Discovering temporal hidden contexts in web sessions for user trail prediction

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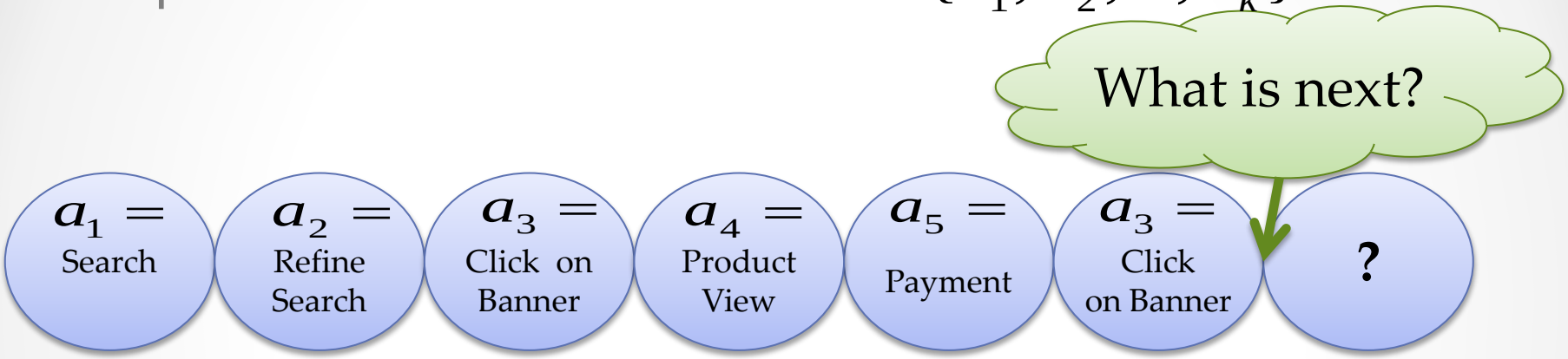
User Trail Prediction

- User web log: $S = \{s_1, s_2, \ldots, s_n\}$
- Alphabet of user actions: $A = \{a_1, a_2, \ldots, a_k\}$



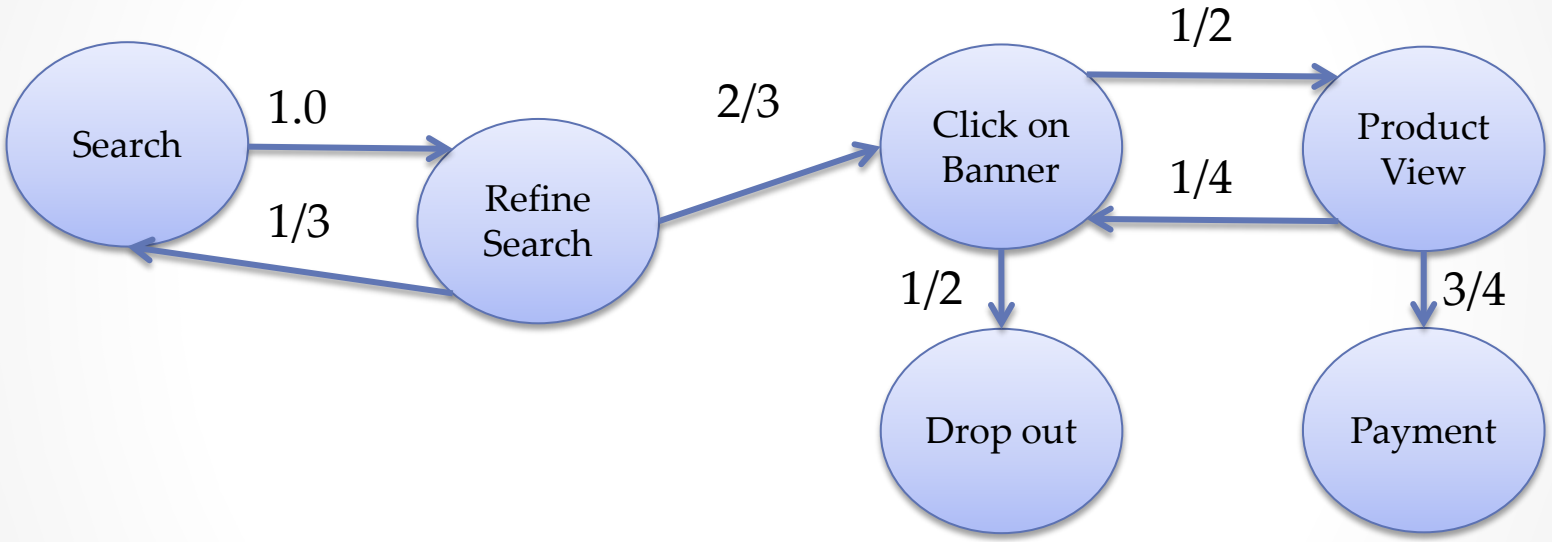
- Can we find contexts helping to build more accurate local models (performing better than a global model)?
- Can we use the same problem formulation to discover some meaningful contexts?

User Web Log

Alphabet of actions: {Search, Refine Search, Click on Banner, Product View, Payment}

Session 1	Search	Refine Search	Click on Banner	Product View	Payment
Session 3	Product View	Payment			
Session 3	Search	Refine Search	Refine Search	Click on Banner	
Session 4	Search	Refine Search	Click on Banner	Product View	Payment
Session 5	Product View	Click on Banner			

User Navigation Graph



Contextual Partitioning

- Approaches to create local models:
  - Horizontal partitions (context is geographical position)

Session 1	Search	Refine Search	Click on Banner	Product View	Payment
Session 3	Product View	Payment			
Session 3	Search	Refine Search	Refine Search	Click on Banner	
Session 4	Search	Refine Search	Click on Banner	Product View	Payment
Session 5	Product View	Click on Banner			

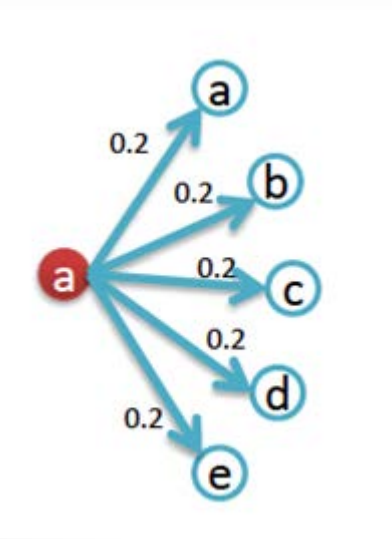
Users from Europe

Users from South America

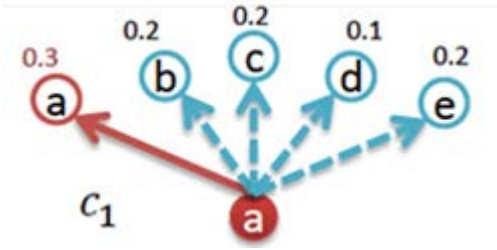
- Where user location is context
- Continents are contextual categories **C**:

C1= "Europe", **C2** = "South America"

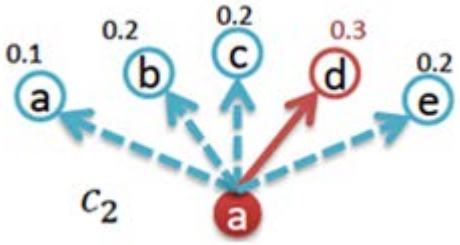
Contextual Local Models



Users from Europe:



Users from South America:



Contextual Partitioning

- Approaches to create local models:
  - Horizontal partition
  - Vertical partition :
    - Two types of behavior:
      - Ready to buy – (**Product View**, **Payment**)

Session 1	Search	Refine Search	Click on Banner	Product View	Payment
Session 2	Product View	Payment			
Session 3	Search	Refine Search	Refine Search	Click on Banner	
Session 4	Search	Refine Search	Click on Banner	Product View	Payment
Session 5	Product View	Click on Banner			

Contextual Partitioning

- Approaches to create local models:
  - Horizontal partition
  - Vertical partition:
    - Two types of behavior:
      - Ready to by – (**Product View**, **Payment**)
      - Just browsing – (**Search**, **Refine Search**, **Click on Banner**)

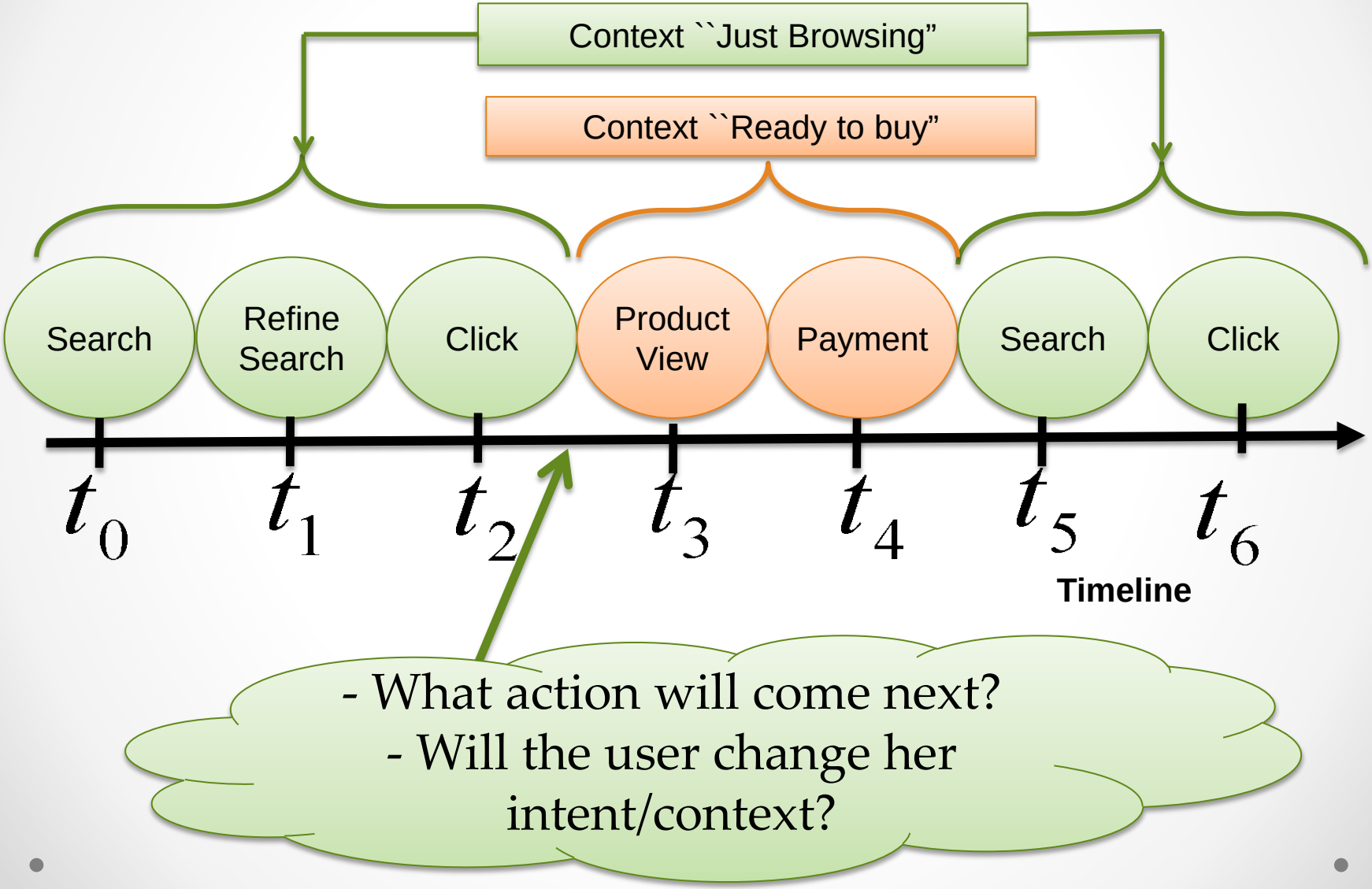
Session 1	Search	Refine Search	Click on Banner	Product View	Payment
Session 2	Product View	Payment			
Session 3	Search	Refine Search	Refine Search	Click on Banner	
Session 4	Search	Refine Search	Click on Banner	Product View	Payment
Session 5	Product View	Click on Banner			

Contextual Partitioning

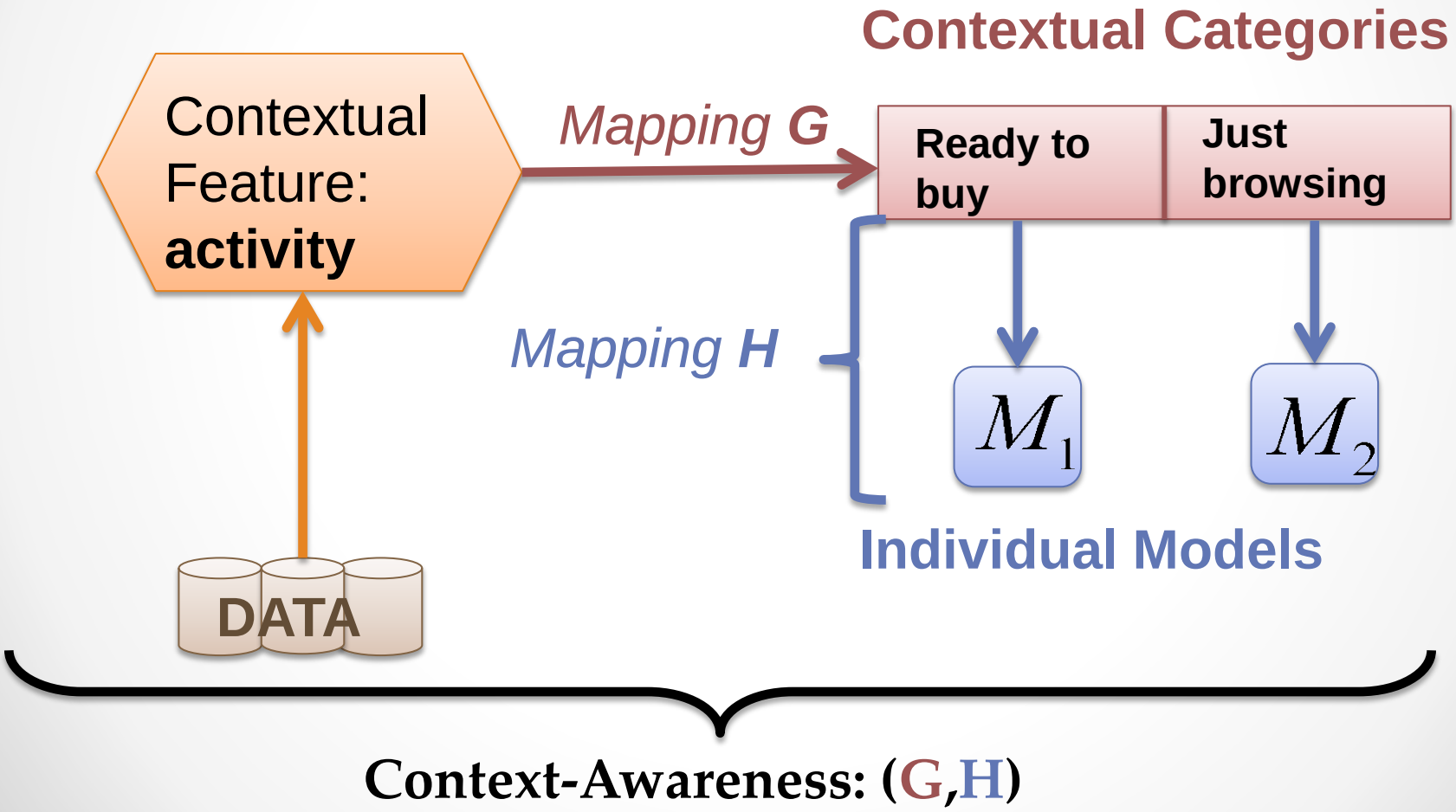
- Approaches to create local models:
  - Horizontal partition
  - Vertical partition:
    - Two types of behavior:
      - Ready to buy – (**Product View**, **Payment**)
      - Just browsing – (**Search**, **Refine Search**, **Click on Banner**)

Session 1	Search	Refine Search	Click on Banner	Product View	Payment
Session 2	Product View	Payment			
Session 3	Search	Refine Search	Refine Search	Click on Banner	
Session 4	Search	Refine Search	Click on Banner	Product View	Payment
Session 5	Product View	Click on Banner			

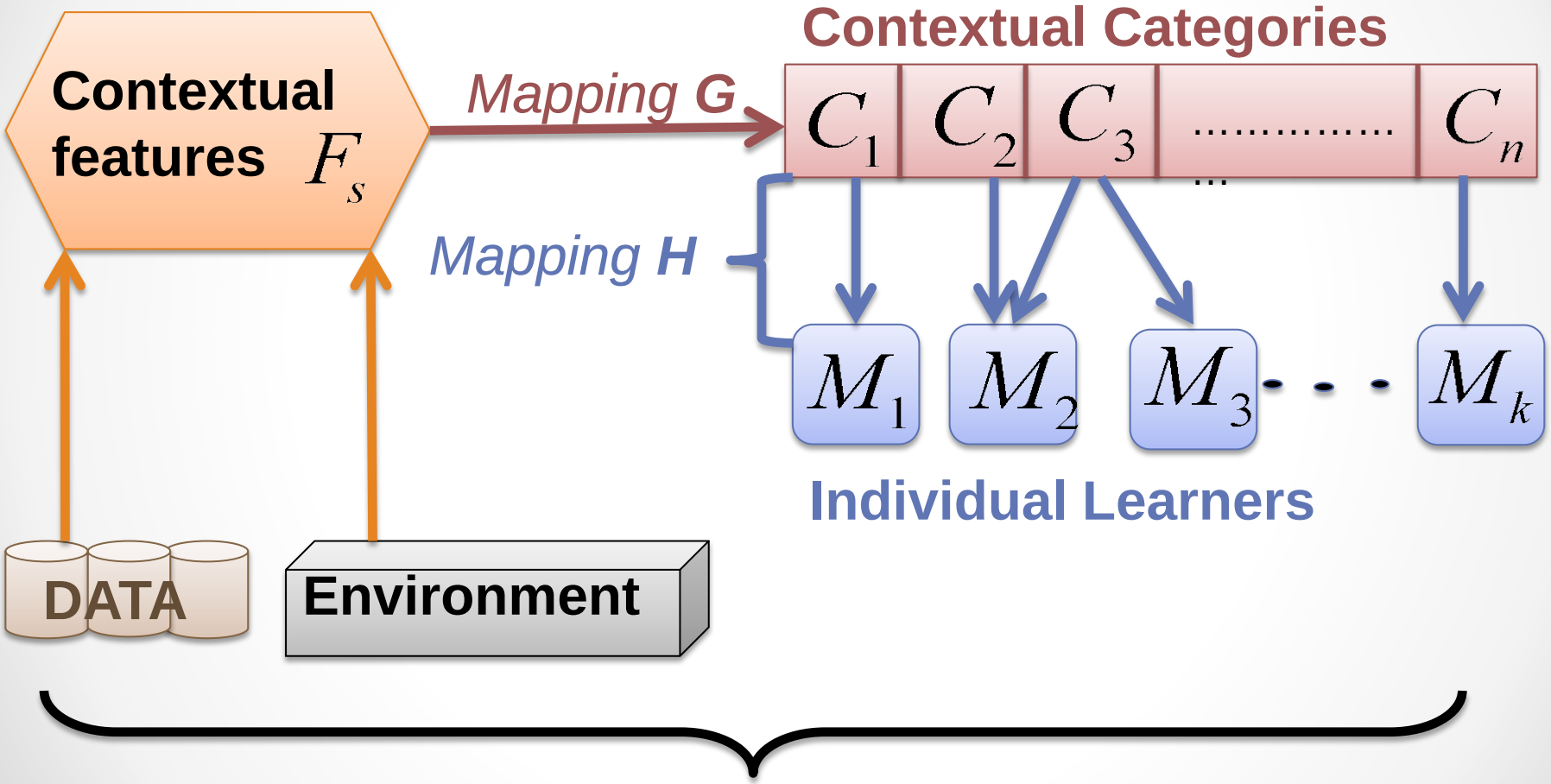
Vertical Partitioning



Context-Awareness Example



Context-Awareness



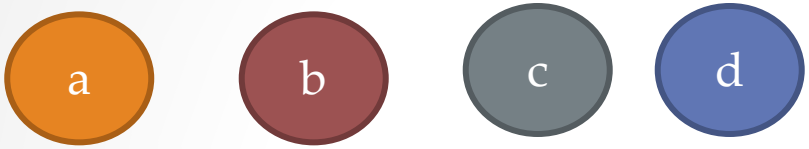
Optimization problem

$$F_{c_i}(T_{validation_i}, M_i) = \sum_{a_j \in T_{validation_i}} F(a_j, M_i)$$

$$EF(E) = \sum_{i=1}^{h} F_{c_i}(T_{validation_i}, M_i)$$

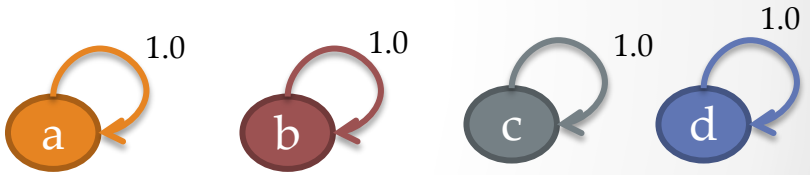
$$EF^* = \arg\max_{E} EF(T_{validation}, M))$$

Hierarchical Clustering



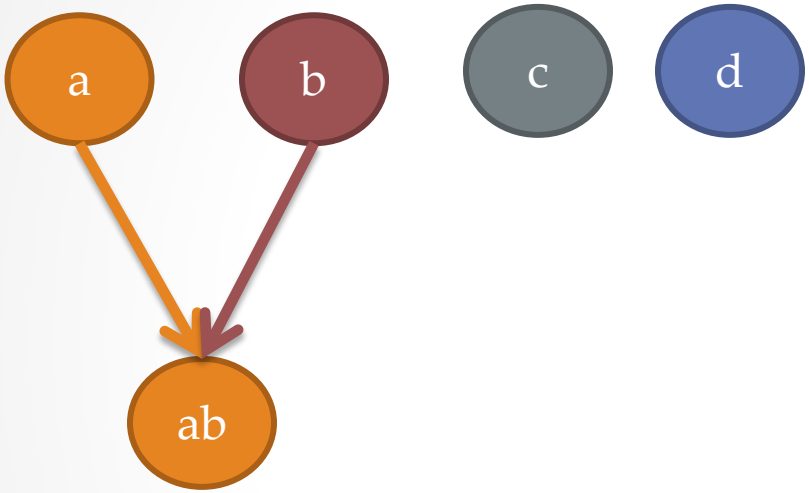
abababababcdcdababcdcdcd

The number of true predictions = 0



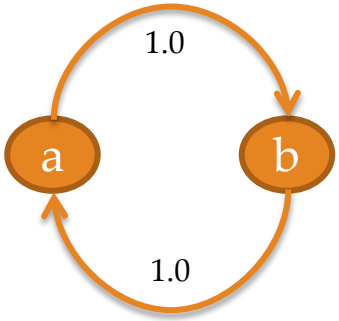
M_1 M_2 M_3 M_4

Hierarchical Clustering

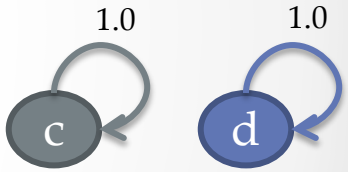


abababababcdcdababcdcdcd

The number of true predictions = 12

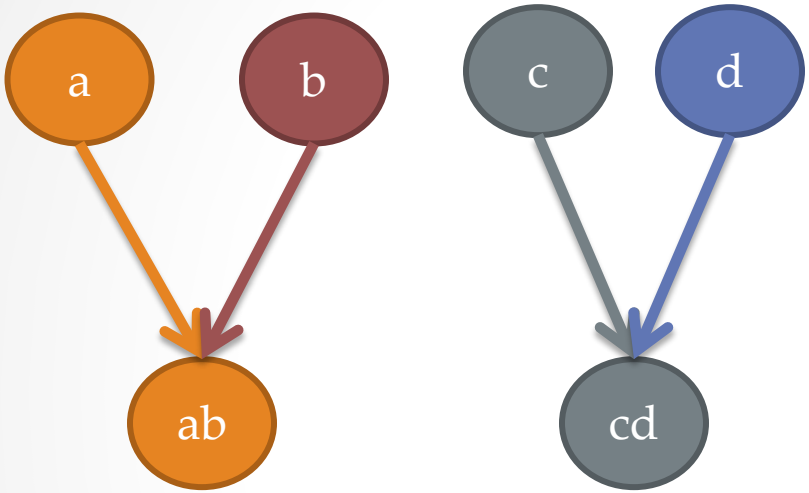


M_1



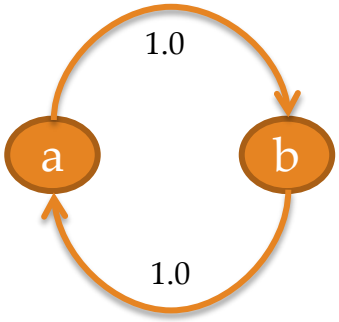
M_2 M_3

Hierarchical Clustering

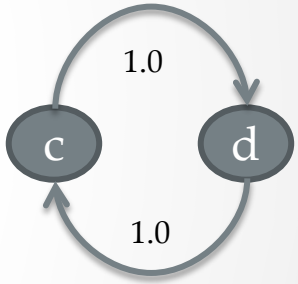


abababababcdcdababcdcdcd

The number of true predictions = 20

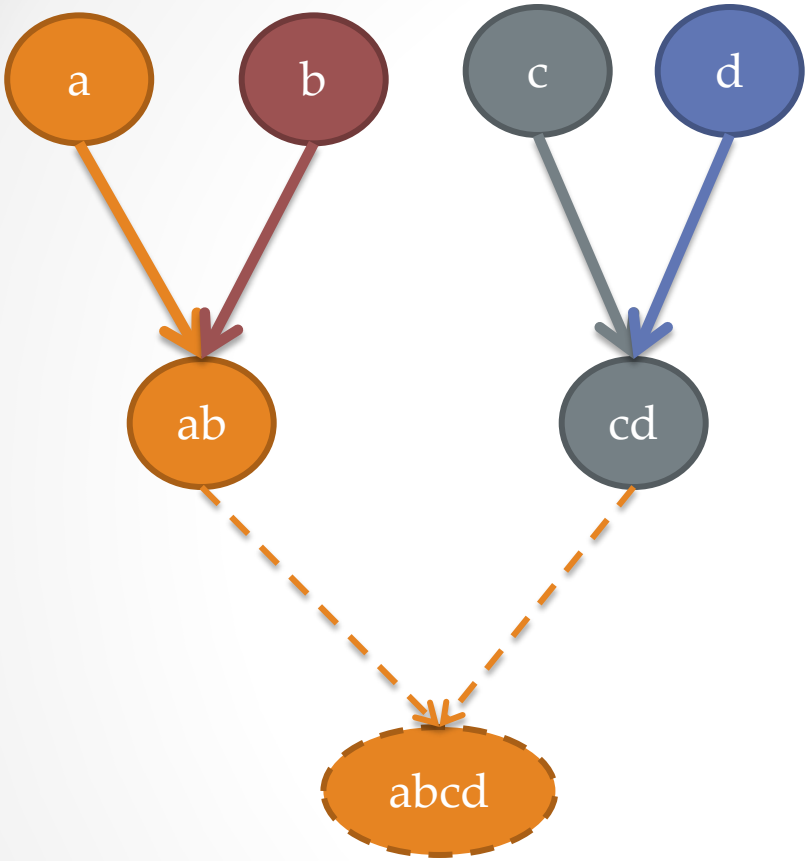


M_1



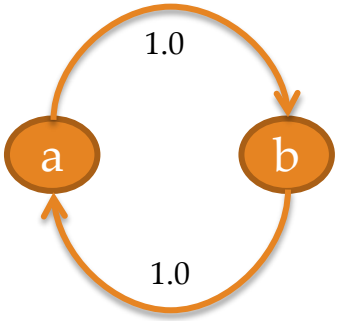
M_2

Hierarchical Clustering

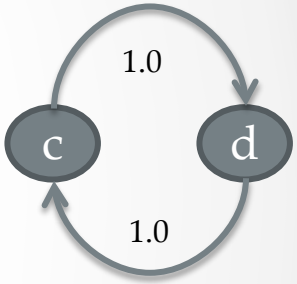


abababababcdcdababcdcdcd

The number of true predictions = 20



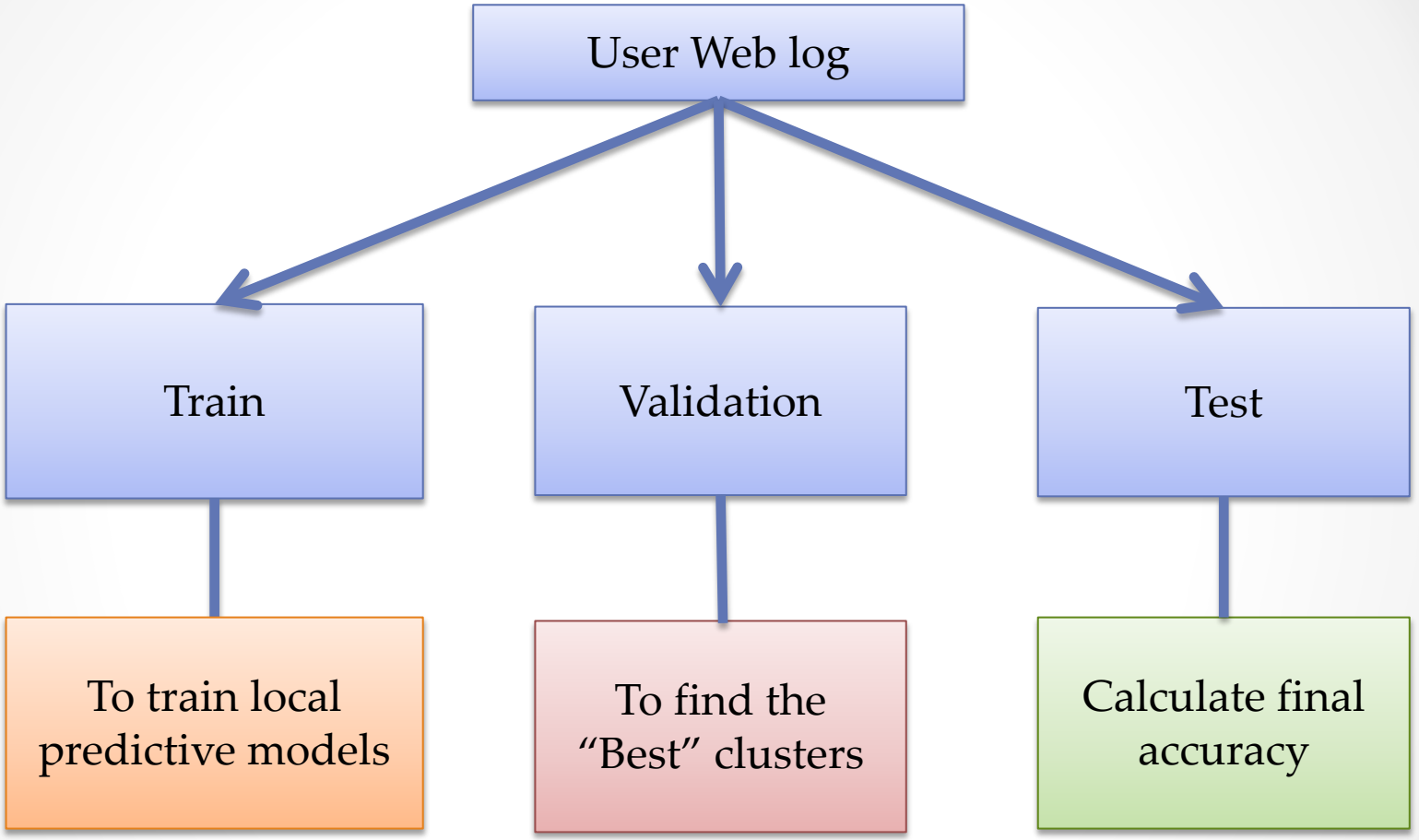
M_1



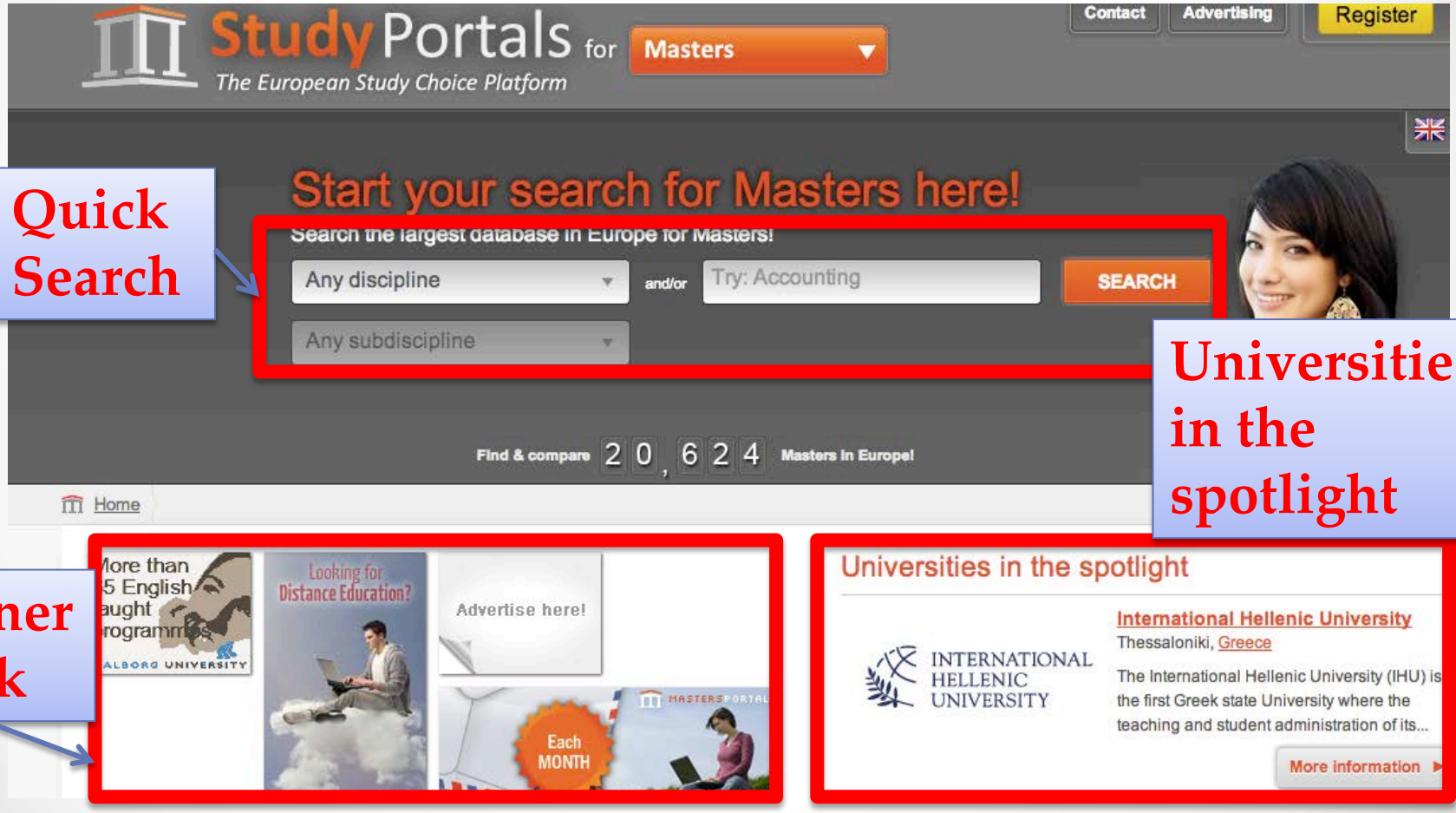
M_2

Stop as long as no additional prediction benefit of merging

Experiment Design



Mastersportal.eu - Homepage

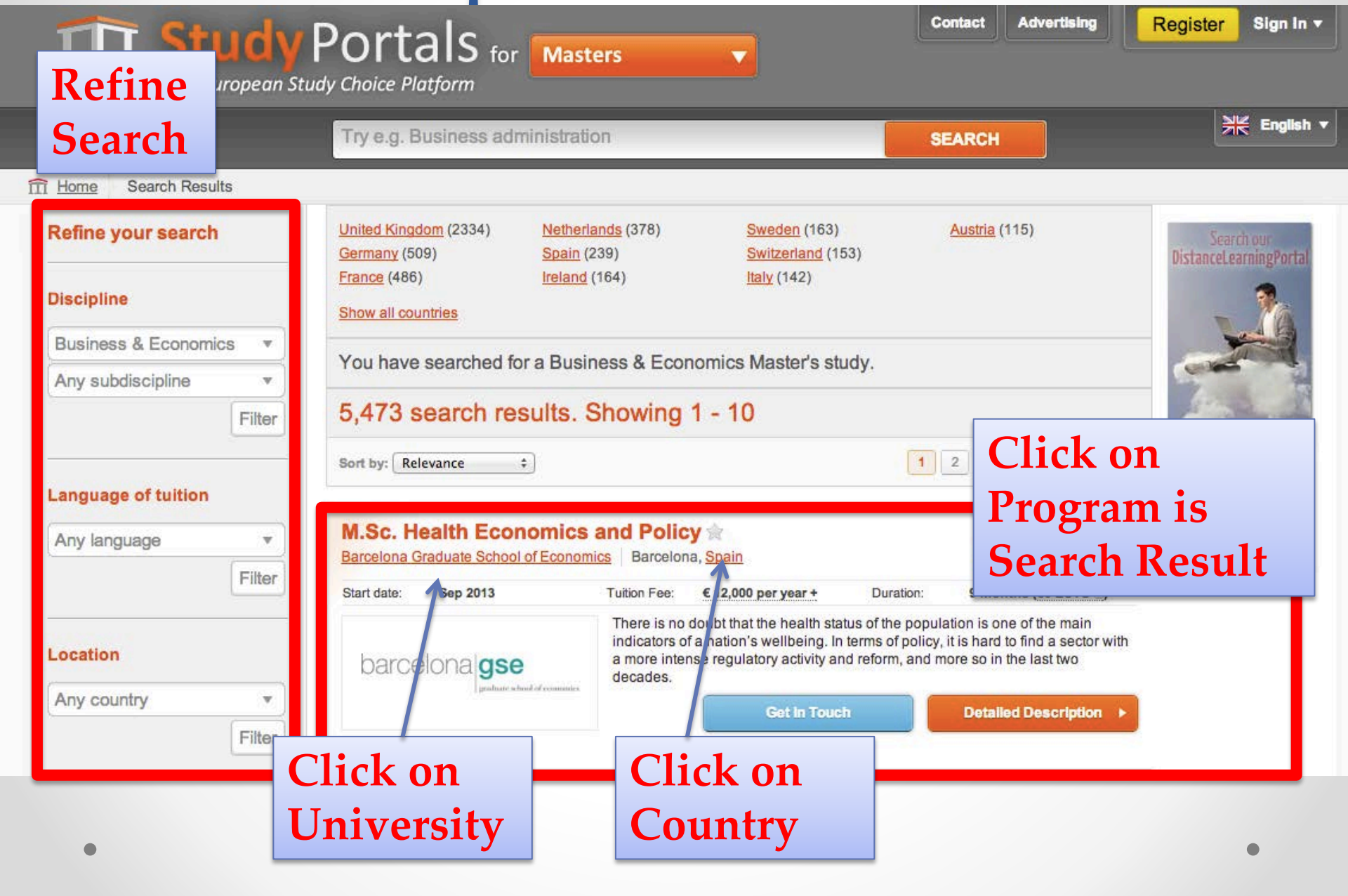


Quick Search

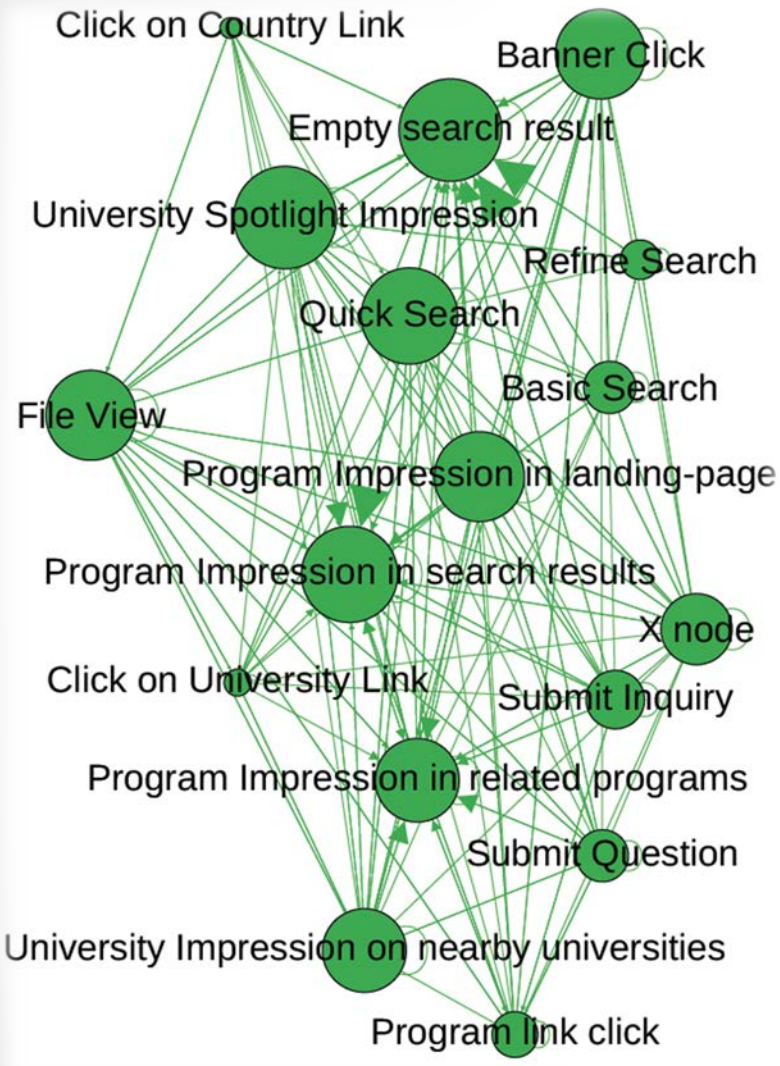
Universities in the spotlight

Banner Click

Mastersportal.eu - Search

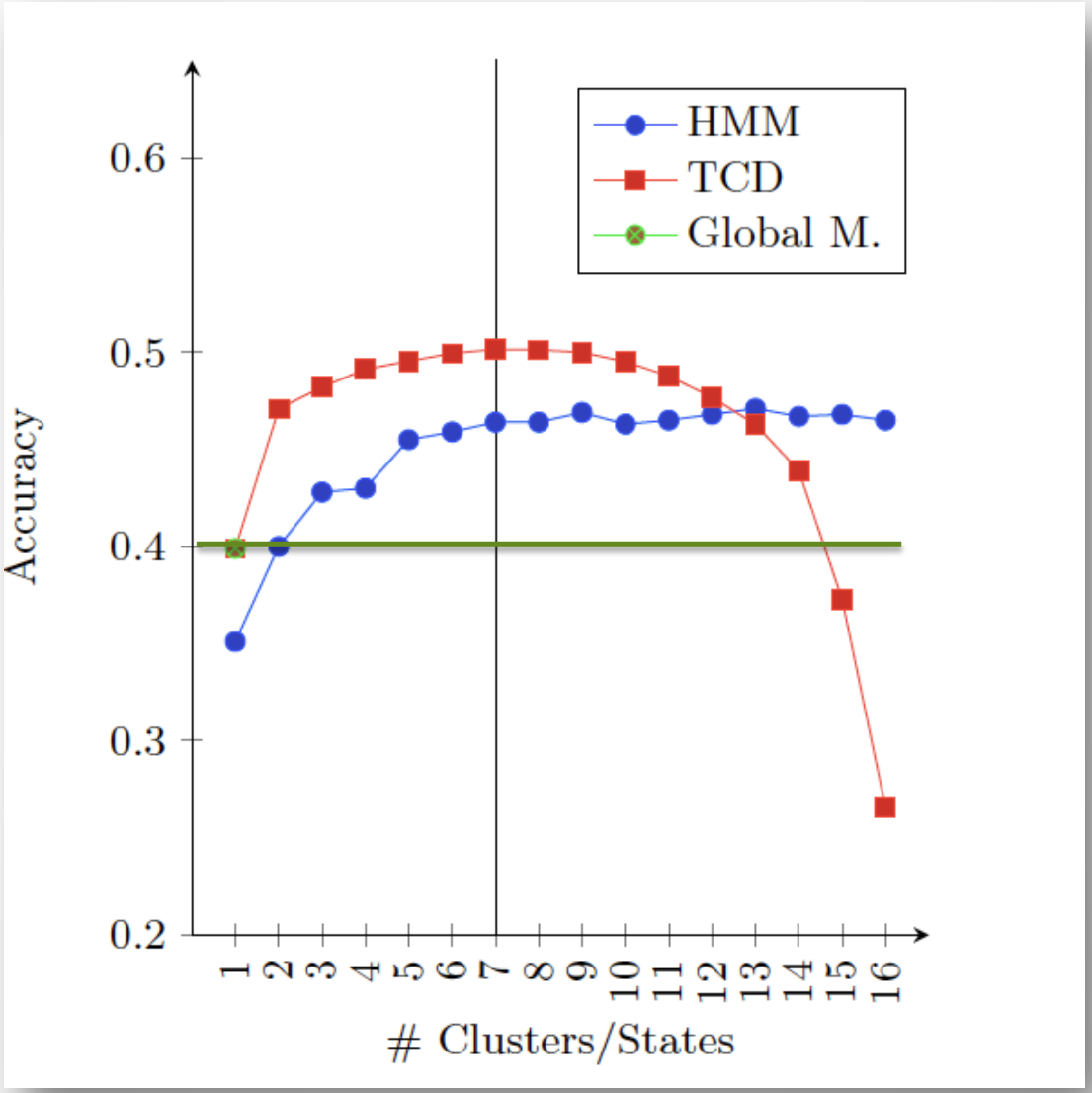


Dataset

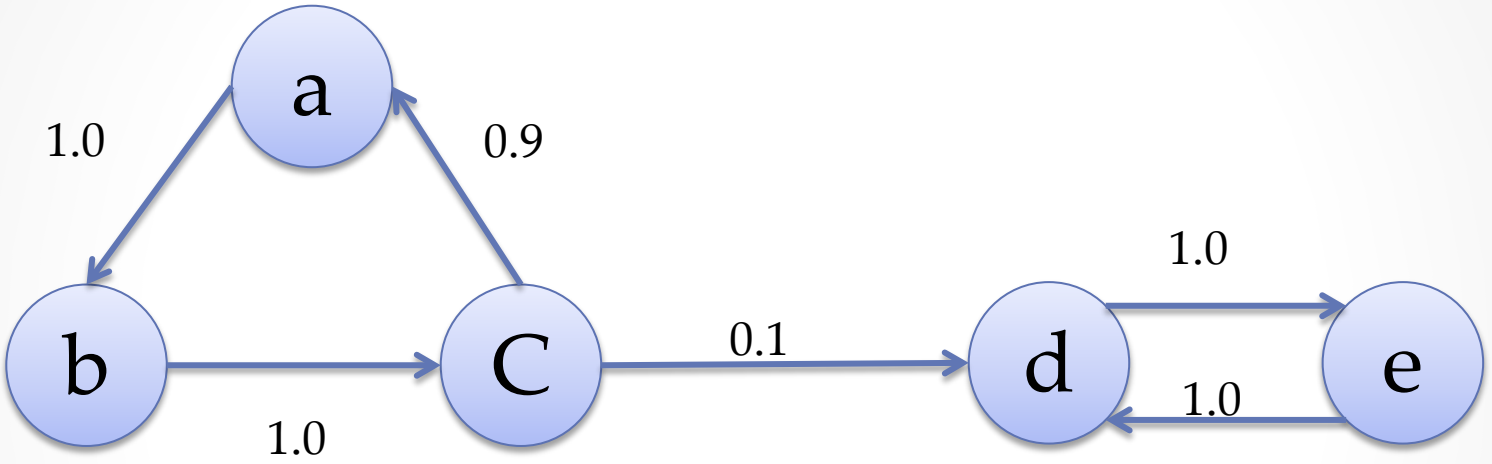


Period	May 2012
#sessions	350.618
#requests	1.775.711

Results


HMM
TCD
Global M.
Accuracy
0.6
0.5
0.4
0.3
0.2
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Clusters/States

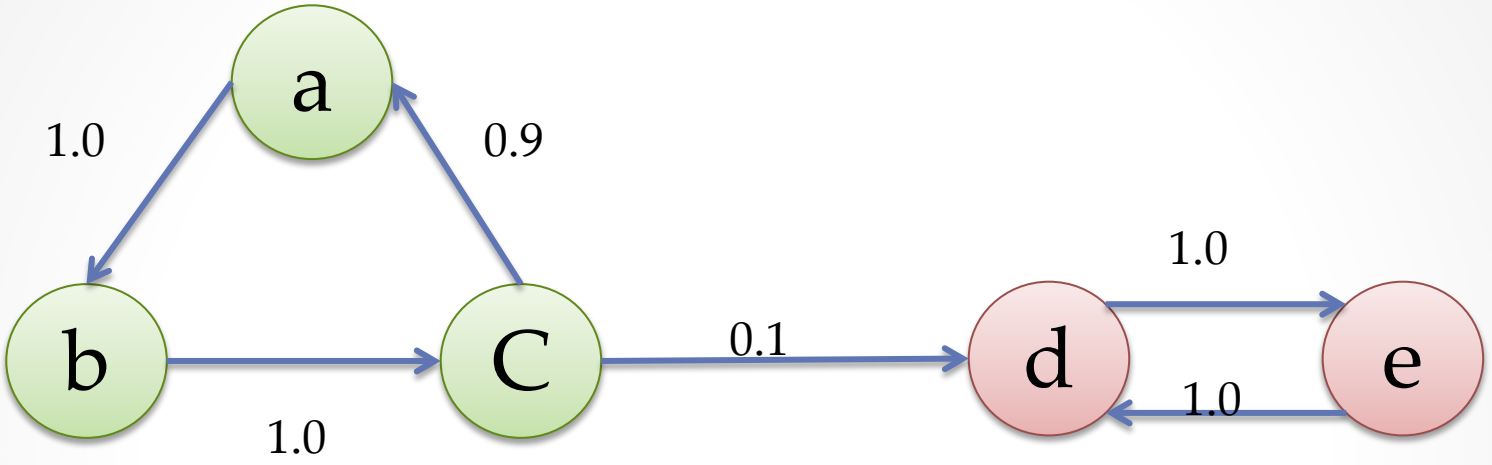
Explaining Results



In theory:
- Ideal local Markov models will be at most as good as an ideal global Markov model

In practice:
- We observe that local models become more accurate

Explaining Results

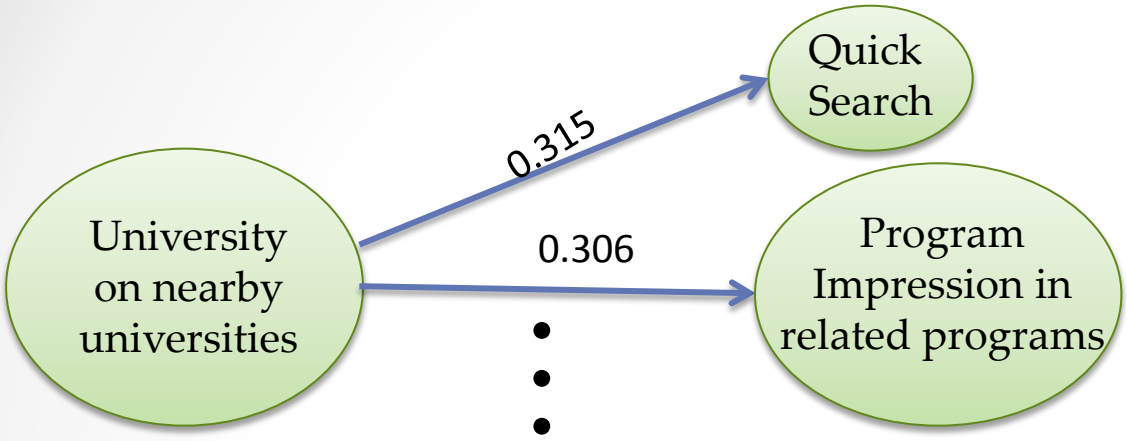


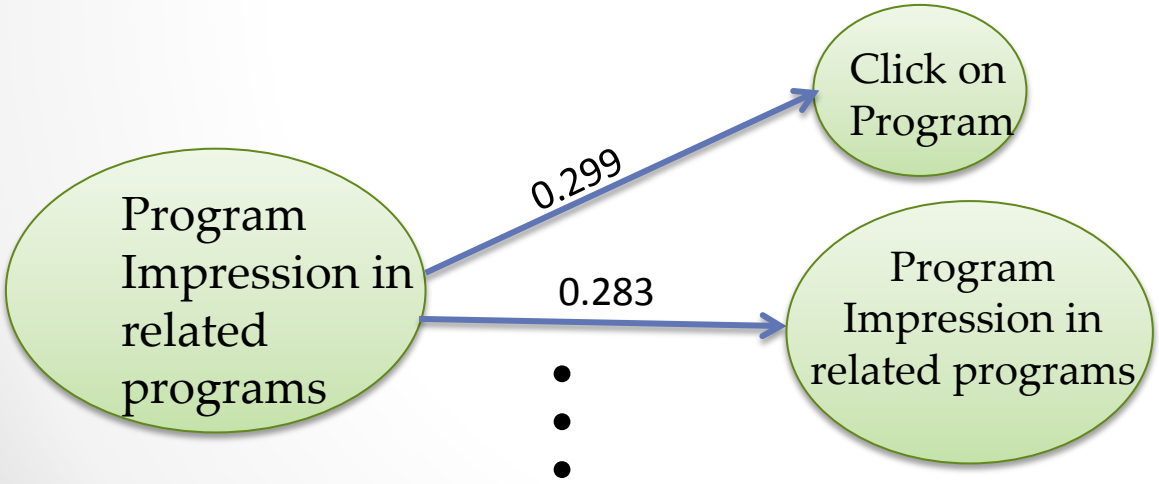
Possible explanation:

1. Users' behavior doesn't follow Markov property
2. "Ambiguous" transition probabilities. Local models can get better estimates

Further study of this phenomenon is required

Explaining Results





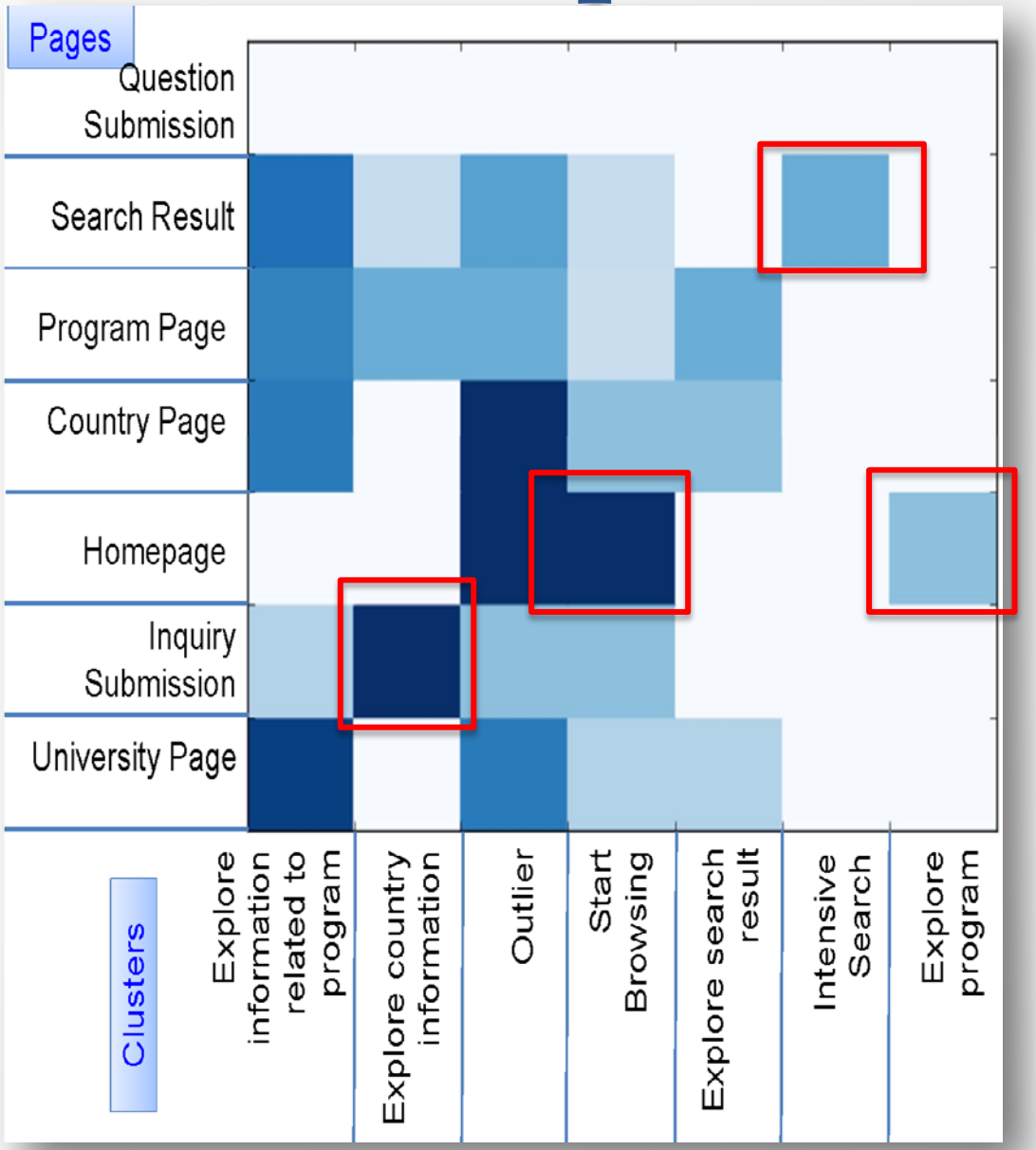
Resulted Clusters

Id	Summary	Cluster
1	Intensive Search	Basic Search, Refine Search, Empty Search Result
2	Explore information related to program	Program impression in search result, Banner click, Program click , Click on university link
3	Start of browsing	University Spotlight impression, Quick search
4	Explore country information	File view, Click on country link
5	Explore search result	Program Impression in related programs, University impression on nearby universities
6	Explore program	Program in landing page, Submit inquiry
7	Outlier	Submit question, X-node

Site Map

- Page is represented as set of possible actions
  - Example: Homepage is (Quick Search, University Spot light impression, Question Submit)
  - Calculate Jaccard similarity between Page and Cluster

Site map


Pages
Question Submission
Search Result
Program Page
Country Page
Homepage
Inquiry Submission
University Page
Clusters
Explore information related to program
Explore country information
Outlier
Start Browsing
Explore search result
Intensive Search
Explore program

Conclusion

- We formulate the problem of temporal context discovery as an optimization problem.
- A hierarchical clustering method is proposed to determine the optimal number of hidden contexts and mine temporal contexts.
- We show a real-world use case in which the contexts as we defined them do exist and are useful for prediction.

Future Works

- Considering multidimensional contextual features (i.e. sessions and activities live in vector space).
  - Strategies for vertical and horizontal partitioning
- Introducing a mechanism for detecting/predicting context switching within a web-session.
- Testing our method on more datasets.

Thank You!

- **C**ontext identification and integration it into prediction models
- **A**ccurately predicting users' desired actions and understanding behavioral patterns of users in various web-applications
- **P**ersonalization and adaptation to diverse customer need and preferences
- **A**ccounting for the practical needs within the considered application areas.

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ULB

studyportals
The European Study Choice Platform

Conclusion

- We formulate the problem of temporal context discovery as an optimization problem.
- A hierarchical clustering method is proposed to determine the optimal number of hidden contexts and mine temporal contexts.
- We show a real-world use case in which the contexts as we defined them do exist and are useful for prediction.

Questions?