

Exploratory search through Preference-enriched Faceted Search

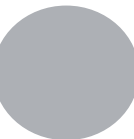
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Heraklion, Crete, GREECE



This work is described in the following paper

- [J. FI 13] Yannis Tzitzikas and Panagiotis Papadakos. Interactive Exploration of Multidimensional and Hierarchical Information Spaces with Real-Time Preference Elicitation. In *Journal FUNDAMENTA INFORMATICA*, Volume 122, Issue 4, pp 357-399, 2013.
- The PFS method was the topic of the PhD thesis of Panagiotis Papadakos (he is now post-doctoral researcher in our lab).

Outline

○ Introduction and Background

- Exploratory Search
- Faceted Exploration

○ Preferences

○ Preference-enriched Faceted Search (PFS)

- Demo Hippalus
- Formally
 - FS
 - PFS
 - Algs
- Evaluation
- Current Investigations

○ Concluding Remarks

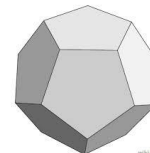
○ References

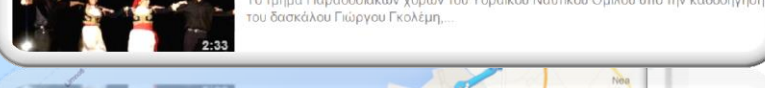
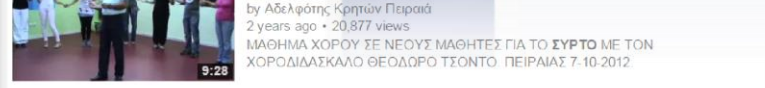
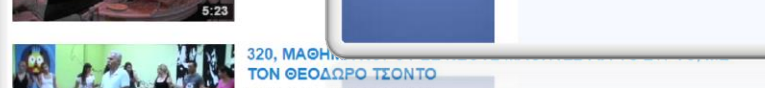
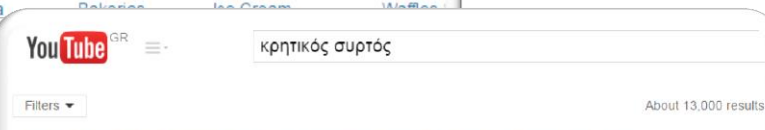
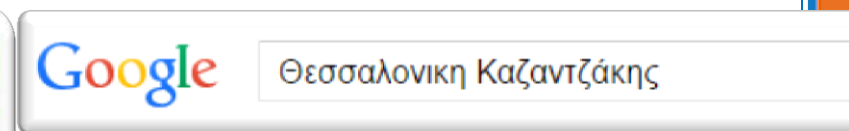
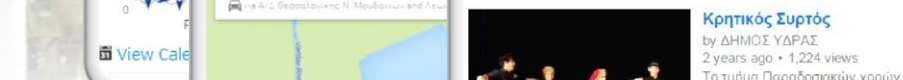
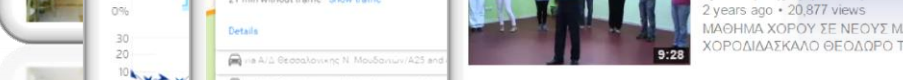
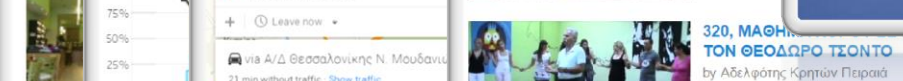
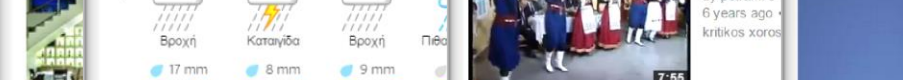
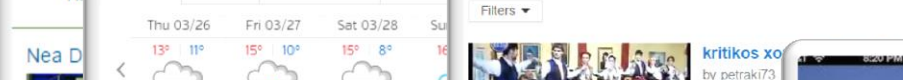
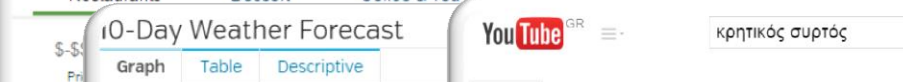
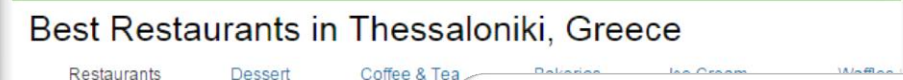
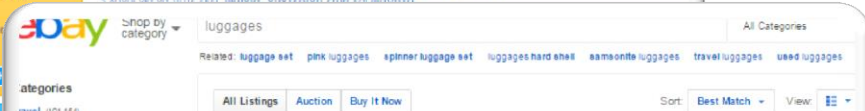
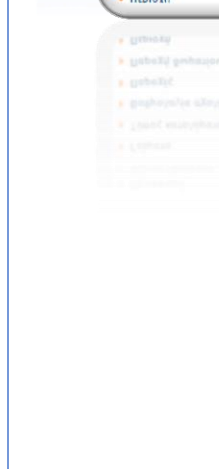
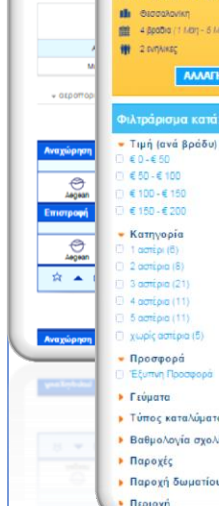
○ Acknowledgements

○ [Extras]

Introduction and Background

Exploratory Search
Faceted Exploration





What Users usually Want/Do when Searching?

Kinds of information needs

- *Precision-oriented*
 - Locate one resource or/and its attributes
e.g. Find the telephone of a store, the website of a firm or person
- *Recall-oriented*
 - Locate a **set** of resources
e.g. Medical information seeking, travel planning, e-shopping

Recall-Oriented Information Needs

- In Recall-Oriented Information Needs:
 - the users require **>1** hit
 - essentially such needs correspond to **decision tasks**
- Examples of Recall-oriented information needs
 - Booking of flights, hotels, ...
 - Product-buying
 - Bibliography search
 - Patent Search
 - Medical Search
 -

Over 60% of web search queries are **recall-oriented**
[Broder 02, Rose and Levinson 04]





How many of you have used a system like **booking.com**?

How many of you have booked the 1st suggestion returned by **booking.com** without looking at any of the rest hotels?

How many of you have entirely read the 1st paper that **Scholar Google** returned to one of your queries (without taking a glance at the rest papers) ?

Exploratory Search



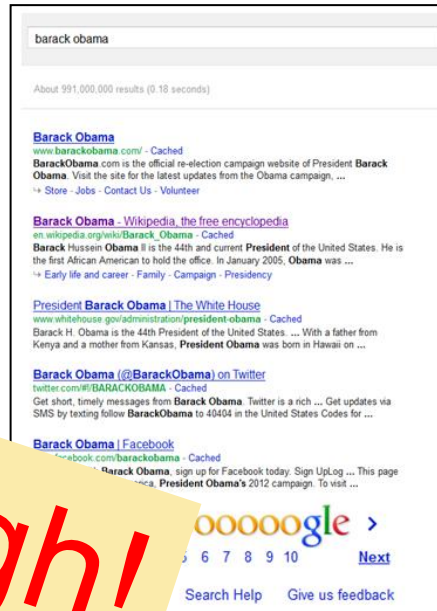
Wikipedia:

“**Exploratory search** is a specialization of information exploration which represents the **activities carried out by searchers** who are either:

- a) **unfamiliar with the domain** of their goal (i.e. need to learn about the topic in order to understand how to achieve their goal)
- b) **unsure about the ways to achieve their goals** (either the technology or the process)
- c) or even **unsure about their goals in the first place**.

Consequently, **exploratory search** covers **a broader class of activities** than typical **information retrieval**, such as *investigating, evaluating, comparing, and synthesizing*, where new information is sought in a defined conceptual area; **exploratory data analysis** is another example of an information exploration activity. Typically, therefore, such users generally **combine querying and browsing** strategies to foster learning and investigation.”

Therefore...



- Ranking is not enough for exploratory search

By GARY MARCHIONINI

EXPLORATORY SEARCH: FROM FINDING TO UNDERSTANDING

Research tools critical for exploratory search success involve the creation of new interfaces that move the process beyond predictable fact retrieval.

F

rom the earliest days of computers, search has been a fundamental application that has driven research and development. For example, a paper published in the inaugural year of the *IBM Journal* 36 years ago outlined challenges of text retrieval that continue to the present [4]. Today's data storage and retrieval applications range from database systems that manage the bulk of the world's structured data to Web search engines that provide access to petabytes of text and multimedia data. As computers have become consumer products and the Internet has become a mass medium, searching the Web has become a daily activity for everyone from children to research scientists.

Some Common Requirements for Effective Exploratory Search



- Allow browsing and inspecting the found hits in **groups** (according to various criteria)
- Allow easy and fast access even to **low ranked** hits
- Offer **overviews** of the search results
 - Compute and show descriptions and **count** information for the various groups, or other **aggregated** values
- Allow **gradual** restriction/ranking of the search results

Faceted Search/Exploration

Faceted Exploration is a **widely** used interaction scheme for **Exploratory Search**

A short (and rather informal) definition:

FE is a **session-based** interactive method for **query formulation** (commonly over a multidimensional information space) through **simple clicks**, that offers

- ✓ an **overview** of the result set (groups and count information)
- ✓ **never leads to empty result sets**



Let's now see some examples from some widely used systems that support faceted search

Example of FDT: Booking.com

Your Search


Sými

1 Night (Sept 12 - Sept 13)

2 adults

[Change Search](#)

[Show map](#)



Map data ©2013 Google

Filter by:

▼ Price (per night)

☒ € 0 - € 49 active

☐ € 50 - € 99

☐ € 100 - € 149

☐ € 150 - € 199

☐ € 200 +

▼ Star Rating

☐ 2 stars (1)

☐ 3 stars (3)

☐ 4 stars (2)

▼ Hotel Type

☐ Apartments (5)

☐ Vacation Homes (2)

☐ Villas (1)

☐ Guesthouses (3)

▼ Review Score

☐ Wonderful: 9+ (2)

☐ Very good: 8+ (5)

☐ Good: 7+ (7)


☐ Pleasant: 6+ (9)

☐ No rating (2)

7 out of 25 properties are available in and around Sými

Showing 1 - 7


Sort by: Recommended Stars Location Price Review Score List Grid



Kirilos Studios
Sými • [Show map](#)


Reservation possible without a credit card

Latest booking: 10 hours ago

Studio - Split Level  Only 2 left € 40


[Book now](#)


These hotels almost match your selected price range.




Symi Garden Studios
Sými • [Show map](#)


Latest Booking: September 8

Studio  Only 2 left € 50

Studio (4 Adults)  Only 4 left € 70

Studio with Sea View and Harbour View Last one!  Last chance! Only 1 left € 70

[Book now](#)





Villa Pinotsi
Sými • [Show map](#)

1 person is looking at this guesthouse.


Reservation possible without a credit card

Latest booking: 1 hour ago

Double or Twin Room  Only 2 left € 55

Double or Twin Room Breakfast included  Only 2 left € 60


[Book now](#)




Kokona
Sými • [Show map](#)


Reservation possible without a credit card

Latest Booking: yesterday

Double or Twin Room  Only 4 left € 58


Double or Twin Room Breakfast included  Only 4 left € 68

[Book now](#)



Grace Hotel & Studios
Sými • [Show map](#)

Latest booking: 22 hours ago

Studio with Sea View  Only 2 left € 60

[Book now](#)

Example: ebay

Related : olympus **om lens** olympus **camera** olympus **digital voice recorder** olympus **dm** olympus **e500** olympus **camera charger** ... ☐ Include description

Categories

- Cameras & Photography** (113,553)
 - Camera & Photo Accessories (73,325)
 - Lenses & Filters (18,488)
 - Digital Cameras (5,129)
 - Film Photography (3,164)
 - Flashes & Accessories (3,069)
 - More ▾
- Business, Office & Industrial** (6,187)
 - Medical/ Lab Equipment (4,441)
 - Office Equipment & Supplies (1,227)
 - Electrical & Test Equipment (289)
 - Industrial Supply/ MRO (45)
 - Other Business & Industrial (10)
 - More ▾

[See all categories](#)

Condition [see all](#)




- ☐ **New** (114,023)
- ☐ **Used** (21,216)
- ☐ **Not specified** (2,341)

All listings **Auction** **Buy It now**

Sort: **Best Match** View:

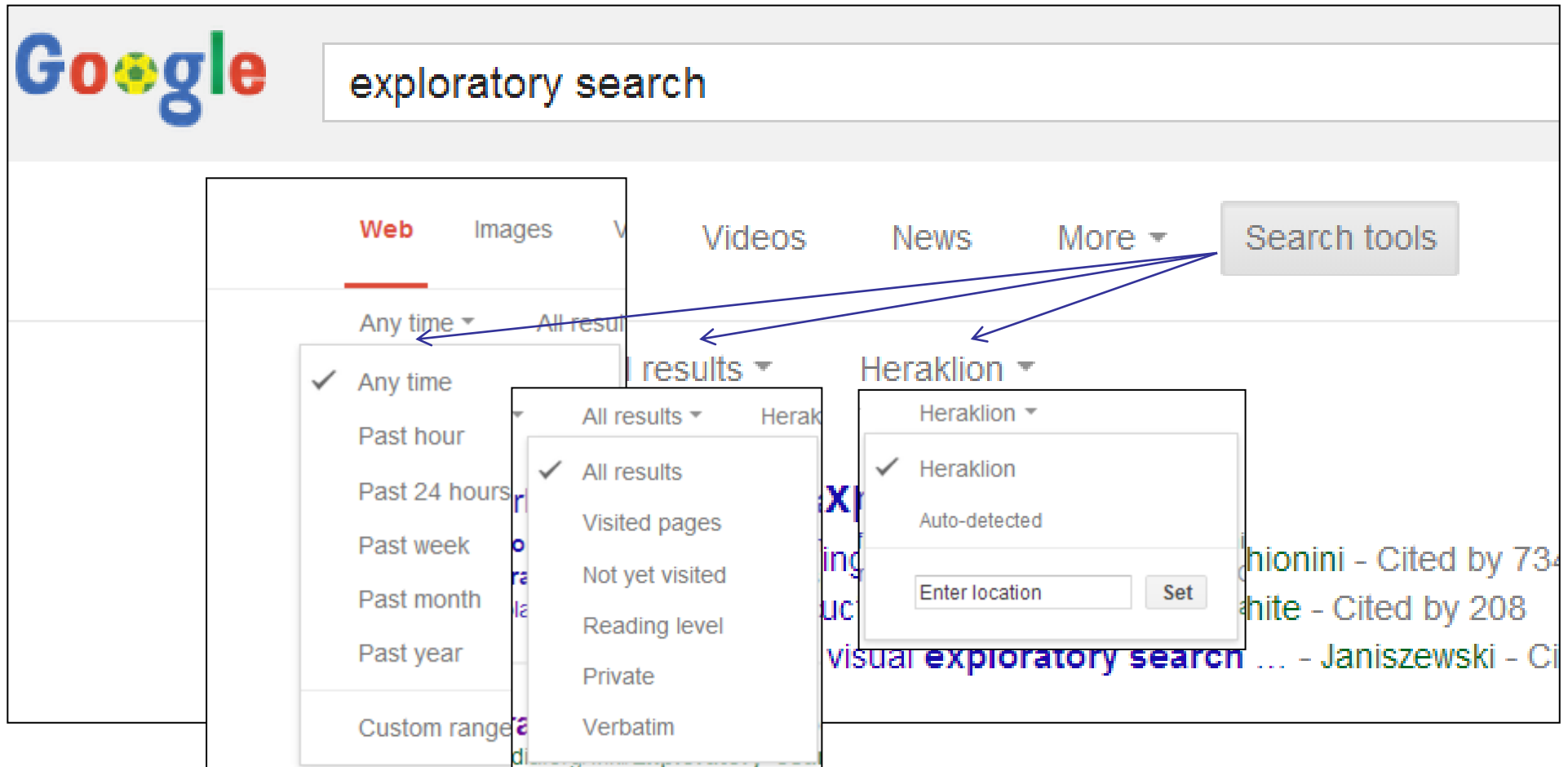
137,645 results for olympus ★ Save search

Worldwide



	Olympus Trip AF MD 35mm Point and Shoot Film Camera	59s left Today 12:20	£1.25 2 bids	Postage not specified
	Olympus SZ-14 Black Digital Camera	Top-rated seller	£79.99 Buy It Now	Postage not specified
	Olympus PEN E-PM1 Black + 14-42mm Lens + FL-LM1 Flash	Top-rated seller	£159.99 Buy It Now	+ £7.99 postage

Example: Google search

(limited functionality: no count information)



Example: Scholar Google



Scholar About 1,430,000 results (0.06 sec)

Articles

Case law

My library

Any time

Since 2014

Since 2013

Since 2010

Custom range...

Sort by relevance

Sort by date

☒ include patents

☒ include citations

Exploratory search: from finding to understanding
[G Marchionini](#) - Communications of the ACM, 2006 - [dl.acm.org](#)
From the earliest days of computers, **search** has been a fundamental application that has driven research and development. For example, a paper published in the inaugural year of the IBM Journal 36 years ago outlined challenges of text retrieval that continue to the present [4]. ...
Cited by 734 Related articles All 18 versions Web of Science: 150 Import into BibTeX Save More

[HTML] Supporting exploratory search. introduction. special issue. communications of the ACM
[RW White](#), [B Kules](#), [SM Drucker](#) - Communications of the ACM, 2006 - [eprints.soton.ac.uk](#)
Online **search** has become an increasingly important part of the everyday lives of most computer users. **Search** engines, bibliographic databases, and digital libraries provide adequate support for users whose information needs are well defined. However, there are ...
Cited by 208 Related articles All 7 versions Web of Science: 10 Import into BibTeX Save More

[PDF] The influence of display characteristics on visual exploratory search behavior
[C Janiszewski](#) - Journal of Consumer Research, 1998 - JSTOR
Visual information **search** is a combination of two distinct types of behavior. Goal-directed **search** behavior occurs when consumers use stored **search** routines to collect information in a deliberate manner. In contrast, **exploratory search** behavior occurs when consumers are ...
Cited by 298 Related articles All 9 versions Web of Science: 99 Import into BibTeX Save More

There are plenty of approaches and systems that Support Faceted Search

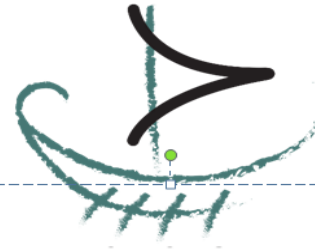
RB++ [45]
Elastic Lists [46]
Flexplorer [47] and Mitos [23]
Flamenco [31]
Faceted search impl. [14]
Dynamic Faceted Search syst. [15]
Hippalus [2]
IOS/XSearch []
Google Scholar/Seach Tools []

Longwell [48]
mspace [49]
Ontogator [50]
MuseumFinland [51]
Camelis2 [22]
Faceted Data Explorer [52]
NFB [53]
GRQL [41]
/facet [32]
Humboldt [42]
VisiNav [21]
Parallax [54]
Faceted Wikipedia [55]
MediaFaces [56]
BrowseRdf [26]
Fuzzy view based search [57]
Odalisque [58]

System: Hippalus (2013-)



Hippalus: Preference-enriched
Faceted Exploration



P. Papadakos^{1,2} and Y. Tzitzikas^{1,2}

First we shall see the faceted search functionality.
(the *preferences* later on)



WHAT NEW CAR SHOULD I BUY?



Hippalus: A system offering Faceted Search

Facets


The set of objects (focus)

The screenshot displays the Hippalus interface, titled "A Preference-Enriched Faceted Exploratory System". On the left, a "Facets" panel lists various attributes with their counts: Body_Type (50), Drive_System (50), Four_Wheels (5), Two_Wheels (45), Front (33), Rear (12), Engine_Power_hp (50), Engine_Torque_Nm (48), Engine_Volume_cc (50), Fuel_Cons_city_l_100_km (43), Fuel_Cons_highway_l_100_km (43), Fuel_Tank_l (46), Fuel_Type (50), ID (50), Manufacturer (50), Max_Speed_km_h (47), Model (50), Number_Of_Doors (50), and Number_Of_Gears (50). A dashed orange box highlights the "Facet-terms" section. A tooltip indicates "Left-click to focus" and "Right-click for preferences". The main "The set of objects (focus)" panel shows a list of car models, numbered 1 through 7, with a status bar indicating "In focus: 50 objects" and "Number of buckets: 23". On the right, the "Preference Actions" panel shows a list of 5 preference rules, each with a "Clear" button. Below this, the "Composition" section shows a "Combination" of terms: Drive_System, Fuel_Cons_city_l_100_km, Fuel_Type, Manufacturer, and Number_Of_Gears. The "Object Restriction History" and "Interesting Objects" sections are also visible.

Facet-terms

- Left-click on a term: action that changes the focus

Hippalus: Interaction over a KB of 50 cars

 Hippalus

Preference-Enriched Faceted Exploratory System

Facets

+

 Acceleration (43)

+

 Body_Type (50)

+

 Doors (50)

+

 Drive_System (50)

+

 Engine_Power (50)

+

 Engine_Torque (48)

+

 Engine_Volume (50)

+

 Fuel_Cons_city (43)

+

 Fuel_Cons_highway (43)

+

 Fuel_Tank (46)

+

 Fuel_Type (50)

+

 Gears (50)

+

 ID (50)

+

 Manufacturer (50)

+

 Model (50)

+

 Price (50)

+

 Speed (47)

+

 Transmission (50)

+

 Trunk (40)

+

 Vehicle_Type (50)

+

 Weight_Empty (39)

+

 Year (50)

In focus: 50 objects Number of buckets: 1

1

- Alfa-Romeo-8C-ID3
- Alfa-Romeo-Brera-ID1
- Alfa-Romeo-MiTo-ID2
- Audi-A3-ID4
- Audi-S8-ID5
- Audi-TT-ID6
- BMW-1-ID7
- BMW-3-ID8
- BMW-7-ID9
- Citroen-C1-ID10
- Citroen-C3-ID11
- Fiat-Bravo-ID12
- Fiat-Punto-ID13
- Ford-Fiesta-ID14
- Ford-Ka-ID15
- Hyundai-i10-ID16
- Hyundai-i30-ID17
- Kia-Ceed-ID18
- Lancia-Delta-ID19
- Mazda-3-ID20
- Mazda-RX-8-ID21
- Mercedes-Benz-A-ID22
- Mercedes-Benz-C-ID23
- Mercedes-Benz-C-ID25
- Mercedes-Benz-SL-ID24
- Mitsubishi-Colt-ID26
- Mitsubishi-X-Trail-ID27
- Nissan-Micra-ID28
- Nissan-Navara-ID29
- Opel-Astra-ID30

Preference Actions

Clear

Composition: Combination

Interesting Objects

Clear

Object Restriction History



Hippalus: FDT interactions

The diagram illustrates the Hippalus FDT (Faceted Display Tool) interactions, showing how users can refine search results through value expansion and object restriction.

Value expansion: Indicated by yellow arrows pointing from the 'Manufacturer' category to the 'Asian' and 'Korean' sub-categories, and from the 'Fuel_Type' category to the 'Gasoline' sub-category.

Object restriction: Indicated by yellow arrows pointing from the 'Asian' and 'Korean' sub-categories to the 'Object Restriction History' window, and from the 'Gasoline' sub-category to the 'Object Restriction History' window.

Object Restriction History: A window titled 'Object Restriction History' showing the history of restrictions applied. It lists the following restrictions:

- Fuel_Type : Fuel_Type ✗
- Manufacturer : Manufacturer ✗
- Manufacturer : Asian ✗
- Manufacturer : Korean ✗
- Fuel_Type : Gasoline ✗

The 'Clear' button is located at the bottom right of the 'Object Restriction History' window.

mouse over: Indicated by a yellow arrow pointing from the 'Gasoline (2)' sub-category to the 'Object Restriction History' window.

Value expansion (Manufacturer): The 'Manufacturer' category (50) is expanded to show sub-categories: American (2), Asian (15), Japanese (12), Korean (3), and European (33). The 'Model' category (50) is also expanded.

Value expansion (Fuel_Type): The 'Fuel_Type' category (3) is expanded to show sub-categories: Diesel (1) and Gasoline (2).

Value expansion (Manufacturer): The 'Manufacturer' category (50) is expanded to show sub-categories: American (2), Asian (15), Japanese (12), Korean (3), and European (33). The 'Model' category (50) is also expanded.

Value expansion (Fuel_Type): The 'Fuel_Type' category (3) is expanded to show sub-categories: Diesel (1) and Gasoline (2).

Object Restriction History: A window titled 'Object Restriction History' showing the history of restrictions applied. It lists the following restrictions:

- Fuel_Type : Fuel_Type ✗
- Manufacturer : Manufacturer ✗
- Manufacturer : Asian ✗
- Manufacturer : Korean ✗
- Fuel_Type : Gasoline ✗

The 'Clear' button is located at the bottom right of the 'Object Restriction History' window.



Preferences

Preferences

Preferences

- are **not** hard constraints
- are **not** necessarily numbers
- are **not** necessarily total orders
- are personalized *wishes* "I like A better than B"
- may be complex covering multiple attributes

Approaches for **Defining** Preferences (not only in databases)



Two main approaches for specifying preferences

○ Qualitative Approach

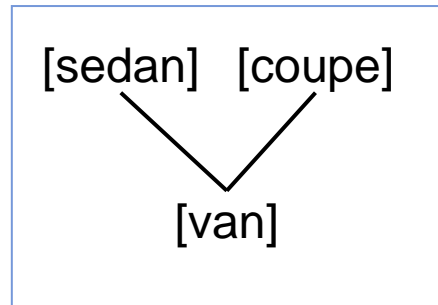
- In the qualitative approach, the preferences between tuples in the answer of a query are specified directly, typically using a **preference binary relation** \succ_{pref}
- E.g. a tuple \mathbf{v} *is more preferred than* a tuple \mathbf{v}' if $\mathbf{v} \succ_{\text{Pref}} \mathbf{v}'$

○ Quantitative Approach

- In the quantitative approach, preferences are specified indirectly using **scoring** functions that associate a numeric score with every tuple of the query answer:
- E.g. a tuple \mathbf{v} *is more preferred than* a tuple \mathbf{v}' if $\text{Score}(\mathbf{v}) > \text{Score}(\mathbf{v}')$

Preferences: Qualitative vs Quantitative

I prefer sedan to van
I prefer coupe to van



≠

Score(sedan)=2
Score(coupe)=2
Score(van) =1

- The **qualitative** approach is more powerful (in terms of expressive power) than the **quantitative** one
- Moreover, there is no obvious method users could follow for specifying and combining scores.

In brief, the qualitative method is **more expressive** and **convenient** for the user, however the evaluation of preference-aware query answers is **sometimes more expensive**.

Preferences and Databases

- Thoroughly studied in the **Database world** but usually
 - Users must be **acquainted** with the **information space** and **available choices** for expressing their preferences
 - **Hierarchically organized attribute values** and **multi-valued attributes** are not supported
 - Preferences are given in **one shot** (not **gradually**)
 - Sometimes users have to formulate **complicated queries** or use **complex UIs**

Our objective (as we shall see):

- Tackle all the above shortcomings by extending Faceted Exploration with preferences

Preference-enriched Faceted Search

Outline

- Introduction and Background
 - Exploratory Search
 - Faceted Exploration
- Preferences
- Preference-enriched Faceted Search (PFS)
 - Introduction
 - Demo Hippalus
 - Formally
 - FS
 - PFS
 - Algs
 - Evaluation
 - Current Investigations
- Concluding Remarks
- References
- Acknowledgements

Objectives and Requirements

○ Objectives

- To provide a **theoretical framework** for **preferences** over multi-dimensional and hierarchical information spaces (including set-valued descriptions)
- To extend the **interaction model** of faceted search with **preferences**

○ Other (Non Functional) Requirements

- The extension should be **easy to use**
 - Without requiring from the user to type anything, without having to be familiar with the information space
- The extension should be **applicable to large information bases**
 - The Multidimensional information spaces with hierarchies and set-valued data can capture various cases: a relational table, the results of a SPARQL Query, an information space derived by a process from text mining, etc

PFS: Preference-enriched Faceted Search

- An extension of the interaction paradigm of **Faceted Exploration** with actions that allow the users to express at browsing time their **preferences**.
 - The user has two kinds of actions
 - Actions that **change** the focus (zoom-in/out/side actions), as in classical Faceted Search
 - Actions that **rank** the focus (based on preferences)
- The proposed model supports **progressive** preference expression, **inherited** preferences and **automatic scope-based resolution of conflicts** over single or **multi-valued attributes** with **hierarchically** organized values.
- Algorithms enabling the **application** of the model over large information bases.

Hippalus and Preferences

Facets

The set of objects (focus) **ranked** according to the **expressed preferences**

History of preference actions

The screenshot shows the Hippalus interface with the following components:

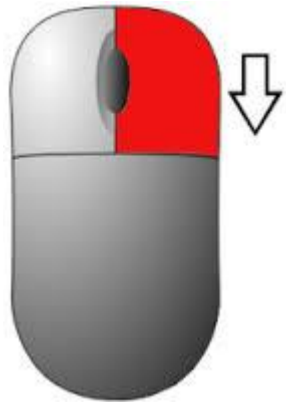
- Facets:** A list of facets on the left, including Body_Type (50), Drive_System (50), Engine_Power_hp (50), Engine_Torque_Nm (48), Engine_Volume_cc (50), Fuel_Consumption_city_100km (43), Fuel_Consumption_highway_100km (43), Fuel_Tank_l (46), Fuel_Type (50), ID (50), Manufacturer (50), Max_Speed_kmh (47), Model (50), Number_Of_Doors (50), and Number_Of_Gears (50).
- Ranked List:** A central list of objects ranked according to expressed preferences. The list shows 23 objects, with the first 7 objects highlighted in blue. A tooltip indicates that left-clicking focuses an object and right-clicking expresses preferences.
- Preference Actions:** A panel on the right showing a history of preference actions, including objects order, term, and best. It also includes a Composition section with buttons for Drive_System, Fuel_Consumption_city_100km, Fuel_Type, Manufacturer, and Number_Of_Gears.
- Object Restriction History:** A section at the bottom right showing the history of object restrictions and interesting objects.

Facet-terms

- Left-click: action that changes the focus
- **Right-click:** actions for expressing **preferences**

Expression of preference priorities

Right-click on the value `Diesel` of the facet `Fuel_Type`



`Diesel` > `Gasoline`
(meaning that I prefer Diesel to Gasoline)

The screenshot shows a software interface with several facets. The 'Fuel_Type (50)' facet is selected, and its dropdown menu is open. The menu has a 'Preferences (Diesel)' section with the following options:

- Best
- Worst
- Preferred to (selected)
- Around this value

The 'Preferred to' option is selected, and a sub-menu is open showing 'Gasoline' as the preferred value. Other facets visible include 'ID (50)', 'Manufa', and 'Max_Sp'.

Live Demo

- Script A

- Prefer Diesel to Gasoline

- For making clear the difference between faceted search and PFS

- Clear Prefs

- Prefer European to Asian

- For making clear the benefit of hierarchies and inherited preferences

Diesel > Gasoline



A Preference-Enriched Faceted Exploratory S

Facets

+

Acceleration_0-100_km-h (43)

+

Body_Type (50)

+

Drive_System (50)

+

Engine_Power_hp (50)

+

Engine_Torque_Nm (48)

+

Engine_Volume_cc (50)

+

Fuel_Cons_city_l_100_km (43)

+

Fuel_Cons_highway_l_100_km (43)

+

Fuel_Tank_l (46)

-

Fuel_Type (50)

Diesel (8)

Gasoline (42)

+

ID (50)

+

Manufacturer (50)

+

Max_Speed_km_h (47)

+

Model (50)

+

Number_Of_Doors (50)

+

Number_Of_Gears (50)

+

Price_Euros (50)

+

Transmission (50)

+

Trunk_l (40)

+

Vehicle_Type (50)

In focus: **50** objects Number of buckets: **2**

Displaying results from 1-50

• Hyundai-i10-ID16

• Mercedes-Benz-C-ID23

• Nissan-Navara-ID29

• Opel-Astra-ID30

• Opel-Corsa-ID31

• Peugeot-207-ID33

• Renault-Twingo-ID35

• Skoda-Octavia-ID39

• Alfa-Romeo-8C-ID3

• Alfa-Romeo-Brera-ID1

• Alfa-Romeo-MiTo-ID2

• Audi-A3-ID4

• Audi-S8-ID5

• Audi-TT-ID6

• BMW-1-ID7

• BMW-3-ID8

• BMW-7-ID9

• Citroen-C1-ID10

• Citroen-C3-ID11

• Fiat-Bravo-ID12

• Fiat-Punto-ID13

• Ford-Fiesta-ID14

• Ford-Ka-ID15

• Hyundai-i30-ID17

• Kia-Ceed-ID18

• Lancia-Delta-ID19

• Mazda-3-ID20

European > Asian



A Preference-Enriched Faceted Exploratory System

Facets		In focus: 50 objects Number of buckets: 3	
		Displaying results from 1-50	
<input checked="" type="checkbox"/>	Acceleration_0-100_km-h (43)	<div>1</div> <ul style="list-style-type: none">• Alfa-Romeo-8C-ID3• Alfa-Romeo-Brera-ID1• Alfa-Romeo-MiTo-ID2• Audi-A3-ID4• Audi-S8-ID5• Audi-TT-ID6• BMW-1-ID7• BMW-3-ID8• BMW-7-ID9• Citroen-C1-ID10• Citroen-C3-ID11• Fiat-Bravo-ID12• Fiat-Punto-ID13• Lancia-Delta-ID19• Mercedes-Benz-A-ID22• Mercedes-Benz-C-ID23• Mercedes-Benz-C-ID25• Mercedes-Benz-SL-ID24• Opel-Astra-ID30• Opel-Corsa-ID31• Peugeot-107-ID32• Peugeot-207-ID33• Renault-Clio-ID34• Renault-Twingo-ID35• Saab-9-3-ID36• Seat-Altea-ID37• Seat-Leon-ID38• Skoda-Octavia-ID39• Skoda-Yeti-ID40• Volkswagen-Golf-ID47• Volkswagen-Scirocco-ID48• Volkswagen-Tiguan-ID49• Volvo-C30-ID50	
<input checked="" type="checkbox"/>	Body_Type (50)		
<input checked="" type="checkbox"/>	Drive_System (50)		
<input checked="" type="checkbox"/>	Engine_Power_hp (50)		
<input checked="" type="checkbox"/>	Engine_Torque_Nm (48)		
<input checked="" type="checkbox"/>	Engine_Volume_cc (50)		
<input checked="" type="checkbox"/>	Fuel_Cons_city_l_100_km (43)		
<input checked="" type="checkbox"/>	Fuel_Cons_highway_l_100_km (43)		
<input checked="" type="checkbox"/>	Fuel_Tank_l (46)		
<input checked="" type="checkbox"/>	Fuel_Type (50)		
<input type="checkbox"/>	Diesel (8)		
<input type="checkbox"/>	Gasoline (42)		
<input checked="" type="checkbox"/>	ID (50)		
<input checked="" type="checkbox"/>	Manufacturer (50)		
<input checked="" type="checkbox"/>	American (2)		
<input checked="" type="checkbox"/>	Asian (15)		
<input checked="" type="checkbox"/>	European (33)		
<input checked="" type="checkbox"/>	Max_Speed_km_h (47)		
<input checked="" type="checkbox"/>	Model (50)		
<input checked="" type="checkbox"/>	Number_Of_Doors (50)		
<input checked="" type="checkbox"/>	Number_Of_Gears (50)		
<input checked="" type="checkbox"/>	Price_Euros (50)		
<input checked="" type="checkbox"/>	Transmission (50)		
<input checked="" type="checkbox"/>	Trunk_l (40)		
<input checked="" type="checkbox"/>	Vehicle_Type (50)		
<input checked="" type="checkbox"/>	Weight_Netto_kg (39)		
<input checked="" type="checkbox"/>	Year (50)		
		<div>2</div> <ul style="list-style-type: none">• Hyundai-i10-ID16• Hyundai-i30-ID17• Kia-Ceed-ID18• Mazda-3-ID20• Mazda-RX-8-ID21• Mitsubishi-Galant-ID26	

How it works

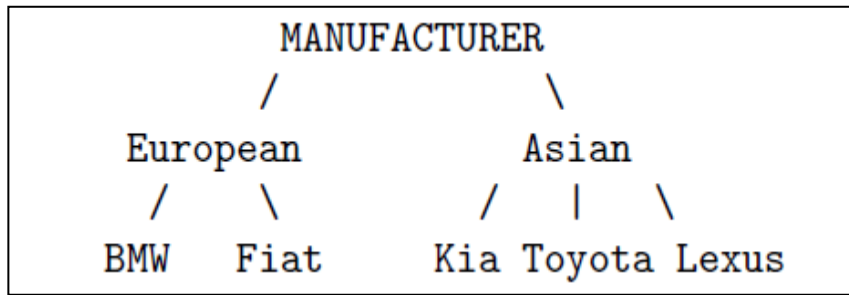
Background

- A **binary relation** over a set A is any subset R of $A \times A$
- A binary relation is a **partial order** if it is reflexive, transitive and antisymmetric.
- A binary relation is a **total order** if it is a partial order and total
 - A relation is total if for every a, b in A , either aRb or bRa
- A **linear extension** of a binary relation R is a total order L such that $R \subseteq L$.
 - A total order T is a linear extension of a partial order R if, whenever aRb it also holds that aLb
- A **bucket order** is a linear order of subsets.
 - Example of a bucket order with four blocks:
 - $\langle \{a, b, c\}, \{d\}, \{e, f\}, \{g, h\} \rangle$

Taxonomy

- A taxonomy T_i is a pair (T_i, \leq_i) , where T_i is a set of terms and \leq_i a partial order over T_i .

Example



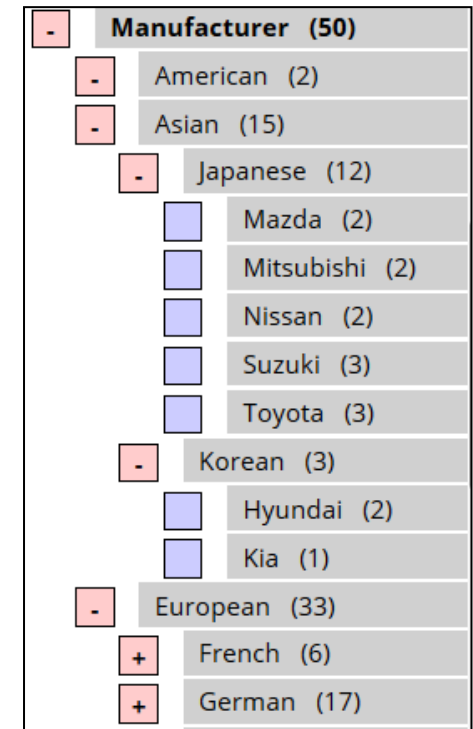
$T = \{ \text{MANUFACTURER, European, Asian, BMW, Fiat, Kia, Toyota, Lexus} \}$

$\leq = \{$

BMW \leq European,
 Fiat \leq European,
 European \leq MANUFACTURER,
 Asian \leq MANUFACTURER,
 Kia \leq Asian,
 Toyota \leq Asian,
 Lexus \leq Asian,

$\}$

The reflexive and transitive relationships have been omitted



Taxonomy (cont'd)

- If $\leq = \emptyset$ then the taxonomy is flat

Example

$T = \{ \text{Cabriolet, Coupe, Crossover, Hatchback, Minivan, Pickup, Roadster, Sedan, Touring} \}$
 $\leq = \emptyset$

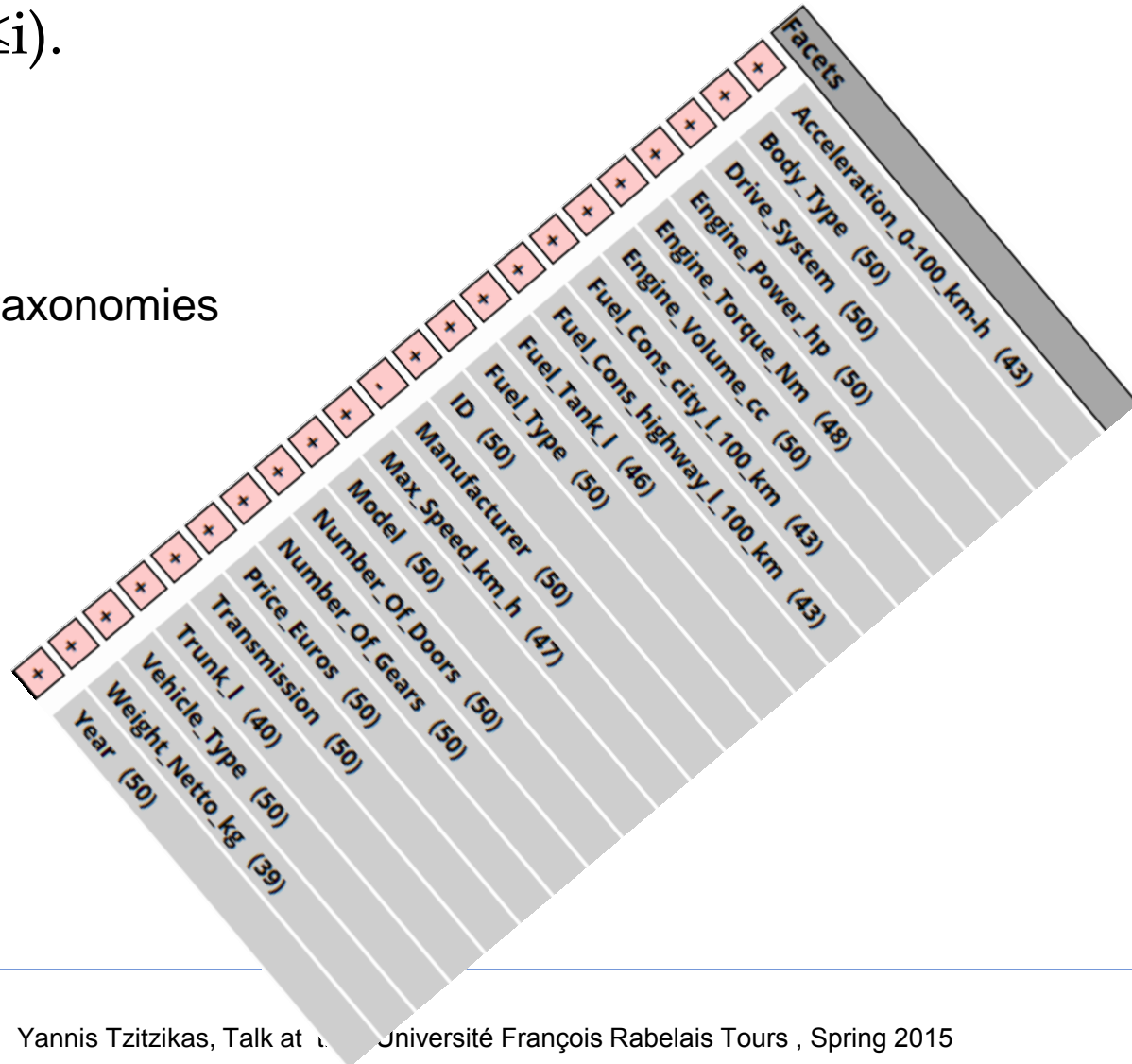
-	Body_Type (50)
<input type="checkbox"/>	Cabriolet (6)
<input type="checkbox"/>	Coupe (2)
<input type="checkbox"/>	Crossover (4)
<input type="checkbox"/>	Hatchback (27)
<input type="checkbox"/>	Minivan (2)
<input type="checkbox"/>	Pickup (1)
<input type="checkbox"/>	Roadster (1)
<input type="checkbox"/>	Sedan (5)
<input type="checkbox"/>	Touring (2)

Faceted Taxonomy

- A faceted taxonomy is a set of taxonomies, i.e. $F=\{F1, \dots, Fk\}$ where $F_i=(T_i, \leq_i)$.

Example

In our demo we have 22 taxonomies



Facets
Acceleration_0-100_km-h (43)
Body_Type (50)
Drive_System (50)
Engine_Power_hp (50)
Engine_Torque_Nm (48)
Engine_Volume_cc (50)
Fuel_Cons_city_l_100_km (43)
Fuel_Cons_highway_l_100_km (43)
Fuel_Tank_l (46)
Fuel_Type (50)
ID (50)
Manufacturer (50)
Max_Speed_km_h (47)
Model (50)
Number_Of_Doors (50)
Number_Of_Gears (50)
Price_Euros (50)
Transmission (50)
Trunk_l (40)
Vehicle_Type (50)
Weight_Netto_kg (39)
Year (50)

Descriptions of Objects

- Let Obj be the set of objects of interest (e.g. the cars in our demo)
- Each object $o \in \text{Obj}$ is **described** (wrt a faceted taxonomy $F=\{F1, \dots, Fk\}$ where $F_i=(T_i, \leq i)$) by associating it (classifying it) with one or more (or none) terms from each T_i .
- Let **o** denote the **description of o**

Example

Assume $F = \{\text{Manufactuer}, \text{BodyType}\}$,

and that $\text{Obj}=\{o1, o2\}$. Their descriptions could be

$o1$ = {Fiat, Minivan}

$o2$ = {Lexus, Sedan}

Descriptions of Objects (cont'd)

- Peugeot-207-ID33 \in Obj
- Peugeot-207-ID33 =

Peugeot-207-ID33		1
<u>Attribute</u>	<u>Value</u>	
Acceleration 0-100 km-h	10.9	
Body Type	Cabriolet	
Drive System	Front	
Engine Power hp	110	
Engine Torque Nm	240	
Engine Volume cc	1560	
Fuel Cons city l 100 km	6.2	
Fuel Cons highway l 100 km	4.3	
Fuel Tank l	50	
Fuel Type	Diesel	
ID	33	
Manufacturer	Peugeot	
Max Speed km h	193	
Model	207	
Number Of Doors	2	
Number Of Gears	5	
Price Euros	18750	
Transmission	Manual	
Trunk l	145	
Vehicle Type	Car	
Weight Netto kg	1423	
Year	2009	

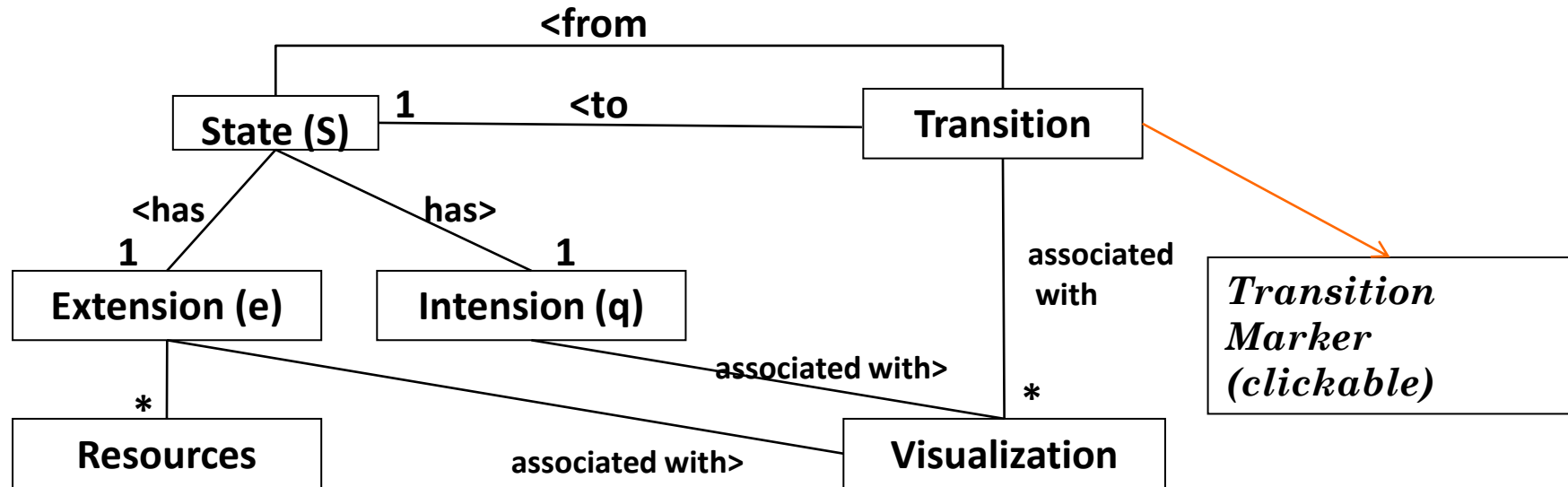
Interpretation of Facets' Terms

- $I(\text{Peugeot}) = \{\text{Peugeot-207-ID33}\}$
- $I(\text{European}) = \emptyset$

By considering the **semantics of \leq** we can define the **model interpretation I**

- $I(t) = \bigcup \{ I(t') \mid t' \leq t \}$
- E.g. if $\text{Peugeot} \leq \text{European}$ then
- $I(\text{Peugeot}) = I(\text{Peugeot}) = \{\text{Peugeot-207-ID33}\}$
- $I(\text{European}) = I(\text{European}) \cup I(\text{Peugeot}) = \{\text{Peugeot-207-ID33}\}$

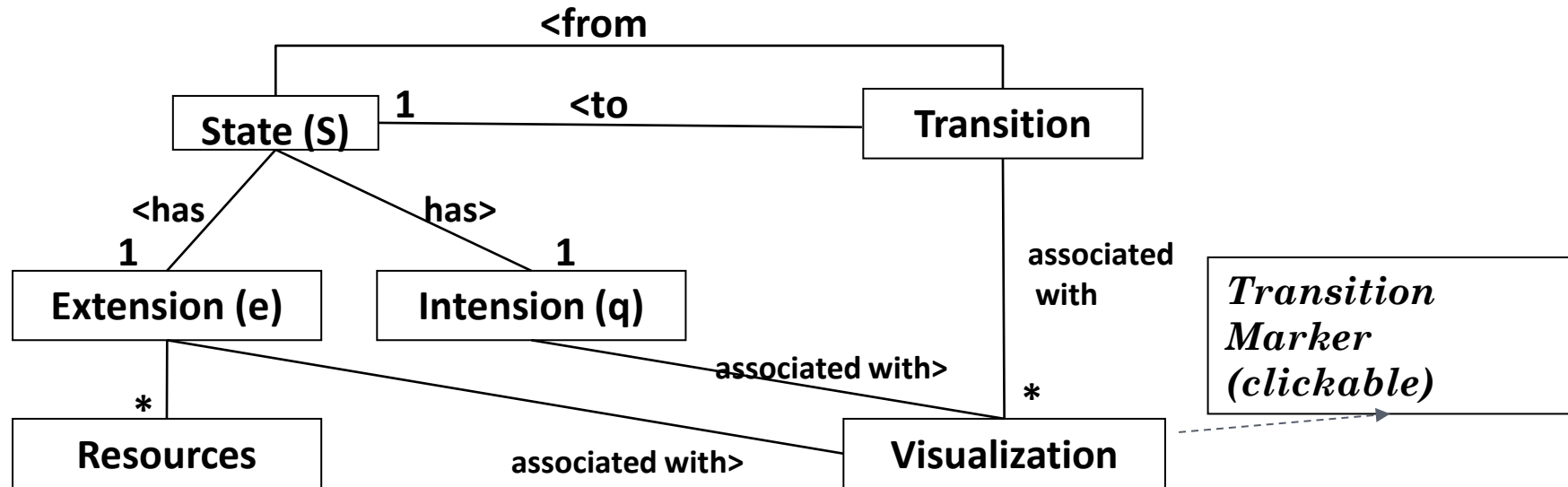
Faceted Search **Interaction** (abstract)



The screenshot shows a web interface for searching tennis players. Red brackets and labels are used to identify key components:

- Transition markers**: Points to the list of search results (e.g., Roger Federer, Rafael Nadal).
- Intension (as visualized)**: Points to the filter criteria (e.g., "Tennis Player", "Country").
- extension**: Points to the detailed information and links for a selected item (e.g., "Top 10 Tennis Players of All Time").
- state**: Points to the overall search context and results area.

Faceted Search **Interaction** (cont'd)



- Only terms that if added to the current query (intension) of the current state will yield to **no empty results** are shown (as Transition Markers).
- On click the user goes to the new state

Formal Synopsis: Taxonomy

TAXONOMY		
Name	Notation	Definition
<i>terminology</i>	T	a set of <i>terms</i> (can capture categorical/numeric values)
<i>subsumption</i>	\leq	a partial order (reflexive, transitive and antisymmetric)
<i>taxonomy</i>	(T, \leq)	T is a terminology, \leq a subsumption relation over T
<i>broaders of t</i>	$B^+(t)$	$\{ t' \mid t < t' \}$
<i>narrowers of t</i>	$N^+(t)$	$\{ t' \mid t' < t \}$
<i>direct broaders of t</i>	$B(t)$	$\text{minimal}_{<}(B^+(t))$
<i>direct narr. of t</i>	$N(t)$	$\text{maximal}_{<}(N^+(t))$
<i>Top element</i>	\top_i	$\top_i = \text{maximal}_{\leq}(T_i)$

Formal Synopsis: Materialized Faceted Taxonomy

MATERIALIZED FACETED TAXONOMIES		
<i>faceted taxonomy</i>	$\mathcal{F} = \{F_1, \dots, F_k\}$	$F_i = (T_i, \leq_i)$, for $i = 1, \dots, k$ and all T_i are disjoint
object domain	Obj	any denumerable set of objects
interpretation of T	I	any function $I : T \rightarrow 2^{Obj}$
<i>materialized faceted taxonomy</i>	(\mathcal{F}, I)	\mathcal{F} is a faceted taxonomy $\{F_1, \dots, F_k\}$ and I is an interpretation of $T = \bigcup_{i=1,k} T_i$
ordering over interpretations	$I \sqsubseteq I'$	$I(t) \subseteq I'(t)$ for each $t \in T$
<i>model</i> of (T, \leq) induced by I	\bar{I}	$\bar{I}(t) = \cup \{I(t') \mid t' \leq t\}$
Descr. of o wrt I	$D_I(o)$	$D_I(o) = \{t \in T \mid o \in I(t)\}$
Descr. of o wrt \bar{I}	$D_I(o) \equiv \bar{D}_I(o)$	$\{t \in T \mid o \in \bar{I}(t)\} = \cup_{t \in D_I(o)} (\{t\} \cup B^+(t))$

Formal Synopsis: Faceted Search Interaction

FDT-INTERACTION: BASIC NOTIONS AND NOTATIONS

<i>focus</i>	ctx	any subset of T such that $ctx = \text{minimal}(ctx)$
<i>projection on F_i</i>	ctx_i	$ctx \cap T_i$

Kinds of zoom points w.r.t. a facet i while being at ctx

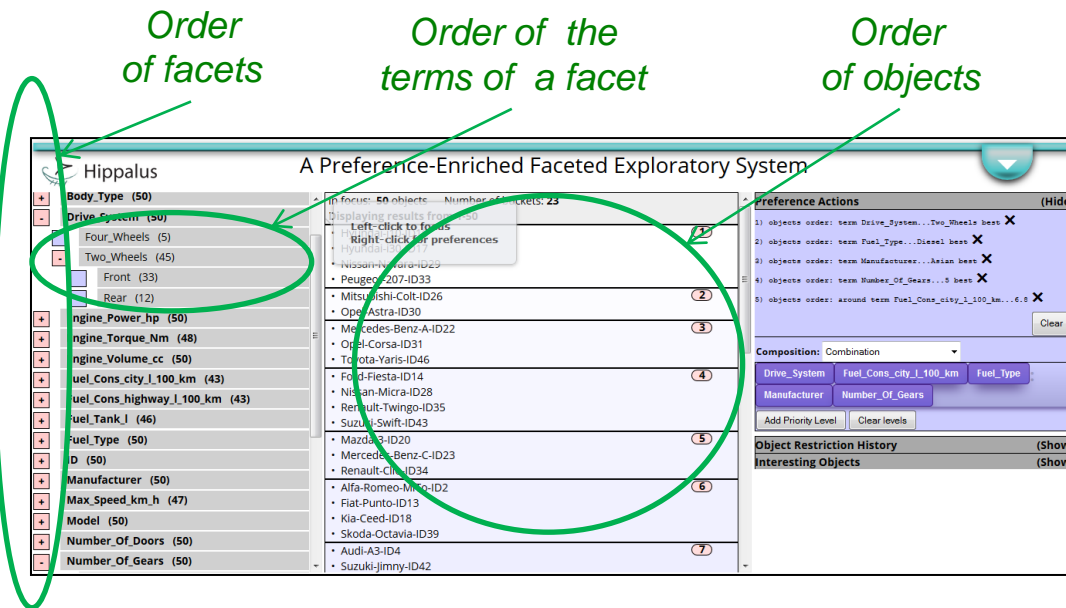
<i>zoom points</i>	$AZ_i(ctx)$	$\{ t \in T_i \mid \bar{I}(ctx) \cap \bar{I}(t) \neq \emptyset \}$
<i>zoom-in points</i>	$Z_i^+(ctx)$	$AZ_i(ctx) \cap N^+(ctx_i)$
<i>immediate zoom-in points</i>	$Z_i(ctx)$	$\text{maximal}(Z_i^+(ctx)) = AZ_i(ctx) \cap N(ctx_i)$
<i>zoom-side points</i>	$ZR_i^+(ctx)$	$AZ_i(ctx) \setminus \{ ctx_i \cup N^+(ctx_i) \cup B^+(ctx_i) \}$
<i>immed. zoom-side points</i>	$ZR_i(ctx)$	$\text{maximal}(ZR_i^+(ctx))$

Restriction over an object set $A \subseteq Obj$

<i>reduced interpretation</i>	I_A	$I_A(t) = I(t) \cap A$
<i>reduced terminology</i>	T_A	$\{ t \in T \mid \bar{I}_A(t) \neq \emptyset \} =$ $\{ t \in T \mid \bar{I}(t) \cap A \neq \emptyset \} = \cup_{o \in A} B^+(D_I(o))$

Enriching Faceted Search with Preferences

- During the interaction the user can make **actions**, i.e. a set $B=\{b_0, \dots, b_N\}$ that express preferences. These actions determine the ordering of the elements shown. These actions are **accumulated**, i.e. the entire set B affects the ordering.
- These actions determine the ordering of:
facets, facet terms, objects



(Notations)

$>$

\neq

\leq

Preference

White $>$ Black

BMW $>$ KIA

Subsumption

Paris \leq France

Cont'd

Order of facets

Order of the terms of a facet

Order of objects

Hippalus
A Preference-Enriched Faceted Exploratory System

Left-click to toggle
Right-click for preferences

Displaying results from 1 to 25

Preference Actions (Hide)

- 1) objects order: team Drive_System...Two_Wheels best X
- 2) objects order: team Fuel_Type...Diesel best X
- 3) objects order: team Manufacturer...Asian best X
- 4) objects order: team Number_Of_Gears...5 best X
- 5) objects order: around team Fuel_Consumption...6.0 X

Composition: Combination

Drive_System Fuel_Consumption_100_km Fuel_Type

Manufacturer Number_Of_Gears

Add Priority Level Clear levels

Object Restriction History (Show)

Interesting Objects (Show)

(F, >)

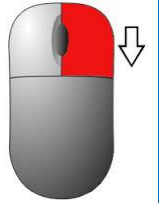
For each taxonomy ($T_i \leq$) the user through actions can define a preference relation $>_i$ over its terms. Initially $>_i = \emptyset$

(Obj, >)

This can lead to k preference relations, one for each T_i .

(T1, >1) (Tk, >k)

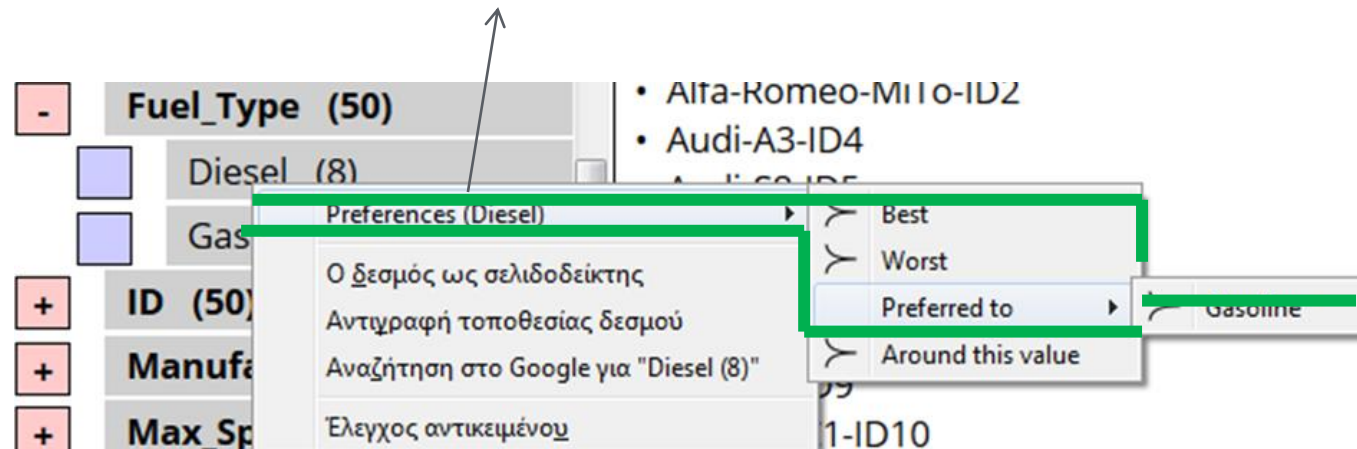
In total k+2 preference relations



Enactment of Preference Actions

- The preference actions are enacted through **right clicking** on an element
 - this element is called the *anchor* of the action
- Right click activates a **pop-up menu** and the user selects the preference action that he wants to

Diesel > Gasoline
(meaning that I prefer Diesel to Gasoline)



PFS: Theoretical Framework

Relative Preferences actions (over Flat Attributes)

- Consider a facet with a (flat) set of terms $T = \{\text{White, Black, Red, Blue}\}$
- At the beginning there is not preference relation over T , i.e. $\succ = \emptyset$
- Suppose the user expresses a relative preference, $\text{Blue} > \text{Red}$.



- The linear extension of $>$ can be
 - $\langle \text{Blue}, \{\text{Red, White, Black}\} \rangle$ // the inactive elements as minimal
 - $\langle \{\text{Blue, White, Black}\}, \text{Red} \rangle$ // inactive elements as maximal
 - $\langle \text{Blue, Red}, \{\text{White, Black}\} \rangle$ // inactive elements at the last block
 - It is a matter of **policy** what of the previous to adopt
 - A system should support more than one policy

Best/Worst actions (over Flat Facets)

Let $T = \{\text{White}, \text{Black}, \text{Red}, \text{Blue}\}$

Example 1:

- Suppose the user expresses the preference **Best**(Blue).
- This is a **shortcut**, i.e. the defined preference relation is
$$> = \{ (\text{Blue} > x) \mid x \in T \setminus \{\text{Blue}\} \}$$
- The linear extension of $>$ is
 - $<\text{Blue}, \{\text{Red}, \text{White}, \text{Black}\} >$

Example 2:

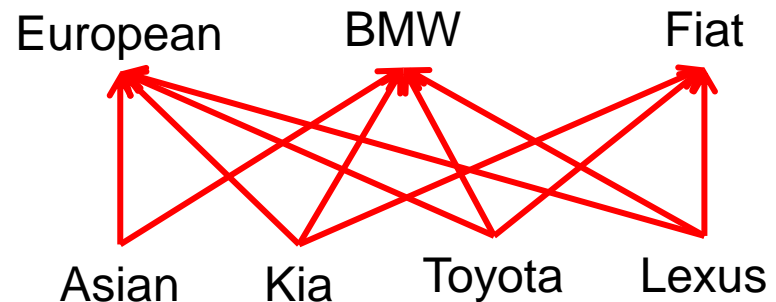
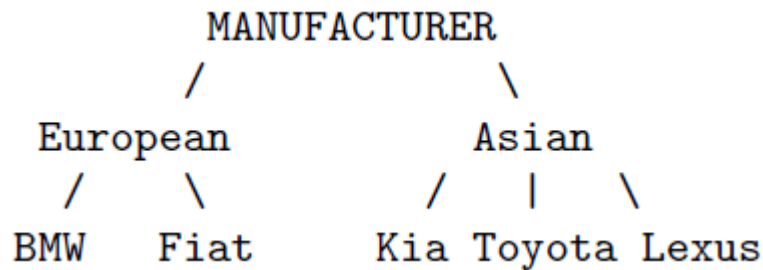
- Suppose the user expresses the preference, **Worst**(Blue).
- This is a **shortcut**, i.e. the defined preference relation is
$$> = \{ (x > \text{Blue}) \mid x \in T \setminus \{\text{Blue}\} \}$$
- The linear extension of $>$ is
 - $<\{\text{Red}, \text{White}, \text{Black}\}, \text{Blue}>$

Example 3:

- Best and Worst: Leads to a linear order where the first block contains the Best, the 3rd block the Worst, the rest elements are placed in the 2nd block

Best/Worst over Hierarchically Organized Facets

- Consider a facet having a hierarchically organized set of values
- $T = \{\text{European, Asian, BMW, Fiat, Kia, Toyota, Lexus}\}$ organized as follows



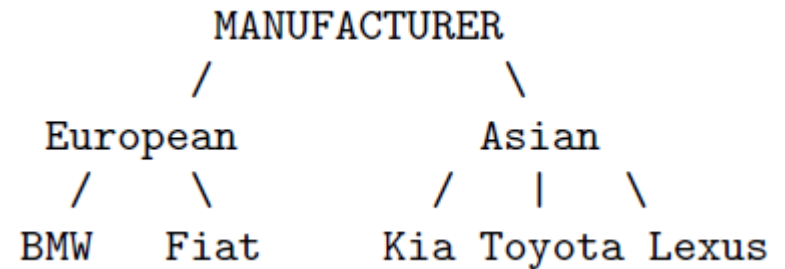
- The non leaf terms can be exploited for **easing** the expressions of preferences (as in faceted search): they are **inherited**!
- Best(European)** is **inherited**, so its semantics will contain Best(BMW) and Best(Fiat)
- The induced linear extension will be
 $\langle \{\text{European, BMW, Fiat}\}, \{\text{Asian, Kia, Toyota, Lexus}\} \rangle$

Cont.

- The same is done with the **relative preferences**

e.g. **European > Asian**,

actually defines the following
preference relation:



{
European > Asian, European > Kia, European > Toyota, European > Lexus,
BMW > Asian, BMW > Kia, BMW > Toyota, BMW > Lexus,
Fiat > Asian, Fiat > Kia, Fiat > Toyota, Fiat > Lexus
}

- The induced linear order will be

<{European,BMW,Fiat}, {Asian,Kia,Toyota,Lexus}

Cont.

But what should happen if the user provides two “**conflicting**” preferences, e.g. **European > Asian**, and **Toyota > Fiat**

The first defines the preference relation:

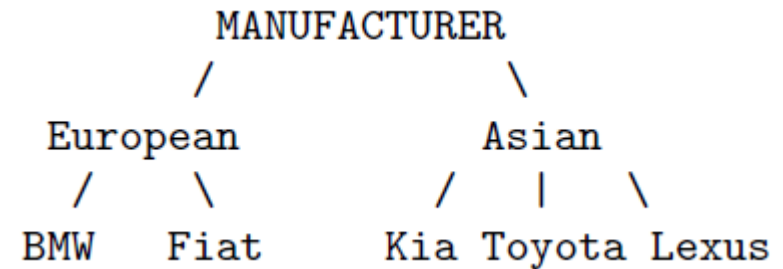
```
{  
European > Asian, European > Kia, European > Toyota, European > Lexus,  
BMW > Asian,      BMW > Kia,      BMW > Toyota,      BMW > Lexus,  
Fiat > Asian,      Fiat > Kia,      Fiat > Toyota,      Fiat > Lexus  
}
```

that contains **Fiat > Toyota** which contradicts the given **Toyota > Fiat**.

Solution: **automatic resolution of the conflict based on scopes**: the ordering of each pair of values is determined by actions having the smallest scope.

So the preference relation will contain **Toyota > Fiat**, it will not contain **Fiat > Toyota**

- Linear Extension: $\langle \{\text{European, BMW, Toyota}\}, \{\text{Asian, Kia, Fiat, Lexus}\} \rangle$



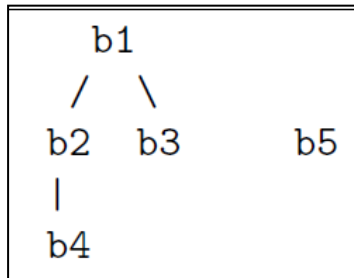
Scope-based Resolution of Conflicts

- A preference relation R over a set of elements E is **valid** iff it is acyclic.
- Each preference action b is **inherited** to its narrower terms. This is the **scope** of b .
- We say that an action b is **equally or more refined than** b' iff $\text{scope}(b) \subseteq \text{scope}(b')$.
- *Scope-based Dominance Rule*
 - If $A \subseteq \text{scope}(b) \subseteq \text{scope}(b')$ then b' is dominated by b on A , and thus action b' should not determine the ordering of A
- The **active scope** of b is defined as
 - $\text{aScope}(b) = \text{scope}(b) \setminus \{e \in \text{scope}(b') \mid b' \text{ is more refined than } b\}$

Example of automatic conflict resolution with 5 conflicting actions

preference	expansion	active scope
b1: <i>Asian</i> \succ <i>European</i>		
b2: <i>European</i> \succ <i>Kia</i>		
b3: <i>BMW</i> \succ <i>Asian</i>		
b4: <i>Kia</i> \succ <i>Fiat</i>		
b5: <i>Toyota</i> \succ <i>Kia</i>		

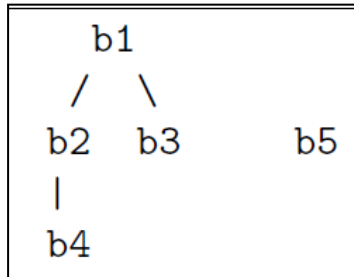
Example of automatic conflict resolution with 5 conflicting actions (cont'd)



Hasse Diagram of the relation *refined* over the actions {b1,...,b5}

preference	expansion	active scope
b1: <i>Asian</i> \succ <i>European</i>	<i>Asian</i> \succ <i>European</i> , <i>Asian</i> \succ <i>BMW</i> , <i>Asian</i> \succ <i>Fiat</i> , <i>Kia</i> \succ <i>European</i> , <i>Kia</i> \succ <i>BMW</i> , <i>Kia</i> \succ <i>Fiat</i> , <i>Toyota</i> \succ <i>European</i> , <i>Toyota</i> \succ <i>BMW</i> , <i>Toyota</i> \succ <i>Fiat</i> , <i>Lexus</i> \succ <i>European</i> , <i>Lexus</i> \succ <i>BMW</i> , <i>Lexus</i> \succ <i>Fiat</i>	
b2: <i>European</i> \succ <i>Kia</i>	<i>European</i> \succ <i>Kia</i> , <i>BMW</i> \succ <i>Kia</i> , <i>Fiat</i> \succ <i>Kia</i>	
b3: <i>BMW</i> \succ <i>Asian</i>	<i>BMW</i> \succ <i>Asian</i> , <i>BMW</i> \succ <i>Kia</i> , <i>BMW</i> \succ <i>Toyota</i> , <i>BMW</i> \succ <i>Lexus</i>	
b4: <i>Kia</i> \succ <i>Fiat</i>	<i>Kia</i> \succ <i>Fiat</i>	
b5: <i>Toyota</i> \succ <i>Kia</i>	<i>Toyota</i> \succ <i>Kia</i>	

Example of automatic conflict resolution with 5 conflicting actions (cont'd)



Hasse Diagram of the relation *refined*

preference	expansion	active scope
b1: <i>Asian</i> \succ <i>European</i>	<i>Asian</i> \succ <i>European</i> , <i>Asian</i> \succ <i>BMW</i> , <i>Asian</i> \succ <i>Fiat</i> , <i>Kia</i> \succ <i>European</i> , <i>Kia</i> \succ <i>BMW</i> , <i>Kia</i> \succ <i>Fiat</i> , <i>Toyota</i> \succ <i>European</i> , <i>Toyota</i> \succ <i>BMW</i> , <i>Toyota</i> \succ <i>Fiat</i> , <i>Lexus</i> \succ <i>European</i> , <i>Lexus</i> \succ <i>BMW</i> , <i>Lexus</i> \succ <i>Fiat</i>	<i>Asian</i> \succ <i>European</i> , <i>Asian</i> \succ <i>Fiat</i> , <i>Toyota</i> \succ <i>European</i> , <i>Toyota</i> \succ <i>Fiat</i> , <i>Lexus</i> \succ <i>European</i> , <i>Lexus</i> \succ <i>Fiat</i>
b2: <i>European</i> \succ <i>Kia</i>	<i>European</i> \succ <i>Kia</i> , <i>BMW</i> \succ <i>Kia</i> , <i>Fiat</i> \succ <i>Kia</i>	<i>European</i> \succ <i>Kia</i> , <i>BMW</i> \succ <i>Kia</i>
b3: <i>BMW</i> \succ <i>Asian</i>	<i>BMW</i> \succ <i>Asian</i> , <i>BMW</i> \succ <i>Kia</i> , <i>BMW</i> \succ <i>Toyota</i> , <i>BMW</i> \succ <i>Lexus</i>	<i>BMW</i> \succ <i>Asian</i> , <i>BMW</i> \succ <i>Kia</i> , <i>BMW</i> \succ <i>Toyota</i> , <i>BMW</i> \succ <i>Lexus</i>
b4: <i>Kia</i> \succ <i>Fiat</i>	<i>Kia</i> \succ <i>Fiat</i>	<i>Kia</i> \succ <i>Fiat</i>
b5: <i>Toyota</i> \succ <i>Kia</i>	<i>Toyota</i> \succ <i>Kia</i>	<i>Toyota</i> \succ <i>Kia</i>

Composing the Preferences of Different Facets

- Actions like those presented so far, lead to the definition of k preference relations, one for each $T_i: >_1, \dots, >_k$.
- They can be composed to define a preference relation over $V = T_1 \times \dots \times T_k$ (in particular over the Cartesian product of their powersets $\wp(T_1) \times \dots \times \wp(T_k)$).
- Two composition methods are proposed: **Pareto** composition and **Prioritized** composition.

Composing the Preferences of Different Facets (cont'd)

Example:

- Sedan **>1** Van
- Diesel **>2** Gasoline

Obj	Type	Fuel
o1	Sedan	Diesel
o2	Sedan	Gasoline
o3	Van	Diesel
o4	Van	Gasoline

Linear extension of

- **>1**
 - $\langle \{o1, o2\}, \{o3, o4\} \rangle$
- **>2**
 - $\langle \{o1, o3\}, \{o2, o4\} \rangle$
- **>(1>2)** // >1 has more priority
 - $\langle \{o1\}, \{o2\}, \{o3\}, \{o4\} \rangle$
- **>(2>1)** // >2 has more priority
 - $\langle \{o1\}, \{o3\}, \{o2\}, \{o4\} \rangle$
- **>(1x2)** // equal priority
 - $\langle \{o1\}, \{o2, o3\}, \{o4\} \rangle$

Composing the Preferences of Different Facets (cont'd)

- The **Prioritized composition** of two preference relations $>_1$ and $>_2$, denoted by $>(1 \blacktriangleright 2)$, means that $>_1$ has more priority than $>_2$.
 - It is defined as:
 - $(a,b) >(1 \blacktriangleright 2) (a',b')$ iff $(a >_1 a')$ or $((a=a') \text{ and } (b >_2 b'))$
- The **Pareto composition** of two preference relations $>_1$ and $>_2$, denoted by $>(1 \times 2)$, means that both have the same priority.
 - It is defined as follows:
 - $(a,b) >(1 \times 2) (a',b')$ iff
 - $(a >_1 a') \text{ and } (b \geq_2 b')$ OR
 - $(b >_2 b') \text{ and } (a \geq_1 a')$
 - The first block of the induced ordering is the **Pareto optimal set**, else called **skyline**.

(skyline)

- An object $o = \langle v_1, \dots, v_K \rangle$ **dominates** an object $o' = \langle v_1', \dots, v_K' \rangle$ if for each $i \in [1..k]$ it holds $v_i \geq v_i'$ και $\exists j \in [1..k]$ such that $v_j' > v_j$
- An object $o \in \text{Obj}$ belongs to the **skyline** if it is **not dominated** by another object



Live demo of priorities

- *Script*

- *Preferences over the terms of two facets*
- *Switch the order*

The syntax of preference actions

```

<stmt> ::= <scopeType> <spec>
<scopeType> ::= facets order : | terms order : | object order :
<spec> ::= <anchor> <rankSpec>
<anchor> ::= facet <Fi>
            | term <tj>
            | object <ok>
            | ε // the empty string
<rankSpec> ::= {lexicographic | count | value | indexedBy} {min|max}
            | best | worst
            | use scoreFunction <score()> {min|max}

<stmt> | facets order : prefer <Fi> to <Fj>
<stmt> | terms order : prefer <ti> to <tj>
<stmt> | object order : prefer <ti> to <tj>

<stmt> | objects order : Pareto <setOfFacets>
<stmt> | objects order : ParetoOptimal <setOfFacets>
<stmt> | objects order : Priority <orderedSetOfFacets>
<stmt> | objects order : Combinational <bucketOrderedSetOfFacets>
```

Algorithms

From a Binary Relation to a Bucket Order

- Algorithm **SourceRemoval** (essentially: *Topological sort*)

Algorithm 2 SourceRemoval(R)

Input: a binary relation R over E

Output: a bucket order over E that respects R

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

Flat Facets and Preferences

Algorithm Apply

- Takes as input *Best*, *Worst* and *Relative Preferences* and produces a bucket order

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

Input: the set of elements E , the set of best elements B , the set of worst elements W , the set of relative preferences 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: $L \leftarrow \text{SourceRemoval}(R)$ //produce blocks with boundaries
 - 4: $I \leftarrow E \setminus (B \cup W \cup \text{dom}(R_{\succ}))$ // I contains the inactive elements
 - 5: $L' \leftarrow \text{addInactiveElements}(L, I, \text{Policy})$
 - 6: **return** L'
-

Hierarchical Facets and Preferences

Algorithm PrefOrder

- Keypoint: Scope-based resolution of conflicts

Algorithm 4 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 (i): Computation of $(\mathcal{B}, \sqsubseteq)$ | Order the actions B based on their scopes |
| 2: Compute the <i>scopes</i> of the actions in \mathcal{B} | |
| 3: Form $(\mathcal{B}, \sqsubseteq)$ | |
| 4: // Part (ii): Efficient Computation of Act. Scopes | Compute the active scopes of B |
| 5: Use $(\mathcal{B}, \sqsubseteq)$ to compute the <i>active scopes</i> of the actions in \mathcal{B} | |
| 6: Use the active scopes to expand the set \mathcal{B} to a set \mathcal{B}' | |
| 7: //Part (iii): Derivation of the final bucket order | Use the active scopes to unfold the |
| 8: $(B, W, R_{\succ}) \leftarrow \text{Parse}(\mathcal{B}')$ | inherited preferences |
| 9: return Apply($E, B, W, R_{\succ}, Policy$) // call to Alg. 1 | |
-

Prioritized Composition

Algorithm MFOOrder

- Keypoint:
 - Produce the bucket order defined by the preferences having the highest priority.
 - Then order each block based on the preferences having the 2nd priority, and so on.

Algorithm 6 MFOrder($A, \mathcal{B}_i, \mathcal{B}_j$)

Input: the objects of current focus A , the set of actions \mathcal{B}_i for facet F_i , and the set of actions \mathcal{B}_j for facet F_j

Output: a bucket order of A corresponding to $\mathcal{B}_i \triangleright \mathcal{B}_j$

-
- 1: We call the Alg. **PrefOrder(A, \mathcal{B}_i)** and let $L = \langle A_1, \dots, A_M \rangle$ be the produced bucket order where M is the number of blocks returned.
 - 2: For each block A_m of L ($1 \leq m \leq M$) where $|A_m| > 1$, we call **PrefOrder(A_m, \mathcal{B}_j)**, returning a bucket order $L_m = \langle A_{m1}, \dots, A_{mz} \rangle$.
 - 3: We replace each block A_m of L with its bucket order L_m and this yields the final bucket order $L = \langle L_1, \dots, L_M \rangle$.
-

Optimized Focus-based Algorithm

- Objective:

- Define an algorithm whose complexity **does not depend on Obj** but on **A** (the current focus).

- Approach

- Define an algorithm which can be applied to large information bases if the user first restricts (through plain faceted search, i.e. with left clicks) to a focus set **A** of reasonable size.
- It is well known that Faceted Search (and consequently PFS) allows restricting very fast the focus set.
 - For instance, the analysis in [Sacco,FQAS'06] shows that **3 zoom operations** on leaf terms are sufficient to reduce an information base of 10^7 objects, described by a taxonomy with 10^3 terms, to an average of 10 objects.
 - A more detailed analysis is available in [Tzitzikas, Papadakos, FI'2013]

FS Convergence

- Assume k complete and balanced tree taxonomies of depth d and degree b . Each leaf indexes 10 objects
- Optimally the number of choices is $k * b * d$ while number of clicks is $k * d$
- 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

Number
of facets

Degree
of the
taxonomies

Depth
of the
taxonomies

Number of
terms the user
will see

Number of
decisions

Optimized Focus-based Algorithm (cont'd)

○ How ... to avoid Obj

- We can understand if an action b is more refined than a b' by looking at the anchors of b and b' (i.e. without having to compute their scopes)
- For each object $a \in A$ we can find the actions to whose active scope a belongs
 - We can understand if $a \in \text{scope}(b)$ by looking at the description of a and the anchor of b (i.e. without having to compute $\text{scope}(b)$)

Computational Complexity

Table 5. Complexity for non-optimized and optimized Alg. PrefOrder and PrefOrder_{opt}

Part	Non-Optimized (Alg. PrefOrder)	Optimized (Alg. PrefOrder _{opt})	Optimized (Alg. PrefOrder _{opt}) for relative prefs
Part 1	$\mathcal{O}(Obj (Obj + \mathcal{B} ^2))$	$\mathcal{O}(\mathcal{B} ^2)$	$\mathcal{O}(\mathcal{B} ^2)$
Part 2	$\mathcal{O}(Obj \mathcal{B} + exp)$	$\mathcal{O}(A (\mathcal{B} + \sqsubseteq) = \mathcal{O}(A \mathcal{B} ^2)$	$\mathcal{O}(A ^2 \mathcal{B} ^2)$
Part 3	$\mathcal{O}(Obj ^2)$	$\mathcal{O}(A ^2)$	$\mathcal{O}(A ^2)$
Overall	$\mathcal{O}(Obj (Obj + \mathcal{B} ^2))$	$\mathcal{O}(A (A + \mathcal{B} ^2))$	$\mathcal{O}(A ^2 \mathcal{B} ^2)$

No Obj

Set-Valued Facets

- Consider a facet Accessories containing terms like:
 - ABS
 - ESP (Electronic Stability Program)
 - AT (Auto-Transmission)
 - DVD
 - GPS
 - ...
- A car can have **more than one** accessories.
- Consequence for preferences
 - As before, the user can express his/her preferences over each of the accessories, and define a preference relation $>_i$
 - However, since each car can have more than once accessories, we should **extend** the preference relation $>_i$ to a binary relation over $P(T_i)$.

Set-Valued Facets (cont'd)

○ Objective

- We want to order two sets s and s' of accessories according to our preference

○ Approach

- We count how many elements of s “win” elements of s' and the other way around. Extra criteria for breaking ties

Def. 3. (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:

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

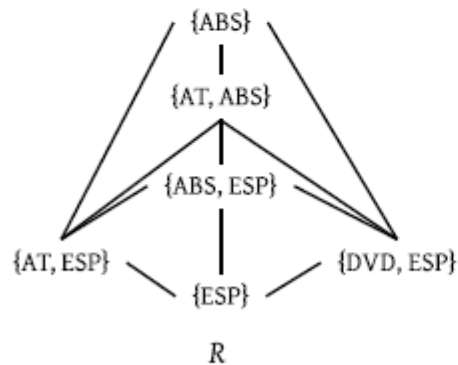
Any subset S of the powerset of E (i.e. $S \subseteq P(E)$), can be ordered according to a preference relation that we will be denoted by $\succ_{\{\}}$, defined by the following rule:

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

Set-valued Facets (cont'd)

- 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



Topological
Sorting
→



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

Set-valued Facets (cont'd)

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

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**

$$wins(\{ABS\}, \{ABS, ESP\}) = wins(\{ABS, ESP\}, \{ABS\}) = 0$$

$$wins(\{AT\}, \{AT, DVD\}) = wins(\{AT, DVD\}, \{AT\}) = 0$$

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

Set-Valued Facets (cont'd)

- Algorithm

- Find the sets of accessories of the cars in A
- Order these sets according to preferences
- Use this ordering for ordering the sets in A

- Various optimizations are described in the paper

- [J. FI 13] Yannis Tzitzikas and Panagiotis Papadakos. Interactive Exploration of Multidimensional and Hierarchical Information Spaces with Real-Time Preference Elicitation. In *Journal FUNDAMENTA INFORMATICA*, Volume 122, Issue 4, pp 357-399, 2013.

Evaluation of PFS with Users

Evaluation with Users

- Evaluate **two** UIs over an information base of 50 cars
 - **plain FDT** UI₁
 - **FDT with preferences** UI₂
- Two user groups
 - **20** participants for **plain** users
 - **6** participants for **expert** users
- Each user completed **4 tasks** (2 with UI₁ and 2 UI₂)
 - **2 tasks** required **prioritized composition** and the **rest 2 Pareto**
 - **Plain user** tasks used criteria over **3 attributes**
 - **Expert user** tasks used criteria over **6 attributes**
- **Graeco-Latin Square Design**
 - rotating both the order of tasks and UIs
 - to control order effects



Evaluation: Qualitative Results

- Users evaluated each UI using a psychometric Likert scale for *Ease of Use, Usefulness, Preference* and *Satisfaction*

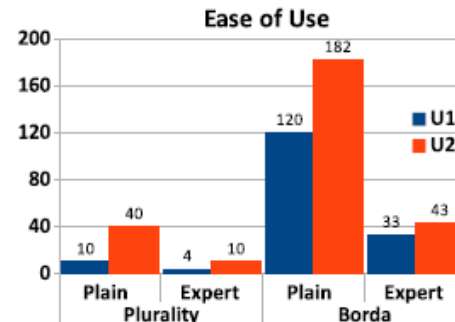
- **Main Result: All users preferred the PFS over the plain FDT**

- plain users preferred it:

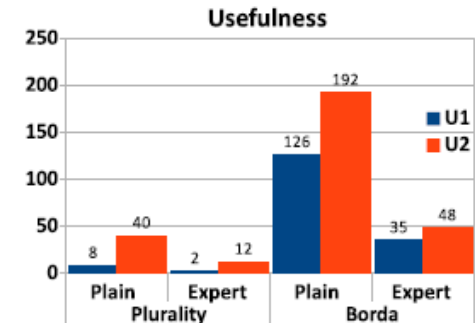
- 75% very strongly
- 20% strongly
- 5% strong enough

- expert users preferred it:

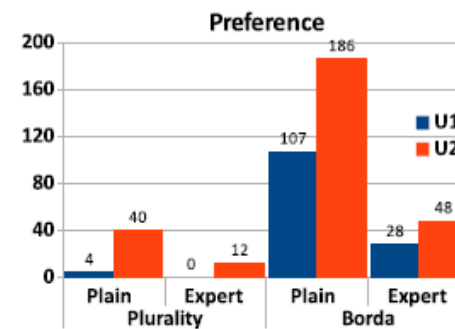
- 50% very strongly
- 50% strong enough



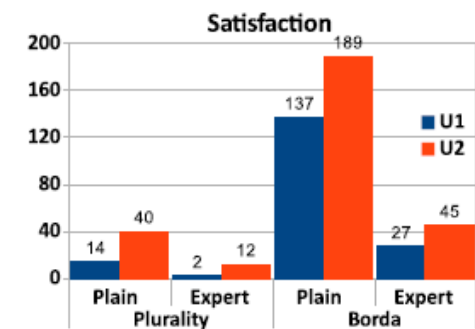
(a)



(b)



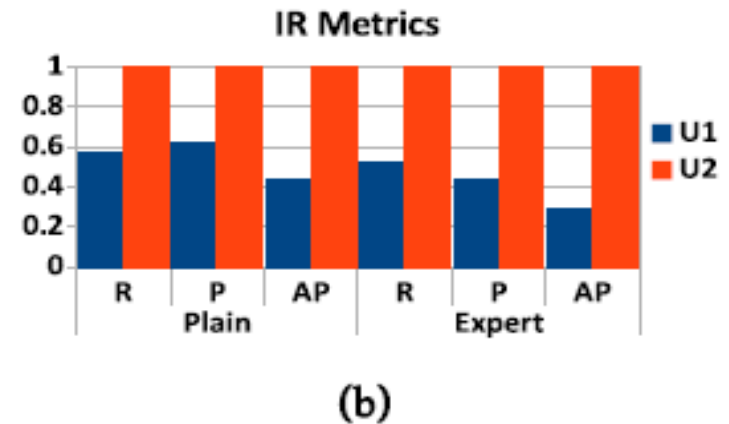
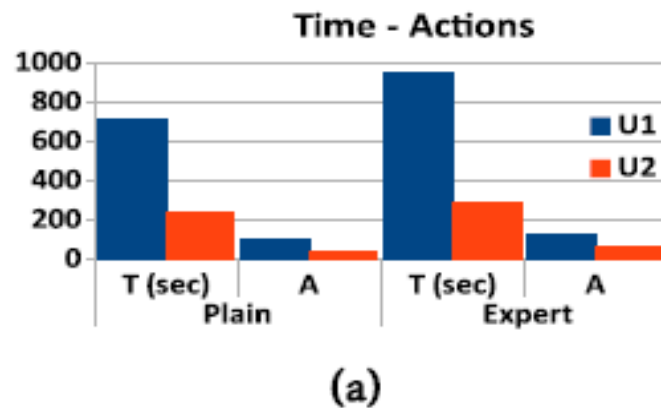
(c)



(d)

Evaluation: Quantitative Results

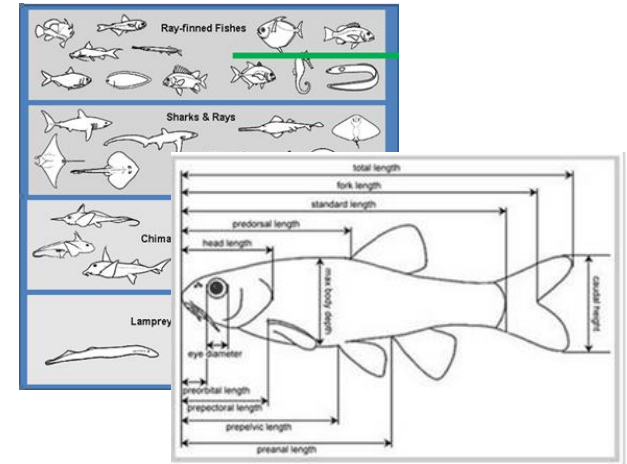
- Users completed **all the tasks successfully** with the preference based UI, **in one third of the time** and with **significantly fewer actions!**
- **None of the users** was able to complete **successfully** both tasks with the plain FDT UI
- *Average Precision* is improved **2.30x** for plain and **3.49x** for expert users on average



Other Application Domains

Investigation of Other Application Domains

- For aiding the **identification of species**
 - Species identification is actually a decision making process comprising steps in which the user makes a selection (or provides as input) that restricts other choices, and so on, until reaching one species. The PFS method offers a flexible process that is order independent.
- As a **Voting Advice Application** (VAA)
 - In comparison to the widely used questionnaire-based VAAs, the PFS-based method is beneficial with respect to expressiveness, responsiveness, transparency, process and time flexibility.
 - We have developed a pilot application for the parliament elections of January 25, 2015 in Greece.



Demos

- Connect with Firefox version 8 or higher:
 - **Car Selection** : <http://62.217.127.128:8080/Hippalus/cars50.jsp>
 - **Fish Identification**: <http://62.217.127.128:8080/Hippalus/fishbase300.jsp>
 - **Voting Advice Application**:
<http://62.217.127.128:8080/Hippalus/parties.jsp>
- Express the following preferences:
 - ... to be decided in class

Other Related Activities

- Title: Faceted Search with **Entity Mining** and **LOD** (Linked Open Data)
 - Facets and terms produced by applying entity mining over the snippets of search hits, where LOD is used as source for entity names
- Motivation
 - LOD contains plenty of information about **Named Entities** (their names, attributes, relationships with other entities, etc)
- Output
 - IOS Entity Mining
 - LOD is used as source for Named Entity Recognition
 - LOD is used for providing more information about the identified entities



The screenshot shows the IOS Entity Mining interface. At the top left is the logo with the text "entity mining" and "ios". A search bar contains the text "barack obama" and a "Search" button. Below the search bar, there are two red boxes: one containing "100 results to mine" and another containing "mine only snippets". The results are divided into two sections: "Person" and "Organization". The "Person" section lists several names, with "Nicolas Sarkozy" highlighted in a red box. A detailed profile for Nicolas Sarkozy is shown, including his current position, birth date, birth place, profession, and web site. The "Organization" section lists several organizations, with "Harvard" highlighted in a red box. A yellow box on the left contains a list of features: "Automatically connects knowledge with documents at query time", "No preprocessing", and "No indexing". A red box at the bottom right contains the text "show all".

entity mining
ios

barack obama

Search

100 results to mine

mine only snippets

Person (1427 entities)

Barack Obama - Wikipedia, the free encyclopedia
Barack Hussein Obama II (born August 4, 1961) is the 44th and current President of the United States. He is the first African American to hold the office. Obama ...
http://en.wikipedia.org/wiki/Barack_Obama - find its entities

Barack Obama
Barackobama.com is the official re-election campaign website of President Barack Obama. Visit the site for the latest updates from

Nicolas Sarkozy
Current President of France
Birth date: 1955-01-28
Birth place: Paris, France
Profession: Lawyer
Web site: <http://www.sarkozy.fr>
Page: http://en.wikipedia.org/wiki/Nicolas_Sarkozy

Organization (842 entities)

Harvard (14)
White House (18)
Congress (14)
University of Hawaii (10)
Columbia University (8)

show all

Quote of the day: "This is a good first step, but it is only a step. Congress needs to pass the rest of my American Jobs Act so that can create jobs and put ...
<https://www.facebook.com/barackobama> - find its entities

- Automatically connects knowledge with documents at query time
- No preprocessing
- No indexing

Cont'd

The screenshot shows a web interface for 'entity mining'. At the top left is a logo with the text 'entity mining' and 'ios' (where 'i' is a magnifying glass over a globe). A search bar contains the text 'barack obama' and a 'Search' button. Below the search bar, it says '100 results to mine' and a checkbox for 'mine only snippets'. On the left, a red box highlights 'Results of selected entities: reset'. Below this, there are three snippets of text from search results, each with a 'find its entities' link. On the right, there are two lists of entities. The first list is titled 'Person (1427 entities)' and lists names with counts and a magnifying glass icon. The second list is titled 'Organization (842 entities)' and lists organizations with counts and a magnifying glass icon. Red boxes highlight specific entities in both lists.

Results of selected entities: reset

Barack Obama
BarackObama.com is the official re-election campaign website of PresidentBarack Obama. Visit the site for the latest updates from the Obama campaign, ...
<http://www.barackobama.com/> - find its entities

About Barack Obama — Barack Obama
Barack Obama is the 44th President of the United States of America. PresidentObama speaking. President Obama was born in Hawaii on August 4th 1961 to a ...
- find its entities

Record - Barack Obama
my was losing more than ...
d quickly to pass the ...
- find its entities

News for barack+obama
Barack Obama - Wikipedia, the free encyclopedia
Barack Hussein Obama II is the 44th and current President of the United States ...
- find its entities

Person (1427 entities)

- Barack Obama (16)
- Michelle Obama (19)
- George W. Bush (16)
- Ann Dunham (15)
- Craig Robinson (15)
- Joe Biden (13)**
- John McCain (8)**
- Kennedy (9)
- Sarkozy (8)
- Clinton (6)

[show all](#)

Organization (842 entities)

- Harvard (14)
- White House (22)**
- Congress (14)

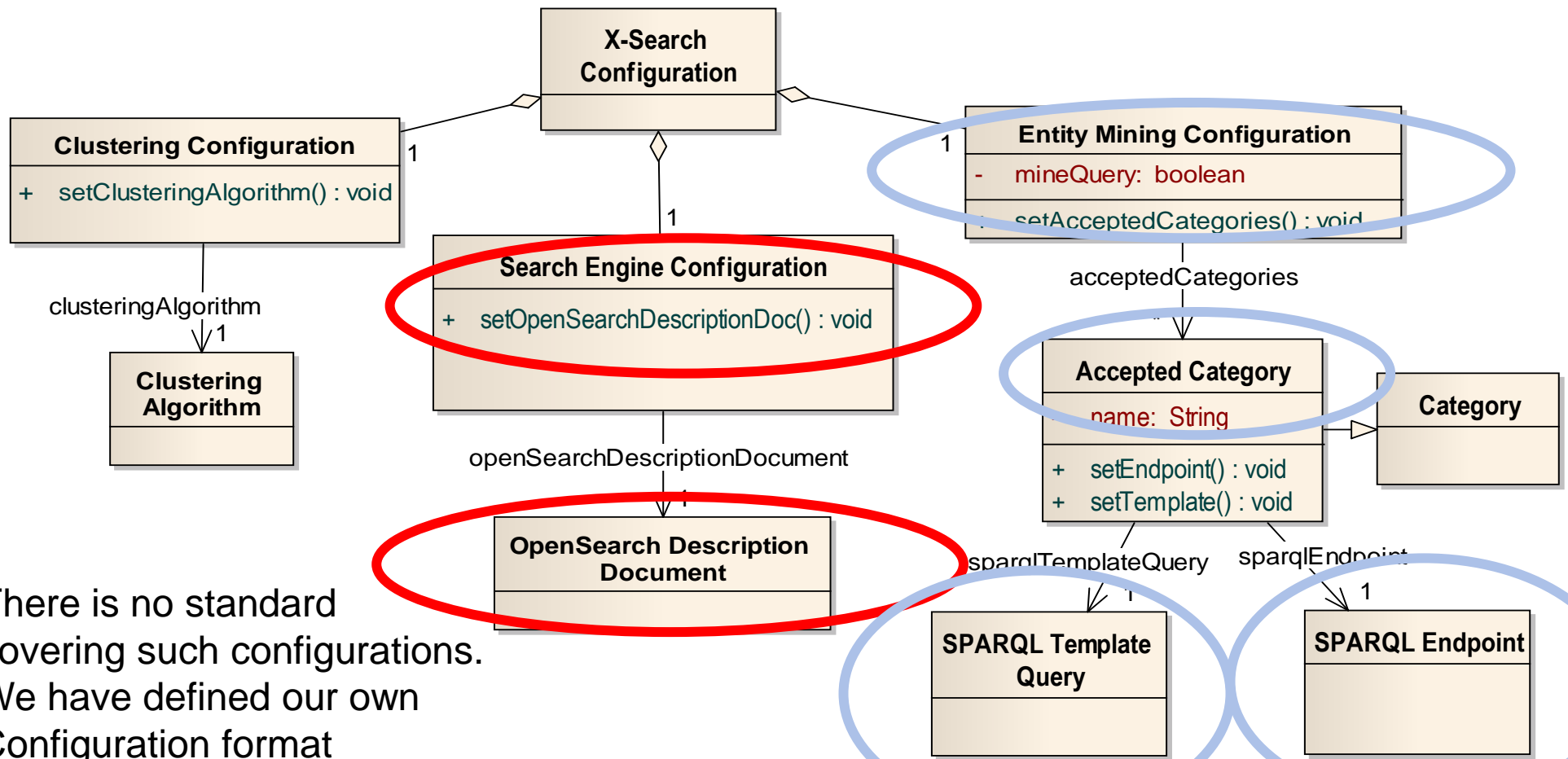
- Exploitation for restricting the focus

Cont'd


- Then we questioned ourselves:
 - Allowing the user to configure himself the entities of interest by exploiting the LOD
- Outcome
 - X-ENS (eXplore ENTities in Search)
- Related Publications
 - [SIGIR'13] P. Fafalios and Y. Tzitzikas, X-ENS: Semantic Enrichment of Web Search Results at Real-Time, 36th International ACM SIGIR Conference, Demo Paper, Dublin, Ireland, 28 July - 1 August 2013



Xsearch-Configurability: The Conceptual Model



There is no standard covering such configurations. We have defined our own Configuration format



[about X-ENS](#) | [admin configuration](#)

results to mine

Tennis Player (39 entities)

- Roger Federer (14)
- Rafael Nadal (7)
- Novak Djokovic (5)
- Andy Roddick (4)
- serena williams (4)
- Maria Sharapova (3)
- Andy Murray (2)
- Tsvetana Pironkova (2)
- Urszula Radwanska (2)
- Vania King (2)


Tennis - ATP World Tour - Home

... photos, video, behind-the-scenes footage of the tennis player and tennis tournament statistics. It opens with ...

<http://www.atpworldtour.com/> - find its entities

Semantic Entity Enrichment (close)

Properties of: Andy Roddick

Description	Depiction
Andrew Stephen "Andy" Roddick (born Aug 30, 1982) is an American professional tennis player and a former World No. 1. He is..	
BirthPlace	BirthDate
Omaha, Nebraska	1982-08-30

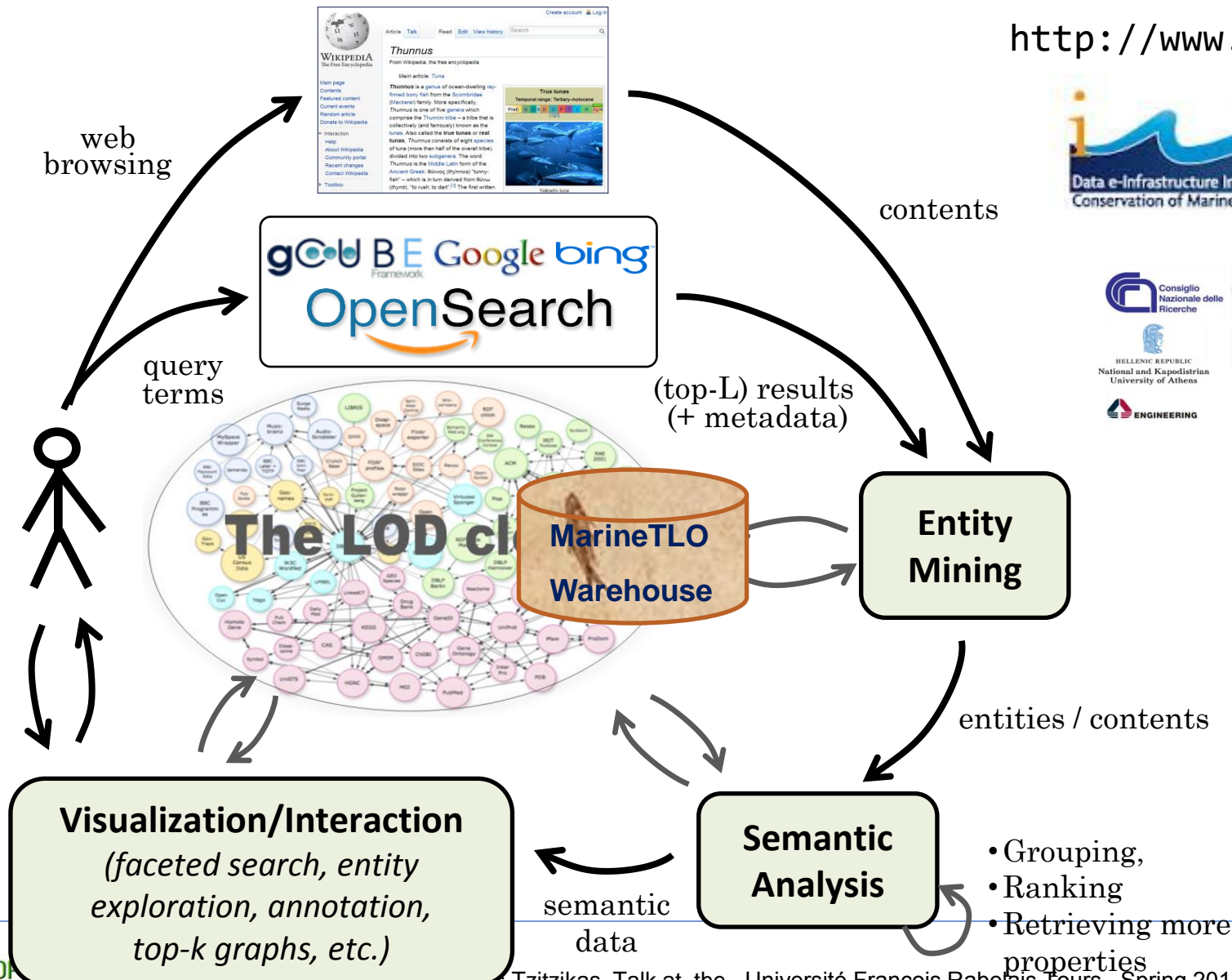
Country (11 entities)

- India (8)
- Canada (3)

top hits

Xsearch in the context of the operating iMarine Research Infrastructure: Semantic post-processing of search results

<http://www.i-marine.eu/>



Example: X-Search deployed in an Operational Research Infrastructure (2012-now)

Semantically Enriched Results

Query: tuna
In Collections: FIGIS

Mined Entities

- FAOCountry(24)
 - Republic of ... (1)
 - Viet nam(1)
 - Venezuela(2)
 - Yugoslavia(2)
 - Senegal(1)
- Species(8)
 - eastern Paci... (1)
 - yellowtail a... (1)
 - Ara(1)
 - pantropical... (1)
 - Indo-Pacific... (1)
- WaterAreas(3)
 - Mediterranea... (1)

Object Metadata

Thunnus albacares (Bonnaterre, 1788) - Fact sheet

Yellowfin **tuna**... (Venezuela), Ca bo Vang (Viet nam), **Tuna** zutoperka (Yugoslavia)... There are important yellowfin **tuna** fisheries throughout tropical and subtropical seas. The most... major surface fishing techniques for yellowfin **tuna** in the Pacific, even though this method

Textual Clustering

- Root(15)
 - fact sheet(27)
 - thunnus(8)
 - stenella(4)
 - linnaeus fac...(3)
 - axis(2)
 - tengraulis...(1)
 - dax fact s...(1)
 - purus lin...(1)

Semantic Entity Exploration

- URI: <http://www.fao.org/figis/flod/entities/codeentity/3e6d22db-1f06-437d-ac4a-9d3c8b895bf5> (open)
- Value: yellowtail amberjack

Semantic Entity Exploration

Properties of: Yellowtail_amberjack

Type	SameAs
Animal (open)	Seriola lalandi (open)
Thing (open)	
Species (open)	
FLODSpecies (open)	
Fish (open)	
CodeEntity (open)	
Eukaryote (open)	
Animal (open)	
Fish (open)	

Subject
Category:Fish of the Red Sea (open)
Category:Fish of the Indian Ocean (open)
Category:Seriola (open)

BinomialAuthority	Class
Georges Cuvier (open)	Actinopterygii (open)
Achille Valenciennes (open)	

Family
Carangidae (open)

Genus	Kingdom	Order	Phylum
Seriola (open)	Animal (open)	Perciformes (open)	Chordate (open)

Depiction	Thumbnail
Seriola lalandi.jpg (open)	200px-Seriola lalandi.jpg (open)

Object Metadata

Thunnus thynnus (L.)

Atlantic bluefin **tuna**... fisheries. Off Sicily, no... oceanic but seasonal... tolerate a... for almost... catches of northern b...

Result of Entity Mining

Result of Textual Clustering

Yannis Tzitzikas, Panel@ExploreDB

Synopsis

Synopsis

- We have discussed information needs of **exploratory nature**
- We have seen the basics of **faceted exploration**
- We have seen an extension of the interaction paradigm of Faceted Exploration with actions that allow the users to express at browsing time their **preferences**. The user has two kinds of actions:
 - actions that change the focus (zoom-in/out/...) and
 - actions that rank the focus
- The proposed model supports **progressive** preference elicitation, **inherited** preferences and automatic **scope-based resolution of conflicts** over single or **multi-valued** attributes with **hierarchically** organized values. Finally we elaborate on the algorithmic perspective and the applicability of the model over large information bases
- The evaluation with users have shown that users completed all the tasks **successfully** with the preference based UI in one third of the time and with **significantly fewer actions**.

Future Work and Research

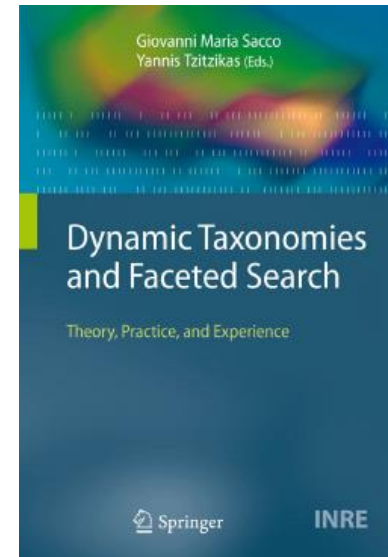
- Investigate requirements stemming from the new applications
 - As a Voting Advice Application
 - As a Species Identification Service
 - Directly over SPARQL results
- Interaction and Algorithms
 - Investigate approaches that rely on fewer preference actions and design faster algorithms for these cases
 - E.g. embed Skyline algorithms for finding fast the first block of the preference-based bucket order

References and Links

References and Links

○ Faceted Search and Dynamic Taxonomies

- Sacco, Giovanni Maria; Tzitzikas, Yannis (Eds.), Dynamic Taxonomies and Faceted Search: Theory, Practice, and Experience, Series: The Information Retrieval Series , Vol. 25, 2009
- Giovanni Maria Sacco: **Dynamic Taxonomies: A Model for Large Information Bases.** [IEEE Trans. Knowl. Data Eng.](#) **12**(3): 468-479 (2000)



○ Browsing Approach for (plain and fuzzy) RDF

- Sébastien Ferré's Publications
- [Nikos Manolis](#), Yannis Tzitzikas: **Interactive Exploration of Fuzzy RDF Knowledge Bases.** [ESWC \(1\) 2011](#): 1-16

Cont.

◦ **Extending Faceted Search with Preferences**

- [J. FI 13] Yannis Tzitzikas and Panagiotis Papadakos. Interactive Exploration of Multidimensional and Hierarchical Information Spaces with Real-Time Preference Elicitation. In *Journal FUNDAMENTA INFORMATICA*, Volume 122, Issue 4, pp 357-399, 2013.
- [ExploreDB'14] Panagiotis Papadakos, Yannis Tzitzikas: Hippalus: Preference-enriched Faceted Exploration. EDBT/ICDT Workshops 2014: 167-172
- P. Papadakos. Interactive Exploration of Multi-Dimensional Information Spaces with Preference Support . PhD Dissertation, University of Crete, November 2013.

◦ **Video Demonstration available at**

<http://www.youtube.com/watch?v=Cah-z7KmlXc>

◦ **Links to Online Prototypes**

<http://www.ics.forth.gr/isl/Hippalus>