Privacy-Preserving Record Linkage

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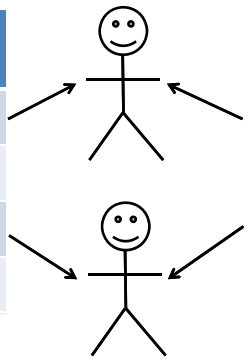
Record linkage

Set of records from Vanderbilt

First Name	Last Name
john	**smith**
lucille	ball
bill	**clinton**
hillary	clinton



Set of records from Emory

First Name	Last Name
jon	**smyth**
taylor	swift
william	**clinton**
jon	bon jovi

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Privacy-preserving record linkage (PPRL)

Set of records from Vanderbilt

First Name	Last Name
john	**smith**
lucille	ball
bill	**clinton**
hillary	clinton

POLICY

Set of records from Emory

First Name	Last Name
jon	**smyth**
taylor	swift
william	**clinton**
jon	bon jovi

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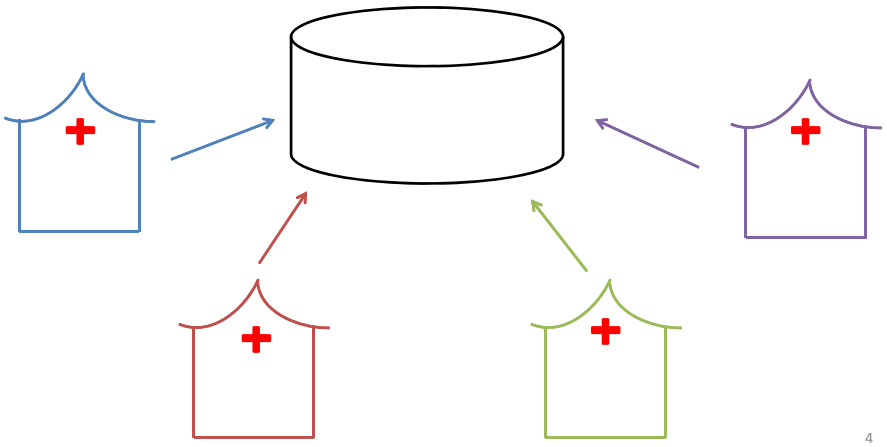
PPRL applications in healthcare

sharing patient data for research



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The NIH requires researchers share de-identified patient data

- **U.S. National Institutes of Health (NIH) data sharing policy**
  - "Data should be made as widely & freely available as possible"
  - Researchers who receive ≥ $500,000 **must** develop a data sharing plan or describe why data sharing is not possible
  - Derived data must be shared in a manner that is devoid of "identifiable information"
- **NIH supported genome-wide association studies policy**
  - Researchers funded for genome-wide association studies must share data

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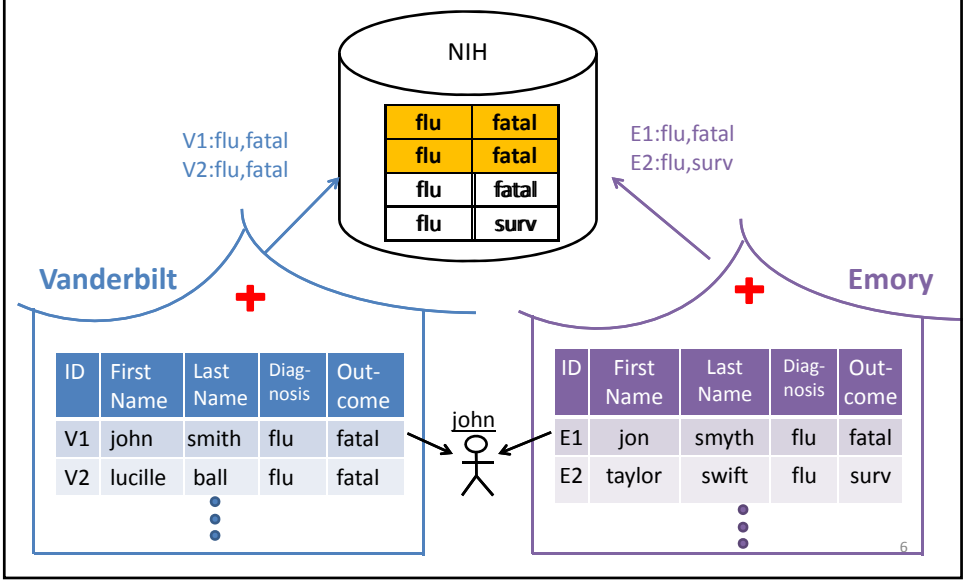
Duplicates: a flaw in the current model for sharing de-identified data



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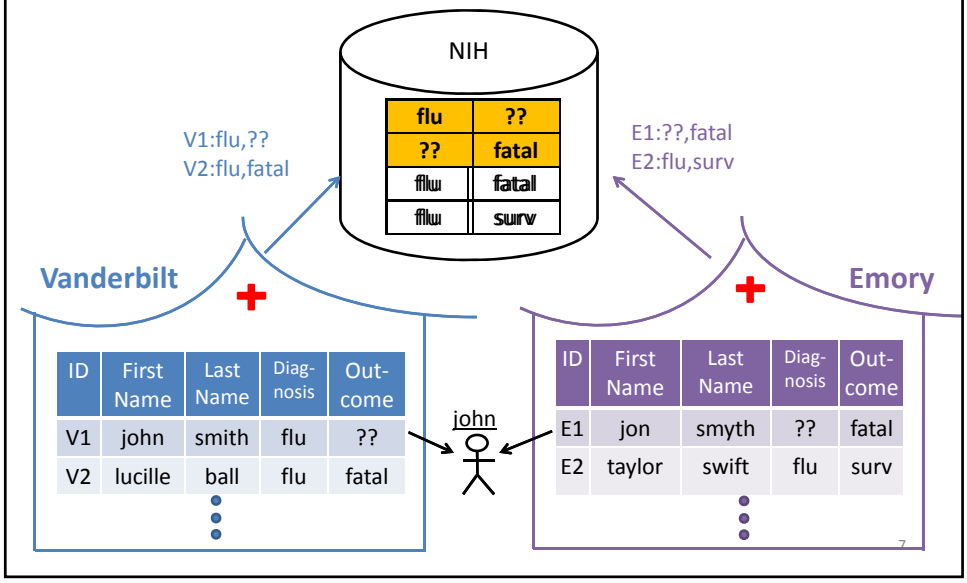
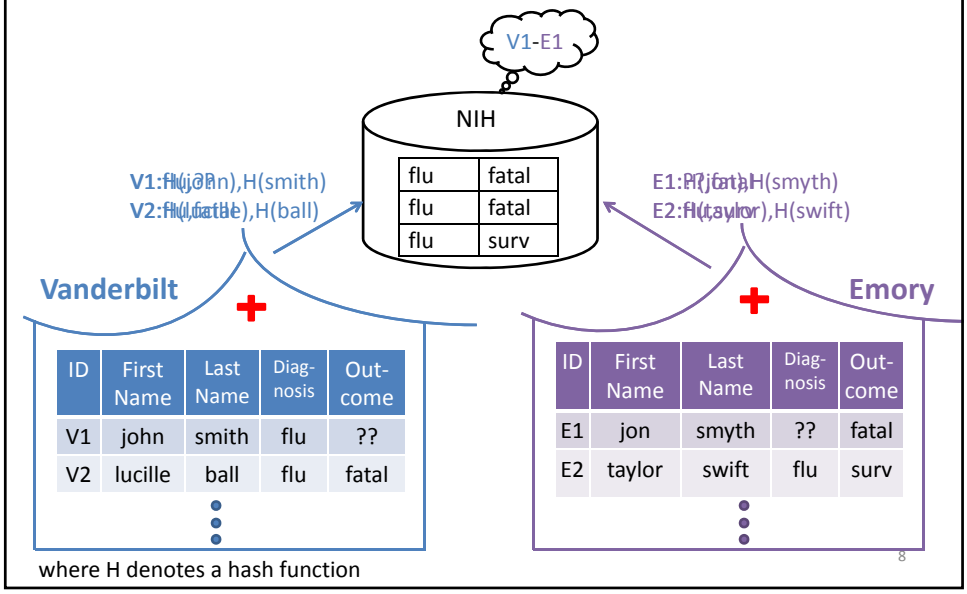
Fragmented data: a flaw in the current model for sharing de-identified data



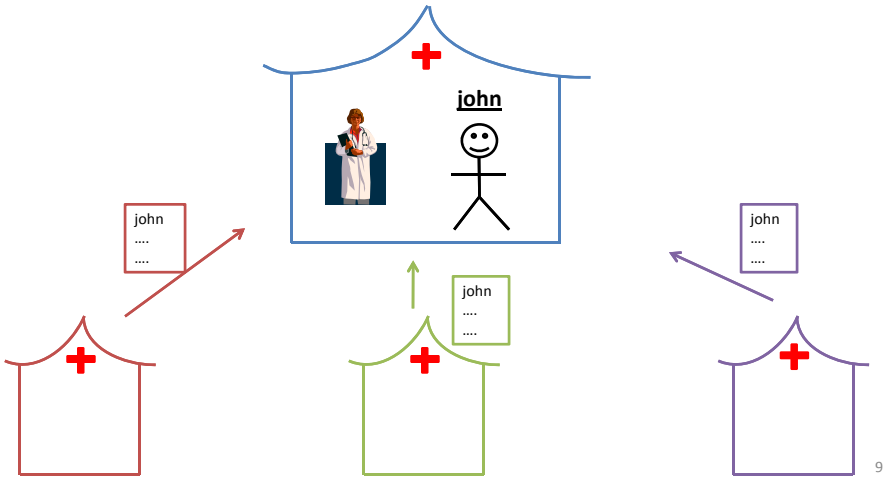
PPRL can improve the model for sharing de-identified data and enable more effective medical research



where H denotes a hash function

PPRL applications in healthcare

improving patient care



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Other PPRL applications

- Business
- Counter-terrorism efforts

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Roadmap

- Definition
- Motivation
- Record linkage
- Privacy-preserving record linkage
  - Background
  - Experimental design
  - Experimental results
  - Discussion
  - Open questions in record linkage
  - Conclusion

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Steps in record linkage

A few assumptions…

1) common schema
2) common method of data standardization
3) records from an institution have been deduplicated (*i.e.*, record linkage has been applied within each institution such that an individual is represented by only a single record within an institution)

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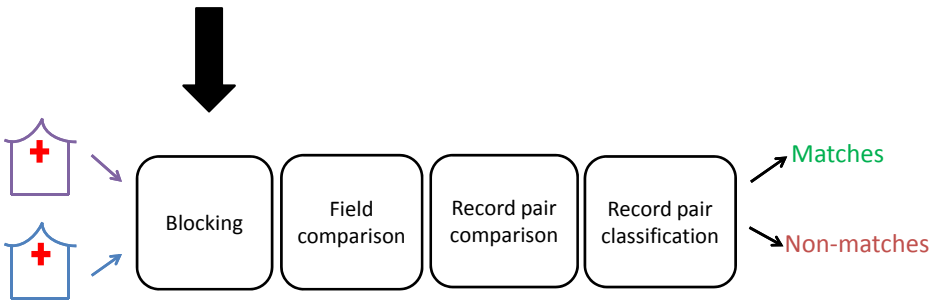
Steps in record linkage



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Blocking: sample dataset

Set of records from Vanderbilt

First Name	Last Name
john	smith
lucille	ball
bill	clinton
hillary	clinton

Set of records from Emory

First Name	Last Name
jon	smyth
taylor	swift
william	clinton
jon	bon jovi

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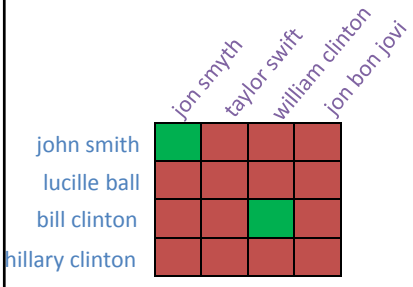
Blocking

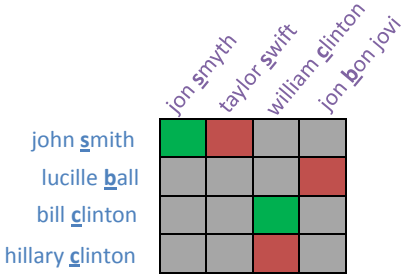
= match
= non-match

no blocking



|Vanderbilt| |Emory| = 16 record pair comparisons

blocking
(first letter of last name)



5 record pair comparisons

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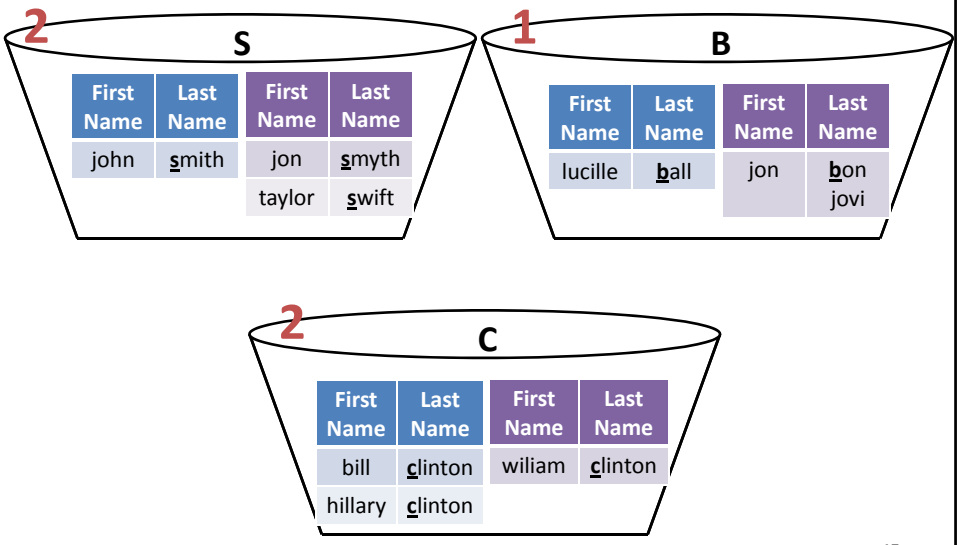
Blocking: another perspective



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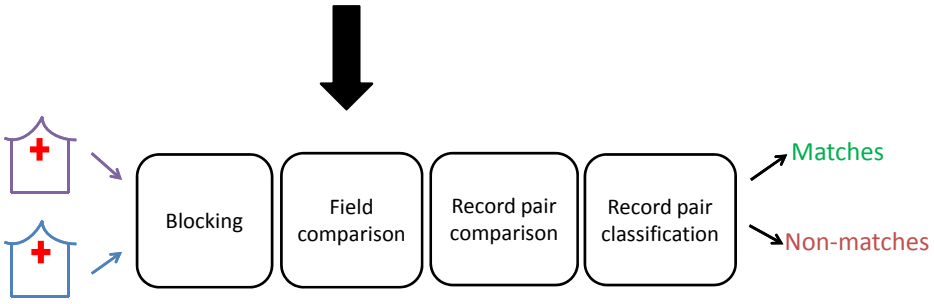
Steps in record linkage



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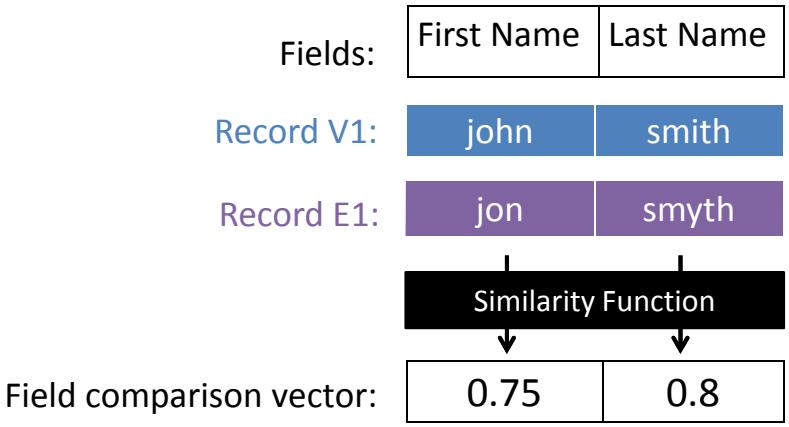
The field comparison step of record linkage



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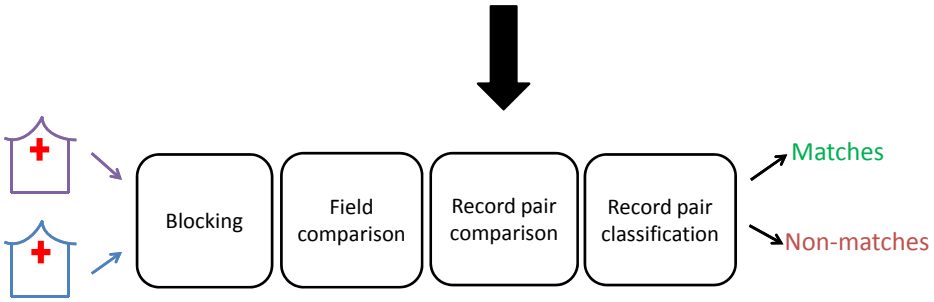
Steps in record linkage



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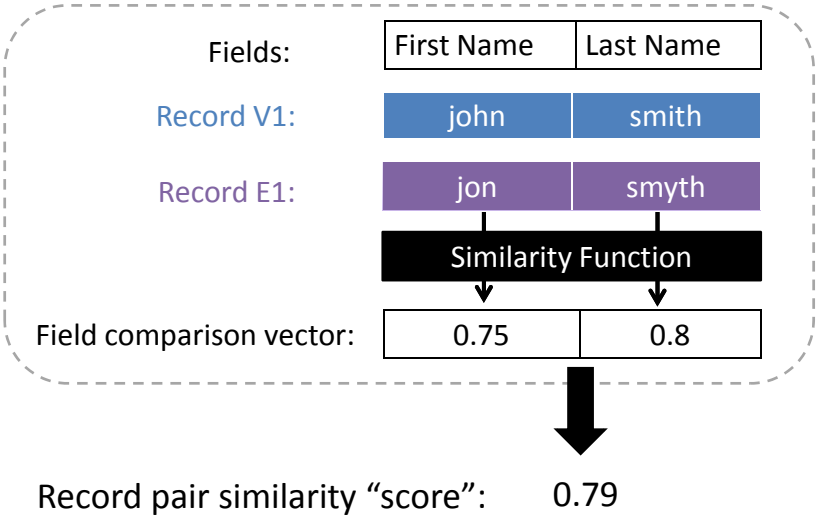
The record pair comparison step of record linkage



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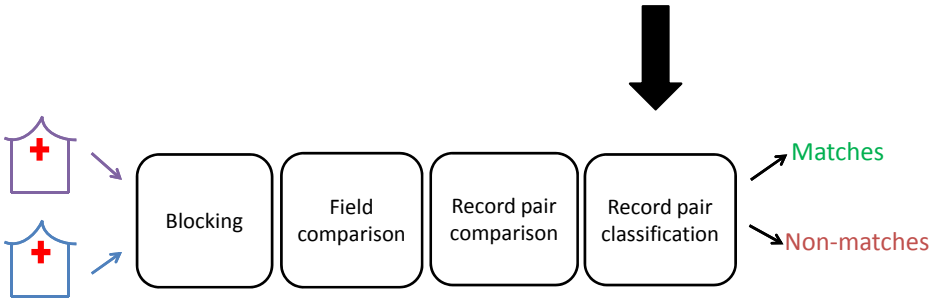
Steps in record linkage



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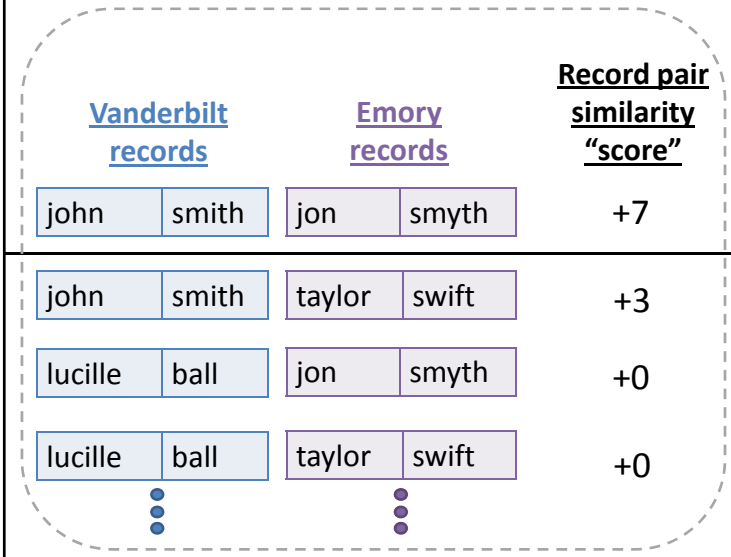
The record pair classification step of record linkage



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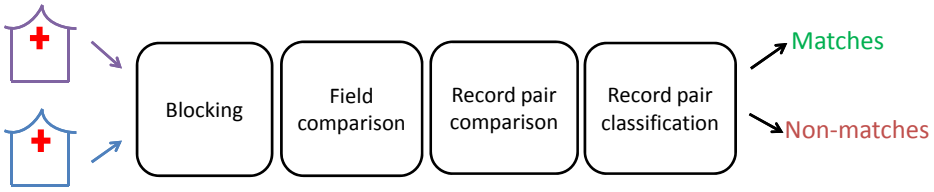
How do we do all of this in a privacy-preserving manner?



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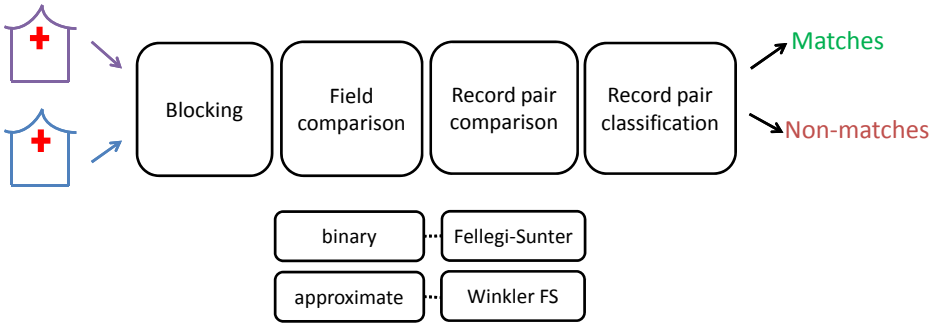
Background



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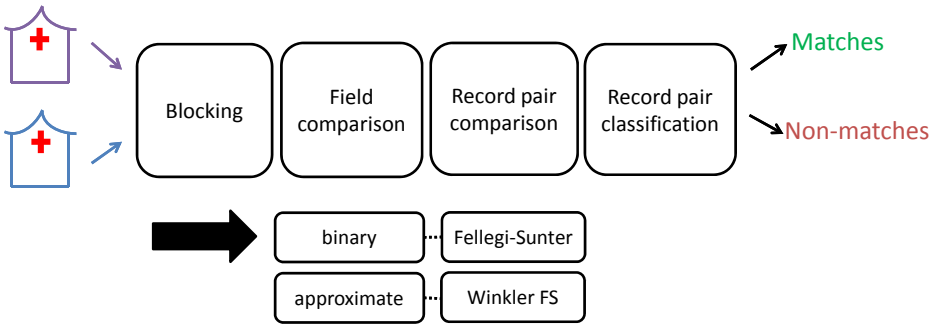
Background



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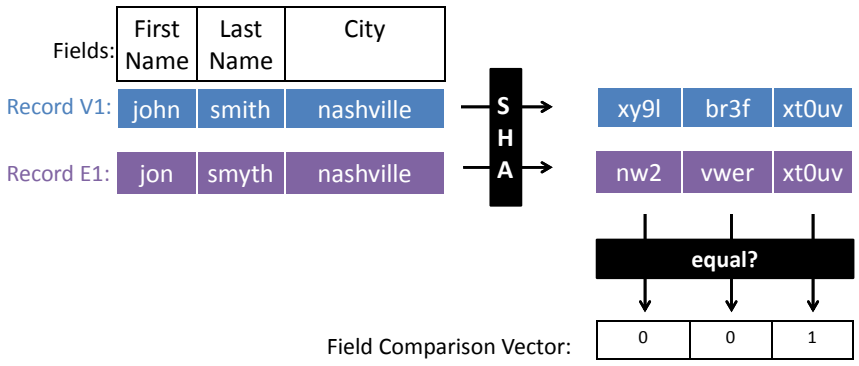
Binary Field Comparison



where SHA refers to the Secure Hash Algorithm

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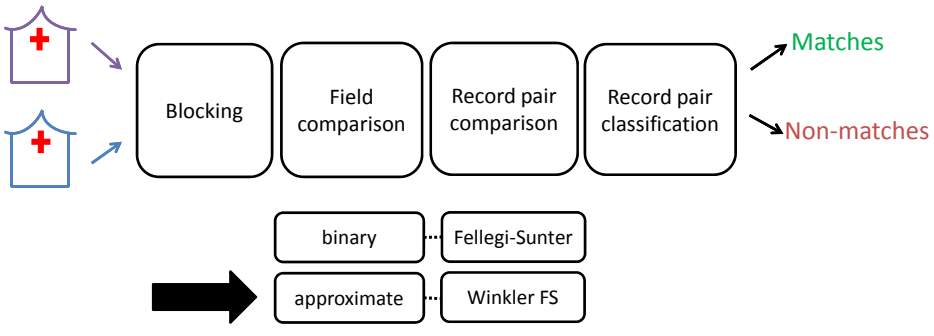
Background



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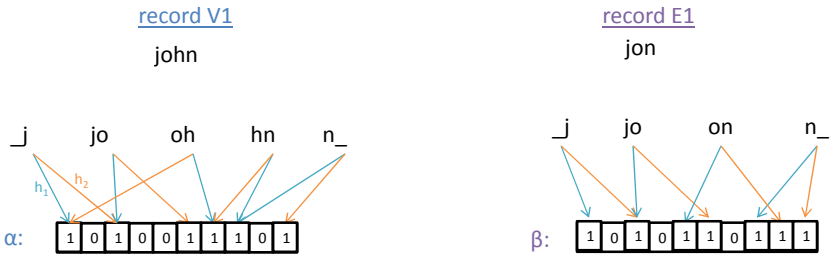
Approximate Field Comparison



$$Dice\ coefficient(\alpha,\beta) = 2\left(\frac{|\alpha \cap \beta|}{|\alpha| + |\beta|}\right) = \frac{2*5}{13} = 0.77$$

Schnell 2009

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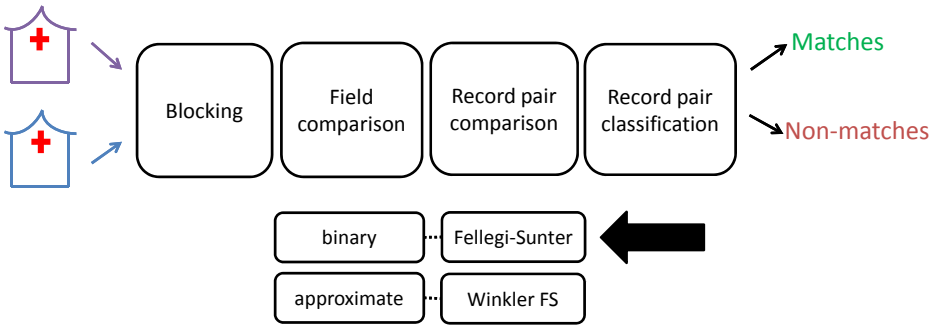
Background



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Fellegi-Sunter (FS)

Conditional probability vectors:

Fields:	First Name	Last Name
Match:	0.8	0.9
Non-match:	0.05	0.02

$\log \frac{0.9}{0.02}$

Weight vectors:

Fields:	First Name	Last Name
Agreement:	1.2	1.95
Disagreement:	-0.68	-1

$\log \frac{1 - 0.9}{1 - 0.02}$

Fellegi 1969

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Fellegi-Sunter (FS)

Fields:	First Name	Last Name
Agreement weights:	1.2	1.95
Disagreement weights:	-0.68	-1

Fields:	First Name	Last Name
Record V1:	john	smith
Record E1:	jon	smyth
Field comparison vector:	0	0
Weight vector:	-0.68	-1

Record pair similarity score: -1.68 (Σ)

Fellegi 1969

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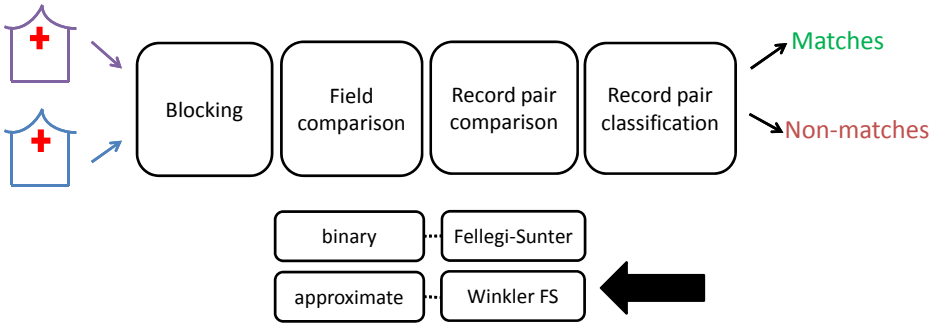
Background



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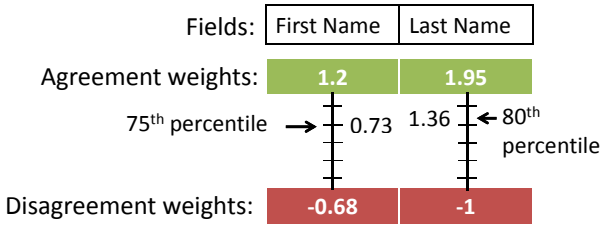
Winkler's Modificaton to Fellegi-Sunter



Fields:	First Name	Last Name
Record V1:	john	smith
Record E1:	jon	smyth
Field comparison vector:	0.75	0.8
Weight vector:	**0.73**	1.36
Record pair similarity score:	2.09	

Porter 1997

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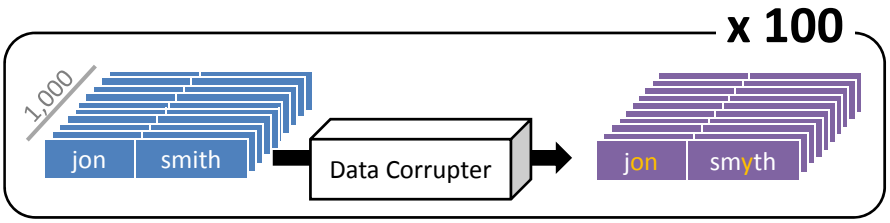
Experimental design

- **Dataset: ~**6 million records from the North Carolina Voter Registration dataset



- **Fields:**

First name	Middle name	Last name	Birth state	Sex	Race	Street name	Street type	Street suffix	City	State

- **Computational resources:** 2 GHz dual core PC with 4GB of memory

Pudjijono 2009

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Experimental results: accuracy

results withheld pending publication

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Experimental results: run time

results withheld pending publication

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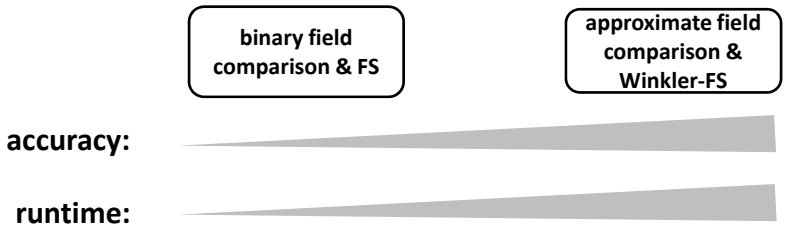
Discussion

Discussion



Limitations

- Controlled environment

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Open questions in record linkage

1. Enforcing one-to-one linkage
2. Decentralized record linkage

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Open questions in record linkage

➡ 1. Enforcing one-to-one linkage
2. Decentralized record linkage

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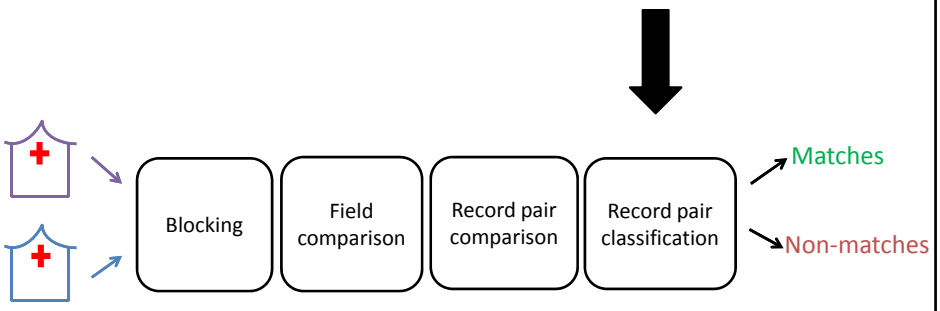
One-to-one linkage



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Reminder: the record pair classification step of record linkage

Vanderbilt records		Emory records		Record pair similarity "score"	Record pair classification
john	smith	jon	smyth	+7	Match
john	smith	taylor	swift	+3	Non-match
lucille	ball	jon	smyth	+0	Non-match
lucille	ball	taylor	swift	+0	Non-match

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One-to-one linkage: sample dataset

Set of records from Vanderbilt

First Name	Last Name	City
john	smith	nashville
bill	clinton	washington dc
hillary	clinton	washington dc

Set of records from Emory

First Name	Last Name	City
jon	smyth	nashville
taylor	swift	nashville
william	clinton	washington dc

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One-to-one linkage

set of records from Vanderbilt			set of records from Emory			score	classification
bill	clinton	washington dc	william	clinton	washington dc	+2	Match
hillary	clinton	washington dc	william	clinton	washington dc	+2	Match
john	smith	nashville	william	clinton	washington dc	+0	Non-match
bill	clinton	washington dc	taylor	swift	nashville	+0	Non-match
hillary	clinton	washington dc	taylor	swift	nashville	+0	Non-match
john	smith	nashville	taylor	swift	nashville	+1	Non-match
bill	clinton	washington dc	jon	smyth	nashville	+0	Non-match
hillary	clinton	washington dc	jon	smyth	nashville	+0	Non-match
john	smith	nashville	jon	smyth	nashville	+1	Non-match

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One-to-one linkage

predicted

First Name	Last Name	City
john	smith	nashville
bill	clinton	washington dc
hillary	clinton	washington dc

First Name	Last Name	City
jon	smyth	nashville
taylor	swift	nashville
william	clinton	washington dc

actual

First Name	Last Name	City
john	smith	nashville
bill	clinton	washington dc
hillary	clinton	washington dc

First Name	Last Name	City
jon	smyth	nashville
taylor	swift	nashville
william	clinton	washington dc

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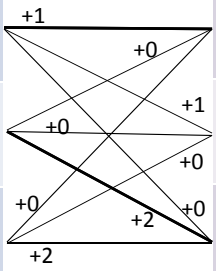
One-to-one linkage

First Name	Last Name	City
john	smith	nashville
bill	clinton	washington dc
hillary	clinton	washington dc



First Name	Last Name	City
jon	smyth	nashville
taylor	swift	nashville
william	clinton	washington dc

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Open questions in record linkage

1. Enforcing one-to-one linkage
2. Decentralized record linkage

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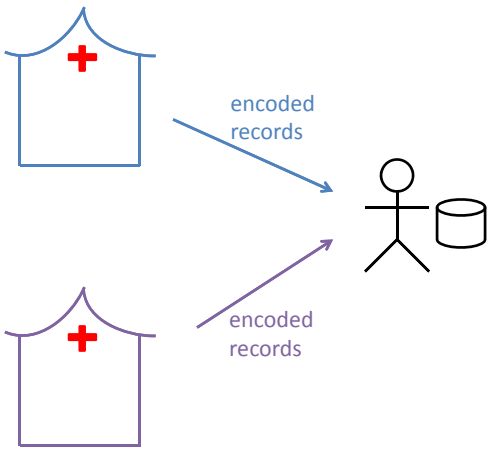
Centralized framework



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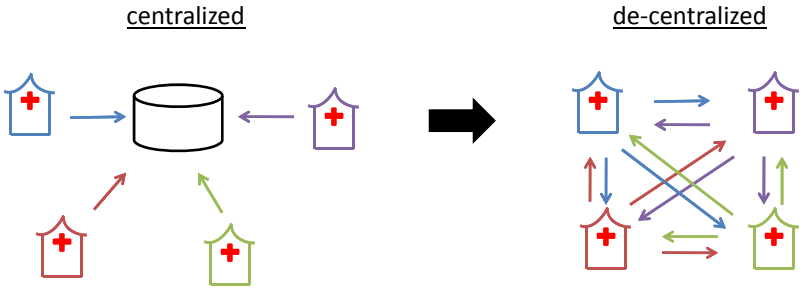
De-centralization of record linkage



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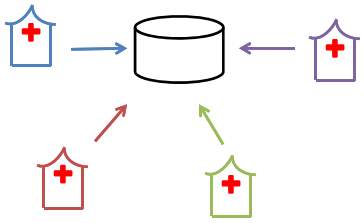
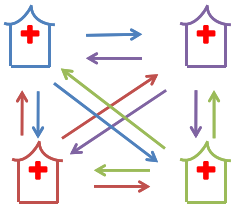
Conclusion



Privacy-preserving record linkage can inform and improve medical research



Privacy-preserving record linkage can improve patient care

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References

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- Fellegi I, Sunter A. A theory for record linkage. *J Amer Stat Assoc.* 1969; 64: 1183–210.
- Porter E, Winkler W, Approximate string comparison and its effect on an advanced record linkage system, Research Report RR97/02, U.S. Census Bureau, 1997.
- Schnell R, Bachteler T, and Reiher J. Privacy-preserving record linkage using Bloom filters. *BMC Medical Informatics and Decision Making* (9). 2009.

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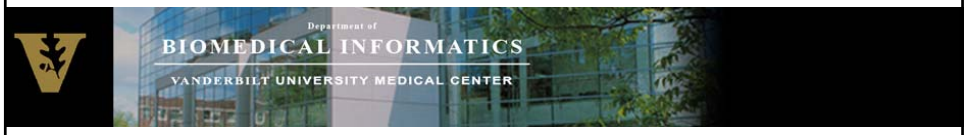
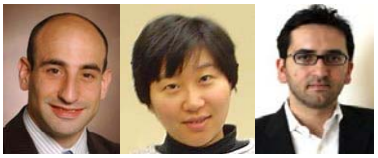
Acknowledgements





U.S. National Library of Medicine grant 2-T15LM07450-06
U.S. National Institutes of Health R01 LM009989

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Thank You

Contact:

ea.durham@vanderbilt.edu

http://hiplab.mc.vanderbilt.edu/

Publications:

- E Durham, M Kantarcioglu, Y Xue, and B Malin. Private medical record linkage with approximate matching. *Proceedings of the American Medical Informatics Association*. 2010 November.

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