Utility evaluation of global recoding by accuracy of discrimination model

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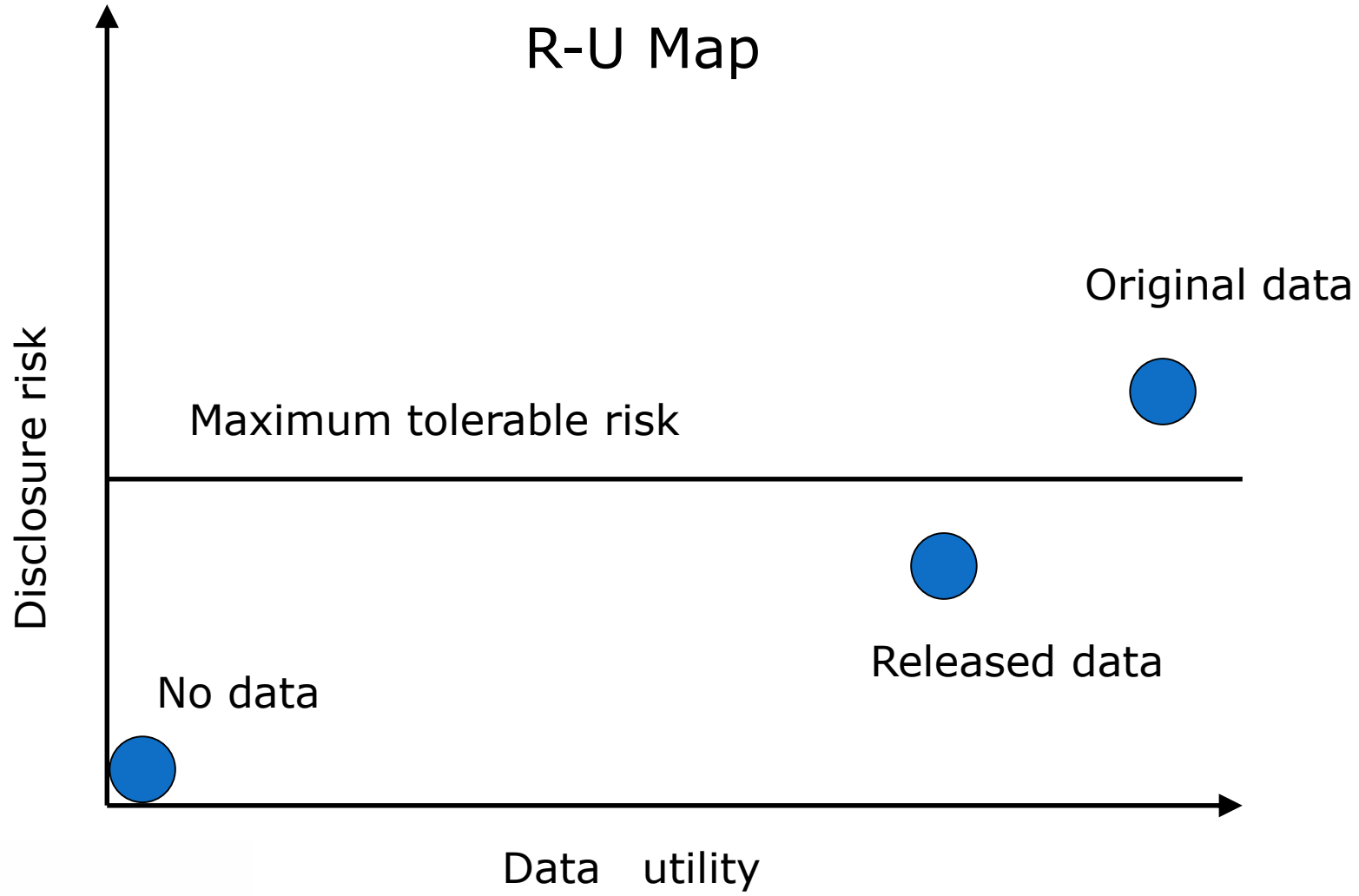
Trade-off between Risk and Utility



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Procedure of global recording (GR)

1. Aggregate category frequency for each variable and sort them.
2. Calculate thresh hold, $th = n \times p$, n:no.subject p:minimum frequency ratio.
3. If the category with minimum frequency is less than th, merge the category and second minimum category.

Category	D	B	F	…
Frequency	26	77	177	…

Merge

If there are plural categories with minimum frequency, merge them.

Category	D	A	C	…
Frequency	26	26	26	…

Merge

4. Repeat Step 3. until minimum frequency exceeds th

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Information loss measure of categorical data

- Many survey item contain categorical variable e.g. census data and unsuitable to information loss measure of continuous variable
- Domingo-Ferror and Torra (2001) proposed the following measures for categorical data
  - Direct comparison of categorical value
  - Contingency table-based measure
  - Entropy-based measure

Evaluation of information loss by model accuracy (1)

- In many applied fields, some statistical model is applied to data including confidentiality protected data.
  - Used discrimination model: Multinomial logistic model
  - Model accuracy（ratio of correct prediction）are evaluated, before and after protecting by GR
- Hypotheses
  - When minimum frequency ratio p increases, information loss by model accuracy increases.
  - When the number of input variables increase, information loss by model accuracy increases.
  - High accuracy models in original data suffer from information loss by GR.

Evaluation of information loss by model accuracy (2)

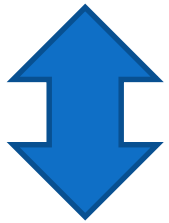
x_i:i-th valuable in original data　　x_i^G : i-th valuable after GR

$X_{sub}^{-i} \subseteq X^{-i} = \{x_1, x_2, \cdots, x_{i-1}, x_{i+1}, \cdots, x_m\}$

$X_{sub,G}^{-i} \subseteq X_G^{-i} = \{x_1^G, x_2^G, \cdots, x_{i-1}^G, x_{i+1}^G, \cdots, x_m^G\}$

A: Original model ：prediction model by original data

$x_i = f(X_{sub}^{-i}),\ i = 1,2,\cdots,p$



Information loss: difference of accuracy between two models

B:Global Recording model ： prediction model by GR data

$x_i = f(X_{sub,G}^{-i}),\ i = 1,2,\cdots,p$

Target varialble x_i in GR model is original variable.

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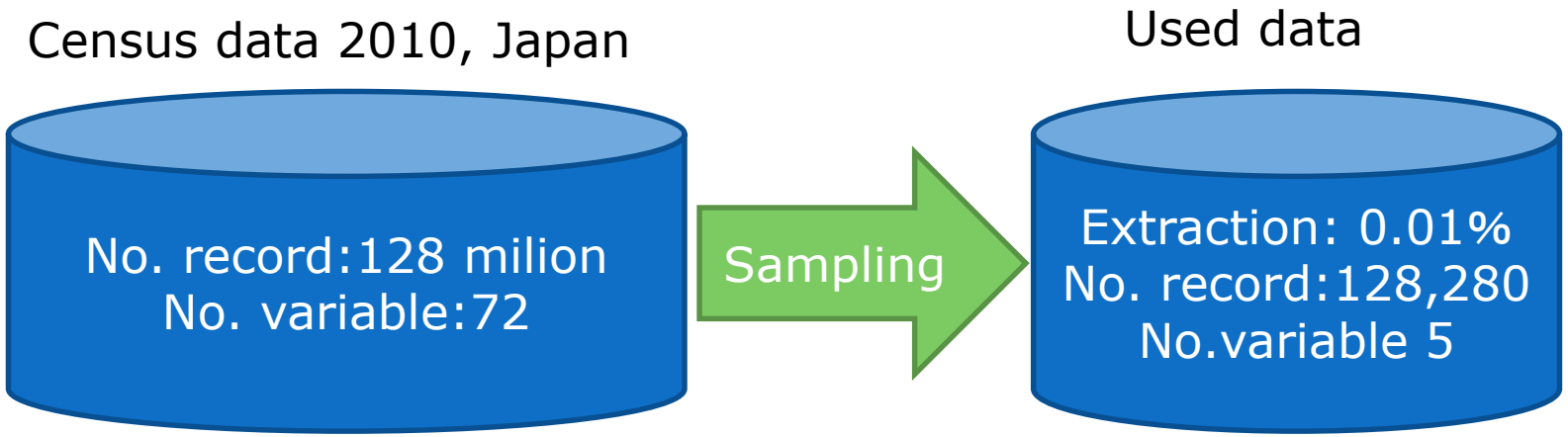
Used data



Used 5 Variable

- Major division of industry
- Major division of occupation
- Type of family
- Classification of nationality
- Type by No. children and age

Preliminary analysis : Cramer's coefficient

	Major division of industry	Major division of occupation	Type of family	Classification of nationality	Type by No. children and age
Major division of industry	–	0.663	0.050	0.024	0.055
Major division of occupation	–	–	0.065	0.027	0.072
Type of family	–	–	–	0.023	0.271
Classification of nationality	–	–	–	–	0.020
Type by No. children and age	–	–	–	–	–

$$V = \sqrt{\frac{\chi_0^2}{n\{(\min(a,b)-1\}}}$$

n: no. record
a: no. category of row
b: no. category of column

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Change of number of category by GR

p=Minimum frequency ratio in GR

Variables	Original	p=0.01	p=0.03	p=0.05
Major division of industry	22	17	10	7
Major division of occupation	13	12	9	8
Type of family	27	16	10	7
Classification of nationality	52	2	1	1
Type by No. children and age	97	29	12	8

Results of information loss (Mean value)

Mean	p=0.01	p=0.03	p=0.05
No. input variables = 1	0.000	0.007	0.010
No. input variables = 2	0.001	0.012	0.019
No. input variables = 3	0.001	0.018	0.029
No. input variables = 4	-0.000	0.024	0.041

- When minimum frequency ratio increases p, information loss increases (accuracy of discrimination model decreases).
- When the number of input variables increase, information loss increases (accuracy of discrimination model decreases).

Top 5 models with highest information loss (1)

No. input variables = 1, No. all models = 20, p=0.05

Model	A:Complete model	B:GR model	Information Loss	Cramer's coefficient
Occupation~Industry	0.812	0.727	0.085	0.663
No.Child & age~Family	0.540	0.481	0.059	0.271
Industry~Occupation	0.767	0.721	0.046	0.663
Family~No.Child & age	0.587	0.569	0.017	0.271
Family~Nationality	0.409	0.408	0.001	0.023

Top 10 models with highest information loss (2)

No. input variables = 2, No. all models = 30, p=0.05, Red:Large Cramer's V

Model	A:Complete model	B:GR model	Information Loss
Occupation~Industry+Nationality	0.812	0.727	0.085
Occupation~Industry+No.Child & age	0.809	0.731	0.078
Occupation~Industry+Family	0.813	0.736	0.076
No.Child & age~Family+Nationality	0.539	0.481	0.058
No.Child & age~Industry+Family	0.538	0.488	0.05
No.Child & age~Occupation+Family	0.537	0.487	0.049
Industry~Occupation+Nationality	0.767	0.721	0.045
Industry~Occupation+No.Child & age	0.76	0.72	0.039
Industry~Occupation+Family	0.76	0.73	0.029
Family~Industry+No.Child & age	0.593	0.571	0.023

Negative information loss (-0.006, Family~Industry)

Predicted class of Family (A:Original model) Accuracy=0.402

	01	02	03	04	05	06	07	08
0	3349	121542	0	0	0	0	0	0
10	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
0	0	0	0	0	0	0	0	0
19	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**VV**
0	0	0	0	0	0	0	3389	0

Predicted class of Family (B:GR model, p=0.05) Accuracy=0.408

	01	02	03	04	05	06	07	08
0	0	128280	0	0	0	0	0	0
10	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
0	0	0	0	0	0	0	0	0
19	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**VV**
0	0	0	0	0	0	0	0	0

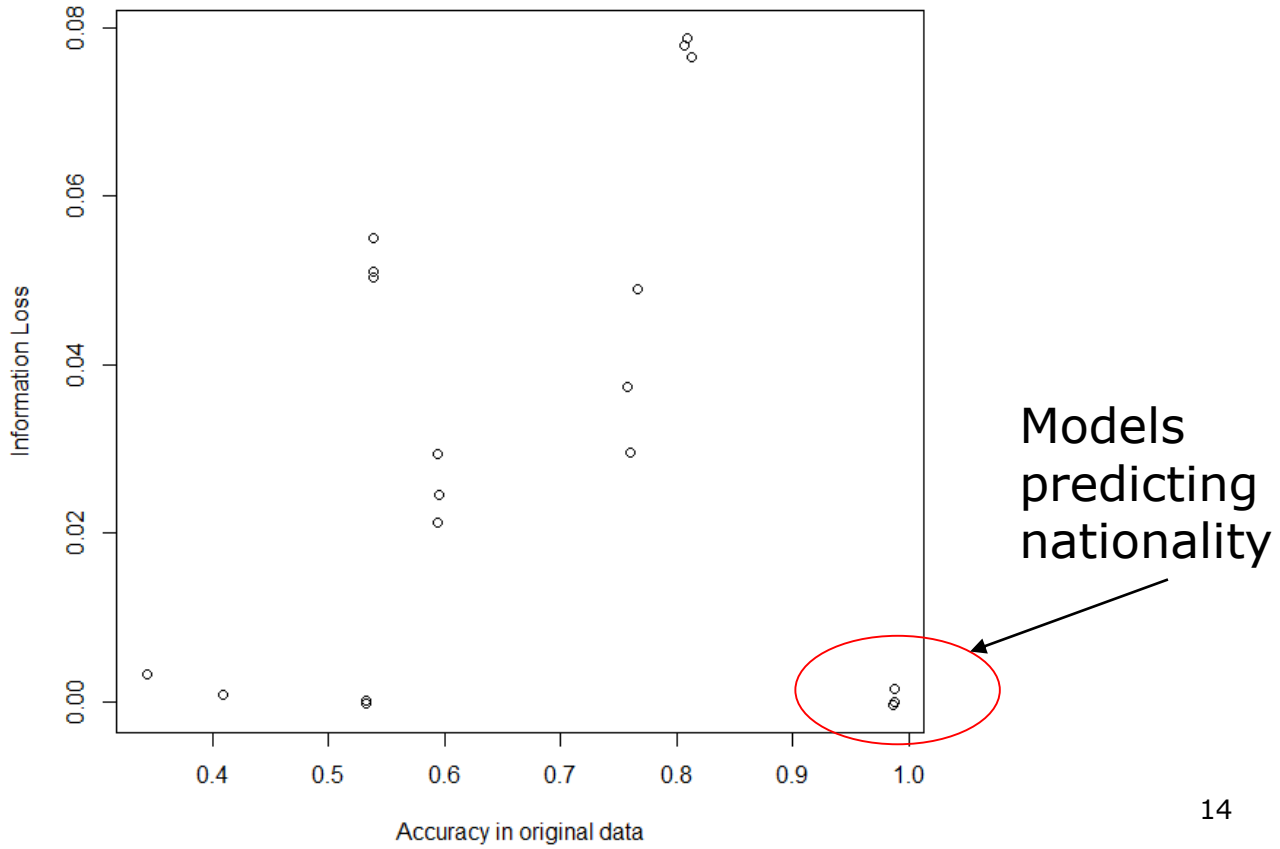
Accuracy in original data VS Information loss

No. input variables = 3, No. all models = 20, p=0.05

Apparently, as accuracy of original model increases, information loss increases

Correlation of all models : 0.017

Correlation except for models predicting nationality: 0.726



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Conclusion

- We provide information to decide p in terms of loss of accuracy
  - In this case study, there is just about no information loss when p is 0.01, Even if p is 0.05 and the number of variables is 4, information loss is 0.041
- Knowledge from this simulation
  - When minimum frequency ratio increases p, information loss by model accuracy increases.
  - When the number of input variables increase, information loss by model accuracy increases ⇒ Large scale model needs to be dealt with cautiously.
  - High accuracy models in original data suffer from information loss by GR except for models predicting dominant category.

References

- Statistical disclosure control, Hundepool A., Domingo-Ferrer J., Franconi L., Giessing S., Nordholt E. S., Spicer K., et al. ,2012, John Wiley & Sons.
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Thank you for your attention!