian $\succ$ European,** **Asian $\succ$ Fiat,** **Toyota $\succ$ European,** **Toyota $\succ$ Fiat,** **Lexus $\succ$ European,** **Lexus $\succ$ Fiat**
b_2 : *European* $\succ$ *Kia*	*European* $\succ$ *Kia*, *BMW* $\succ$ *Kia*, ~~*Fiat* $\succ$ *Kia*~~	**European $\succ$ Kia,** **BMW $\succ$ Kia**
b_3 : *BMW* $\succ$ *Asian*	*BMW* $\succ$ *Asian*, *BMW* $\succ$ *Kia*, *BMW* $\succ$ *Toyota*, *BMW* $\succ$ *Lexus*	**BMW $\succ$ Asian,** **BMW $\succ$ Kia,** **BMW $\succ$ Toyota,** **BMW $\succ$ Lexus**
b_4 : *Kia* $\succ$ *Fiat*	*Kia* $\succ$ *Fiat*	**Kia $\succ$ Fiat**
b_5 : *Toyota* $\succ$ *Kia*	*Toyota* $\succ$ *Kia*	**Toyota $\succ$ Kia**

- By applying Alg. `PrefOrder` we get (only for the leaves):
- $\langle$ {*BMW*}, {*Asian*, *Toyota*, *Lexus*}, {*European*}, {*Kia*}, {*Fiat*} $\rangle$

Case Flat MV

Question

- How can we order multi-valued attributes based on preferences defined over single terms?

Case Flat MV: MoreWins-Rule

Definition (Induced Preference over Sets: *MoreWins-Rule*)

If s, s' are two subsets of E, with $wins(s, s')$ we will denote the number of "times" s beats s' according to $\succ$. Formally:

$$wins(s, s') = |\{(e, e') \mid e \in s, e' \in s', e \succ e'\}|$$

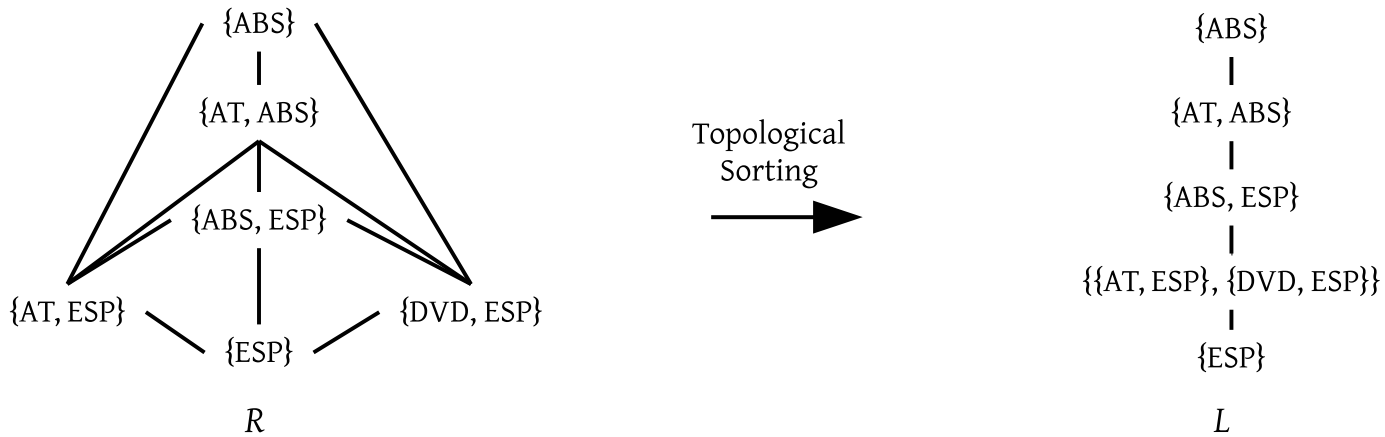
Any subset S of the powerset of E (i.e. $S \subseteq P(E)$), can be ordered according to a preference relation denoted by $\succ_{\{\}}$, defined by the following rule:

$$s \succ_{\{\}} s' \text{ iff } wins(s, s') > wins(s', s)$$

Case Flat MV: Example

- Let $E = \{ABS, ESP, AT, DVD\}$
- Let ABS be **best**, ESP be **worst** and $ABS \succ AT$
- Let $S = \{\{ABS\}, \{ESP\}, \{ABS, ESP\}, \{AT, ABS\}, \{AT, ESP\}, \{DVD, ESP\}\}$

$w(s, s')/w(s', s)$	{ABS}	{ESP}	{ABS,ESP}	{AT, ABS}	{AT, ESP}	{DVD, ESP}	all
{ABS}	0/0	1/0	1/0	1/0	2/0	2/0	5/0
{ESP}	0/1	0/0	0/1	0/2	0/1	0/1	0/5
{ABS,ESP}	0/1	1/0	1/1	1/2	2/1	2/1	3/2
{AT,ABS}	0/1	2/0	2/1	1/1	3/0	3/0	4/1
{AT,ESP}	0/2	1/0	1/2	0/3	1/1	1/1	1/3
{DVD,ESP}	0/2	1/0	1/2	0/3	1/1	1/1	1/3



- $L = \langle \{ABS\}, \{AT, ABS\}, \{ABS, ESP\}, \{\{AT, ESP\}, \{DVD, ESP\}\}, \{ESP\} \rangle$

Case Flat MV: Breaking ties

Question

- But how to break ties when we compare sets with only **best** or only **worst** elements?

Case Flat MV: MoreGoodLessBad-rule

Definition (Breaking ties: *MoreGoodLessBad-rule*)

- If $wins(s, s') = wins(s', s) = 0$ and $Support(s) > Support(s')$ then $s \succ_{\{\}} s'$, where $Support(s) = \sum_{e \in s} sup(e)$ and $sup(e) = |\{e' \in E \mid e \succ e'\}| - 1$

- Let both *ABS* and *ESP* be **best** and *AT* and *DVD* be **worst**

$$\begin{aligned} wins(\{ABS\}, \{ABS, ESP\}) &= wins(\{ABS, ESP\}, \{ABS\}) = 0 \\ wins(\{AT\}, \{AT, DVD\}) &= wins(\{AT, DVD\}, \{AT\}) = 0 \end{aligned}$$

- Then, $Support(\{ABS, ESP\}) = 2 > Support(\{ABS\}) = 1 > Support(\{AT\}) = -1 > Support(\{AT, DVD\}) = -2$
- So, $L = \langle \{ABS, ESP\}, \{ABS\}, \{AT\}, \{AT, DVD\} \rangle$

Case Flat MV: Algorithm

Algorithm 4 `ApplyOverSets`$(E, B, W, R_{\succ}, Policy)$

Input: the set of elements E (here each element of E is a set), the set of best elements B, the set of worst elements W, a set of relative relationships $R_{\succ}$, and *Policy* for *inactive* elements

Output: a bucket order over E

1: $R_{bw} \leftarrow \{(b, w) \mid b \in B, w \in W\}$
2: $R \leftarrow R_{bw} \cup R_{\succ}$
3: $R \leftarrow Closure_{transitivity}(R)$ // Addition of the transitively induced links
4: **for** each $e, e' \in E$, s.t. $e \neq e'$ **do**
5: **if** $wins(e, e') > wins(e', e)$ **then**
6: set $e \succ_{\{\}} e'$
7: **else if** $wins(e, e') < wins(e', e)$ **then**
8: set $e' \succ_{\{\}} e$
9: **else if** $wins(e, e') = wins(e', e) = 0$ **then**
10: *resolve the tie by computing the support*(e) *and support*(e')
11: $L \leftarrow$ `SourceRemoval`$(\succ_{\{\}})$
12: $I \leftarrow E \setminus dom(\succ_{\{\}})$ // I is the set of inactive elements
13: $L' \leftarrow$ `addInactiveElements`$(L, I, Policy)$
14: **return** L'

Case Hierarchical MV

Question

- What about relative preference actions over hierarchical organized multi-valued attributes?

Ordering → Hierarchical MV (Relative)

- Exploit **inheritance** by combining `PrefOrder` and `ApplyOverSets`

Algorithm 5 PrefOrderSetValued(E, $\mathcal{B}$, *Policy*)
Input: the set of elements E (E is a family of sets), the set of actions $\mathcal{B}$, and *Policy* for *inactive* elements
Output: a bucket order over E

1: // *As in Alg.* `PrefOrder`
2: Compute the *scopes* of the actions in $\mathcal{B}$ and form $(\mathcal{B}, \sqsubseteq)$
3: Use $(\mathcal{B}, \sqsubseteq)$ to compute the *active scopes* of the actions in $\mathcal{B}$
4: Use the active scopes to expand the set $\mathcal{B}$ to a set $\mathcal{B}'$
5: $(B, W, R_{\succ}) \leftarrow \text{Parse}(\mathcal{B}')$
6: // *As in Alg.* `ApplyOverSets` |
7: $R_{bw} \leftarrow \{(b, w) \mid b \in B, w \in W\}$
8: $R \leftarrow R_{bw} \cup R_{\succ}$
9: $R \leftarrow \mathit{Closure}_{\mathit{transitivity}}(R)$ // Addition of the transitively induced links
10: Compute $\succ_{\{\}}$ based on *wins* and *support* as in Alg. `ApplyOverSets`
11: $L \leftarrow \texttt{SourceRemoval}(\succ_{\{\}})$
12: $I \leftarrow E \setminus \mathit{dom}(\succ_{\{\}})$ // I is the set of inactive elements
13: $L' \leftarrow \texttt{addInactiveElements}(L, I, \mathit{Policy})$
14: **return** L'

Algorithms: Composition of Preference Actions

Composition of object scoped actions over different facets

- **Prioritized Composition**
- **Pareto Composition**
- **Combination of the above**

Algorithmic Complexity & Optimizations

Algorithms: Complexities

For Ordering Facets & Terms

- The number of **facets** and **terms** is usually small

For Ordering Objects

- Number of *Obj* can be **huge**
- Cost of computing scopes is very high (i.e. based on objects)

By exploiting **FDT**

- A **few clicks** can reduce objects to a focus A
- Preferences can be applied when $|A|$ is **relatively small** (less than a threshold)

Algorithms: Complexities & Optimizations (Exploiting FDT)

- Compute $b_1 \sqsubseteq b_2$ **without computing scopes** based on objects
  - ... but by using **anchors and the subsumption relation** $\leq$
  - ... this can be done **very fast** using labeling
- Derivation of objects ordering in A by using the descriptions of objects in A

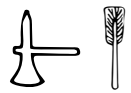
Alg.	**Object-based**	**Focus-based**
`SourceRemoval& Apply`	$\mathcal{O}(\lvert Obj\rvert^2)$	$\mathcal{O}(\lvert A\rvert^2)$
`PrefOrder`	$\mathcal{O}(\lvert Obj\rvert(\lvert Obj\rvert + \lvert\mathcal{B}\rvert^2))$	$\mathcal{O}(\lvert A\rvert^2\lvert\mathcal{B}\rvert^2)$
`ApplyOverSets`	$\mathcal{O}(\lvert T_i\rvert^3 + \lvert E\rvert^2 avgSetSize^2)$, $\lvert E\rvert \leq \min(2^{\lvert T_i\rvert}, \lvert Obj\rvert)$	$\mathcal{O}(\lvert T_i\rvert^3 + \lvert E\rvert^2 avgSetSize^2)$, $\lvert E\rvert \leq \min(2^{\lvert T_i\rvert}, \lvert A\rvert)$
`MFPriority`	$\mathcal{O}(\lvert Obj\rvert(k\lvert Obj\rvert + \lvert\mathcal{B}\rvert^2)$	$\mathcal{O}(\lvert A\rvert(k\lvert A\rvert + \lvert\mathcal{B}\rvert^2)$
`MFPareto`	$\mathcal{O}(\lvert Obj\rvert(k\lvert Obj\rvert^2 + \lvert\mathcal{B}\rvert^2)$	$\mathcal{O}(\lvert A\rvert(k\lvert A\rvert^2 + \lvert\mathcal{B}\rvert^2)$

Usually $|\mathcal{B}| < |T_i| < |Obj|$ and $|A| \ll |Obj|$.
In the worst case $|\mathcal{B}| = \frac{|T_i|(|T_i|-1)}{2}$

Executive Summary of the Preference Framework

Key aspects of our approach:

- Support of **hierarchically organized attribute values**
- Support of **multi-valued attributes**
- Support **"aggregated" semantics of several preference actions** (needed for the **gradual** method that we want to support at the interaction level) with a **scope-based method for resolving conflicts**
- **Prioritized** and **Pareto** multi-facet composition
- Algorithms for **producing the preference-based ordering** without **having to compute the scopes** of the actions

Hippalus 

Application: Implemented Hippalus

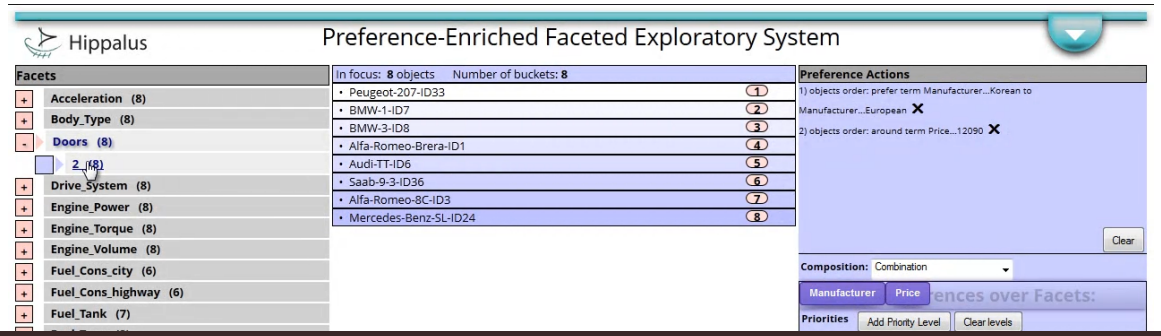
Hippalus offers:

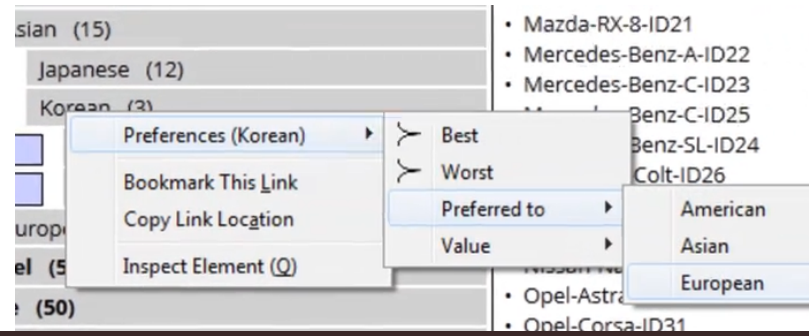
- **Browsing** and **exploration** of RDF sources using the FDT paradigm
- Enriched with the **proposed preference framework**

Hippalus uses:

- **Jena** framework
- Preference actions provided through **HTML5 context menus** (best, worst, lexicographic, count, value, relative, around)
- **HTML5 drag & drop for composition** of preference actions over different facets

- A demo of Hippalus is available at http://www.youtube.com/watch?v=Cah-z7KmlXc





Demo

Evaluation

- 1. Study of FDT convergence and preferences
- 2. Evaluation of DiFEPreKO hypothesis
- 3. Evaluating Exploratory Interaction Schemes
- 4. Evaluation of `Hippalus` system

1. Choices and Effort: FDT Convergence + Preferences

FDT converges fast

- i.e. the user can **greatly restrict the focus** with **a few clicks**
- Optimizations are based on the assumption that focus A can be reduced **very fast**

Enrichment of FDT with preference actions

- Assuming that the **most preferred option** for each facet is **prompted first**

  ... ideally **reduces** the number of **choices** to the number of **required clicks**

Examples

- Assume k complete and balanced tree taxonomies of **depth** d and **degree** b. Each leaf indexes **10 objects**
- Optimally the number of **choices** is $\mathbf{k} * \mathbf{b} * \mathbf{d}$ while number of **clicks** is $\mathbf{k} * \mathbf{d}$
- Selection of desired **10 objects** from a **peta-sized** collection needs only **30 clicks**
- **Dynamic** taxonomies will further **reduce** the number of **choices**

$n/10$	k	b	d	**Num. of Choices** $b * d * k$	**Num. of Clicks** $k * d$
531.441 ($\sim 10^6$)	3	3	4	36	12
3.486.784.401 ($\sim 10^{11}$)	5	3	4	60	20
$\sim 10^{15}$	10	3	3	90	30

2. User Based: DiFEPreKO Hypothesis

DiFEPreKO Hypothesis: Difficulty of Formulating Effective Preferences without Knowing the Options

Without the ability to view and explore the existing choices, the expression of preferences is time-consuming and in most cases results to incomplete preferences (i.e. preferences that are not sufficient for selecting the most desired option from a particular set of choices).

- **30 Participants:** 18 male and 12 female from 12 countries
- Initially participants were asked to **intentionally** express **preferences** regarding the ideal car they can buy
- Afterwards they were asked to select the car they would buy from **a list of 50 cars**

Results:

- On average users expressed in **10 minutes 9.73 intentionally** preferences
- They spent **4 minutes** on average to select the ideal car from the list
- Only **20%** selected the ideal car according to their **intentionally defined preferences**
- Users spent a lot of time expressing preferences that are **not applicable** to the characteristics provided in the list of cars or are not **consistent** with their final decision

2. User Based: DiFEPreKO Hypothesis (Statistical Significance)

Null Hypothesis

More than half of the users expressed their preferences without exploring available cars, and were returned the ideal car for them from a car collection.

Alternate Hypothesis

Less than half of the users expressed their preferences without exploring available cars, and were returned the ideal car for them from a car collection.

Statistical Significance Results:

- We have a **very strong** evidence against the *Null Hypothesis* (α value of 0.01)

3. User Based: Exploration Approaches

- We evaluated **3 different exploratory UIs** over `Mitos` (Clustering, FDT, Clustering + FDT)
- **2 users groups**: 10 *Plain* users and 3 *Expert* ones
- **Four exploratory tasks** based on tasks refinement steps described in (Kules and Capra, 2008)

Results (described in detail in (Papadakos et al., 2012a):

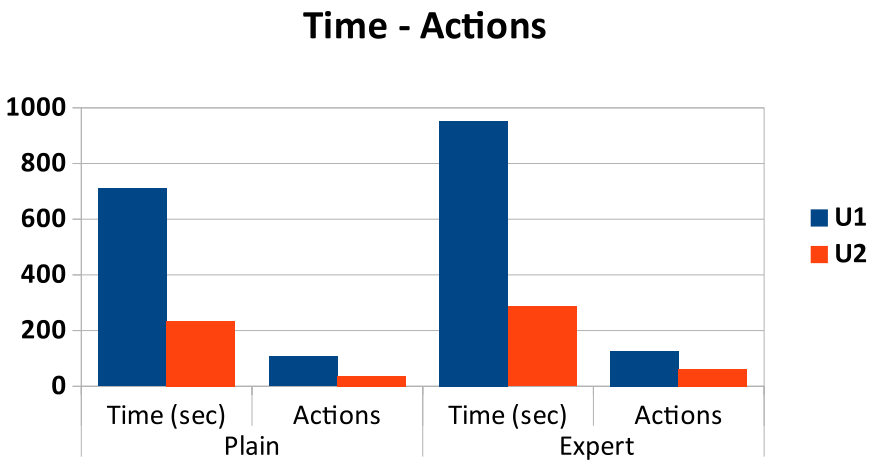
- FDT-based approaches were **the most preferred**
- **Higher degree of task completeness** with FDT-based approaches (20% for advanced users)
- **Least number of queries** with FDT-based approaches (50% for advanced users)
- More than 50% of both plain and expert users were **highly satisfied** from FDT-based UIs
- The clustering only UI was **the least preferred** for 65% of plain users
- Clustering was **the least satisfactory UI** (16.6% and 12.5% for advanced and plain users resp.)
- With 95% confidence degree, only 5% of the regular users were not satisfied by the FDT only interface

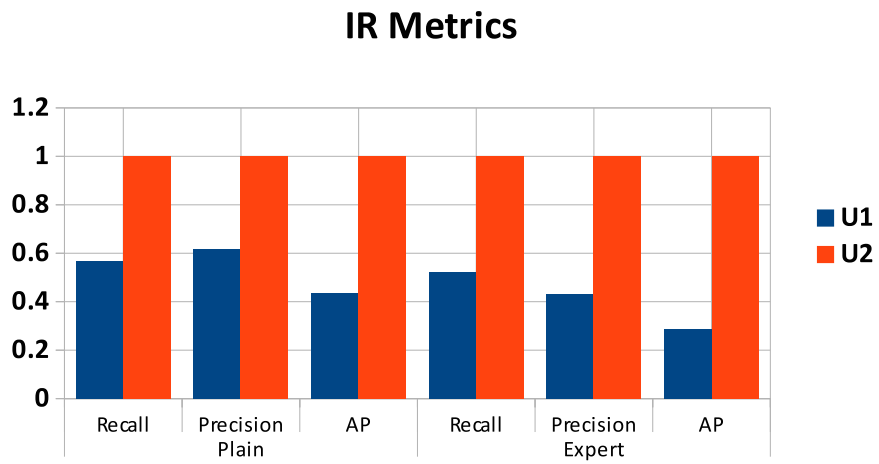
4. User Based: Hippalus (Evaluation Setup)

- We evaluated **2 different UIs** over Hippalus (plain FDT and FDT + preferences)
- **2 users groups**, **20 participants for plain** and **6 expert users**
- Each user completed **four tasks**, 2 for both UIs, using both Pareto and Priority composition
  - Tasks were designed over the most commonly user expressed attributes of the DiFEPreKO hypothesis (i.e. Price, Manufacturer, Engine Volume, Body Type, Fuel Type)
  - Plain users tasks used criteria over 3 attributes
  - Expert users tasks used criteria over 6 attributes
- **Graeco-Latin** Square Design rotating both the order of tasks and the order in which participants experience interfaces (Kelly, 2009)
  - Control order effects and increase the chance that results can be attributed to the experimental treatments and conditions
- Information base of only **50** cars

4. User Based: Hippalus (Results)

- **All users preferred** the preference UI over the plain FDT
  - Plain users: 75% preferred it **very strongly**, 20% **strongly**, 5% **strong enough**
  - Expert users: 50% preferred it **very strongly** and 50% **strongly**
- **None of the users** was able to successfully complete both tasks with the plain FDT
  - Only **10%** of plain and **16.6%** of expert users completed successfully one of the two tasks
- All users completed **successfully all** of the tasks using the **preference UI**
- On average with the **preference UI** they used **a third of the time** to complete the tasks
- ... using a **third of user interactions** compared to the plain FDT





Conclusion & FW

Concluding...

- We introduced a **preference framework** especially suited for the interaction scheme of **FDT**

The framework supports:

- **Incremental** preference specification mode
- **Hierarchically organized** attribute values
- **Scope-based** method for resolving conflicts
- **Multi-valued** attributes
- Session-based **Prioritized** and **Pareto** composition

Algorithmic perspective:

- Studied the **complexities** of the algorithms supporting the above framework
- Provided logical optimizations so that algorithms are **independent of the size of the information base** (depend only on the focus A)

Concluding...

Results show that:

- The hypothesis that users cannot express complete and effective preferences without knowing the available choices is **supported**
- FDT allows **restricting the information space very fast** and is the **most preferred** UI for **exploratory tasks**
- Evaluation over `Hippalus` showed that the **preference-based UI helped** the users to
  - **successfully** find the **desired results**
  - in **less time** (1/3 of the time in our experiments)
  - and with **less interactions** (1/3 of the interactions in our experiments)

Future Research

Applicability

- Develop wrappers that can be used for feeding `Hippalus` with results of queries over different sources like:
  - OpenSearch compatible search engines
  - Database sources
  - SPARQL queries over different SPARQL endpoints

Algorithms

- It is still interesting to investigate optimizations for the case where the current answer is very big

Structure of the information space

- Investigate required advancements of the interaction model and preference framework
  - ... for information spaces with more complex structures like RDF/S
  - ... or objects accompanied with numbers expressing different quality aspects (i.e. trust, authority, popularity, accuracy, specificity)

Publications

Related to the application of FDT over a WSE

1) Tzitzikas, Y., Armenatzoglou, N., and Papadakos, P. **FleXplorer: A Framework for Providing Faceted and Dynamic Taxonomy-based Information Exploration**. In *Procs of FIND'2008 (at DEXA '08)*, pages 212–216. Torino, Italy, 2008. ISSN 1529-4188. Doi=10.1109/DEXA.2007.4312888
2) Papadakos, P., Kopidaki, S., Armenatzoglou, N., and Tzitzikas, Y. **Exploratory Web Searching with Dynamic Taxonomies and Results Clustering**. In *Procs of the 13th European Conference on Digital Libraries (ECDL'09)*. 2009a
3) Papadakos, P., Kopidaki, S., Armenatzoglou, N., and Tzitzikas, Y. **"Exploratory Web Searching with Dynamic Taxonomies and Results Clustering"**. In *HDMS '09: Proceedings of the 8th Hellenic Data Management Symposium*. 2009b
4) Papadakos, P. **"Exploratory Web Searching with Dynamic Taxonomies, Results Clustering and Visualization"**. In *ECDL '09 DC: Proceedings of the 13th European Conference on Digital Libraries Doctoral Consortium*. Corfu, Greece, 2009. Http://www.ieee-tcdl.org/Bulletin/v6n1/Papadakos/papadakos.html
5) Kopidaki, S., Papadakos, P., and Tzitzikas, Y. **STC+ and HSTC: Two Novel Online Results Clustering Methods for Web Searching**. In *WISE'09: Procs of the 10th Intern. Conf. on Web Information Systems Engineering*. 2009
6) Papadakos, P., Armenatzoglou, N., Kopidaki, S., and Tzitzikas, Y. **On Exploiting Static and Dynamically Mined Metadata for Exploratory Web Searching**. *Knowledge and Information Systems*, 30(3):493–525, 2012a

Extension of FDT with Preferences

1) Papadakos, P., Tzitzikas, Y., and Zafeiri, D. **An Interactive Exploratory System with Real-Time Preference Elicitation**. In *Procs of the 13th International Conference on Web Information Systems Engineering (WISE'12)*. 2012b
2) Tzitzikas, Y. and Papadakos, P. **Interactive Exploration of Multi-Dimensional and Hierarchical Information Spaces with Real-Time Preference Elicitation**. *Fundamenta Informaticae*, 122(4):357–399, 2013
Under Review
3) Papadakos, P. and Tzitzikas, Y. **Comparing the Effectiveness of Intentional Preferences versus Preferences over Specific Choices: A User Study**. *International Journal of Information Technology & Decision Making*, no datea. Under review
4) Papadakos, P. and Tzitzikas, Y. **Hippalus: Preference-enriched Faceted Exploration**. *1st International Workshop on Exploratory Search in Databases and the Web (ExploreDB 2014)*, no dateb. Under review

Related to IR indexing and Querying

1) Papadakos, P., Theoharis, Y., Marketakis, Y., Armenatzoglou, N., and Tzitzikas, Y. **Mitos: Design and Evaluation of a DBMS-Based Web Search Engine**. In *Procs of the 12th Pan-Hellenic Conference on Informatics, (PCI'08)*. Greece, 2008a
2) Papadakos, P., Vasiliadis, G., Theoharis, Y., Armenatzoglou, N., Kopidaki, S., Marketakis, Y., Daskalakis, M., Karamaroudis, K., Linardakis, G., Makrydakis, G., Papathanasiou, V., Sardis, L., Tsialiamanis, P., Troullinou, G., Vandikas, K., Velegrakis, D., and Tzitzikas, Y. **The Anatomy of Mitos Web Search Engine**. *CoRR, Information Retrieval*, abs/0803.2220, 2008b. Available at http://arxiv.org/abs/0803.2220
3) Papadakos, P., Theoharis, Y., Marketakis, Y., Armenatzoglou, N., and Tzitzikas, Y. **Object-Relational Database Representations for Text Indexing**. *CoRR*, abs/0906.3112, 2009c

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Kopidaki, S., Papadakos, P., and Tzitzikas, Y. **STC+ and HSTC: Two Novel Online Results Clustering Methods for Web Searching**. In *WISE'09: Procs of the 10th Intern. Conf. on Web Information Systems Engineering*. 2009.

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Thank you!

Questions?

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*Image and modified XeLaTeX template available from https://github.com/drbunsen/drbunsen-beamer

Ευρωπαϊκή Ένωση
Ευρωπαϊκό Κοινωνικό Ταμείο

ΕΠΙΧΕΙΡΗΣΙΑΚΟ ΠΡΟΓΡΑΜΜΑ
ΕΚΠΑΙΔΕΥΣΗ ΚΑΙ ΔΙΑ ΒΙΟΥ ΜΑΘΗΣΗ
επένδυση στην κοινωνία της γνώσης
ΥΠΟΥΡΓΕΙΟ ΠΑΙΔΕΙΑΣ & ΘΡΗΣΚΕΥΜΑΤΩΝ, ΠΟΛΙΤΙΣΜΟΥ & ΑΘΛΗΤΙΣΜΟΥ
ΕΙΔΙΚΗ ΥΠΗΡΕΣΙΑ ΔΙΑΧΕΙΡΙΣΗΣ

ΕΣΠΑ 2007-2013
πρόγραμμα για την ανάπτυξη
ΕΥΡΩΠΑΪΚΟ ΚΟΙΝΩΝΙΚΟ ΤΑΜΕΙΟ

Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης