BDTLN + ROOT ERL 7002

The Travelling Analyst Problem

Orienteering applied to exploratory data analysis

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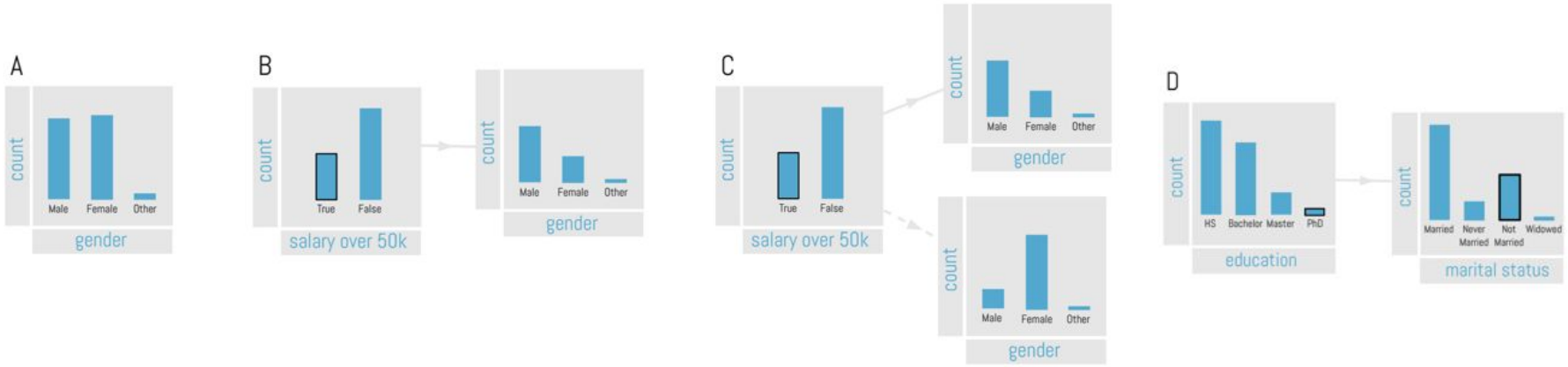
Exploratory Data Analysis

- Interactive analysis of large volumes of data



- Outcome: a sequence of meaningful queries

- **Challenge** *: how to produce this sequence automatically?*

Comparison Queries

```
select t1.continentexp as "Continent", April as "April", May as "May"
from
(select month, continentexp, sum(cases) as April
from covid
where month = '4'
group by month, continentexp) t1,
(select month, continentexp, sum(cases) as May
from covid
where month = '5'
group by month, continentexp) t2
where t1.continentexp = t2.continentexp;
```

sum of cases

Continent	April	May
Europe	863874	608110
Oceania	2812	467
America	1104862	1404912
Africa	31598	92626
Asia	333821	537584

$$\pi_{a,val,val'}((\gamma_{a,agg(m)\rightarrow val}(\sigma_{b=val}(R))) \bowtie (\gamma_{a,agg(m)\rightarrow val'}(\sigma_{b=val'}(R))))$$

Comparison is a common activity for data analysts (Zgraggen 2018)

Comparison queries - Limit the search space

continentexp	countriesandterritories	day	month	cases	deaths
America	Curacao	29	5	1	0
America	Curacao	28	5	0	0
America	Curacao	27	5	0	0
America	Curacao	26	5	1	0
America	Curacao	25	5	1	0
America	Curacao	24	5	0	0
America	Curacao	23	5	0	0
America	Curacao	22	5	0	0
America	Curacao	21	5	0	0
America	Curacao	20	5	0	0
America	Curacao	19	5	0	0
America	Curacao	18	5	0	0
America	Curacao	17	5	0	0
America	Curacao	16	5	0	0

Schema : *A* categoricals attributes, *M* measures, *G* aggregations {min, max, sum, avg}

Instance (10^3 lines)

Active Domain : *v* values

$$\pi_{a,val,val'}((\gamma_{a,agg(m)\rightarrow val}(\sigma_{b=val}(R))) \bowtie (\gamma_{a,agg(m)\rightarrow val'}(\sigma_{b=val'}(R))))$$

$$\text{Search space} = (\sum_{i \in [1 \dots n]} {}_{adom(Ai)}C_2) \cdot (|A|-1) \cdot |G| \cdot |M|$$

Problem statement

Given all possible comparison queries on a database :

- Find the sequence of queries
- Maximizing interestingness
- Such that it can be executed in limited time budget
- The distance over the sequence is minimal.

- The distance can be turned into an epsilon-bound.
- The execution time is given by DBMS

Distance between queries

- **Metric adapted from [Aligon 14]**

Q1

Age Group	Average deaths	
	India	UK
0-18	4	2
18-25	43	12
25-50	641	607
50-65	3000	3777
65+	5600	4286

Intuitively, d(Q1, Q2) < d(Q1, Q3)

Q2

Age Group	Average deaths	
	Germany	UK
0-18	4	2
18-25	43	12
25-50	641	607
50-65	3000	3777
65+	5600	4286

Q3

Eye color	Average deaths	
	Germany	UK
Blue	23	34
Green	43	45
Brown	567	345

Interest of a query

- **Interest = p-value of statistical tests validating the query result as evidence of an insight (Zgraggen 18)**

Age Group	Average deaths	
	India	UK
0-18	4	2
18-25	43	12
25-50	641	607
50-65	3000	3777
65+	5600	4286

- Insight -> H0“Deaths are independent of Age”
- One evidence: average deaths in UK and India by Age Group
- Verification -> Statistical test
- Interest -> 1 - p-value

Problem Formulation

- Extension of the Orienteering Problem, with a service time
- Model based on formulations from (Kara 16, Gunawan 16)

Data

$c_{i,j}$ the distance between queries, q_i and q_j. (Positive integer)
t_i denotes the execution time of q_i (Positive integer)
v_i is theinterestingness score associated with q_i (real number in [0,1])

Variables

$x_{i,j}, (i,j) \in 1..n, x_{i,j} = 1$ if q_i comes directly before q_j in the solution, 0 otherwise
$x_{0,i}, i \in 1..n, x_{i,j} = 1$ if q_i is the first query of the solution, 0 otherwise
$x_{i,n+1}, i \in 1..n, x_{i,j} = 1$ if q_i is the last query of the solution, 0 otherwise
$s_i, i \in 1..n$: boolean variables denoting the presence of q_i in the solution.
$u_i, i \in 1..n$: integer variables used in subtour elimination constraints.

Model

objective

$$max \sum_{i=1}^{n} v_i s_i \quad (1)$$

under constraints

$$\sum_{i=1}^{n} \sum_{j=1, j\neq i}^{n} c_{i,j} x_{i,j} \leq \epsilon_d \quad (2)$$

$$\sum_{i=1}^{n} t_i s_i \leq \epsilon_t \quad (3)$$

$$\sum_{i=0, j\neq i}^{n} (x_{i,j}) - s_j = 0, \forall j \in 1..n \quad (4)$$

$$\sum_{j=1, j\neq i}^{n+1} (x_{i,j}) - s_i = 0, \forall i \in 1..n \quad (5)$$

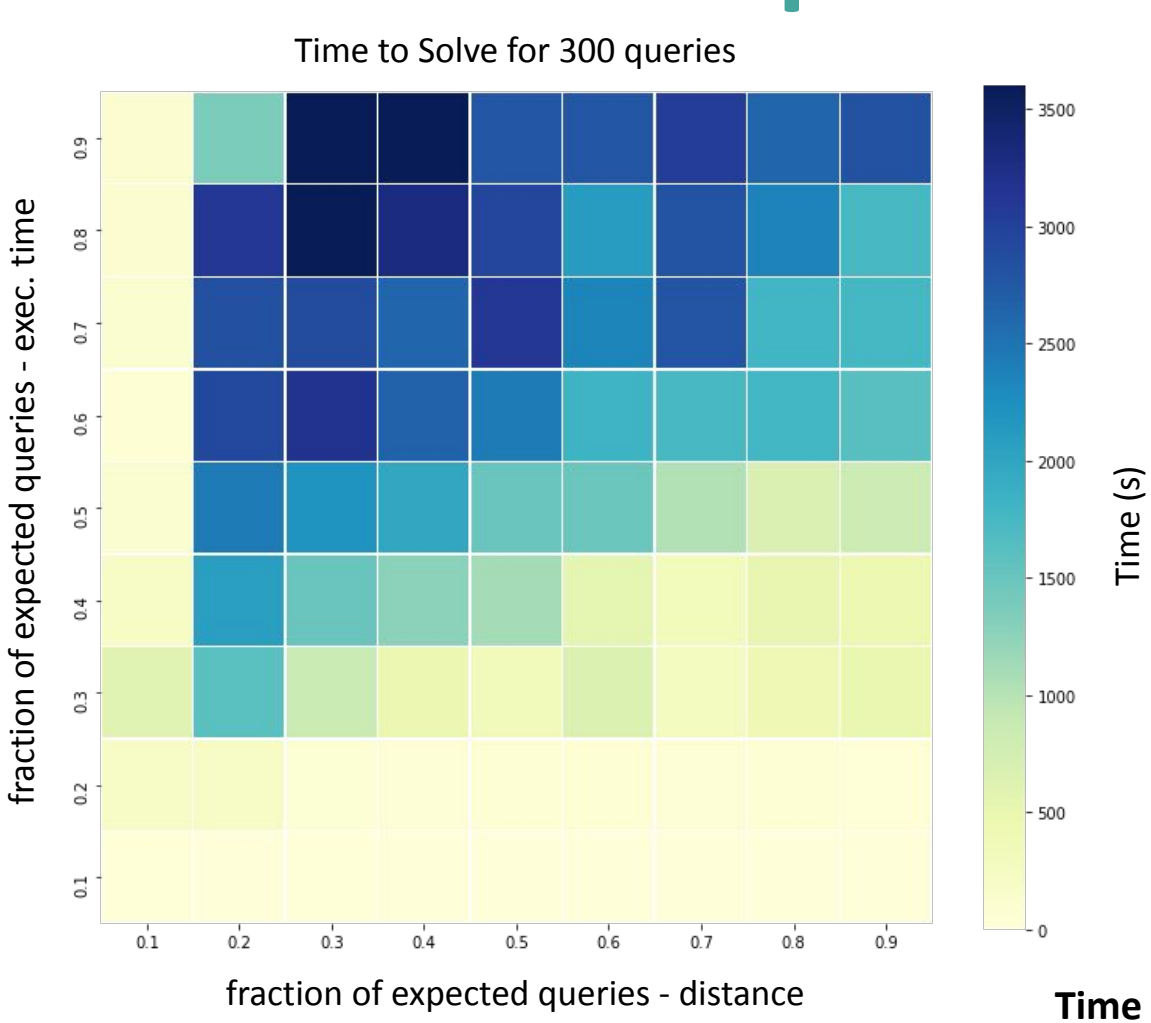
$$\sum_{j=1}^{n} x_{0j} = \sum_{i=1}^{n} x_{i,n+1} = 1 \quad (6)$$

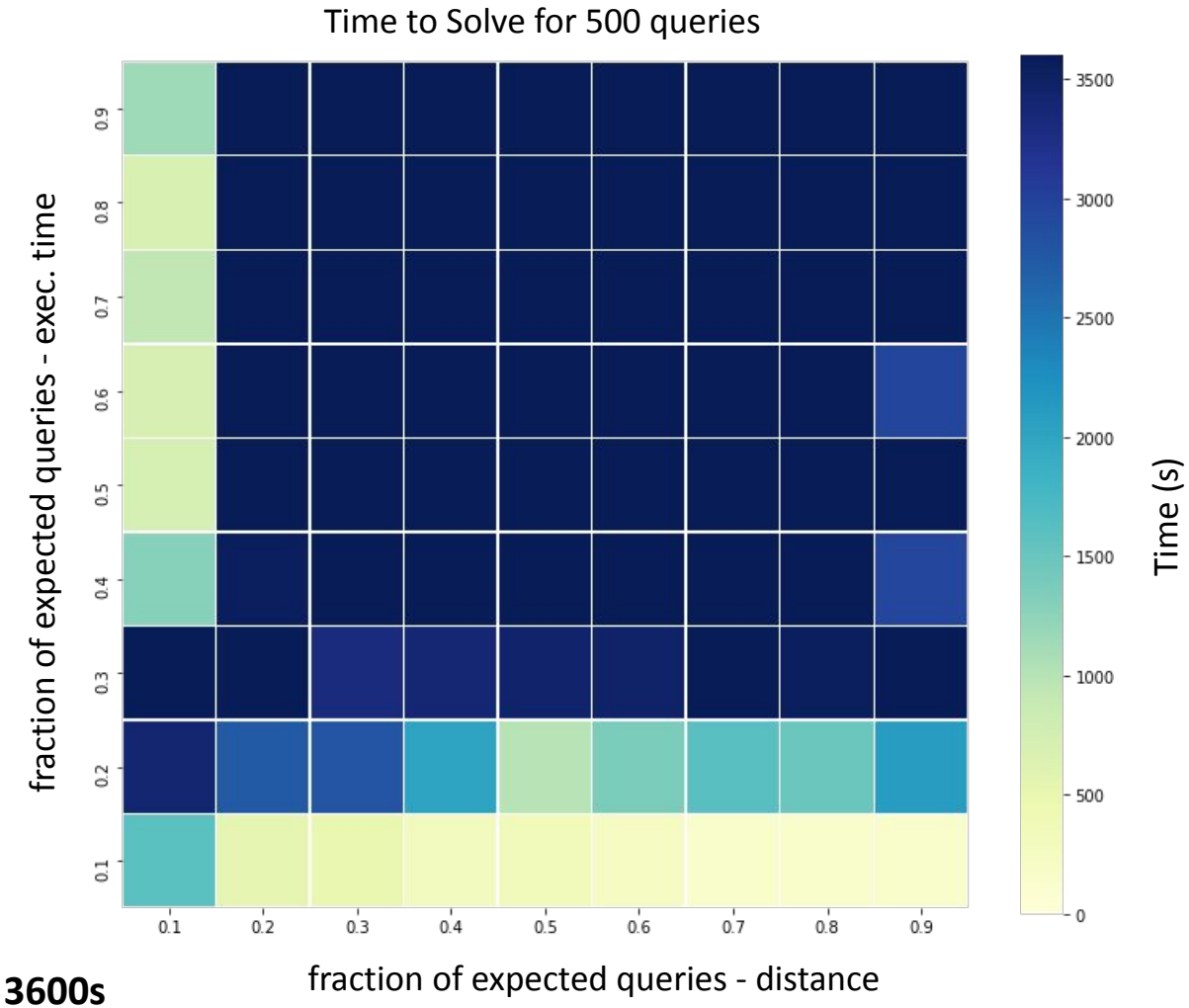
$$2 \leq u_i \leq n, i \in 1..n \ , \ u_i - u_j + 1 \leq (n-1)(1 - x_{ij}), (i,j) \in 1..n \quad (7)$$

Influence of epsilon-constraints

- Distances (integer) drawn from uniform distribution U(1,10)
- Interestingness (real) drawn from U(0,1)
- time (integer) drawn from U(5,50)
- Epsilon constraints expressed as a fraction of expected queries based on distribution mean

Influence of epsilon-constraints





Time OUT : 3600s

Constraint generation strategy

- Constraint generation strategy for subtour elimination (Pferschy 17)
  - Preliminary experiments shows substantial speedups on hard instances

Perspectives

- Exact solution is still tractable for smallest real instances (> 10^3 queries)
- Mathheuristics (VPLS) for large instance (> 10^4 queries)
- ‘Faster’ Heuristics for larger instances of the problem (> 10^6 queries)
- Addressing more generic query pattern (> 10^9 queries)
- Extension of the problem where a limited disk space can be used (indexing) to speed up some queries

References

Aligon 14 : Similarity measures for OLAP sessions, Julien Aligon, Matteo Golfarelli, Patrick Marcel, Stefano Rizzi, Elisa Turricchia, Knowledge and information systems 2014

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Pferschy 17: Generating subtour elimination constraints for the TSP from pure integer solutions, Ulrich Pferschy & Rostislav Staněk, Central European Journal of Operations Research 2017

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Thank You for Listening

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