Assessing Response Quality by Using Multivariate Control Charts for Numerical and Categorical Response Quality Indicators

Jiayun Jin Prof. Geert Loosveldt

KU Leuven

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Outline

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- Statistical Process Control (SPC)
Example: beer bottling process

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One variable at a time

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- Multivariate Statistical Process Control (MSPC)

Conventional tool: Hotelling T^2 statistic

Multivariate tool: Principal Component Analysis (PCA)

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Multivariate tool: Principal Component Analysis (PCA)

Multiple numerical variables simultaneously

In the field of surveys:

- $\bar{X}/R$ chart (Peng and Feld 2011, Reed and Reed 1997)
- $\bar{X}/S$ chart (Jin et al. 2019; Jans and colleagues 2013; Sirkis and Jans 2011)
- p chart (Pierchala and Surti 1999; Corsetti et al. 2010)
- exponentially weighted moving average control chart (Peng and Feld 2011)

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Handle a mixture of numerical and categorical variables

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- ① How can we (a) identify and (b) interpret out-of-control signals (outliers) by using a mixture of numerical and categorical response quality indicators simultaneously?
- ② How can we obtain the in-control data?
- ③ What are the most important indicators that discriminate the outliers from the in-control interviews?

- Round 8 of the European Social Survey (ESS) Belgium
- CAPI;
- From 14 September 2016 to 31 January 2017;
- 138 interviewers and 1766 respondents; Response rate 56.8%

Theoretical framework: Satisficing theory (Krosnick 1991; Simon 1956)

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Response styles	Indicator	Meaning	Measured item	Type of variable
Acquiescence	average	The average score of oppositely-worded items that measure one construct	E1/E2; E1/B33;E17/E18	numeric
	illogical	Whether responses are self-contradictory	E1/E2; E1/B33;E17/E18	categorical
Non-differentiation	sd	The standard deviation of all responses to one block of items	B6-B12 B26-B32	numeric
	max	The maximum sequence of identical responses to one block of items	B6-B12 B26-B32	numeric
Extreme answers	perc.ex	The proportion of extreme answers	B6-B12 B26-B32	numeric
Middle answers	perc.mi	The proportion of middle answers	B6-B12 B26-B32	numeric
Item nonresponse rate	perc.unanswered	The amount of item nonresponse divided by the number of all applicable items	Overall questionnaire	numeric
Rounding value reports	multiple_30	Whether respondents give rounding value responses to an item for which a numbering answer is required	A1	categorical

Dataset (numerical and categorical)

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PCA Mix model(Chavent et al. 2017))

- Data preprocessing
- Generalized Singular Value Decomposition
- Scores generating

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PCA Mix component scores (numerical)

- T^2 value for interview i

$$T_i^2 = \sum_{a=1}^A \frac{t_i a^2}{\lambda_a}$$

- number of bootstrap samples: 1000
- $\alpha = 0.01$

- $|CL^{i+1} - CL^i| < \epsilon$ with $\epsilon = 0.0005$

The first PCA Mix model

Principal components	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7	PC 8
Eigenvalue	1.85	1.61	1.41	1.04	0.97	0.47	0.37	0.28
Proportion	23.08	20.10	17.60	13.03	12.13	5.88	4.64	3.55
Cumulative	23.08	43.18	60.77	73.80	85.92	91.81	96.45	100.00
Squared loadings								
max	0.006	0.010	0.535	0.233	0.148	0.003	0.004	0.062
sd	0.537	0.091	0.172	0.021	0.016	0.053	0.007	0.103
average	0.125	0.665	0.018	0.002	0.002	0.014	0.171	0.003
perc.ex	0.631	0.072	0.004	0.115	0.028	0.041	0.001	0.109
perc.mi	0.000	0.025	0.472	0.288	0.083	0.124	0.004	0.004
perc.unanswered	0.485	0.011	0.169	0.080	0.017	0.219	0.018	0.001
multiple_30	0.004	0.009	0.017	0.296	0.673	0.000	0.000	0.000
illogical	0.058	0.725	0.022	0.008	0.003	0.017	0.166	0.003

Obtaining of in-control data

$$CL^{(1)} = 22.86 \text{ with } \alpha = 0.01$$

Obtaining of in-control data

The estimated control limits are decreased as the most extreme outliers are removed one by one

$$|CL^{(42)} - CL^{(41)}| = 0.00002$$

Obtaining of in-control data

$$CL^{(41)} = 18.91 \text{ with } \alpha = 0.01$$

Interpret one outlier—an interview with extremely large T^2 value

Interpreting outliers

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the responsible principal component(s)

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the responsible principal component(s)

the responsible original variable(s)

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- 1 more extreme answers (48.61% versus 5.38 %) and longer sequences of identical answers (4.43 versus 2.27)
- 2 a lower rate of item nonresponse

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98.2% of the test interviews are correctly classified.

	Actual in-control	Actual outlier
Predicted in-control	860	12
Predicted outlier	4	7

- Multiple quality indicators can be monitored simultaneously
- Not all indicators identify multivariate control equally
- The next step: real-time monitoring from the beginning of survey data collection

Thank you very much!