Tell Me Something I Don't Know: Randomization Strategies for Iterative Data Mining

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Motivation

- **Exploratory data mining**
- **Different algorithms used**
  - **Output different types of patterns**
    - **Itemsets, clusters, subgraphs, etc..**
  - **Obtain collections of results**
- **Do all results present different information?**
  - **If they look different, do they present the same information?**

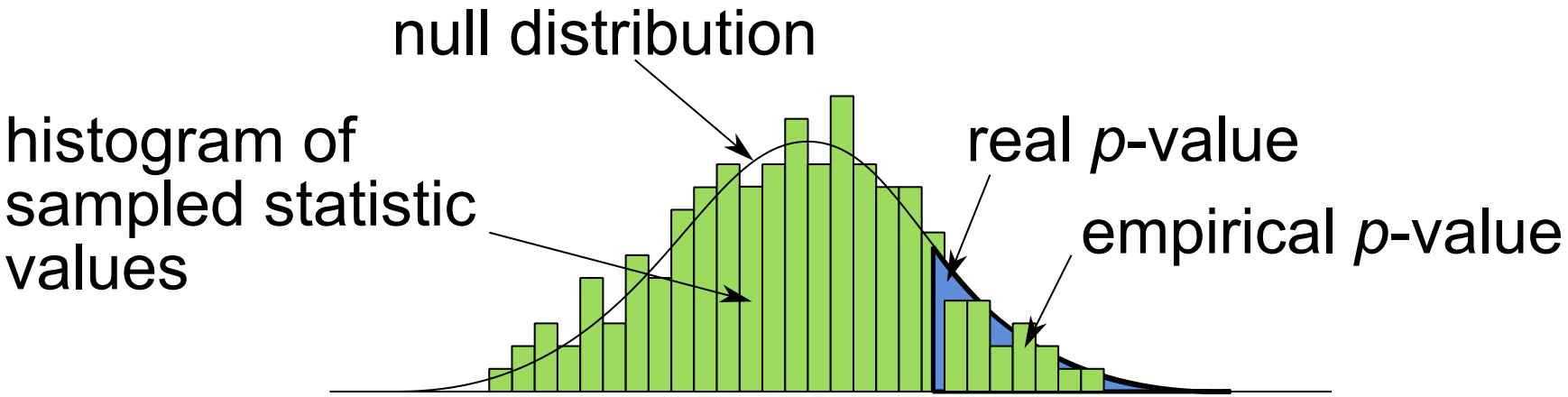
Basic idea

- **Use randomization to assess statistical significance**
- **First tell the user something that is significant**
- **Then tell something that is not implied by previous information**
  - **Randomize while maintaining previous information**
- **Iterate**

Outline of the presentation

- Problem and basic idea
- Motivating example
- Approach and solutions
- Iterative data mining examples
- Conclusions

Empirical p-values



- **Choose a test statistic**
- **Null distribution**
  - **Use randomization**
- ***p*-value**
- **Multiple hypothesis testing**

Motivating example

- **Locations where**
  - **Rat**
  - **Gorilla**
  - **Bird**
  - **Otter**

  have been found
- **Assuming independence, co-occurrence by chance?**

Original dataset

	R	G	B	O
Location 1	1	1	0	0
Location 2	1	1	0	0
Location 3	1	1	1	1
…	1	1	1	1
	0	0	1	1
	0	0	1	1
	0	0	0	0
	0	0	0	0

Motivating example

- **Locations where**
  - **Rat**
  - **Gorilla**
  - **Bird**
  - **Otter**

  have been found
- **Assuming independence, co-occurrence by chance?**

1st randomized

R	G	B	O
1	0	1	1
0	1	0	0
1	1	0	1
0	1	0	0
0	1	1	0
1	0	1	1
0	0	1	0
1	0	0	1

Motivating example

- **Locations where**
  - **Rat**
  - **Gorilla**
  - **Bird**
  - **Otter**

  have been found
- **Assuming independence, co-occurrence by chance?**

2nd randomized

R	G	B	O
0	1	0	0
1	1	0	1
1	0	1	1
1	0	1	0
0	1	0	0
0	0	1	1
0	0	1	0
1	1	0	1

Motivating example

- **Locations where**
  - **Rat**
  - **Gorilla**
  - **Bird**
  - **Otter**

  have been found
- **Assuming independence, co-occurrence by chance?**

3rd randomized

R	G	B	O
1	0	0	1
1	1	1	0
0	0	1	0
0	1	1	1
1	0	0	0
0	1	0	1
0	0	0	1
1	1	1	0

Motivating example

- **Locations where**
  - **Rat**
  - **Gorilla**
  - **Bird**
  - **Otter**

  have been found
- **Assuming independence, co-occurrence by chance?**
- **All co-occurrences significant**

N^{th} randomized

R	G	B	O
1	1	1	0
1	0	1	1
0	0	1	0
1	0	1	0
0	1	0	0
0	0	0	1
1	1	0	1
0	1	0	1

Motivating example

- Fix the information about RG
- Assume independence, given the co-occurrence count of RG
- What else is there in the data?

Original dataset

R	G	B	O
1	1	0	0
1	1	0	0
1	1	1	1
1	1	1	1
0	0	1	1
0	0	1	1
0	0	0	0
0	0	0	0

Motivating example

- Fix the information about RG
- Assume independence, given the co-occurrence count of RG
- What else is there in the data?

1st randomized

R	G	B	O
0	0	1	1
1	1	0	0
0	0	1	0
1	1	0	1
0	0	1	1
1	1	0	0
1	1	0	1
0	0	1	0

Motivating example

- Fix the information about RG
- Assume independence, given the co-occurrence count of RG
- What else is there in the data?

2nd randomized

R	G	B	O
0	0	1	0
0	0	1	0
1	1	1	1
1	1	0	0
0	0	0	1
1	1	0	0
0	0	1	1
1	1	0	1

Motivating example

- **Fix the information about RG**
- **Assume independence, given the co-occurrence count of RG**
- **What else is there in the data?**

3rd randomized

R	G	B	O
1	1	0	0
0	0	1	1
0	0	0	0
1	1	0	1
1	1	1	1
0	0	1	0
0	0	0	1
1	1	1	0

Motivating example

- Fix the information about RG
- Assume independence, given the co-occurrence count of RG
- What else is there in the data?
- RG, RGB and RGO by chance
  - Co-occurrence count of RG explains these
- BO, RBO, GBO and RGBO still significant

N^{th} randomized

R	G	B	O
1	1	0	1
0	0	1	0
1	1	1	1
0	0	0	0
0	0	1	1
1	1	0	0
0	0	0	1
1	1	1	0

Motivating example

- Fix the information about RG and BO
- Assume independence, given co-occurrence counts of RG and BO
- What else is there in the data?

Original dataset

R	G	B	O
1	1	0	0
1	1	0	0
1	1	1	1
1	1	1	1
0	0	1	1
0	0	1	1
0	0	0	0
0	0	0	0

Motivating example

- Fix the information about RG and BO
- Assume independence, given co-occurrence counts of RG and BO
- What else is there in the data?

1st randomized

R	G	B	O
1	1	0	0
0	0	1	1
1	1	1	1
0	0	0	0
0	0	1	1
1	1	0	0
1	1	1	1
0	0	0	0

Motivating example

- Fix the information about RG and BO
- Assume independence, given co-occurrence counts of RG and BO
- What else is there in the data?

2nd randomized

R	G	B	O
0	0	1	1
1	1	0	0
0	0	0	0
1	1	1	1
1	1	0	0
0	0	1	1
0	0	1	1
1	1	0	0

Motivating example

- Fix the information about RG and BO
- Assume independence, given co-occurrence counts of RG and BO
- What else is there in the data?

3rd randomized

R	G	B	O
0	0	0	0
0	0	1	1
1	1	0	0
1	1	0	0
0	0	0	0
0	0	1	1
1	1	1	1
1	1	1	1

Motivating example

- Fix the information about RG and BO
- Assume independence, given co-occurrence counts of RG and BO
- What else is there in the data?
- All else by chance
- Conclusion: Column sums and RG and BO explain data

N^{th} randomized

R	G	B	O
1	1	0	0
0	0	1	1
0	0	0	0
1	1	1	1
1	1	0	0
0	0	0	0
1	1	1	1
0	0	1	1

Problem

- **Do different results explain same the structure?**
- **How to iteratively tell something new?**
- **We consider only 0-1 data**

Outline of the presentation

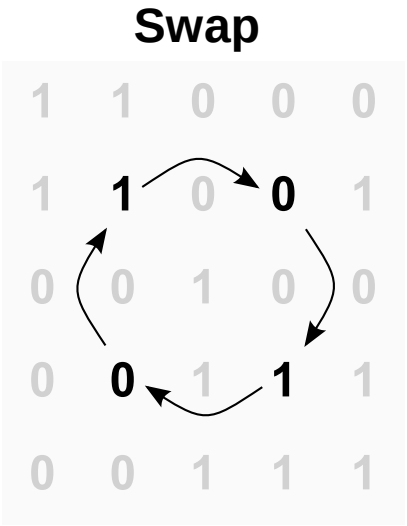
- Problem and basic idea
- Motivating example
- **Approach and solutions**
- Iterative data mining examples
- Conclusions

Approach

- **Use randomization to obtain empirical *p*-values**
- **First assess if results significant in general case**
- **Iterate**
  - **Select part of significant result**
  - **Constraint randomization with that part**
  - **Assess the rest**
- **All information of non-significant results contained in constraints**

Solutions

- **Baseline**
  - Maintain column and row sums (margins)
  - Swap randomization (Cobb *et al.* 2003)
- **Randomize and maintain frequencies of selected itemsets**
  - Exact solution NP-hard
- **Maintain frequencies approximately**
  - Swap randomization is a Markov-chain
  - Use Metropolis-Hastings

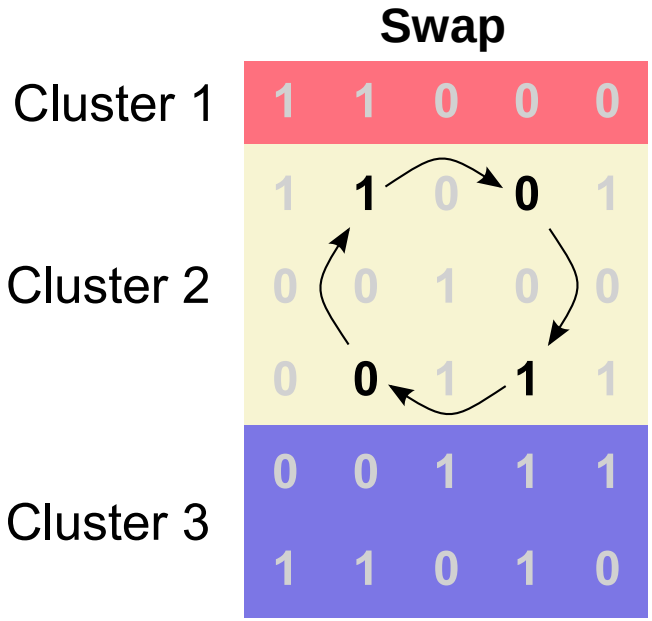


Solutions

- **Iterate (standard Metropolis-Hastings)**
  - Find a random swap
  - Calculate error in maintained frequencies
  - Perform swap
    - Always, if error does not increase
    - With decreasing probability in increasing error
- **With enough swaps, matrix is random while satisfying constraints**
  - Mixing time hard to estimate
  - Besag and Clifford

Solutions

- **Randomize and maintain cluster structure**
  - **Clustering on rows**
  - **Randomize in each cluster separately**
  - **Keeps clustering error constant**



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Iterative data mining examples

- **Significant itemsets of size 2**
  - **Compare itemset and clustering constraints**
- **Discovering significant itemsets iteratively**
  - **Example iterative process**

Significant itemsets of size 2

- **Assess the significance of all possible size 2 itemsets**
- **Paleo dataset**
  - **Items are species**
  - **Transactions are excavation sites**

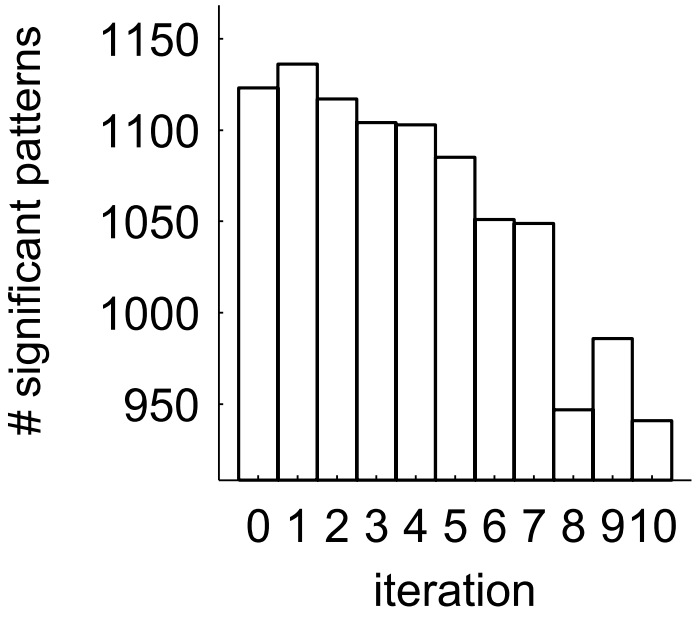
Significant itemsets of size 2

- **Randomize and maintain clustering structure**
  - **With 3 clusters, no itemset significant**
- **Randomize and maintain frequencies of adjacent itemsets**
  - **Some itemsets significant**
  - **Clustering significant**

Discovering significant itemsets iteratively

- **Only consider itemsets of size 2 and 3**
  - **Count number of significant itemsets**
- **Iteratively add one itemset to constraints**
  - **Select itemset with smallest *p*-value**
  - **Count number of significant itemsets**

Discovering significant itemsets iteratively



Iterative data mining examples

- **More detailed experiments in the paper and poster**

Paleo		CM	
		N	S
IM	N	8977	**0**
	S	614	**0**

Paleo		M	
		N	S
IM	N	**8832**	145
	S	60	**544**

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- **Conclusions**

Conclusions

- **Different results may explain the same phenomenon**
- **Iteratively find significant information in data**
- **Statistical significance to measure overlap**
- **Example shown in specific problem area**

- **Questions?**
- **Comments?**
- **More information at the poster in today's session**