Problem of Missing Data in Census Who Are the Non-Response Respondents

Jan Hora, Jiří Grim

Institute of Information Theory and Automation
Academy of Sciences of the Czech Republic

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Outline

1. Standard methods for census results publication
2. Data reproduction by means of a statistical model
   - Basic idea
   - Definition
3. Experimental results - Czech census 2001
   - Missing data
   - Model calculation and it's accuracy
   - Error distribution
4. Demo - Interactive data presentation
5. Conclusions

Standard methods for census results publication

Basic problem: Completeness and accuracy vs. Privacy

- Task 1: Complex and accurate representation of the census result
- Task 2: Preserve anonymity of single persons
- Problem: Even anonymized query form could be identified

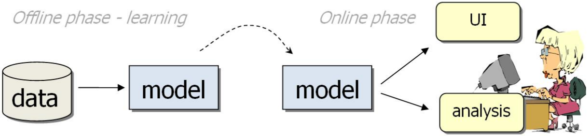
Aggregated data, Tables

perfect accuracy
limited information amount published

Anonymized sets of microdata (1-10% of the original data set)

unlimited possibilities for query formulation
anonymization required, limited distribution, limited accuracy

Data reproduction by means of a statistical model



Statistical model as a knowledge base for probabilistic expert system

- Model is "trained" to represent the original data set
- Model is used instead of the original data
- Statistical properties represented without the original data
- Accuracy decreases with subpopulation size

Statistical model - distribution mixture

Census data .. N-dimensional discrete finite data set $\mathcal{S}$
Query-form .. N-dimensional vector $\mathbf{x}$ of answers

Assumption

$\mathbf{x}$ .. random vector,
$\mathcal{S}$ .. set of iid observations of $\mathbf{x}$,
$P(\mathbf{x})$ can be approximated by a distribution mixture.

$$P(\mathbf{x}) = \sum_{m=1}^{M} w_m F(\mathbf{x}|m) = \sum_{m=1}^{M} w_m \prod_{n=1}^{N} p_n(x_n|m)$$

M	.. component count
w_m	.. weight of the m-th component
$F(\mathbf{x}\|m)$	.. conditional distribution
$p_n(.\|m)$	.. marginal conditional distribution of x_n

Census and Missing data

- $N = 24$ questions, $|\mathcal{S}| = 10230060$ respondents
- 1524240 incomplete records, 2933427 total non-response

	Text of question (name of variable)	Number of values	Non-response in %	Shannon entropy in %
1.	Region of residence	14	0.00	96.88
2.	Type of residence	3	0.00	32.92
3.	Economic activity	10	0.80	67.80
4.	Birth place (relatively)	6	1.95	74.65
5.	Religion	6	0.00	60.57
6.	Occupation type	14	3.89	68.33
7.	Sex	2	0.00	99.95
8.	Marital status	4	0.55	81.01
9.	Education	14	1.11	78.04
10.	Age	9	0.03	96.09
11.	Category of flat	5	0.53	27.81
12.	Bathroom	5	0.59	14.02
13.	Size of flat	7	0.64	80.62
14.	Internet and PC	4	2.85	49.11
15.	Legal relation to flat	9	0.39	72.43
16.	Gas supply	3	0.78	64.54
17.	Number of rooms over 8m^2	7	0.64	80.57
18.	Number of cars in household	4	3.39	71.32
19.	Number of persons in flat	6	0.00	93.79
20.	Vacational property	6	7.45	42.10
21.	Telephone in flat	5	1.80	80.88
22.	Water supply	4	0.35	8.02
23.	Type of heating	6	0.53	74.81
24.	Toilet	6	0.50	16.73

Two ways of handling the missing data

I. Extended model - non-response as a new possible answer

- Simple solution
- Non-responding respondents form specific subpopulations
- ⇒ analysis of their properties

II. Substitution - missing values filling-up

- Model estimated from incomplete data
- Estimated model used for missing data substitution
- Correct substitution cca 73%

Example - Model accuracy

Czech census 2001 - Model with $M = 15000$ components

Used model	Model with substituted values	Extended model with missing values
Mean relative error in %:	**4.07**	**4.10**
Standard deviation of the relative error:	6.33	5.83
Maximum relative error of the model in %:	240.84	250.90
Number of relative errors exceeding 100%:	925	1037
Mean absolute error:	**470**	**459**
Standard deviation of the absolute error:	951	791
Maximum absolute error of the model:	45779	56808
Number of combinations tested:	**3503448**	**3895873**

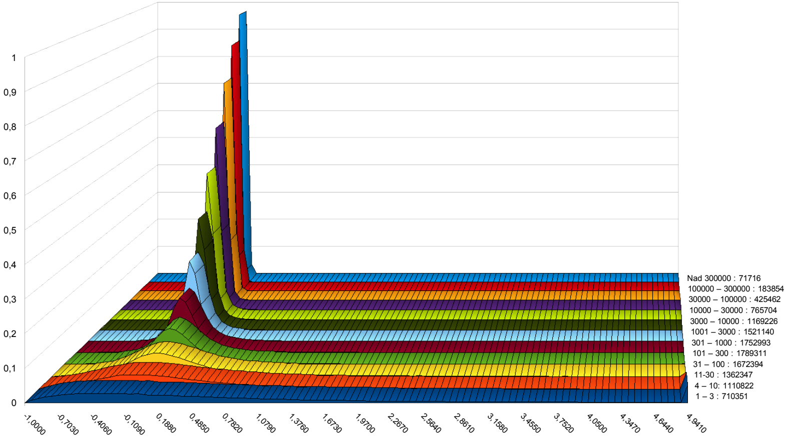
Validation set $\mathcal{A}$: Combinations of up to 4 answers greater than 1612

Mean relative error:

$$\epsilon_R(\mathcal{A}) = \frac{1}{|\mathcal{A}|} \sum_{A \in \mathcal{A}} \frac{|\hat{P}(A) - P(A)|}{\hat{P}(A)} \qquad P(A) \text{.. original size, } \hat{P}(A) \text{ .. estimated size}$$

Example - Accuracy depending on the subpopulation size

Relative error distribution according to the subpopulation size



(x-axe: error distribution, z-axe: subpopulation size)

Interactive data presentation

Conclusions

Method characteristics

- Guaranteed anonymity
- Accuracy comparable to microdata sets
- Successfully implemented for Czech Census 2001

Non-Response handling

- Non-Responding respondents analysis
- Filling-up the missing values

Thank You for Attention

Demo application: *http://ro.utia.cas.cz/dem.html*

Jan Hora, *hora@utia.cas.cz*
Jiří Grim, *grim@utia.cas.cz*

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