

Module 4: Deterministic Blocking

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Reading

- ▶ Binette and Steorts (2020)
- ▶ Steorts, Ventura, Sadinle, Fienberg (2014)
- ▶ Murray (2016)

Agenda

- ▶ Data Cleaning Pipeline
- ▶ Blocking
- ▶ Traditional Blocking
- ▶ Probabilistic Blocking

Load R packages

```
knitr::opts_chunk$set(echo = TRUE, fig.width=4, fig.height=4)  
library(RecordLinkage)  
library(blink)
```

Data Cleaning Pipeline

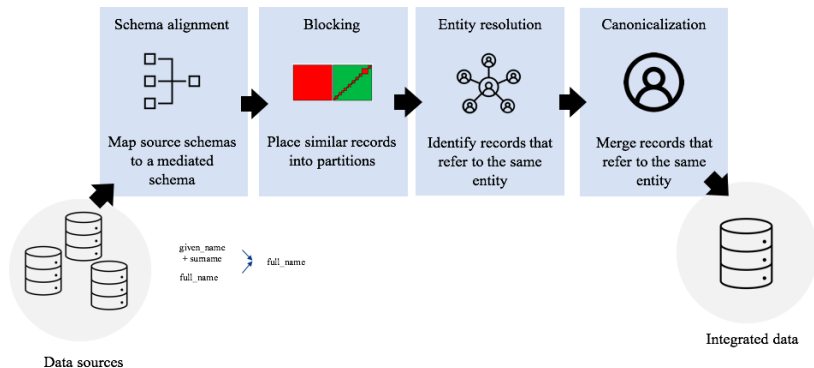


Figure 1: Data cleaning pipeline.

Blocking

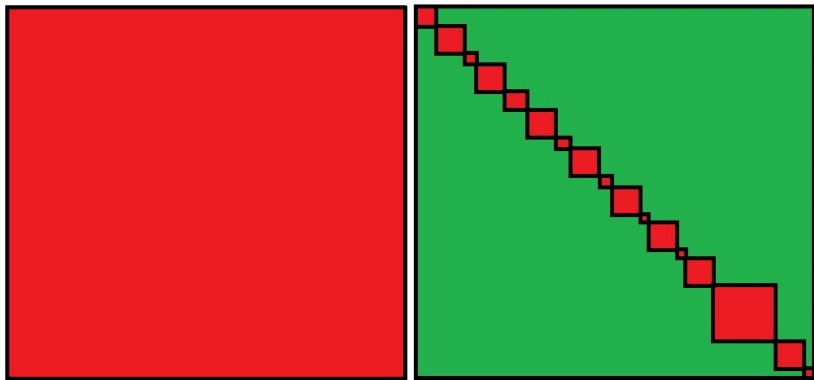


Figure 2: Left: All to all record comparison. Right: Example of resulting blocking partitions.

Blocking

- ▶ Blocking partitions similar records into partitions/blocks.
- ▶ ER is only performed within each blocks.

Traditional Blocking

- ▶ A deterministic (fixed) partition is formed based upon the data.
- ▶ A partition is created by treating certain fields that are thought to be nearly error-free as fixed.
- ▶ Benefits: simple, easy to understand, and fast to implement.
- ▶ Downsides: the blocks are treated as error free, which is not usually accurate and can lead to errors in the ER task that cannot be accounted for.

Example: Blocking on date of birth year.

Probabilistic Blocking

- ▶ A probability model is used to cluster the data into blocks/partitions.

Example: Fellegi-Sunter (1969), or Locality Sensitive Hashing

Under both blocking approaches, record pairs that do not meet the blocking criteria are automatically classified as non-matches.

Example: Traditional blocking

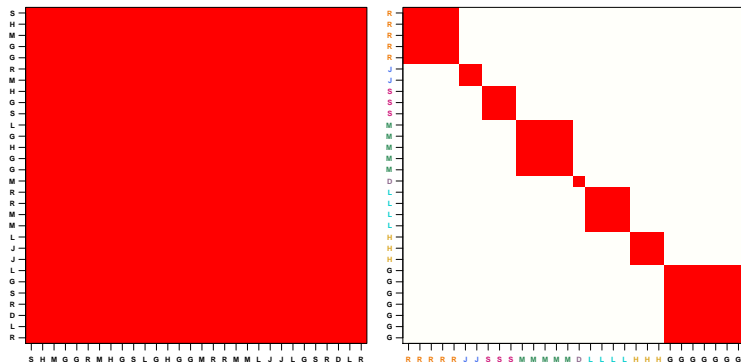


Figure 3: All-to-all record comparisons (left) versus partitioning records into blocks by lastname initial and comparing records only within each partition (right).

Example: RLdata500

```
library(RecordLinkage)
data(RLdata500)
head(RLdata500)
```

##	fname_c1	fname_c2	lname_c1	lname_c2	by	bm	bd
## 1	CARSTEN	<NA>	MEIER	<NA>	1949	7	22
## 2	GERD	<NA>	BAUER	<NA>	1968	7	27
## 3	ROBERT	<NA>	HARTMANN	<NA>	1930	4	30
## 4	STEFAN	<NA>	WOLFF	<NA>	1957	9	2
## 5	RALF	<NA>	KRUEGER	<NA>	1966	1	13
## 6	JUERGEN	<NA>	FRANKE	<NA>	1929	7	4

RLdata500 (Continued)

```
# Total number of all to all record comparisons  
choose(500,2)
```

```
## [1] 124750
```

RLdata500 (Continued)

```
# Block by last name initial
```

```
last_init <- substr(RLdata500[, "lname_c1"], 1, 1)  
head(last_init)
```

```
## [1] "M" "B" "H" "W" "K" "F"
```

```
# Total number of blocks
```

```
length(unique(last_init))
```

```
## [1] 20
```

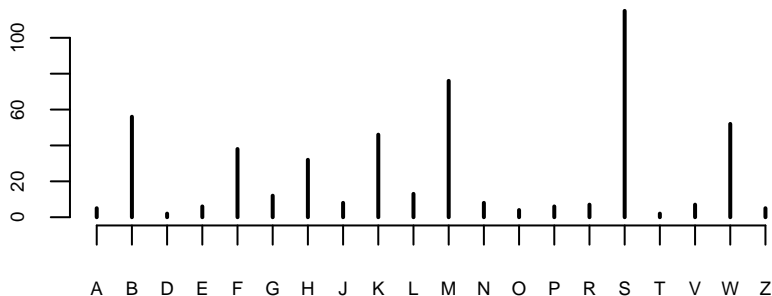
RLdata500 (Continued)

```
# Total number of records per block  
recordsPerBlock <- table(last_init)  
head(recordsPerBlock)
```

```
## last_init  
##  A  B  D  E  F  G  
##  5 56  2  6 38 12
```

RLdata500 (Continued)

```
# Block sizes can vary  
plot(recordsPerBlock,  
      cex.axis=0.6, xlab="", ylab="")
```



RLdata500 (Continued)

```
# Total number of records pairs per block
```

```
choose(recordsPerBlock, 2)
```

```
## last_init
```

```
##      A      B      D      E      F      G      H      J      K      L      M
##    10 1540      1     15    703     66    496     28 1035     78 2850
##      T      V      W      Z
##      1     21 1326     10
```

```
# Reduction on comparison space
```

```
sum(choose(recordsPerBlock, 2))
```

```
## [1] 14805
```


RLdata500 (Continued)

What is the overall dimension reduction from the original space to the reduced space induced by blocking?

Recall the original space of comparisons was

```
choose(500, 2)
```

```
## [1] 124750
```

We have reduced the number of comparisons to

```
sum(choose(recordsPerBlock, 2))
```

```
## [1] 14805
```

How do we calculate the reduction ratio?

The reduction ratio is

RR = % comparisons eliminated by blocking.

```
(choose(500, 2) - sum(choose(recordsPerBlock, 2))) /  
choose(500, 2)
```

```
## [1] 0.8813226
```

How do we calculate the reduction ratio (via a function)?

```
reduction.ratio <- function(block.labels) {  
  n_all_comp = choose(length(block.labels), 2)  
  n_block_comp = sum(choose(table(block.labels), 2))  
  
  (n_all_comp - n_block_comp) / n_all_comp  
}  
  
reduction.ratio(last_init)
```

```
## [1] 0.8813226
```

Pairwise Precision

```
labels = unique(last_init)

# Number of matching pairs among blocks
n_matches = sapply(labels, function(label) {
  # Records in a given blocks
  records = which(last_init == label)
  # Number of matches in that block
  sum(duplicated(identity.RLdata500[records]))
})

# Total number of pairs
n_pairs = sum(choose(table(last_init), 2))

sum(n_matches) / n_pairs

## [1] 0.003377237
```

Pairwise Precision

```
precision <- function(block.labels, IDs) {  
  labels = unique(block.labels)  
  
  # Number of matching pairs among blocks  
  n_matches = sapply(labels, function(label) {  
    records = which(block.labels == label)  
    sum(duplicated(IDs[records]))  
  })  
  
  # Total number of pairs  
  n_pairs = sum(choose(table(block.labels), 2))  
  
  sum(n_matches) / n_pairs  
}  
  
precision(last_init, identity.RLdata500)
```

```
## [1] 0.003377237
```

Pairwise Recall

```
recall <- function(block.labels, IDs) {  
  precision(IDs, block.labels)  
}
```

Italian Survey on Household and Wealth (SHIW)

We will now explore a case study to the SHIW

```
install.packages("italy", repos='http://cran.us.r-project.org')
```

```
## Installing package into '/Users/rebeccasteorts/Library/R/
## (as 'lib' is unspecified)
```

```
##
```

```
## The downloaded binary packages are in
```

```
## /var/folders/bv/xhclmwh90zg08bvwnjvxtrz80000gn/T//Rtmpo
```

```
#library(devtools)
```

```
#devtools::install_github("cleanzr/italy")
```

```
library(italy)
```

SHIW

- ▶ The SHIW is a sample survey 383 households conducted by the Bank of Italy every two years.
- ▶ The data set is anonymized to remove first and last name (and other sensitive information).
- ▶ The following attribute information is available:
 - ▶ PARENT (parental status)
 - ▶ GENDER
 - ▶ ANASC (year of birth)
 - ▶ NASCREG (working status)
 - ▶ CIT (employment status)
 - ▶ ACOM4C (branch of activity)
 - ▶ STUDIO (town size)
 - ▶ Q (quality of life status)
 - ▶ QUAL (whether or not Italian national)
 - ▶ SETT (highest educational level obtained)
 - ▶ ireq (region of Italy)

Explore Data

```
head(italy08) # first year of SHIW
```

##		id	PARENT	SEX	ANASC	NASCREG	CIT	ACOM4C	STUDIO	Q	
## 1	1040021	1	2	1948	16	1	0	5	1		
## 2	1040022	10	2	1952	16	1	0	7	1		
## 3	1110521	1	1	1972	20	1	2	5	1		
## 4	1110522	3	1	1935	20	1	2	2	3		
## 5	1110523	3	2	1941	20	1	2	3	3		
## 6	119401	1	1	1941	7	1	0	4	3		

```
head(italy10) # second year of SHIW
```

##		id	PARENT	SEX	ANASC	NASCREG	CIT	ACOM4C	STUDIO	Q	
## 1	1040021	1	2	1948	16	1	0	5	3		
## 2	1040022	11	2	1952	16	1	0	7	1		
## 3	1110521	1	2	1941	20	1	2	3	3		
## 4	1110522	2	1	1935	20	1	2	2	3		
## 5	1110523	6	1	1972	20	1	2	5	1		
## 6	119721	1	2	1948	16	1	2	2	2		

Reformat Data

```
id08 <- italy08$id
id10 <- italy10$id
id <- c(italy08$id, italy10$id) # combine the id
italy08 <- italy08[-c(1)] # remove the id
italy10 <- italy10[-c(1)] # remove the id
italy <- rbind(italy08, italy10)
```

Your turn

- ▶ Construct a blocking criterion for the SHIW data set.
- ▶ Provide code to construct the blocks
- ▶ Are your blocks well balanced?
- ▶ What is the reduction ratio?
- ▶ What is the pairwise recall and precision?
- ▶ Would you recommend your blocking criterion for an ER task?
Why or why not.

Your turn solution

I will block on gender. Why?

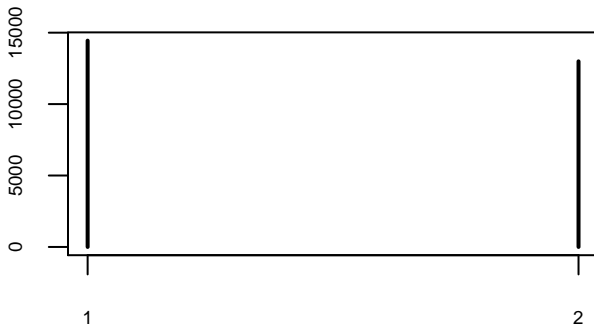
```
# block by gender  
blockByGender <- italy$SEX  
recordsPerBlock <- table(blockByGender)  
head(recordsPerBlock)
```

```
## blockByGender  
##      1      2  
## 14442 12993
```

Your turn solution

The block sizes are similar. But note, they are still quite large.

```
# Checking block sizes  
plot(recordsPerBlock,  
      cex.axis=0.6, xlab="", ylab="")
```



Your turn solution

```
print(rr <- reduction.ratio(blockByGender))
```

```
## [1] 0.4986234
```

We have reduced the overall space by roughly 50 percent.

Your turn solution

```
precision(blockByGender, id)
```

```
## [1] 3.599727e-05
```

```
recall(blockByGender, id)
```

```
## [1] 0.9113109
```

This is not an optimal blocking criterion as ideally, we would want both the precision and recall to be close to 1.

Your turn solution

```
blockRule <- italy$SEX & italy$ANASC  
precision(blockRule, id)
```

```
## [1] 1.980464e-05
```

```
recall(blockRule, id)
```

```
## [1] 1
```