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Anonymization and Re-identification for Personal Transaction Data Report from PWSCUP 2016

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Privacy Concern

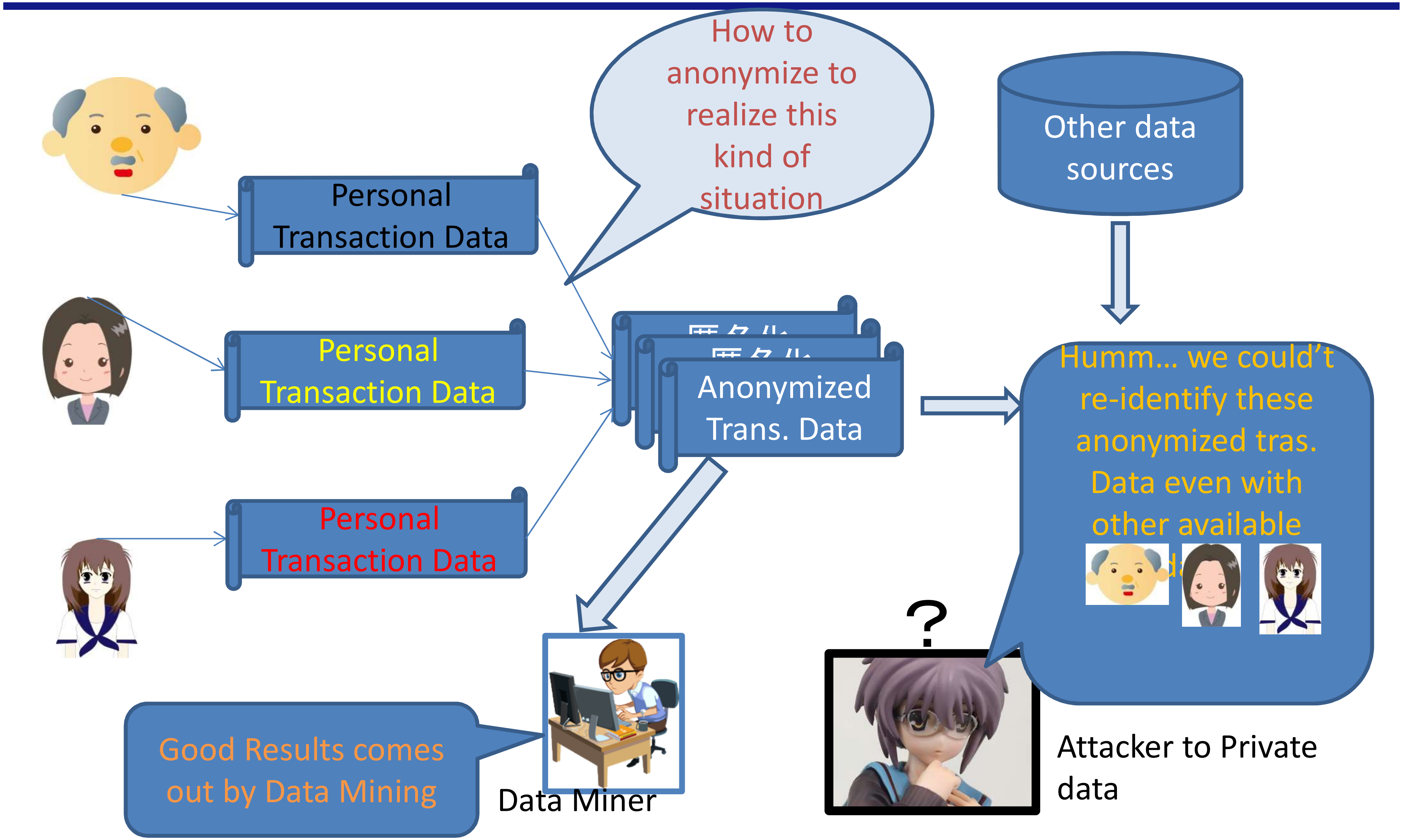
- Data subject’s private data is a very profitable big data.
- Privacy protection is necessary to use these private data.
- In EU, GDPR focuses on this privacy protection issue legally, technically aiming at IT businesses.
- In Japan, last year, the private data protection acts have been revised, which introduces the new concept of “anonymized private data.”

- Anonymized private data can be treated as if they are not personal data any more,
- meaning that they are even transferred to the third party without data subject’s consent.

- The way to transform personal data into anonymized private data has not been clearly defined at least in technical sense.
- We have to estimate how easily an anonymized personal data is re-identified, in order to give the technical evaluation to legal authorities who make the definition of anonymized private data.

- For this purpose, we organized PWSCUP last October.
- The competition of PWSCUP was: for given transaction data (400 people transaction of purchasing for one year period),
- 1) 15 teams submitted anonymized transaction data by their own methods.
- 2) Each team tried to re-identify other teams' anonymized transaction date.
- The winner is the team whose anonymized data has the highest score of utility + # of non-re-identified person.

The situation we want to work out by anonymization



Personal Transaction Data

Personal Transaction Data

Personal Transaction Data

How to anonymize to realize this kind of situation

Anonymized Trans. Data

Other data sources

Humm… we could’t re-identify these anonymized tras. Data even with other available

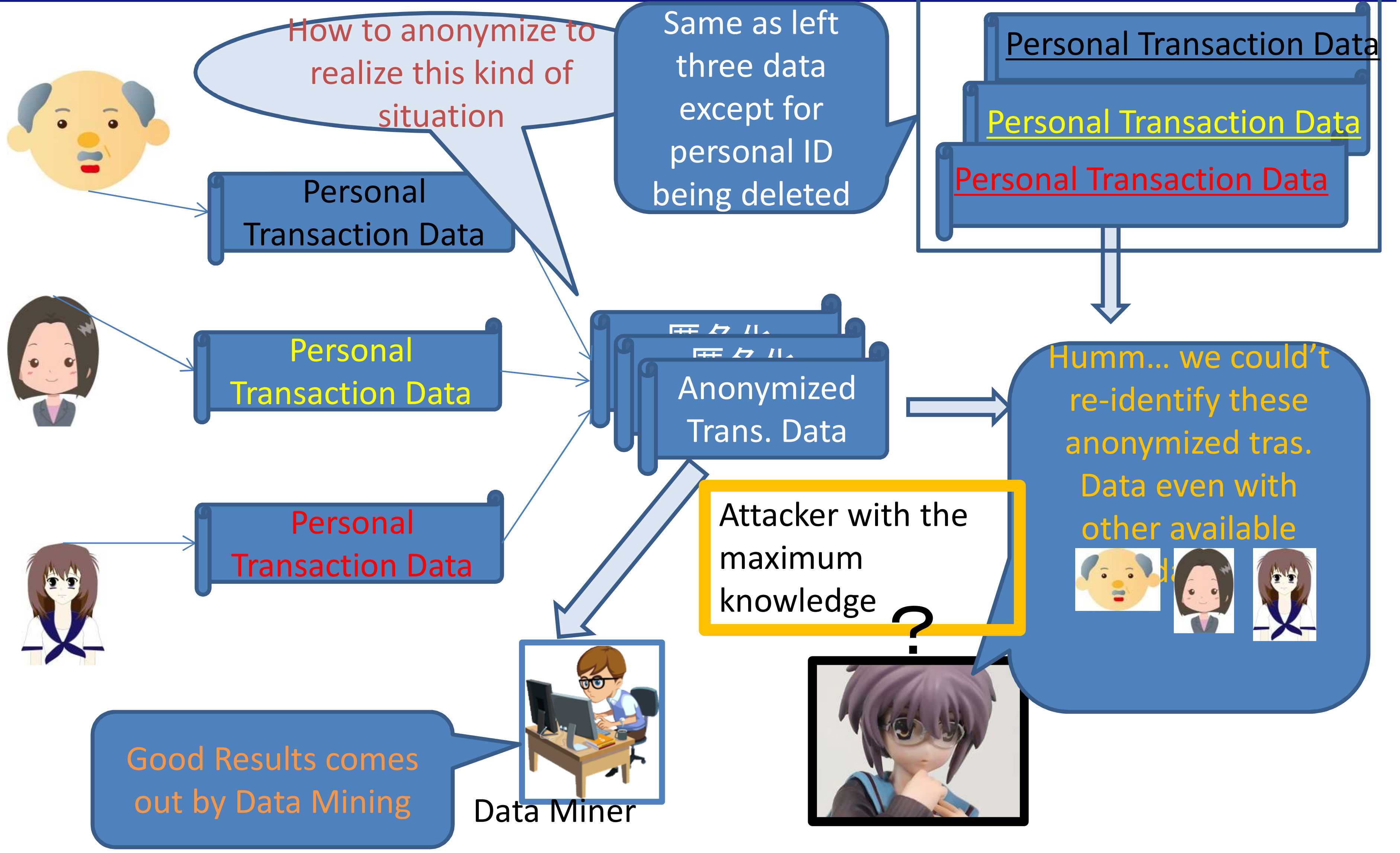
?

Attacker to Private data

Data Miner

Good Results comes out by Data Mining

The situation we want to work out by anonymization



How to anonymize to realize this kind of situation

Same as left three data except for personal ID being deleted

Personal Transaction Data

Personal Transaction Data

Personal Transaction Data

Personal Transaction Data

Personal Transaction Data

Personal Transaction Data

匿名化

匿名化

Anonymized Trans. Data

Humm… we could't re-identify these anonymized tras. Data even with other available d

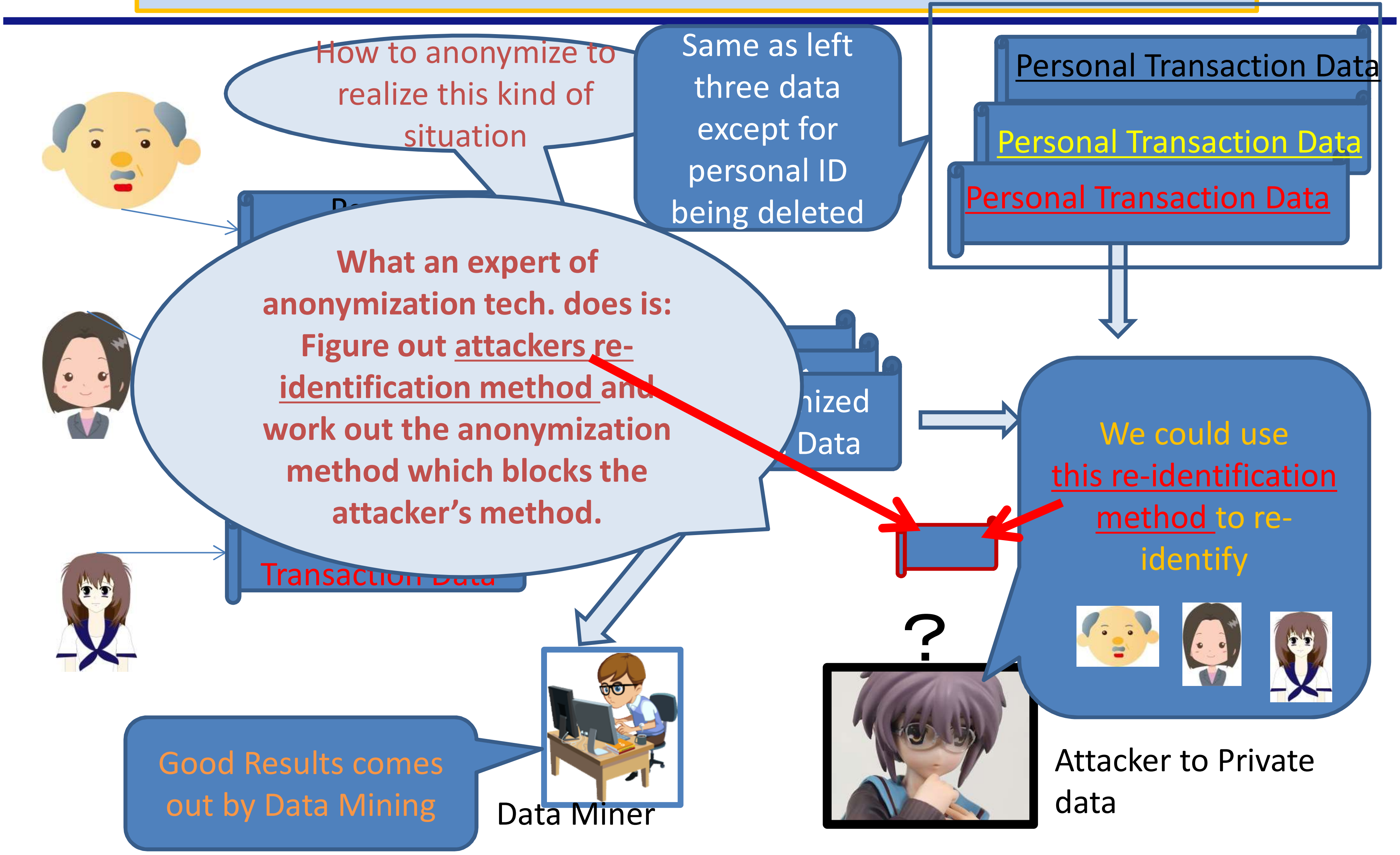
Attacker with the maximum knowledge

?

Data Miner

Good Results comes out by Data Mining

PWSCUP： Expert of anonym. tech. does this way ！



How to anonymize to realize this kind of situation

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Personal Transaction Data

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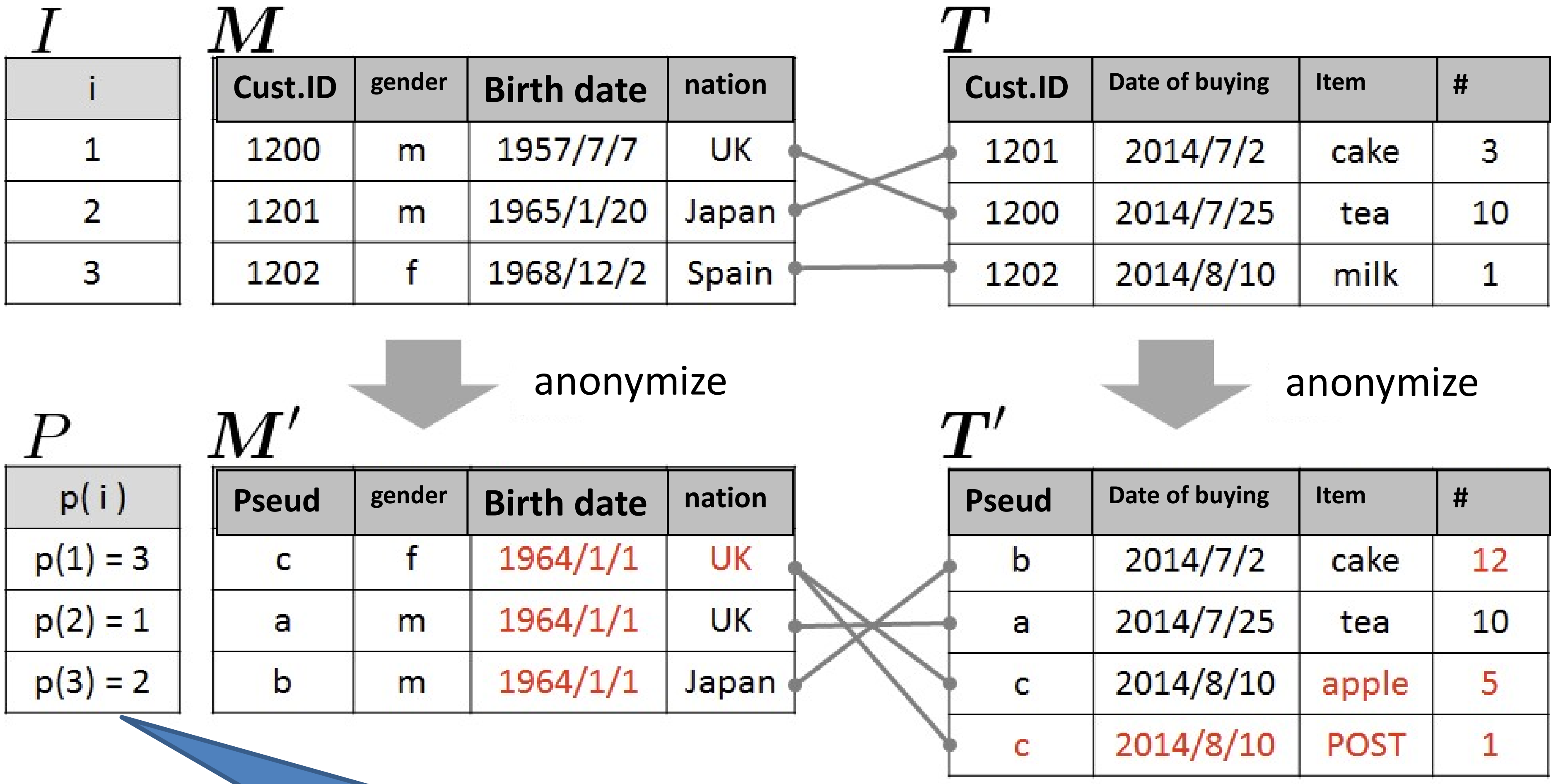
What an expert of anonymization tech. does is: Figure out attackers re-identification method and work out the anonymization method which blocks the attacker's method.

We could use this re-identification method to re-identify

Good Results comes out by Data Mining

Record of Purchase DB used at PWSCUP



I

i
1
2
3

M

Cust.ID	gender	Birth date	nation
1200	m	1957/7/7	UK
1201	m	1965/1/20	Japan
1202	f	1968/12/2	Spain

T

Cust.ID	Date of buying	Item	#
1201	2014/7/2	cake	3
1200	2014/7/25	tea	10
1202	2014/8/10	milk	1

P

p(i)
p(1) = 3
p(2) = 1
p(3) = 2

M'

Pseud	gender	Birth date	nation
c	f	1964/1/1	UK
a	m	1964/1/1	UK
b	m	1964/1/1	Japan

T'

Pseud	Date of buying	Item	#
b	2014/7/2	cake	12
a	2014/7/25	tea	10
c	2014/8/10	apple	5
c	2014/8/10	POST	1

p(i) : order of records
＝permutation of row # of table data

Attackers with Maximum Knowledge Model and PWSCUP task

- Attacker, who does re-identification, knows M and T.
- Then, try to figure out the permutation {p(i), i=1,n} from anonymized M’and T’,

  which is re-identification

  - Re-identification rate is the ratio of being properly re-identified.

Utility measure : *cmae*

- Clustering customer by gender and nationality
  - Notation
  - {C}: The whole cluster . *s*: Subset of C. *p: permutation*
  - T|s : customer data of T which is in *s* of T
  - *tj* :j-th record of T

Average cost of item in cluster s:$\mu_{up}(T|s) = \frac{\sum_{tj \in T|s} unit\ cost\ of\ tj \ \ \cdot \#\ of\ t_j}{\sum_{tj \in T|s} \#\ of\ t_j}$

Average absolute error for the whole cluster

C: $cmae(M, M', T, T') = \sum_{s \in C} \frac{|\mu_{up}(T|s)| - |\mu_{up}(T\prime|s)|}{|C|}$

Utility measure : subset

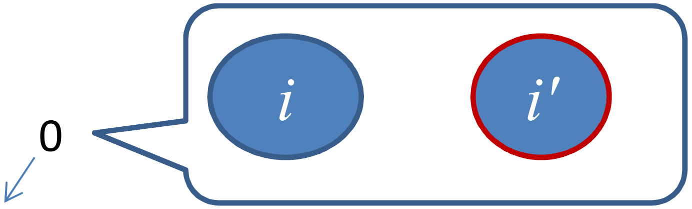
- X’ is a set of 10 selected customers from M’.
- X is a counter part of X’ in M.
- The following subset means the maximum value of difference between average of total purchase of X and that of X’, for consecutive 30 days: $subset((M,T),(M'T'),p) = max_{X',D}(|\mu_{tp}(X',D,T')| - |\mu_{tp}(X,D,T)|)$

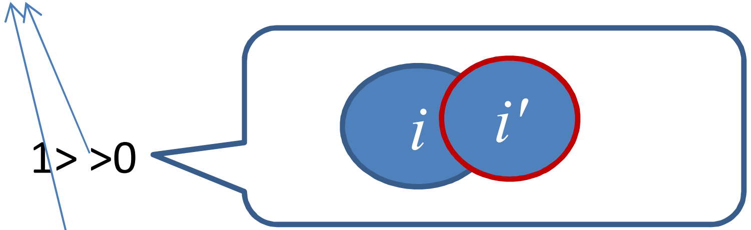
Utility measure : ut-jaccard

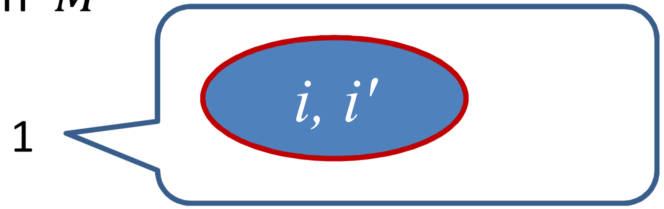
- $S(T,i)$: a set of items purchased by customer c_i , described in T.
- $S(T',i)$: a set of items purchased by customer c_i , described in T’.
- Jaccard coeffcient :
- $d\big(S(T,i),S(T',i)\big) = 1 - \frac{|S(T,i)\cap S(T\prime,i)|}{|S(T,i)\cup S(T\prime,i)|}$
- Sum of d within M :

$$ut - jaccard(M,M',T,T',p)$$
$$= \frac{1}{n'}\sum\nolimits_{i=1}^{n'} d\big(S(T,i),S(T',i)\big)$$

where n' is a number of records in M'







Utility measure : RFM(M, M', T, T’)

- Customers M / M‘ are clustered by

  Recency (last purchasing date),

  Frequency(frequency of purchasing) and

  Monetary (amount of money paid) of T / T’.

- Then RFM(M, M', T, T’) is the normalized RMS between these two clusters is .

Imposed condition on utility measures and anonymization schema

- $subset \leq 50000$

  and ut-jaccard $\leq 0.7 \cdot (\#\ of\ records\ in\ T)$

- The condition on ut-jaccard is severe,

because we could not do big change of data value or shuffling records order.

Imposed condition on utility measues and anonymization schema

1. Anonymizers try to work out anonymization method which satisfies the condition on ut-jaccard as tightly as possible.
2. Attackers try to work out re-identification method considering the above mentioned anonymization method.
3. The anonymizers try to develop anonymization methods that overcome the above mentioned re-identification methods.

First of all, how to design effective re-identification method?

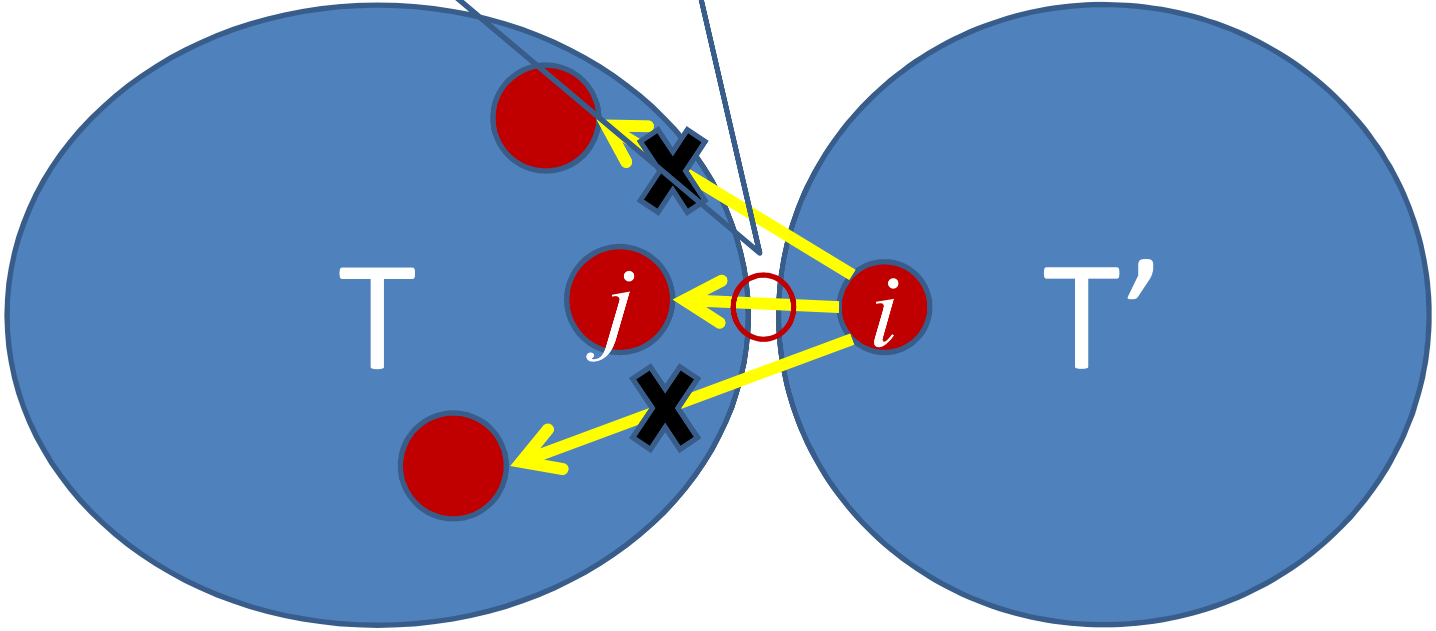
- Each team submits anonymized data which preserve purchased item set of each customer to high extent.

- Customers' purchased item sets are very diverse.
- Then it is hard to make re-identification difficult while maintaining the condition of ut-jaccard.

- Considering this, we proposed the re-identification method: ***re-itemset*** shown in the next slide.

Effective re-identification method: ***re-itemset***

The most similar S(T,j) to S(T’,i) in terms of ut-jaccard =S(T,i)’s counterpart



Outline of anti "***re-itemset***"

1. Make a *ci* centered cluster which consists customers *cj(j≠i)* whose *S*(*T* ; *j*) is similar to *S*(*T* ; *i*). → Precisely described later

2. Modify *cj*'s items in order to make all customers within *ci* centered cluster have the same item set ,
   - all customers in *ci* centered are regarded as *ci*.
   - → At most one customer is re-identified within one cluster, say *ci*.
   - Then, we want to minimize the number of clusters under the condition of utility measures such as "ut-jaccard≤0.7"

Expected re-identification rate and the results of PWSCUP competition

- Our anonymization algorithm satisfies
  “ut-jaccard≤0.7･(# of records in T) as well as other utility conditions.

- In PWSCUP, 400 customers are divided into 89 clusters with ut-jaccard =0.699

- We expect that re-itemset algorithm does not re-identify more than 90 customer if more than one customers within one cluster are re-identified as we planned.

- Great!! At most 89 customers are re-identified on PWSCUP re-identification phase.

Randomizing customer’s item set in clustering of anonymization

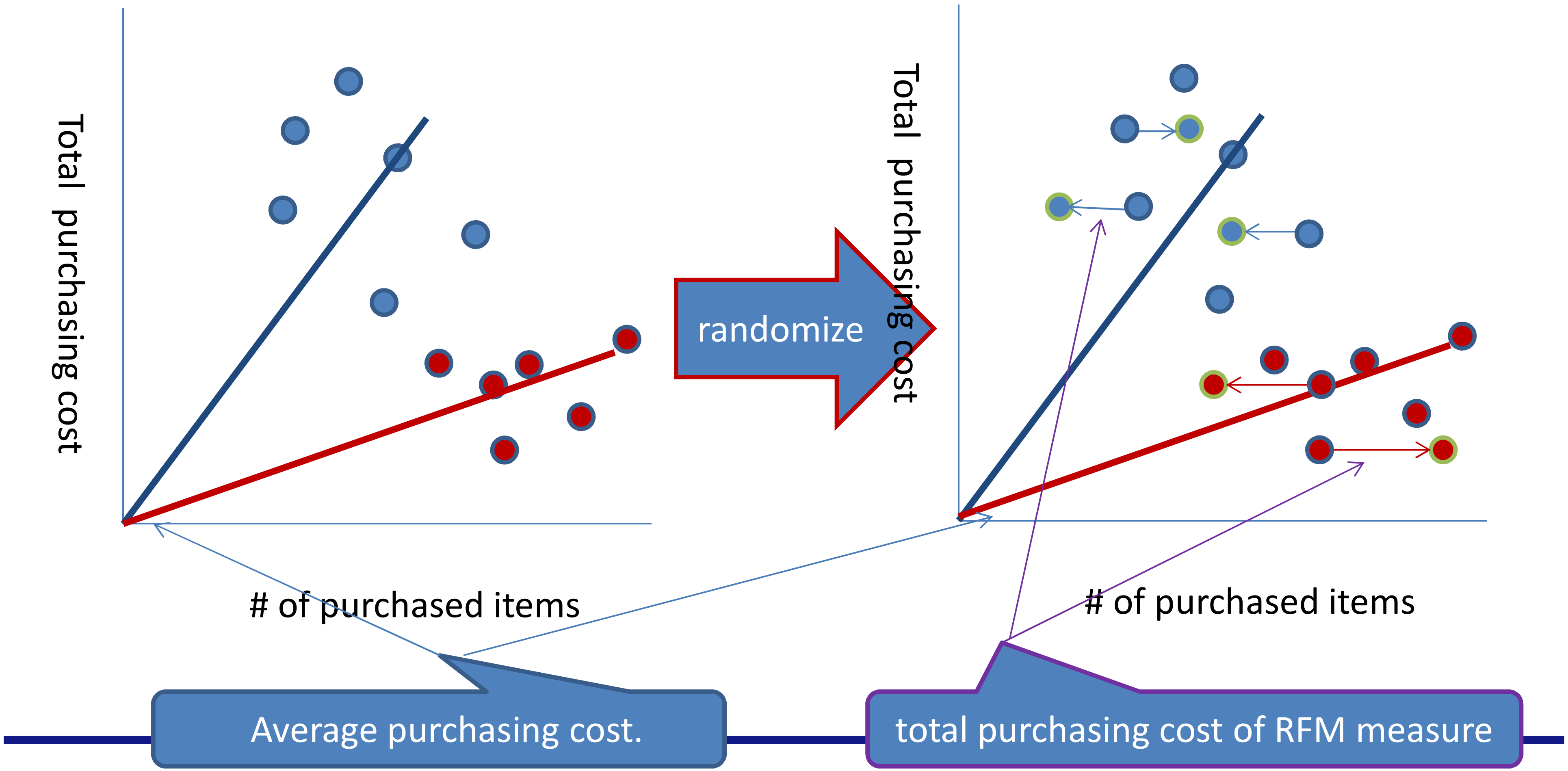
- In order that less than 90 customers within one cluster are re-identified, we may highly randomize customer’s item set in one cluster or clustering itself.

- But, too much randomization degrades utilities.

➢ We need the method including both of randomization of clustering and item set and maintaining utilities.

Sketch of randomization

- ➢Randomize not to be re-identified within the cluster
- ➢Keep utility measures as invariant as possible



Average purchasing cost.

total purchasing cost of RFM measure

Summary of PWSCUP

- Many teams seem to employ ***re-itemset*** tuned to ut-jaccard as re-identification method.

- At PWSCUP re-identification phase, at most 89 customer (22.5% of 400 customers) of our team’s anonymized data got re-identified as we expected.

- As explained, 89 is the upper bound of ***re-itemset*** tuned to ut-jaccard.

- **Note that the value of this 22.5% depends on**
  - **employed utility measures**
  - **nature of target data base.**

- Thus, 22,5% is to be regarded as a reference value of this PWSCUP contest. → We do not have a one fits all approach!