Record Linkage

Hye-Chung Kum (kum@tamu.edu)
Associate Professor
Population Informatics Lab (https://pinformatics.org/)

3

3

Record Linkage

- Goal :To identify the same real world entity in different tables
- Other names:
  - Record Linkage
  - Entity Resolution
  - Deduplication (Link to self)
  - Merge / Purge

4

4

Record Linkage Example

EISID : E1	EISID : E2	EISID : E3	EISID : E4
ssn : 085-66-9980 first name : Sally last name : Hill MI : L DOB : 3/4/1999	ssn : 143-25-9304 first name : Emily last name : Brown MI : K DOB : 6/2/2004	ssn : 354-563-2343 first name : Mary last name : Johnson MI : G DOB : 5/13/1983	ssn : 532-34-9183 first name : David last name : Ford MI : J DOB : 10/2/1990

SISID : S1	SISID : S2	SISID : S3	SISID : S4
ssn : 085-66-9980 first name : Sally last name : Hill MI : L DOB : 3/4/1999	ssn : 143-52-9304 first name : Emily last name : Brown MI : K DOB : 6/2/2004	ssn : 354-563-2343 first name : Mary last name : Hawkins MI : J DOB : 5/13/1983	ssn : 532-34-9183 first name : David last name : Ford MI : J DOB : 2/10/1990

5

Inherent Nature of Real Data

- Data are expressed differently
  - nick names
- Data change over time
  - person's last name
- Data are not unique attributes
  - John Smith
- Missing Data
  - ssn are often missing
- Errors in Data
  - Rule of thumb : 5% error in administrative data

6

Record Linkage Example

EISID : E1	EISID : E2	EISID : E3	EISID : E4
ssn : 085-66-9980 first name : Sally last name : Hill MI : L DOB : 3/4/1999	ssn : 143-**25**-9304 first name : Emily last name : Brown MI : K DOB : 6/2/2004	ssn : 354-563-2343 first name : Mary last name : **Johnson** MI : G DOB : 5/13/1983	ssn : 532-34-9183 first name : David last name : Ford MI : J DOB : **10/2**/1990
SISID : S1	SISID : S2	SISID : S3	SISID : S4
ssn : 085-66-9980 first name : Sally last name : Hill MI : L DOB : 3/4/1999	ssn : 143-**52**-9304 first name : Emily last name : Brown MI : K DOB : 6/2/2004	ssn : 354-563-2343 first name : Mary last name : **Hawkins** MI : **J** DOB : 5/13/1983	ssn : 532-34-9183 first name : David last name : Ford MI : J DOB : **2/10**/1990

7

What does this mean?

- Exact match will not work
  - Only 60% to 70% with exact match
  - Privacy protection through one way hash
  - Privacy preserving using set union
- Must have approximate match !
  - Probably will require some manual review of “uncertain region”

8

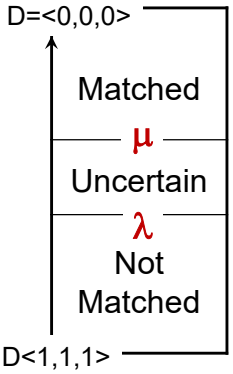
Approximate Matching Methods

- Capture as many of the false negatives
- While introducing as little of the false positives
- Probabilistic Methods
  - Naïve Bayes : Probabilistic Record Linkage
    - Newcombe (1959)
    - by Fellegi and Sunter (1969)
  - Other Machine learning models
    - Actively learning
- Deterministic Methods

9

Probabilistic Record Linkage

- Block/Score
- D = <$dist_{SSN}$, $dist_{NAME}$, $dist_{DOB}$ >
- Train model : Need test data
- Estimate the two threshold
- Resolve the uncertain region manually
- Naïve Bayes Model

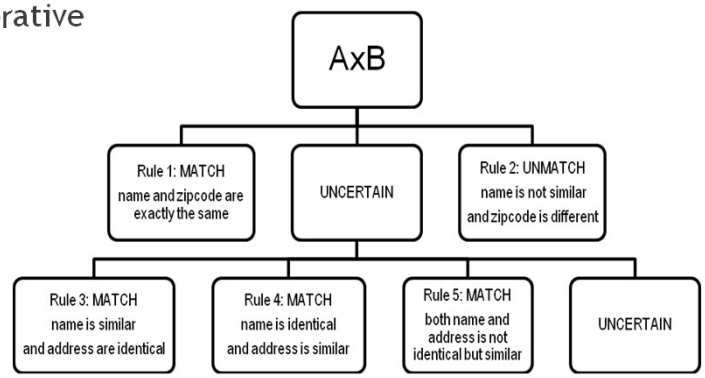


$$(\mathbf{R_A}, \mathbf{R_B}) \in \begin{cases} M & if\ l(\underline{s}) = \dfrac{p(\underline{s}|M)}{p(\underline{s}|U)} \geq \dfrac{p(U)}{p(M)}, \\ U & otherwize \end{cases} \qquad where\ l(\underline{s}) = \frac{p(\underline{s}|M)}{p(\underline{s}|U)}\ is\ the\ likelihood\ ratio$$

10

Deterministic Matching Methods

- Rule Based : iterative



11

Comparison

- Exact Matching
  - Only when data is clean.
  - Great when it works, but doesn't work in many situations
  - Example: SSN, County FIPS Code
- Deterministic Approximate Matching
  - Easier to interpret/control
  - Can manage complexity to levels desired
  - More difficult to fine tune for complex data
- Probabilistic Approximate Matching
  - Can handle more complex data
  - Depends on the data being linked
  - Difficult to interpret what is being linked or not.

12

Example from papers

- SEER
  - Boscoe FP, Schrag D, Chen K, et al. Building capacity to assess cancer care in the Medicaid population in New York State. *Health Services Research* 2011;46(3):805-20.
- Vital records
  - Bronstein J, Lomatsch C, Fletcher D, Wooten T, Lin TM, Nugent R, Lowery C. Issues and Biases in Matching Medicaid Pregnancy Episodes to Vital Records Data: The Arkansas Experience. *Maternal and Child Health Journal*, 2009;13(2):250-259

13

Cleaning Data Example

EISID : E1	EISID : E2	EISID : E3	EISID : E4
ssn : 085-66-9980 first name : Sally last name : Hill MI : L DOB : 3/4/1999	ssn : 143-**25**-9304 first name : Emily last name : Brown MI : K DOB : 6/2/2004	ssn : 354-563-2343 first name : Mary last name : **Johnson** MI : G DOB : 5/13/1983	ssn : 532-34-9183 first name : David last name : Ford MI : J DOB : **10/2**/1990

```
* Note that you do not know which is correct;
* But you have to sync it to one value;
if ssn= '532-34-9183' then dob=mdy(10,2,1990);
```

ssn : 085-66-9980 first name : Sally last name : Hill MI : L DOB : 3/4/1999	ssn : 143-**52**-9304 first name : Emily last name : Brown MI : K DOB : 6/2/2004	ssn : 354-563-2343 first name : Mary last name : **Hawkins** MI : **J** DOB : 5/13/1983	ssn : 532-34-9183 first name : David last name : Ford MI : J DOB : **2/10**/1990

14

Finding duplicate records I

```
* Both tables are sorted by county;
* If need to find duplicates in multiple vars;
* Combine the multiple vars into one variable
first, then run same code;

data dupcnty;
merge tab1 tab2;
by county;
if !(first.county & last.county);
```

15

Finding duplicate records II

```
* Both tables are sorted by county;
data dupcnty;
merge tab1(in=aa) tab2(in=bb);
by county;
src=aa*10+bb;

proc freq;
tables src;

proc print data=dupcnty(obs=30);
where src~=11;
```

16

Approximate Matching Example standardize on caps

EISID : E1	EISID : E2	EISID : E3	EISID : E4
ssn : 085-66-9980 first name : Sally last name : Hill MI : L DOB : 3/4/1999	ssn : 143-**25**-9304 first name : Emily last name : Brown MI : K DOB : 6/2/2004	ssn : 354-563-2343 first name : Mary last name : **Johnson** MI : G DOB : 5/13/1983	ssn : 532-34-9183 first name : David last name : ford MI : J DOB : **10/2**/1990

```
* Create a new standardize variable to link on;
linklname=lowcase(lname);
```

ssn : 085-66-9980 first name : Sally last name : Hill MI : L DOB : 3/4/1999	ssn : 143-**52**-9304 first name : Emily last name : Brown MI : K DOB : 6/2/2004	ssn : 354-563-2343 first name : Mary last name : **Hawkins** MI : **J** DOB : 5/13/1983	ssn : 532-34-9183 first name : David last name : Ford MI : J DOB : **2/10**/1990

17

Approximate Matching Example standardize on space

EISID : E1	EISID : E2	EISID : E3	EISID : E4
ssn : 085-66-9980 first name : Sally last name : Hill MI : L DOB : 3/4/1999	ssn : 143-**25**-9304 first name : Emily last name : Brown MI : K DOB : 6/2/2004	ssn : 354-563-2343 first name : Mary last name : **Johnson** MI : G DOB : 5/13/1983	ssn : 532-34-9183 first name : David last name : fordJr MI : J DOB : **10/2**/1990

```
* Create a new standardize variable to link on;
linklname=compress(lowcase(lname));
```

ssn : 085-66-9980 first name : Sally last name : Hill MI : L DOB : 3/4/1999	ssn : 143-**52**-9304 first name : Emily last name : Brown MI : K DOB : 6/2/2004	ssn : 354-563-2343 first name : Mary last name : **Hawkins** MI : **J** DOB : 5/13/1983	ssn : 532-34-9183 first name : David last name : Ford Jr MI : J DOB : **2/10**/1990

18

Approximate Matching Example standardize on variations

EISID : E1	EISID : E2	EISID : E3	EISID : E4
ssn : 085-66-9980 first name : Sally last name : Hill MI : L DOB : 3/4/1999	ssn : 143-**25**-9304 first name : Emily last name : Brown MI : K DOB : 6/2/2004	ssn : 354-563-2343 first name : Mary last name : **Johnson** MI : G DOB : 5/13/1983	ssn : 532-34-9183 first name : David last name : ford MI : J DOB : **10/2**/1990

```
* Create a new standardize variable to link on;
linklname=compress(lowcase(lname));
linklname=tranwrd(linkname, 'jr', '' );
```

ssn : 085-66-9980 first name : Sally last name : Hill MI : L DOB : 3/4/1999	ssn : 143-**52**-9304 first name : Emily last name : Brown MI : K DOB : 6/2/2004	ssn : 354-563-2343 first name : Mary last name : **Hawkins** MI : **J** DOB : 5/13/1983	ssn : 532-34-9183 first name : David last name : Ford Jr MI : J DOB : **2/10**/1990

19

Other useful functions

- Appendix 2 (p59) of ARHQ Report

```
vto=translate(vfrom, '        ',"()',-.");
vto=lowcase(compress(vto));
vto=tranwrd(vto, "ctr", "center");
vto=tranwrd(vto, "medical", "med");
* vto=tranwrd(vto, "med", "medical");
* medical center = ?;
vto=tranwrd(vto, "texas", "tx");
vto=tranwrd(vto, "hospital", "hosp");
```

20

Validate your approximate link

```
data table1;
linkv=compress(lowcase(lname));

data table2;
linkv=compress(lowcase(lname));

data linked; * approximate link;
merge table1 table2 (rename=(lname=lname2));
by linkv;

proc print data=infn(obs=100);
where lname~=lname2;
```

21

Take Away

- When merging data
  - Use numeric codes whenever possible
  - Remember to use uniform formatting
  - Use string functions to standardize variables
  - Check if the key provides unique rows
    - 1-to-1 or 1-to-N mapping
- Pay attention to what rows link and what do not
- Consider how many rows should link
  - Example: 20% expected 18% achieved
- Validate by printing
  - Links made
  - Links not made

22

N to N linkage

- Merge : max(n1, n2)
- Proc sql: will give you n1*n2

```
proc sql;
    create table n2nfull as
        select *
        from data.mcareidx as t1, data.fidx as t2
        where (t1.zip=t2.zip);
```

23