Pattern mining in personal demographic trajectories

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Possible life events

- First job (job)
- The highest education degree is obtained (education)
- Leaving parents' home (separation)
- First partner (partner)
- First marriage (marriage)
- First child birth (children)
- Break-up (parting)
- ... (divorce)

Data and problem statement
[Ignatov et al., 2015],[Blockeel et al., 2001]

Generation and Gender Survey (GGS): three waves panel data for 11 generations of Russian citizens starting from 30s

Binary classification

1545 men

3312 women

Examples of sequential patterns

- $\langle\{education, separation\}, \{work\}, \{marriage\}, \{children\}\rangle(m)$
- $\langle\{work\}, \{marriage\}, \{children\}\{education\}\rangle(f)$
- $\langle\{partner\}, \{marriage, separation\}, \{children\}\rangle(f)$

Basic definitions

Texbooks of Han et al., Zaki & Meira, Aggarwal et al., etc

- $s = \langle s_1, ..., s_k \rangle$ is the **subsequence** of $s' = \langle s'_1, ..., s'_k \rangle$ ($s \preceq s'$) if $k \leq k'$ and there exist $1 \leq r_1 < r_2 < ... < r_k \leq k'$ such $s_j = s'_{r_j}$ for all $1 \leq j \leq k$.
- $support(s, D)$ is the **support** of a sequence s in D, i.e. the number of sequences in D such that s is their subsequence.

$$support(s, D) = |\{s' | s' \in D, s \preceq s'\}|$$

- s is a **frequent closed sequence (sequential pattern)** if there is no s' such that $s \prec s'$ and

$$support(s, D) = support(s', D)$$

Example

Let D be a set of sequences:

Таблица: Dataset D.

s_1	$\{a, b, c\}\{a, b\}\{b\}$
s_2	$\{a\}\{a, c\}\{a\}$
s_3	$\{a, b\}\{b, c\}$

- $I = \{a, b, c\}$ is the set of all items (atomic events)
- $\langle\{a, b\}\{b\}\rangle$ belongs to s_1 and s_3 but it is missing in s_2
- $support_D(\langle\{a, b\}\{b\}\rangle) = 2$
- $\{\langle\{a\}\rangle, \langle\{c\}\rangle, \langle\{a\}\{c\}\rangle, \langle\{a, b\}\{b\}\rangle, \langle\{a, c\}\{a\}\rangle\}$ is the set of closed sequences.

Contiguous prefix-based sequential patterns

- $s = \langle s_1, ..., s_k \rangle$ is a **contiguous prefix-based subsequence** of $s' = \langle s'_1, ..., s'_k \rangle$ ($s* = s'$) if $k \leq k'$ and $\forall i \in k' : s_i = s'_i$.
- **Support of contiguous prefix-based sequences**
  Let T be a set of sequences.

$$support(s, T) = \frac{|\{s' | s' \in T, s* = s'\}|}{|T|}$$

Contiguous prefix-based sequential patterns

- Let $0 < minSup \leq 1$ be a minimal support parameter and D is a set of sequences then **searching for prefix-based contiguous sequential patterns** is the task of enumeration of all prefix-based contiguous sequences s such that $support(s, D) \geq minSup$. Every sequence s with $support(s, D) \geq minSup$ is called a **prefix-based contiguous sequential pattern**.
- Prefix-based contiguous sequential pattern (PGSP) p is called **closed** if there is no PGSP d of greater of equal support such that $d = p*$.

Contiguous sequential patterns

Example

Таблица: D is a set of sequences.

s_1	$\{a\}\{b\}\{d\}$
s_2	$\{a\}\{b\}\{c\}$
s_3	$\{a,b\}\{b,c\}$

$$s = \langle\{a\}\{b\}\rangle$$

- $I = \{a, b, c\}$ is the set of all items (atomic events)
- $s_1 = s*; s_2 = s*$
- $s_3 \neq s*$
- $Supp_D(s) = \frac{2}{3}$
- $\langle\{a\}\{b\}\rangle$ is closed, $\langle\{a\}\rangle$ is not closed.

CAEP: Classification by Aggregating Emerging Patterns
G. Dong et al., 1999

Growth Rate

$$growth\_rate_{D' \to D''}(X) = \begin{cases} \frac{supp_{D''}(X)}{supp_{D'}(X)} \text{ if } supp_{D'}(X) \neq 0 \\ 0 \text{ if } supp_{D''}(X) = supp(X) = 0 \\ \infty \text{ if } supp_{D''}(X) \neq 0 \text{ and } supp_{D'}(X) = 0 \end{cases}$$

Class score

$$score(s, C) = \sum_{e \subseteq s, e \in E(c)} \frac{growth\_rate_C(e)}{growth\_rate_C(e) + 1} \cdot supp_c(e)$$

Emerging patterns for classification

s is a new object

$$normal\_score_{\oplus}(s) = \frac{\sum_{p \in P_{\oplus} : p \sqsubseteq s} GrowthRate(p, \mathbb{K}_{\oplus}, \mathbb{K}_{\ominus})}{median(GrowthRate(P_{\oplus}))}$$

$$normal\_score_{\ominus}(s) = \frac{\sum_{p \in P_{\ominus} : p \sqsubseteq s} GrowthRate(p, \mathbb{K}_{\ominus}, \mathbb{K}_{\oplus})}{median(GrowthRate(P_{\ominus}))}$$

Classification via emerging patterns

$$class(s) = \begin{cases} positive\ \ if\ normal\_score_{\oplus}(s) > normal\_score_{\ominus}(s) \\ negative\ \ if\ normal\_score_{\oplus}(s) < normal\_score_{\ominus}(s) \\ undetermined\ if\ normal\_score_{\oplus}(s) = normal\_score_{\ominus}(s) \end{cases}$$

Execution example

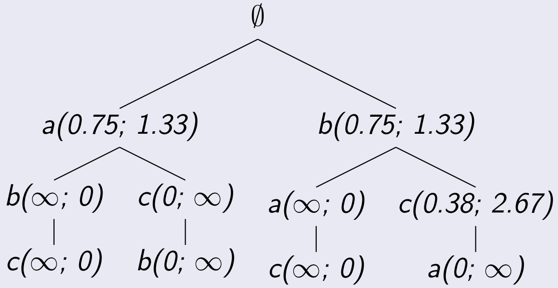
Input sequences

$class\_0 : \{\langle\{a\}\{b\}\{c\}\rangle, \langle\{b\}\{a\}\{c\}\rangle, \langle\{b\}\{a\}\{c\}\rangle, \langle\{b\}\{c\}\rangle\}$
$class\_1 : \{\langle\{a\}\{c\}\{b\}\rangle, \langle\{b\}\{c\}\{a\}\rangle, \langle\{b\}\{c\}\{a\}\rangle\}$

Prefix tree

- $\emptyset$
  - $a(1;\ 1)$
    - $b(1;\ 0)$
      - $c(1;\ 0)$
    - $c(0;\ 1)$
      - $b(0;\ 1)$
  - $b(2;\ 2)$
    - $a(2;\ 0)$
      - $c(2;\ 0)$
    - $c(1;\ 2)$
      - $a(0;\ 2)$

Counting Growth Rate

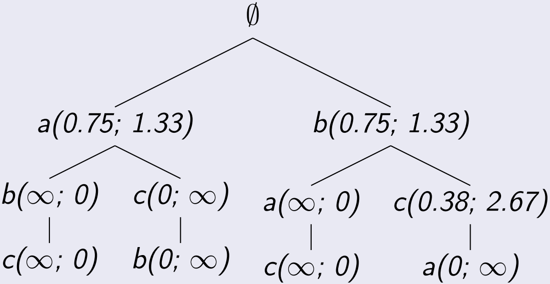


Growth rate

$$0.75 = \frac{1}{4} / \frac{1}{3}; 1.33 = \frac{1}{3} / \frac{1}{4}$$

$$0.38 = \frac{1}{4} / \frac{2}{3}; 2.67 = \frac{2}{3} / \frac{1}{4}$$

Computing Score



New sequence

$$minGR = 2$$

$$\langle\{b\};\{c\};\{a\}\rangle - ???$$

$$Score_0 = 0$$

$$Score_1 = 2.67 + \infty = \infty$$

Comparison of closed and non-closed patterns

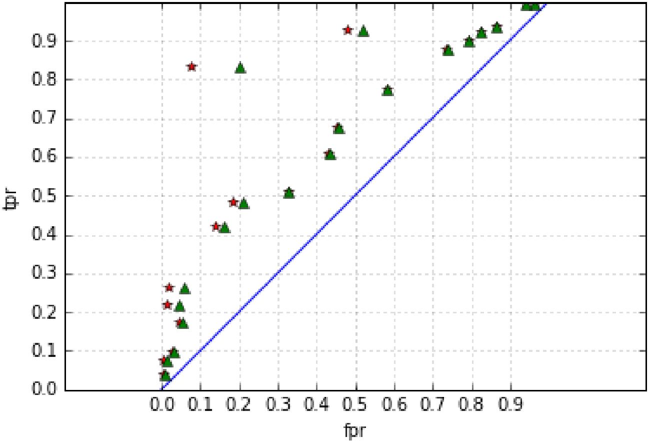


Рис.: TPR vs FPR for closed and non-closed patterns

Experiments and results

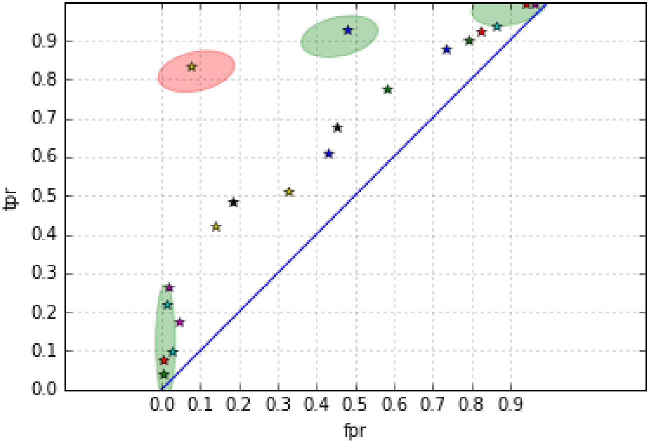


Рис.: TPR-FPR for classification by gender via contiguous prefix-based patterns

Interesting patterns (women)

$$(\langle\{work, separation\}, \{marriage\}, \{children\}, \{education\}\rangle, [\infty, 0.006])$$

$$(\langle\{separation, partner\}, \{marriage\}\rangle, [\infty, 0.006])$$

$$(\langle\{work, separation\}, \{marriage\}, \{children\}\rangle, [\infty, 0.008])$$

$$(\langle\{work, separation\}, \{marriage\}\rangle, [\infty, 0.009])$$

Interesting patterns (men)

$$(\langle\{education\},\{marriage\},\{work\},\{children\},\{separation\}\rangle,[10.6,0.006])$$

$$(\langle\{education\},\{marriage\},\{work\},\{children\}\rangle,[12.7,0.007])$$

$$(\langle\{educ\},\{work\},\{part\},\{mar\},\{sep\},\{ch\}\rangle,[10.6,0.006])$$

Experiments and results

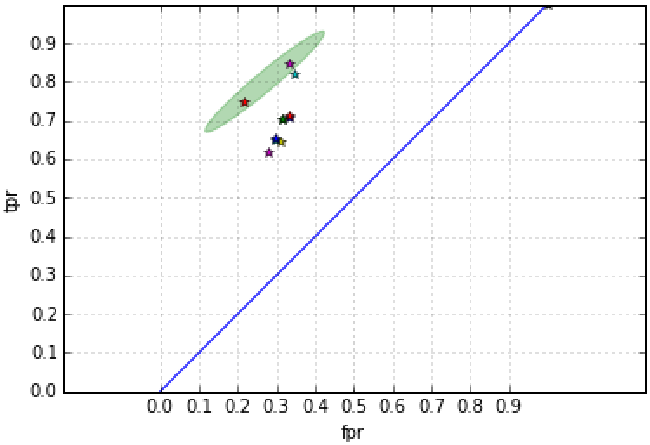


Рис.: TPR-FPR for classification by generation via contiguous prefix-based patterns

Interesting patterns (Different Generations; Women)

Old women

$$(\langle\{work\}, \{separation\}\rangle, [1.85, 0.38])$$

$$(\langle\{work\}, \{marriage, separation\}\rangle, [3.92, 0.08])$$

Young women

$$(\langle\{education\}\rangle, [1.84, 0.26])$$

$$(\langle\{education\}, \{work\}\rangle, [4.01, 0.1])$$

Experiments and results

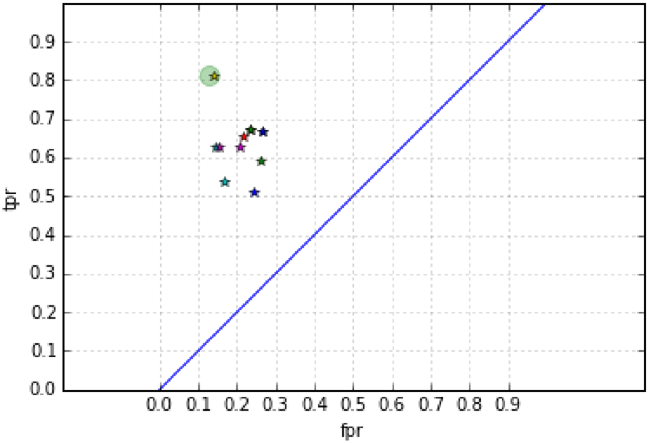


Рис.: TPR-FPR for classification by generation via contiguous prefix-based patterns

Interesting patterns (Different Generations; Men)

Old men

$$(\langle\{work\},\{marriage, separation\},\{education\}\rangle, [13.52, 0.025])$$

$$(\langle\{work\},\{marriage\},\{separation\}\rangle, [22.87, 0.042])$$

$$(\langle\{work\},\{marriage\},\{separation\},\{education\}\rangle, [\infty, 0.0208])$$

Young men

$$(\langle\{education\},\{work\},\{separation\},\{marriage\},\{children\}\rangle, [10.58, 0.020])$$

$$(\langle\{education\},\{work\},\{separation, partner\},\{marriage\}\rangle, [8.65, 0.016])$$

$$(\langle\{education\},\{marriage, separation\}\rangle, [7.69, 0.015])$$

Conclusion

1. We have studied several pattern mining techniques for demographic sequences including pattern-based classification in particular.
2. We have fitted existing approaches for sequence mining of a special type (contiguous and prefix-based ones).
3. The results for different demographic groups (classes) have been obtained and interpreted.
4. In particular, a classifier based on emerging sequences and pattern structures has been proposed.

Conclusion

Thank you!

Questions?