Entity Resolution: Glue for Middleware

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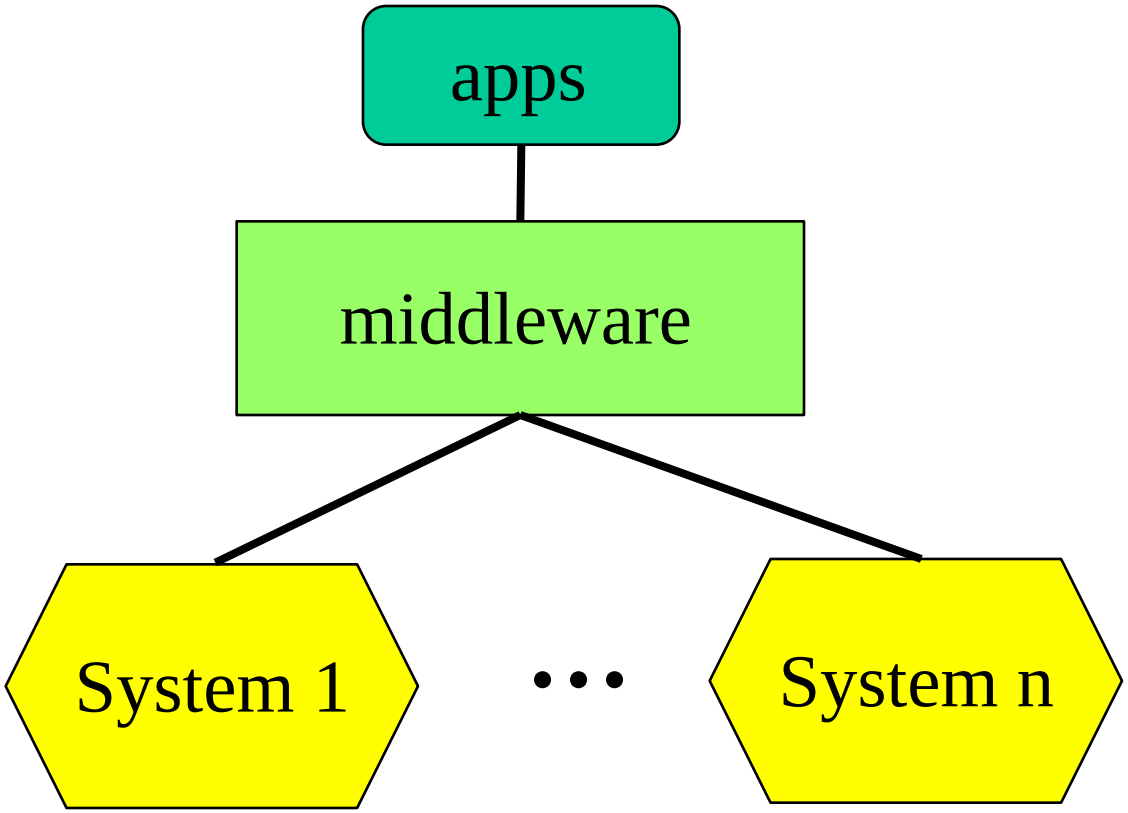
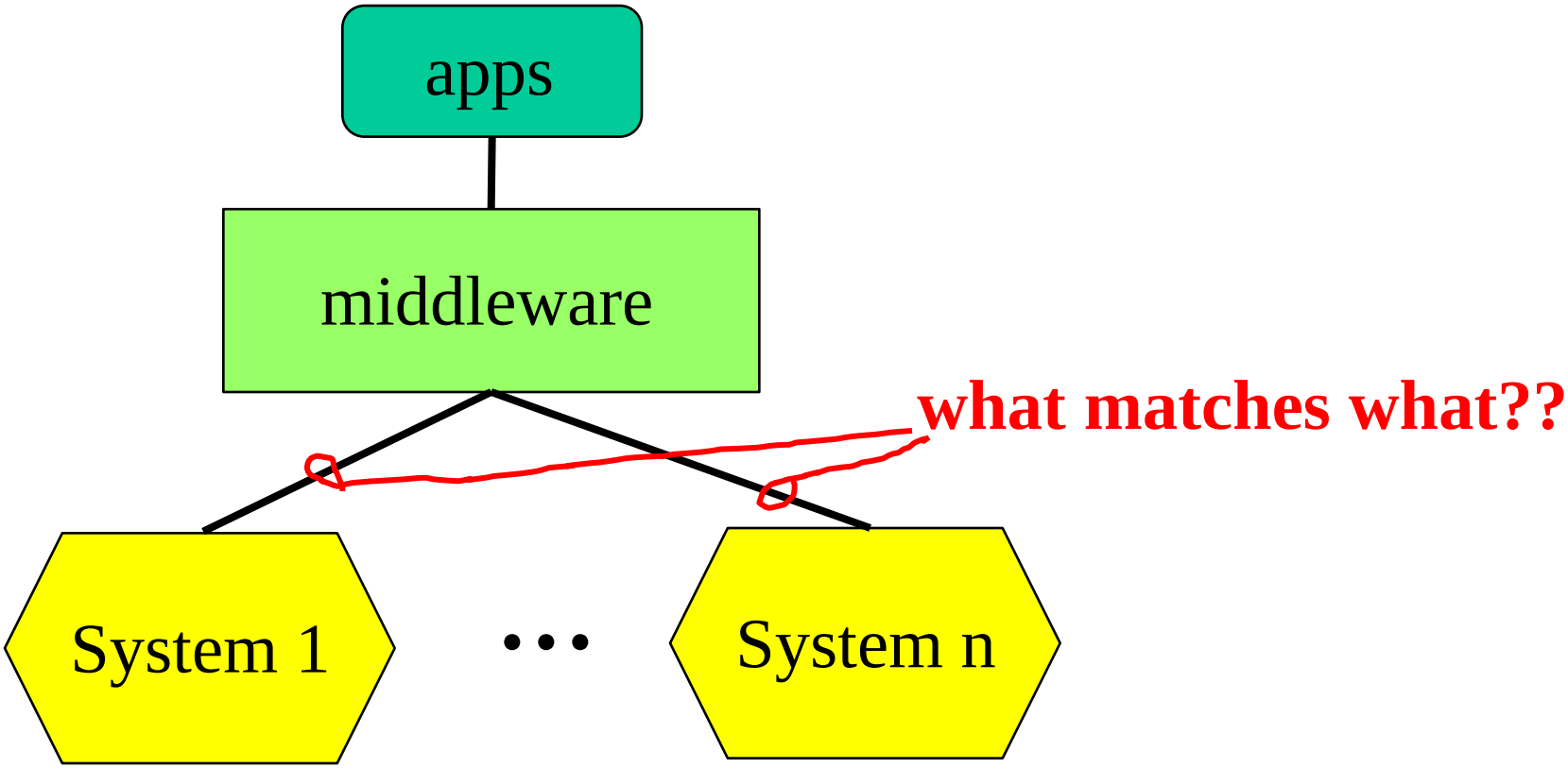
Middleware



Middleware



Matching

- Execution Level
  - matching ports, calls, parameters, workflows ...
- Data Level
  - matching records, attributes, values ...

Matching

- Execution Level
- Data Level
  - Ontology
  - Schema
  - Instance

Example: Stock Options

- Ontology

Strike Price

Black–Scholes Valuation

Stock Option

Market Valuation

Stock Grant

Date of Option

Deferred Compensation

Taxable Income

Example: Stock Options

- Schema

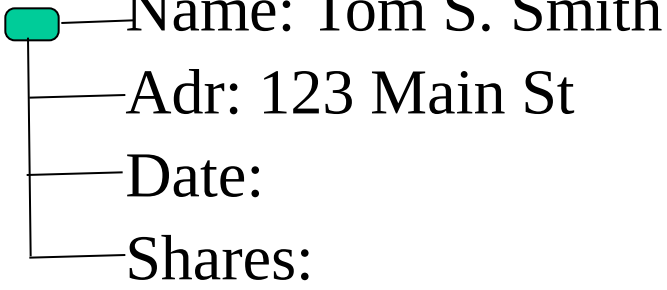
Stock_Option(Date, Price, Shares, Holder, Plan, ...)

Option(Date, StrikePrice, Shares, Employee, Restrictions, ...)

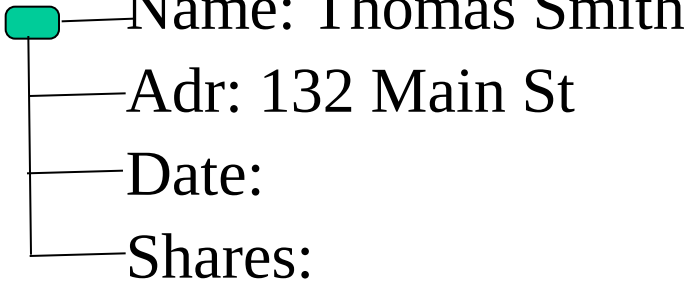
Example: Stock Options

- Instance

Option 1



Option 2

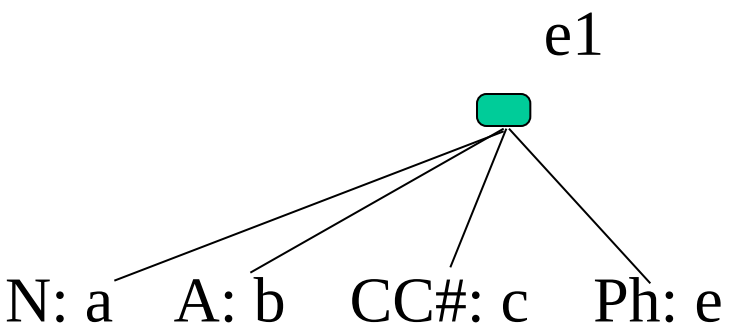


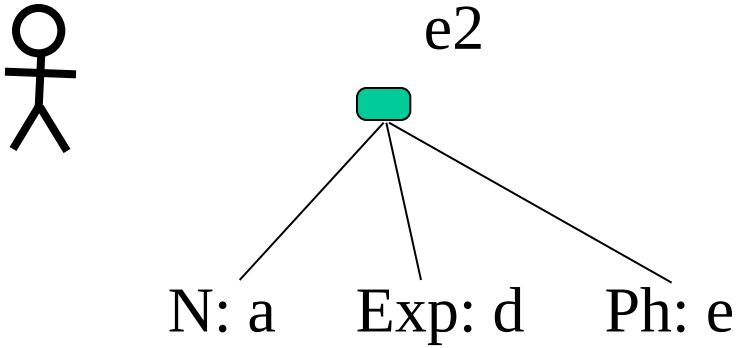
This Talk

- Instance Resolution
  - a.k.a. Entity Resolution
  - a.k.a. De-Duplication
  - a.k.a. Record Linkage

Applications

- comparison shopping
- mailing lists
- classified ads
- customer files
- counter-terrorism

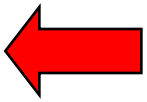




Why is ER Challenging?

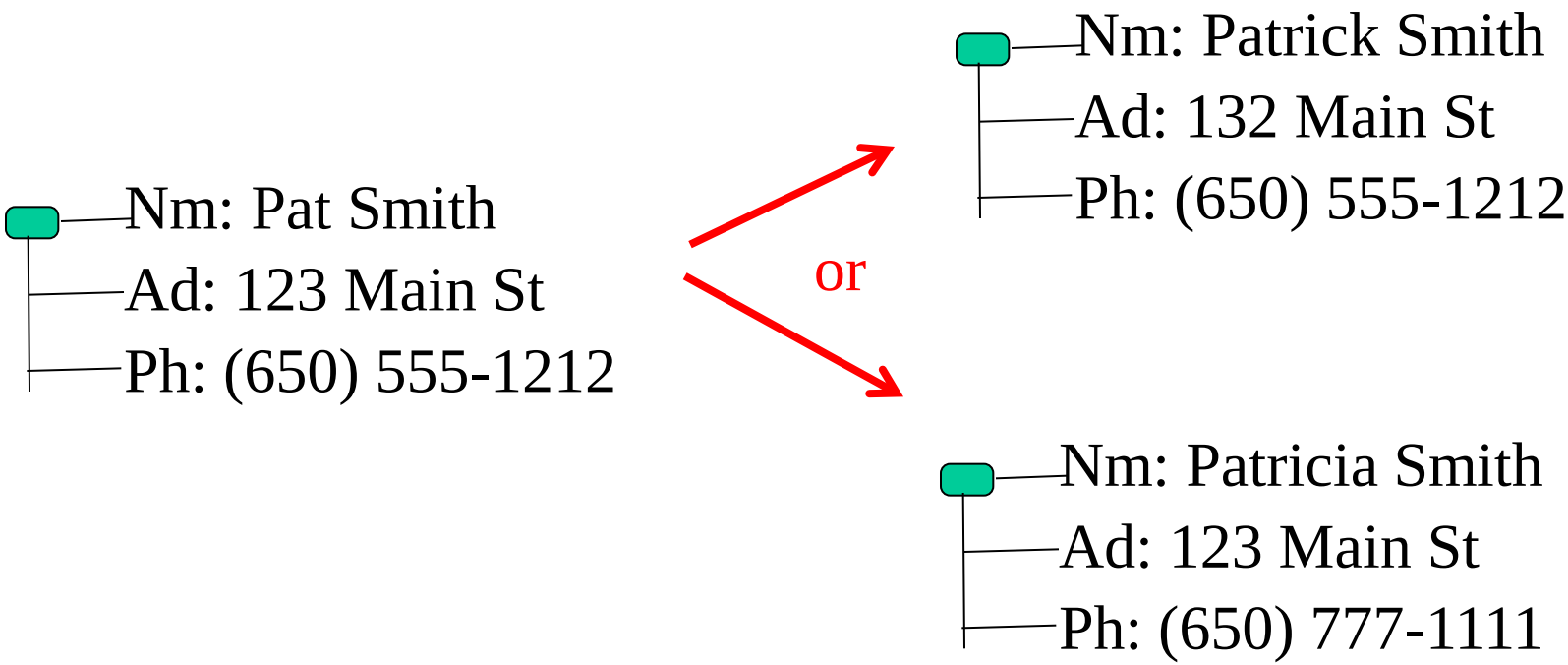
- Huge data sets
- No unique identifiers
- Lots of uncertainty
- Many ways to skin the cat

Outline

- Taxonomy 
- Swoosh Algorithm
- Distributed ER
- More on blocking

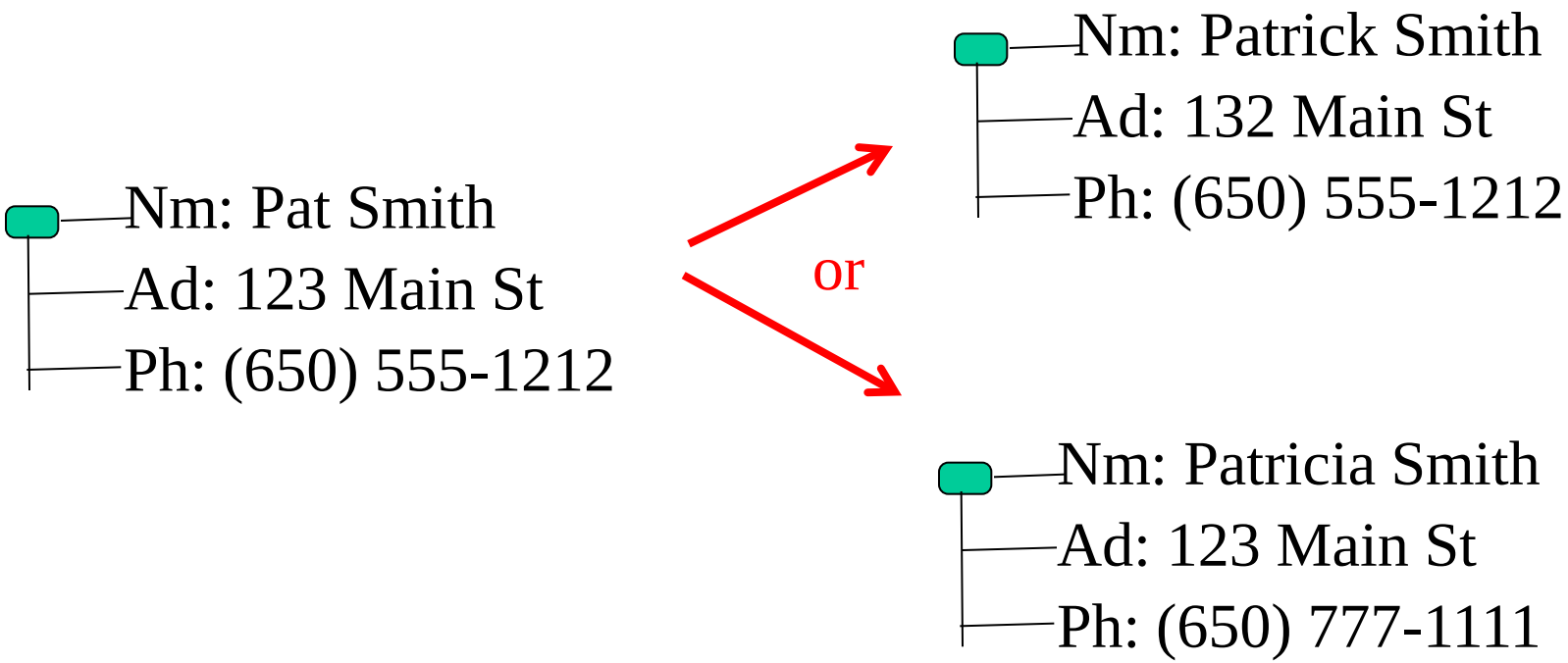
Taxonomy: Pairwise vs Global

- Decide if *r*, *s* match only by looking at *r*, *s*?
- Or need to consider more (all) records?



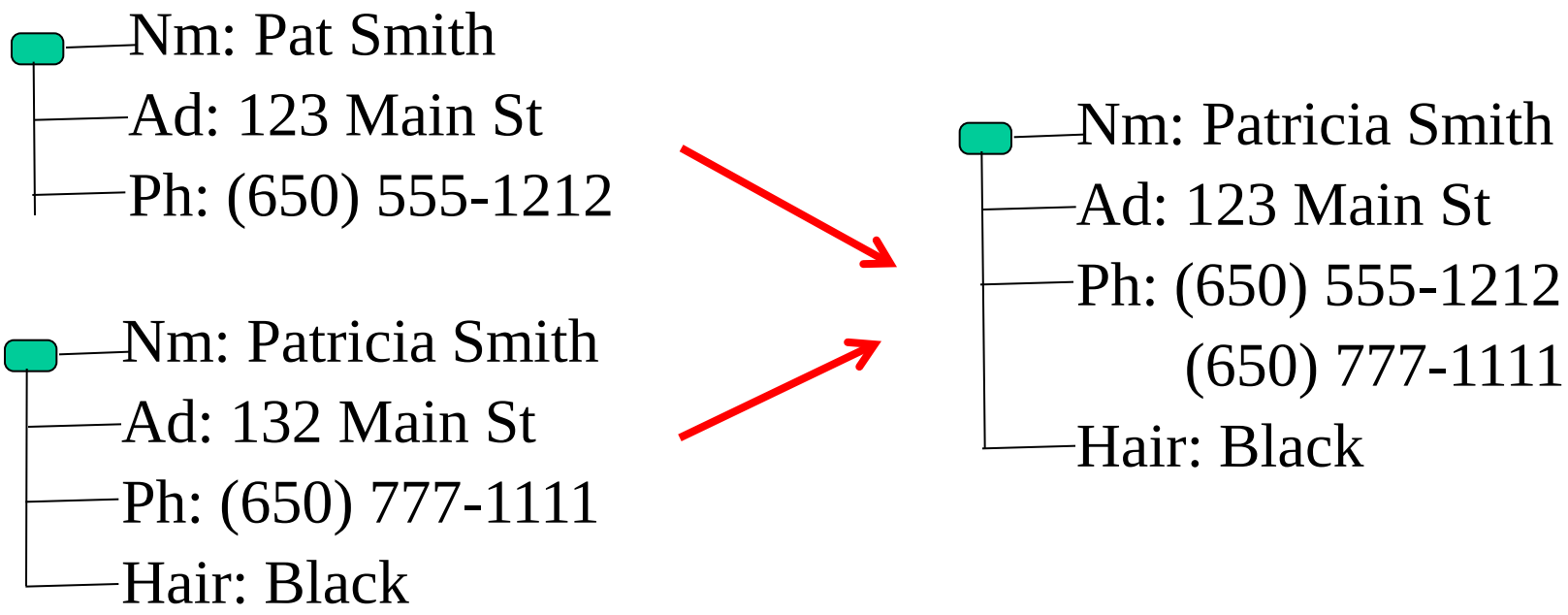
Taxonomy: Pairwise vs Global

- Global matching complicates things a lot!
  - e.g., change decision as new records arrive



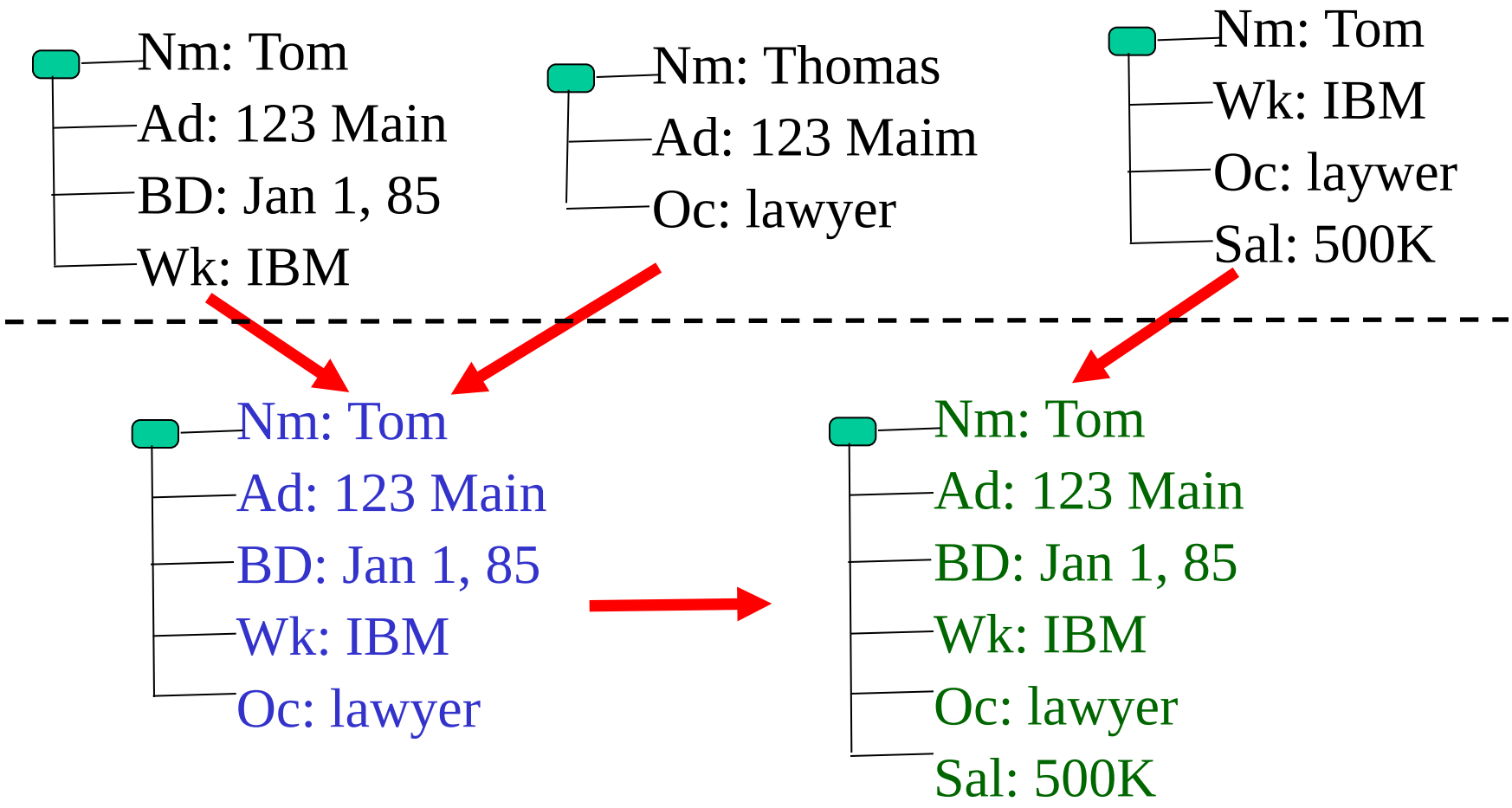
Taxonomy: Outcome

- Partition of records
  - e.g., comparison shopping
- Merged records



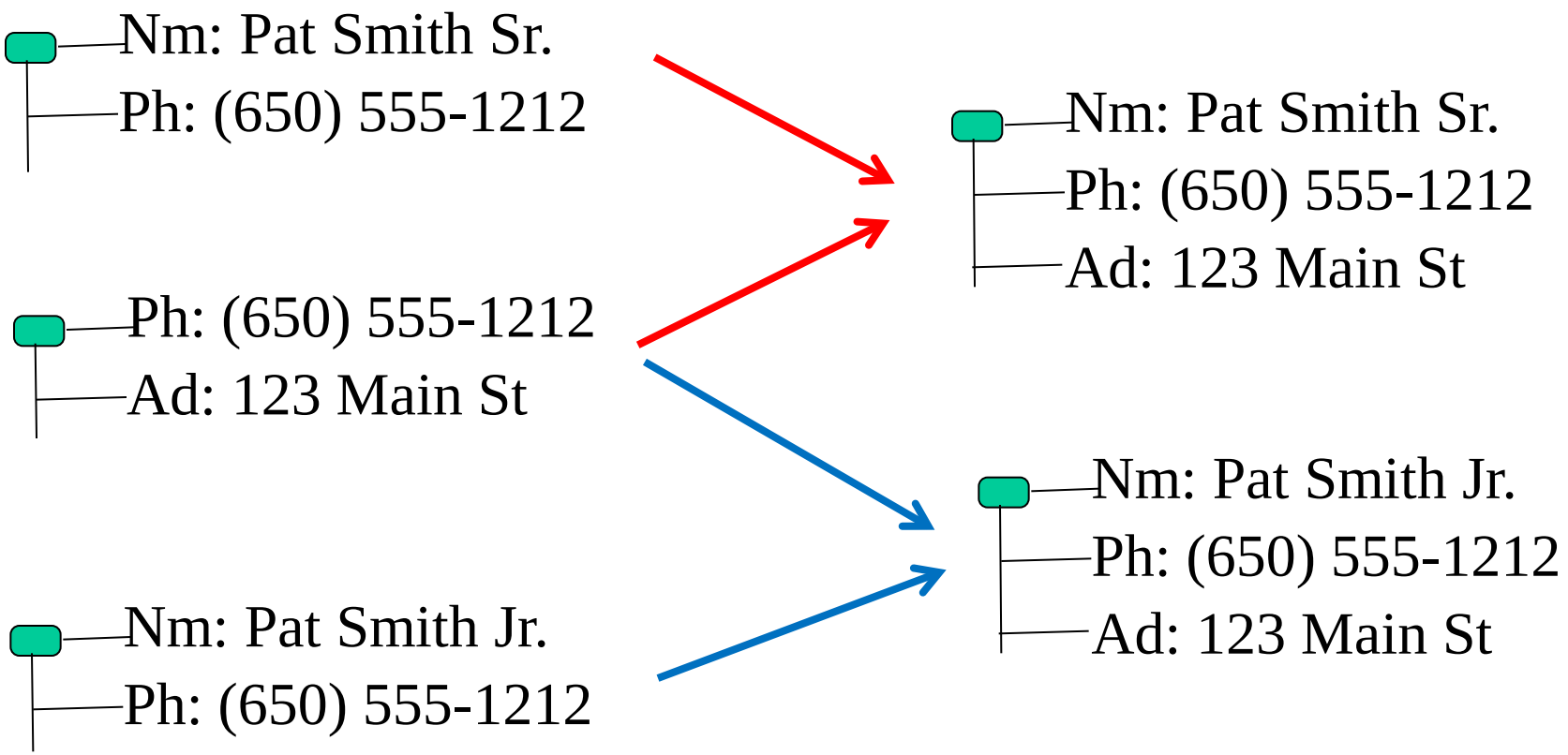
Taxonomy: Outcome

- Iterate after merging



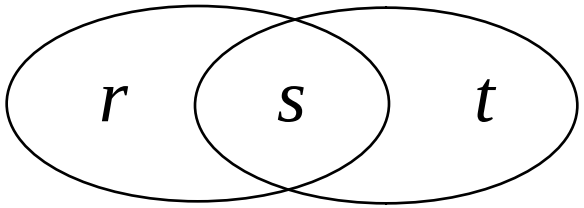
Taxonomy: Record Reuse

- One record related to multiple entities?

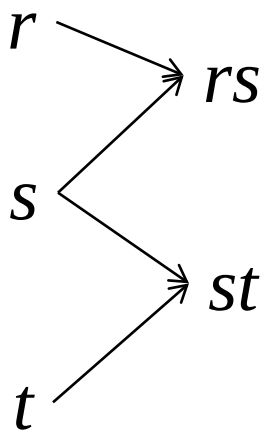


Taxonomy: Record Reuse

- Partitions

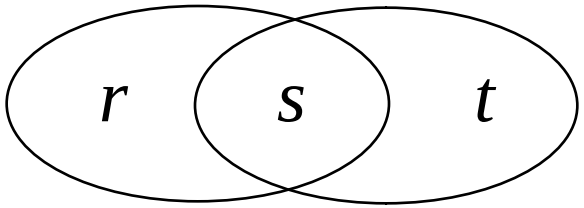


- Merges

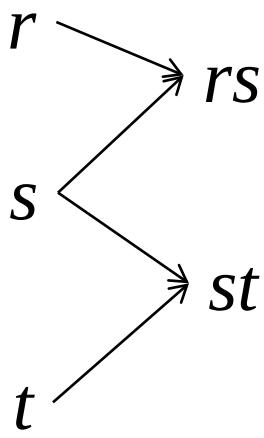


Taxonomy: Record Reuse

- Partitions

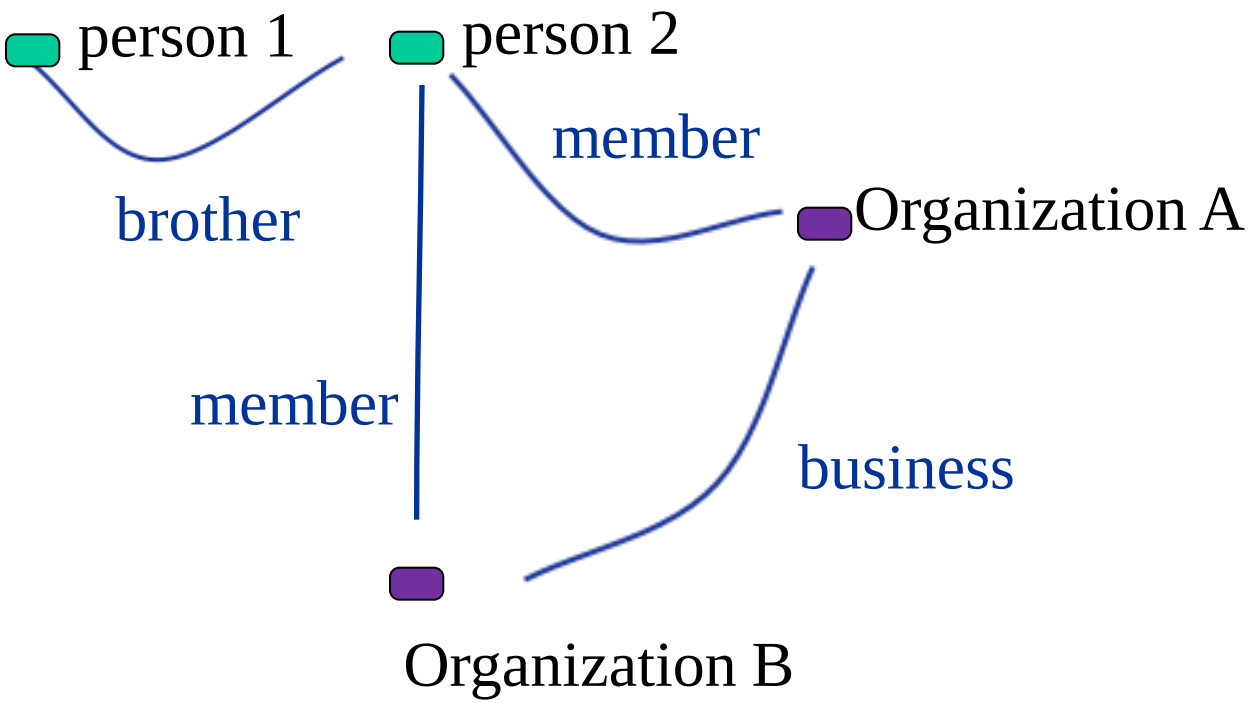


- Merges

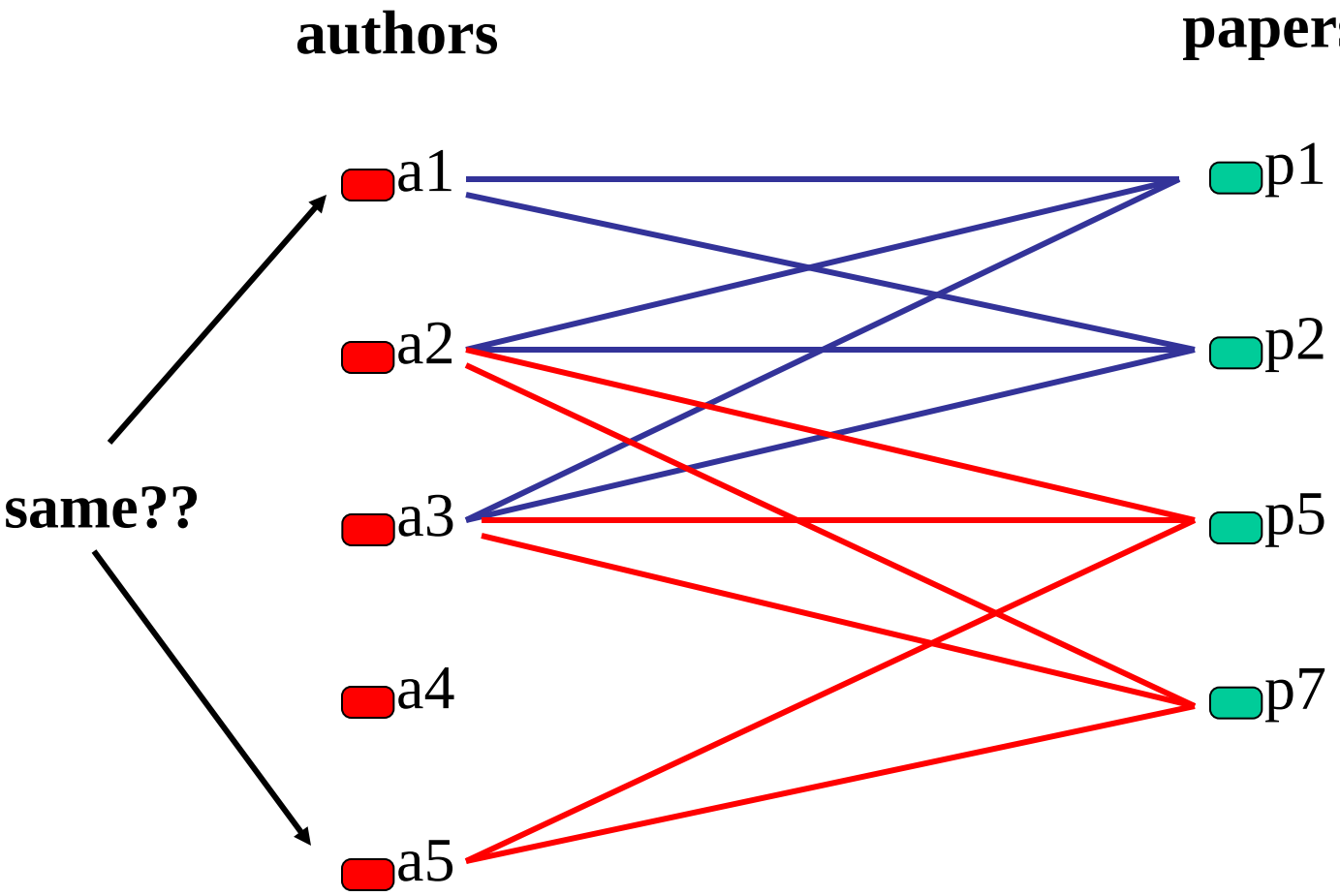


- Record reuse ➡ complex and expensive!

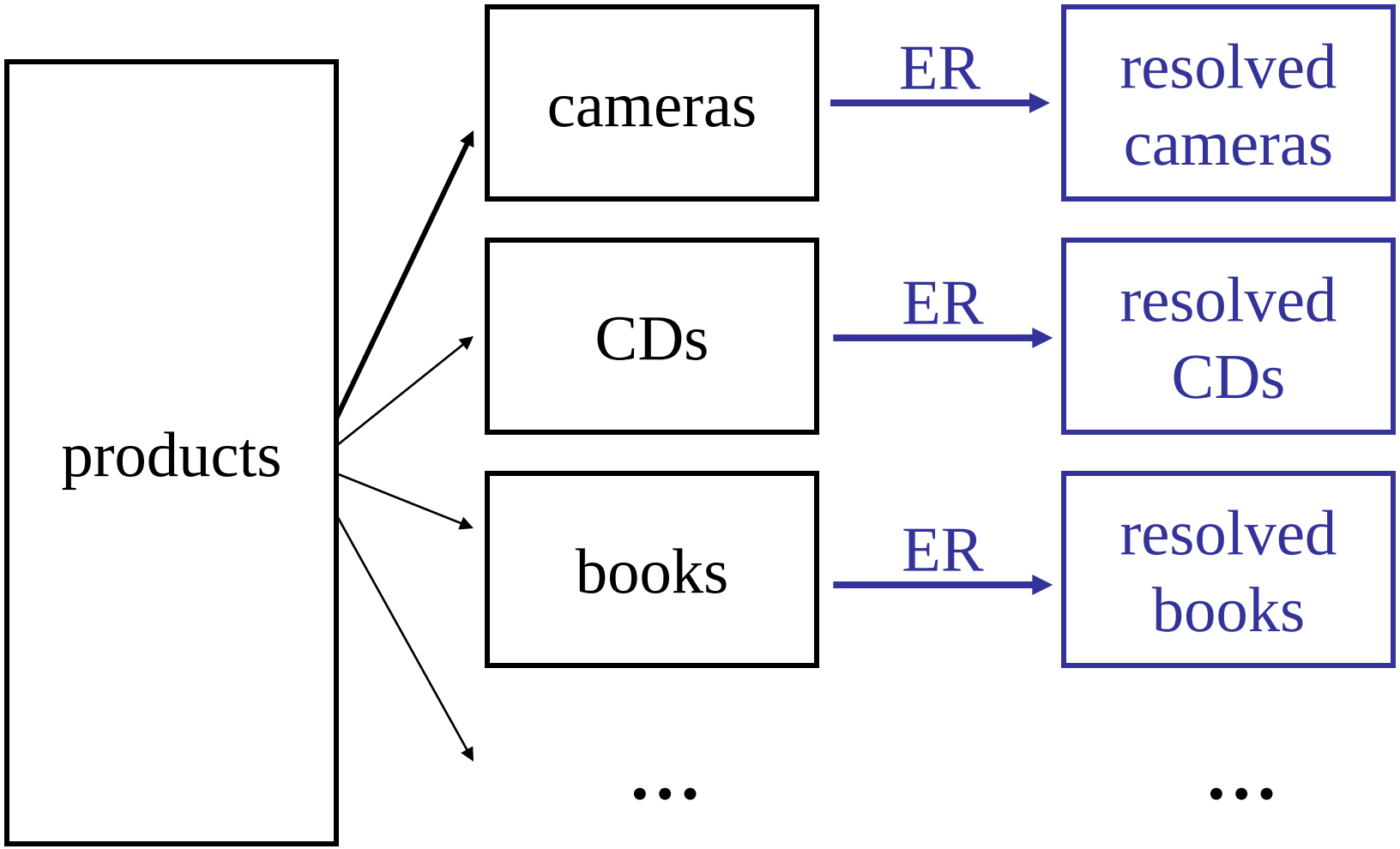
Taxonomy: Multiple Entity Types



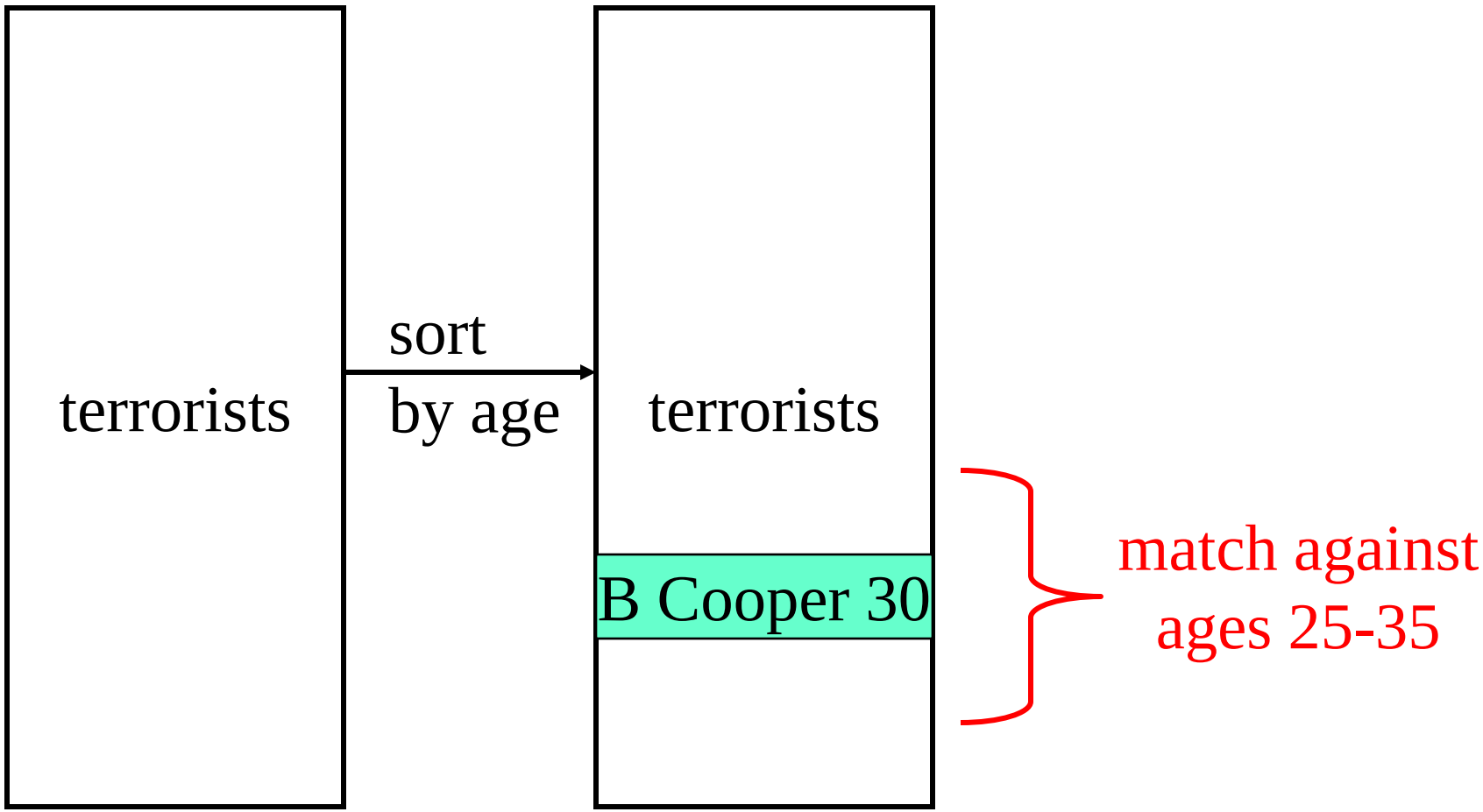
Taxonomy: Multiple Entity Types



Taxonomy: Exact vs Approximate



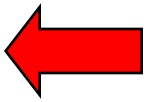
Taxonomy: Exact vs Approximate



Taxonomy: Other Variations

- Managing uncertainty
- Similarity computation

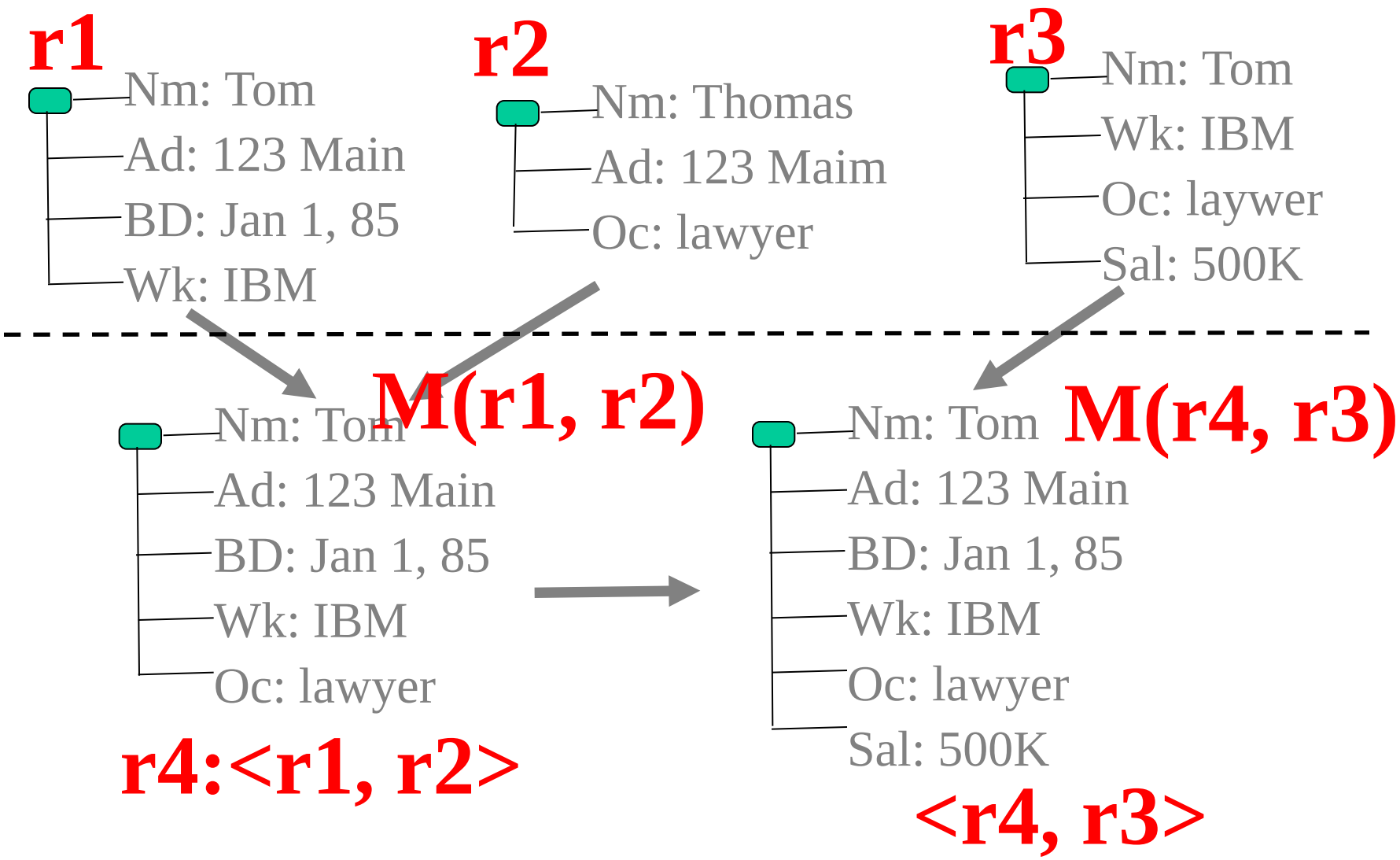
Outline

- Taxonomy
- Swoosh Algorithm 
- Distributed ER
- More on blocking

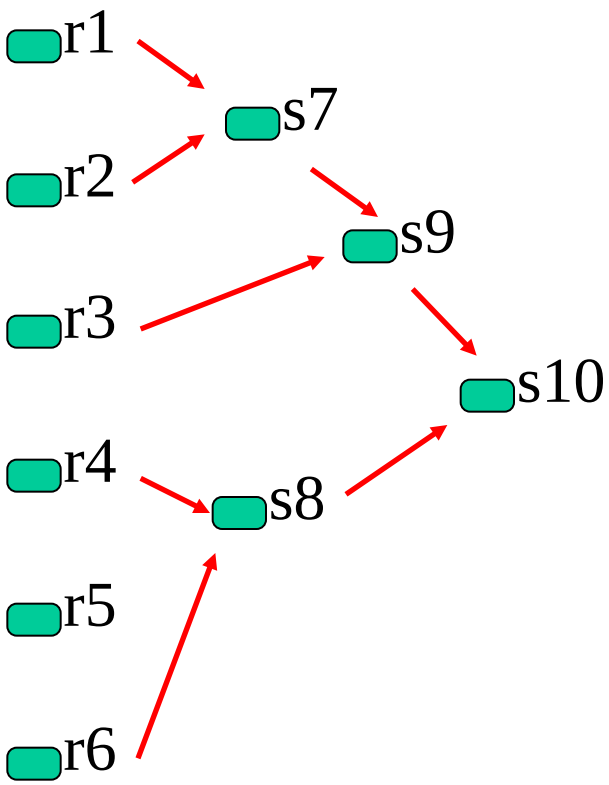
Scenario

- Pairwise matching
- Record merging
- No record reuse
- Single entity type

Model


r1
Nm: Tom
Ad: 123 Main
BD: Jan 1, 85
Wk: IBM
r2
Nm: Thomas
Ad: 123 Maim
Oc: lawyer
r3
Nm: Tom
Wk: IBM
Oc: laywer
Sal: 500K
M(r1, r2)
Nm: Tom
Ad: 123 Main
BD: Jan 1, 85
Wk: IBM
Oc: lawyer
r4:<r1, r2>
M(r4, r3)
Nm: Tom
Ad: 123 Main
BD: Jan 1, 85
Wk: IBM
Oc: lawyer
Sal: 500K
<r4, r3>

Correct Answer



ER(R) = All derivable records.....

Minus “dominated” records

Question

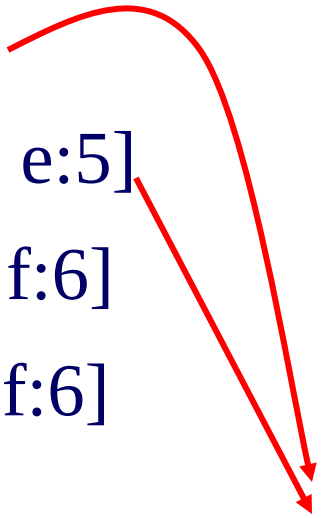
- What is best sequence of match, merge calls that give us right answer?

Brute Force Algorithm

- Input R:
  - r1 = [a:1, b:2]
  - r2 = [a:1, c: 4, e:5]
  - r3 = [b:2, c:4, f:6]
  - r4 = [a:7, e:5, f:6]

Brute Force Algorithm

- Input R:
  - r1 = [a:1, b:2]
  - r2 = [a:1, c: 4, e:5]
  - r3 = [b:2, c:4, f:6]
  - r4 = [a:7, e:5, f:6]



- Match all pairs:
  - r1 = [a:1, b:2]
  - r2 = [a:1, c: 4, e:5]
  - r3 = [b:2, c:4, f:6]
  - r4 = [a:7, e:5, f:6]
  - r12 = [a:1, b:2, c:4, e:5]

Brute Force Algorithm

- Match all pairs:
  - r1 = [a:1, b:2]
  - r2 = [a:1, c: 4, e:5]
  - r3 = [b:2, c:4, f:6]
  - r4 = [a:7, e:5, f:6]
  - r12 = [a:1, b:2, c:4, e:5]

- Repeat:
  - r1 = [a:1, b:2]
  - r2 = [a:1, c: 4, e:5]
  - r3 = [b:2, c:4, f:6]
  - r4 = [a:7, e:5, f:6]
  - r12 = [a:1, b:2, c:4, e:5]
  - r123 = [a:1, b:2, c:4, e:5, f:6]

Question # 1

Brute Force Algorithm

- Input R:
  - r1 = [a:1, b:2]
  - r2 = [a:1, c: 4, e:5]
  - r3 = [b:2, c:4, f:6]
  - r4 = [a:7, e:5, f:6]
- Match all pairs:
  - r1 = [a:1, b:2]
  - r2 = [a:1, c: 4, e:5]
  - r3 = [b:2, c:4, f:6]
  - r4 = [a:7, e:5, f:6]
  - r12 = [a:1, b:2, c:4, e:5]

Can we delete r1, r2?

Question # 2

Brute Force Algorithm

- Match all pairs:
  - r1 = [a:1, b:2]
  - r2 = [a:1, c: 4, e:5]
  - r3 = [b:2, c:4, f:6]
  - r4 = [a:7, e:5, f:6]
  - r12 = [a:1, b:2, c:4, e:5]
- Repeat:
  - r1 = [a:1, b:2]
  - r2 = [a:1, c: 4, e:5]
  - r3 = [b:2, c:4, f:6]
  - r4 = [a:7, e:5, f:6]
  - r12 = [a:1, b:2, c:4, e:5]
  - r123 = [a:1, b:2, c:4, e:5, f:6]

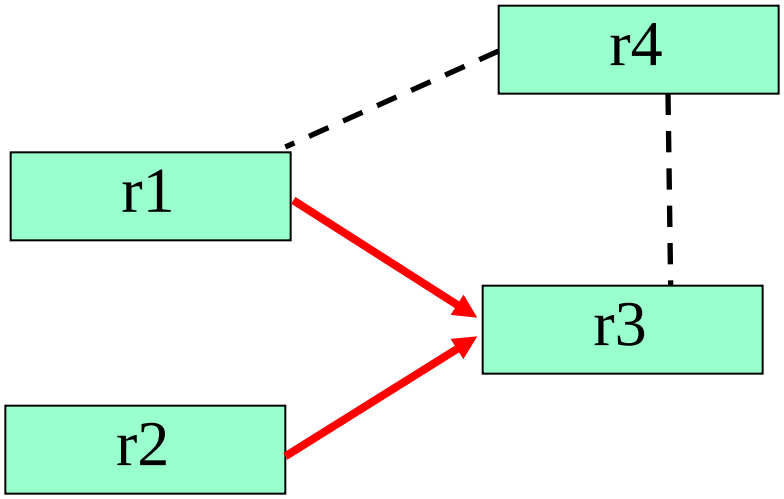
Can we avoid comparisons?

ICAR Properties

- Idempotence:
  - M(r1, r1) = true; <r1, r1> = r1
- Commutativity:
  - M(r1, r2) = M(r2, r1)
  - <r1, r2> = <r2, r1>
- Associativity
  - <r1, <r2, r3>> = <<r1, r2>, r3>

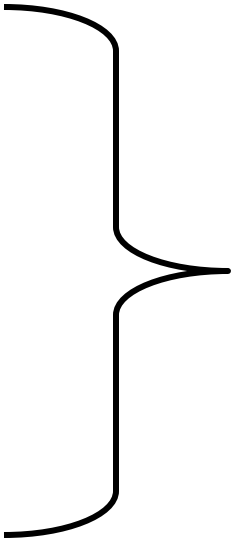
More Properties

- Representativity
  - If <r1, r2> = r3, then
    for any r4 such that M(r1, r4) is true
    we also have M(r3, r4) = true.



ICAR Properties ➔ Efficiency

- Commutativity
- Idempotence
- Associativity
- Representativity

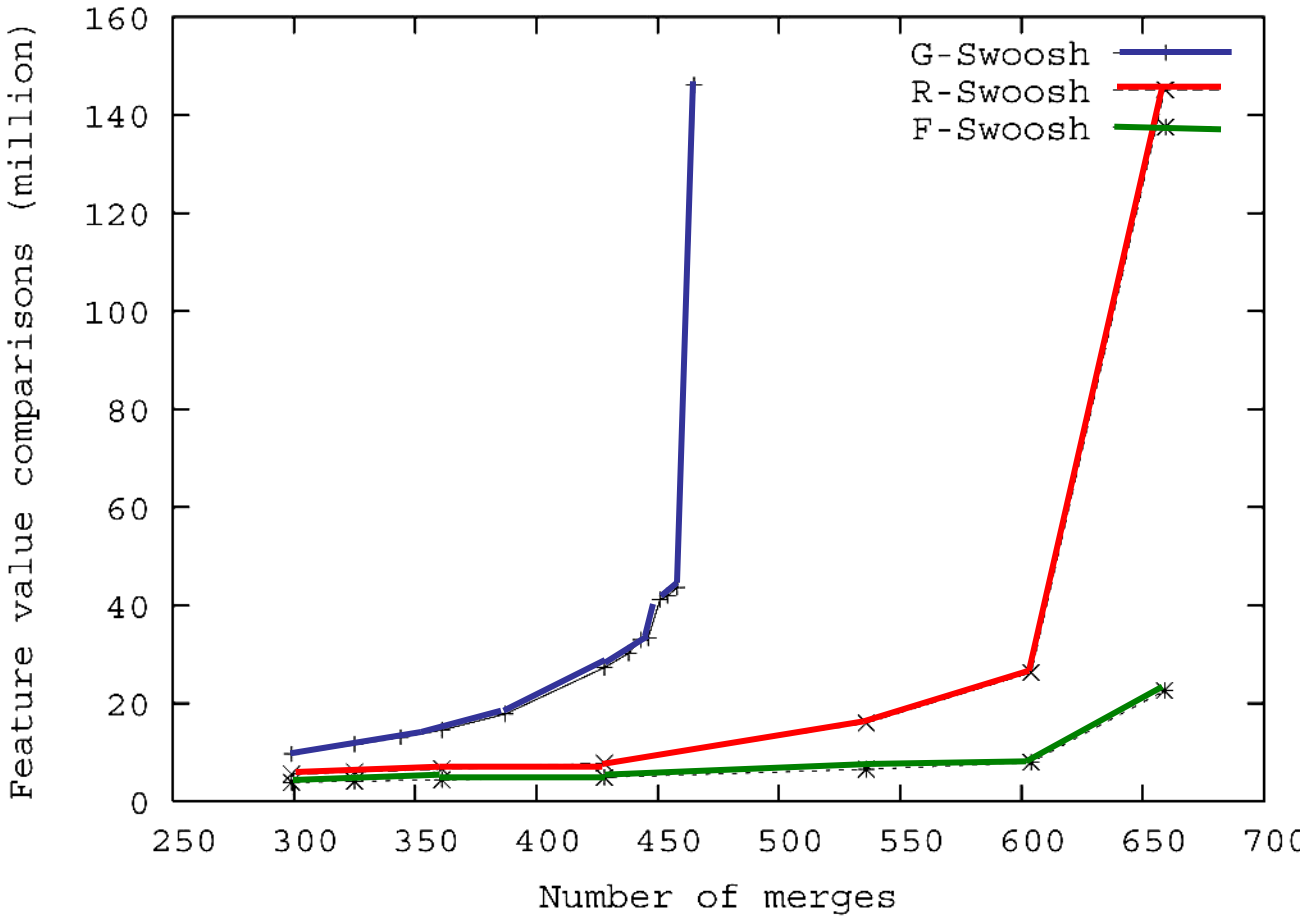


- Can discard records
- ER result independent of processing order

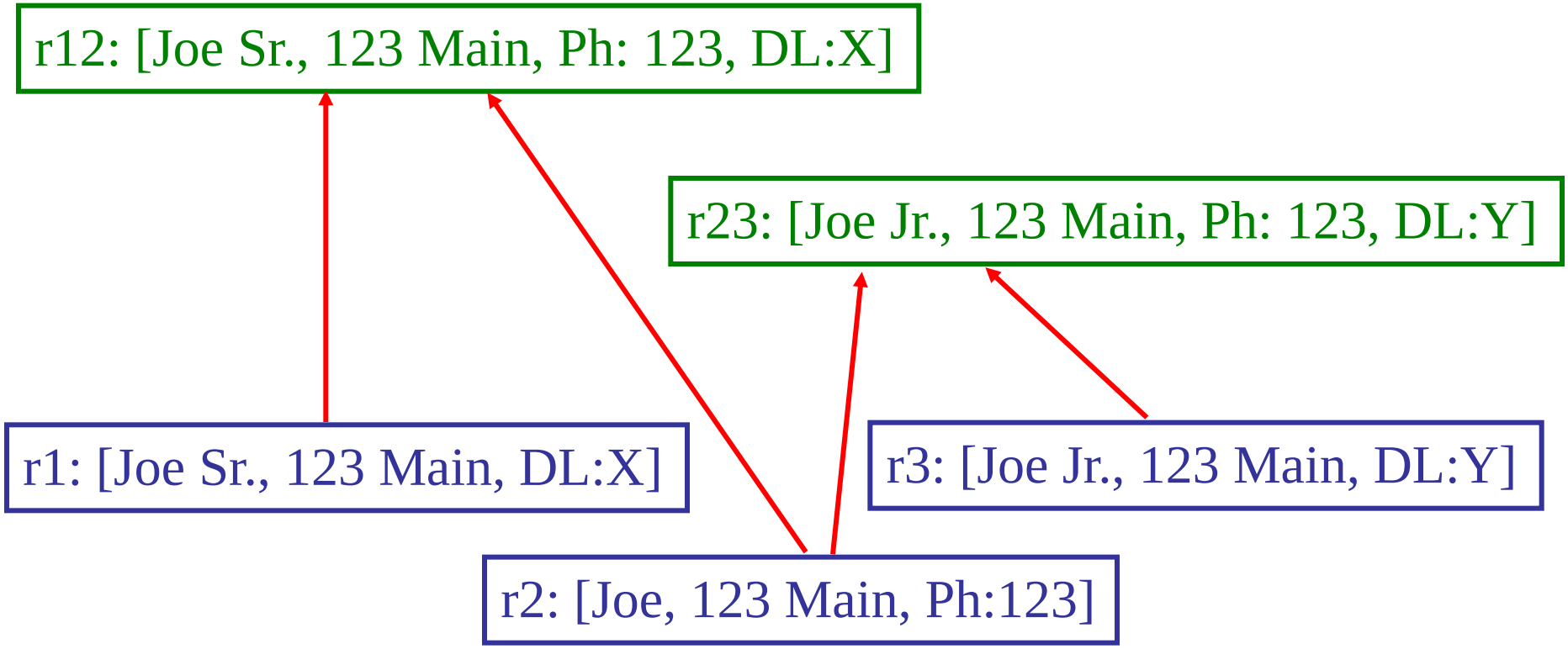
Swoosh Algorithms

- Record Swoosh
  - Merges records as soon as they match
  - Optimal in terms of record comparisons
- Feature Swoosh
  - Remembers values seen for each feature
  - Avoids redundant value comparisons

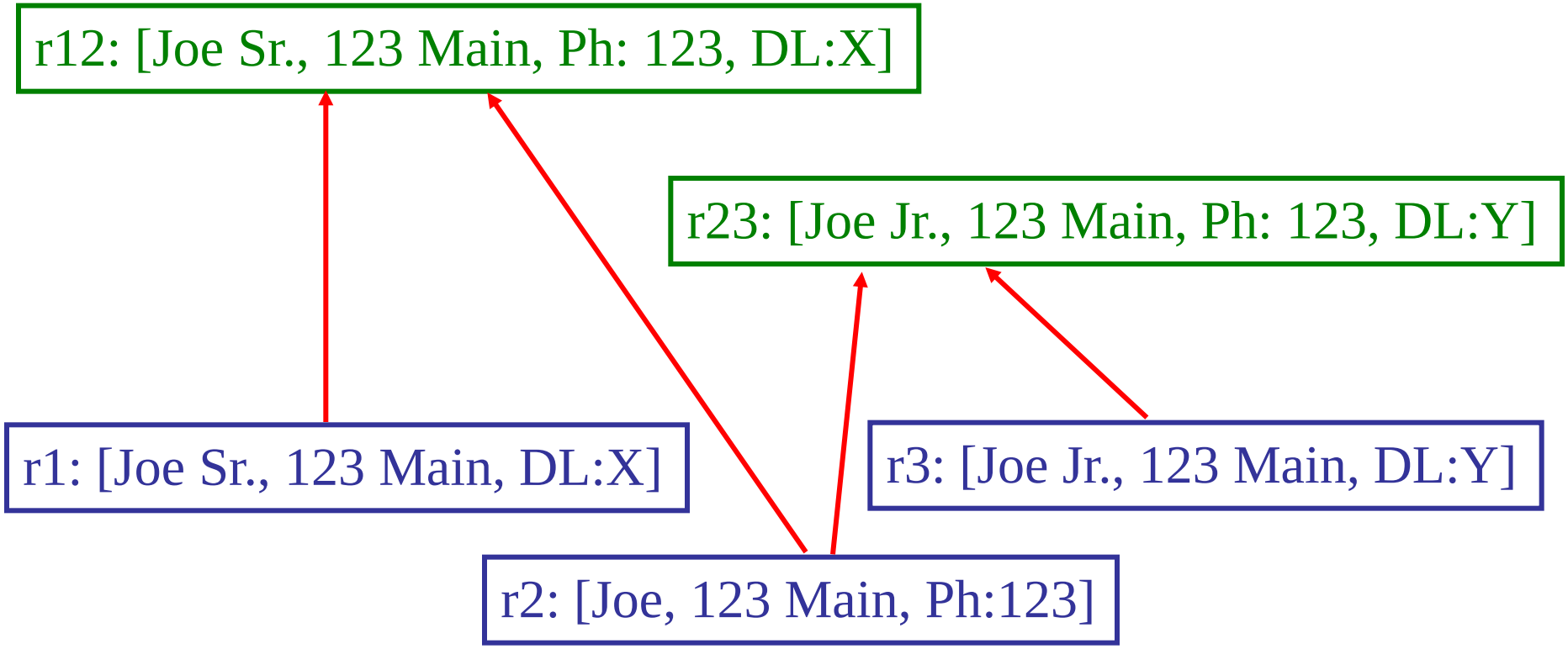
Swoosh Performance



If ICAR Properties Do Not Hold?



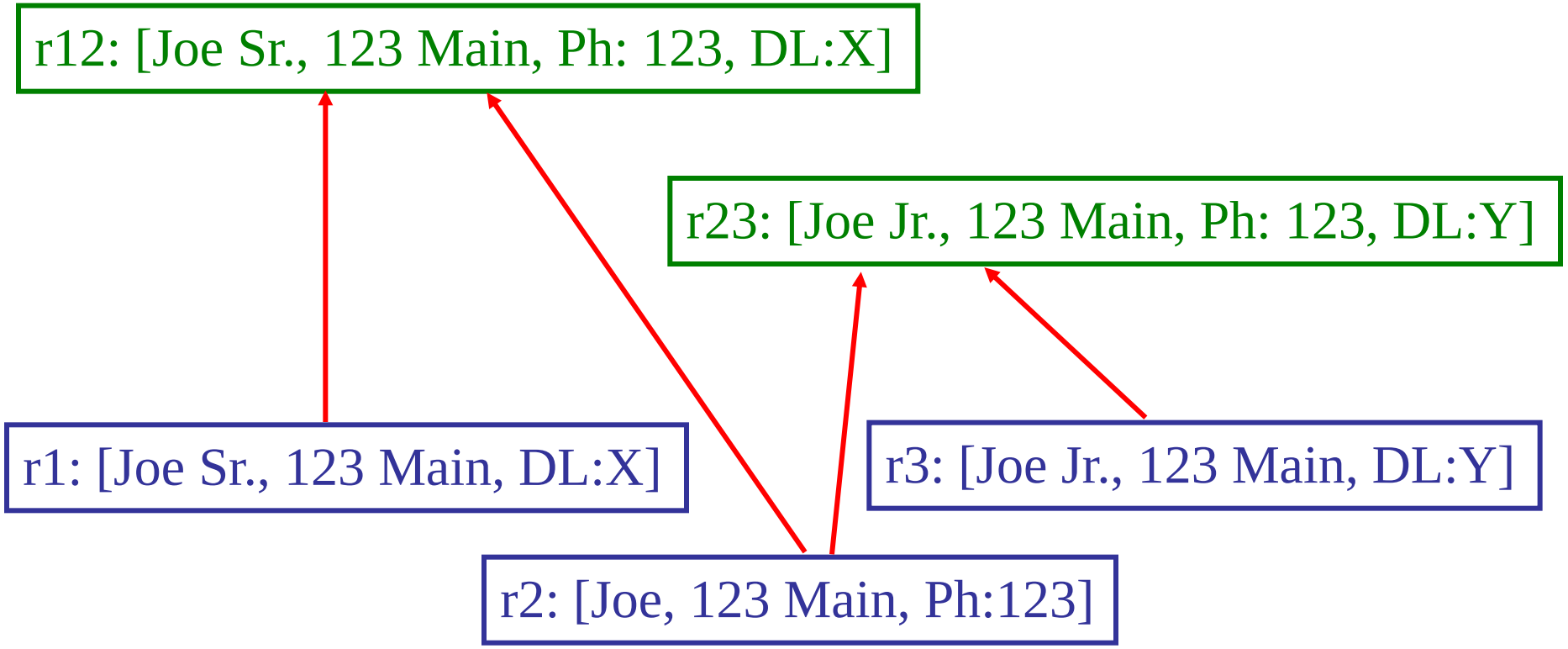
If ICAR Properties Do Not Hold?



Full Answer: ER(R) = {r12, r23, r1, r2, r3}

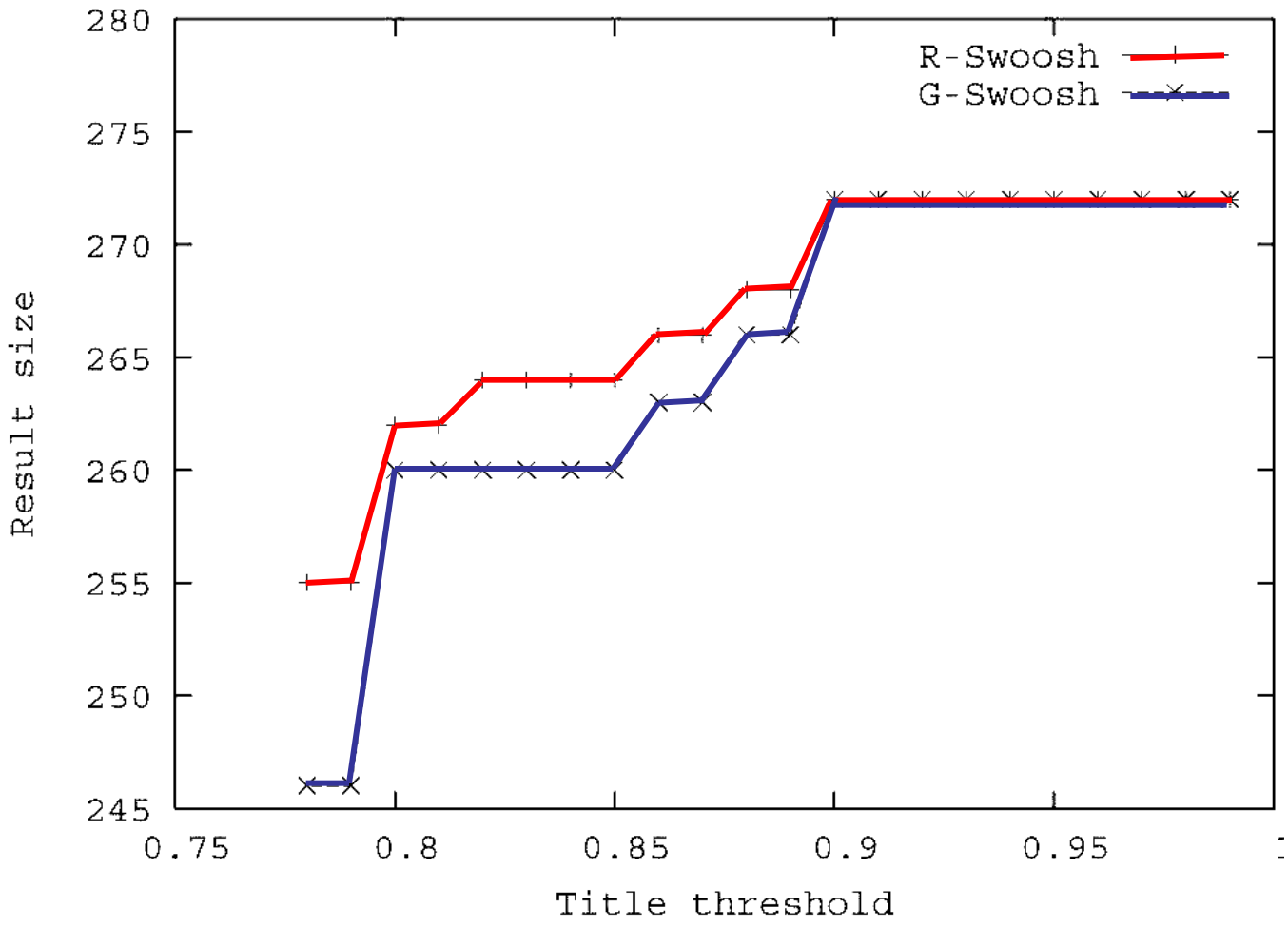
Minus Dominated: ER(R) = {r12, r23}

If ICAR Properties Do Not Hold?



Full Answer: ER(R) = {r12, r23, r1, r2, r3}
Minus Dominated: ER(R) = {r12, r23}
R-Swoosh Yields: ER(R) = {r12, r3} or {r1, r23}

Swoosh Without ICAR Properties



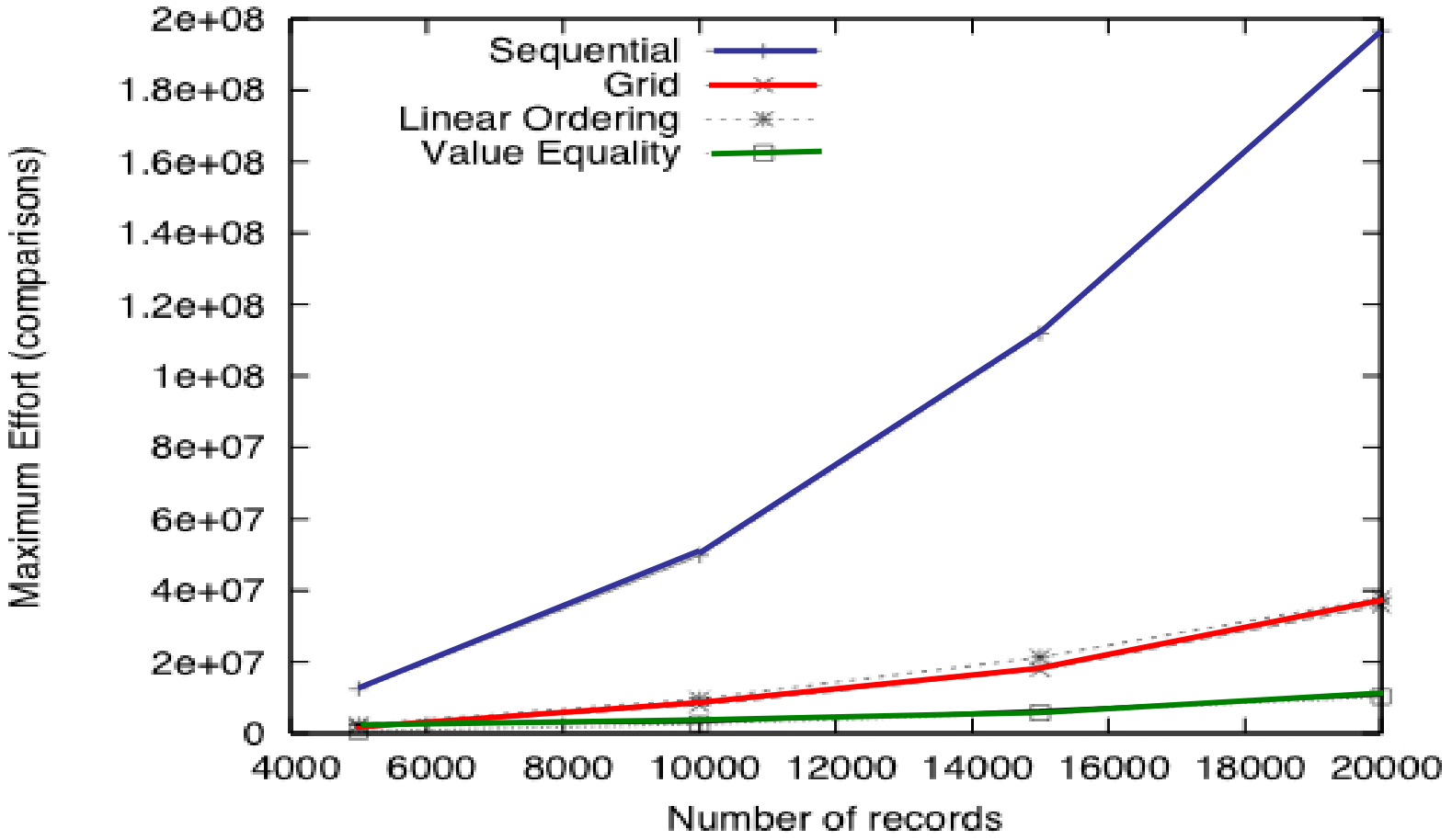
Distributed Swoosh

r1
r2
r3
r4
r5
r6
...

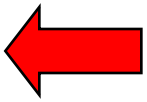
Distributed Swoosh

P1	P2	P3
r1	r1	
	r2	r2
r3		r3
r4	r4	
	r5	r5
r6		r6
...	...	...

DSwoosh Performance



Outline

- Swoosh Algorithm
- Distributed ER
- More on blocking 

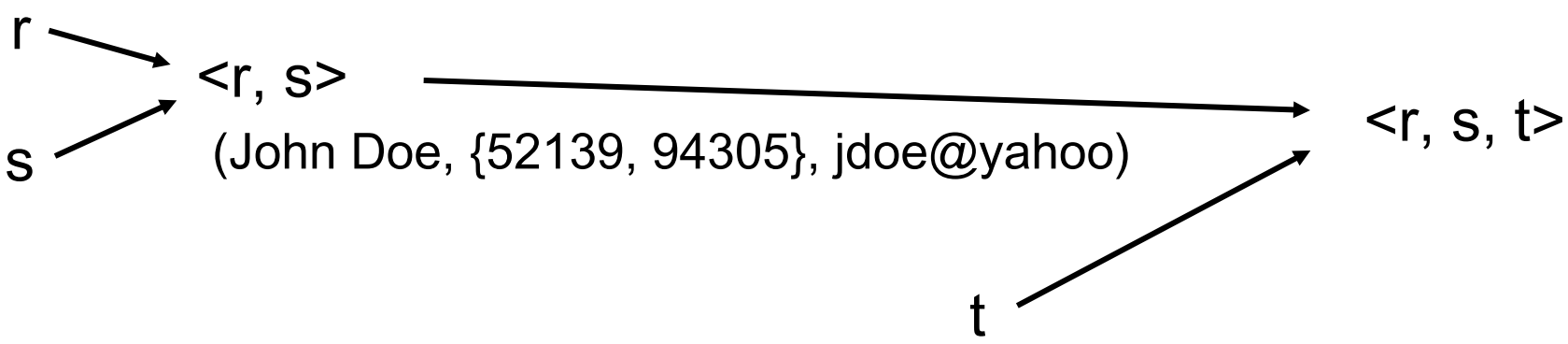
Iterative Blocking: Example

Record	Name	Addr (zip)	Email
r	John Doe	52139	jdoe@yahoo
s	John Doe	94305	
t	J. Foe	94305	jdoe@yahoo
u	Bobbie Brown	12345	bob@gmail
v	Bobbie Brown	12345	bob@gmail

Example

Record	Name	Addr (zip)	Email
r	John Doe	52139	jdoe@yahoo
s	John Doe	94305	
t	J. Foe	94305	jdoe@yahoo
u	Bobbie Brown	12345	bob@gmail
v	Bobbie Brown	12345	bob@gmail

Iterative ER:



Blocking

Record	Name	Addr (zip)	Email
r	John Doe	52139	jdoe@yahoo
s	John Doe	94305	
t	J. Foe	94305	jdoe@yahoo
u	Bobbie Brown	12345	bob@gmail
v	Bobbie Brown	12345	bob@gmail

Criterion	Partition by	$b_{-,1}$	$b_{-,2}$	$b_{-,3}$
SC1	zip code	r	s, t	u,v
SC2	1st char last name	r, s	t	u, v

Blocking

Record	Name	Addr (zip)	Email
r	John Doe	52139	jdoe@yahoo
s	John Doe	94305	
t	J. Foe	94305	jdoe@yahoo
u	Bobbie Brown	12345	bob@gmail
v	Bobbie Brown	12345	bob@gmail

Criterion	Partition by	$b_{-,1}$	$b_{-,2}$	$b_{-,3}$
SC1	zip code	r	s, t	u,v
SC2	1st char last name	r, s	t	u, v

Will miss: < r, s, t >

Blocking

Record	Name	Addr (zip)	Email
r	John Doe	52139	jdoe@yahoo
s	John Doe	94305	
t	J. Foe	94305	jdoe@yahoo
u	Bobbie Brown	12345	bob@gmail
v	Bobbie Brown	12345	bob@gmail

Criterion	Partition by	$b_{-,1}$	$b_{-,2}$	$b_{-,3}$
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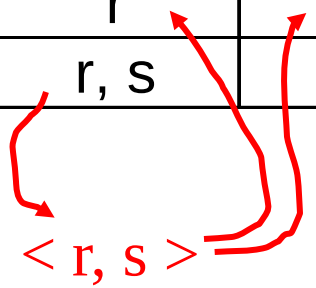
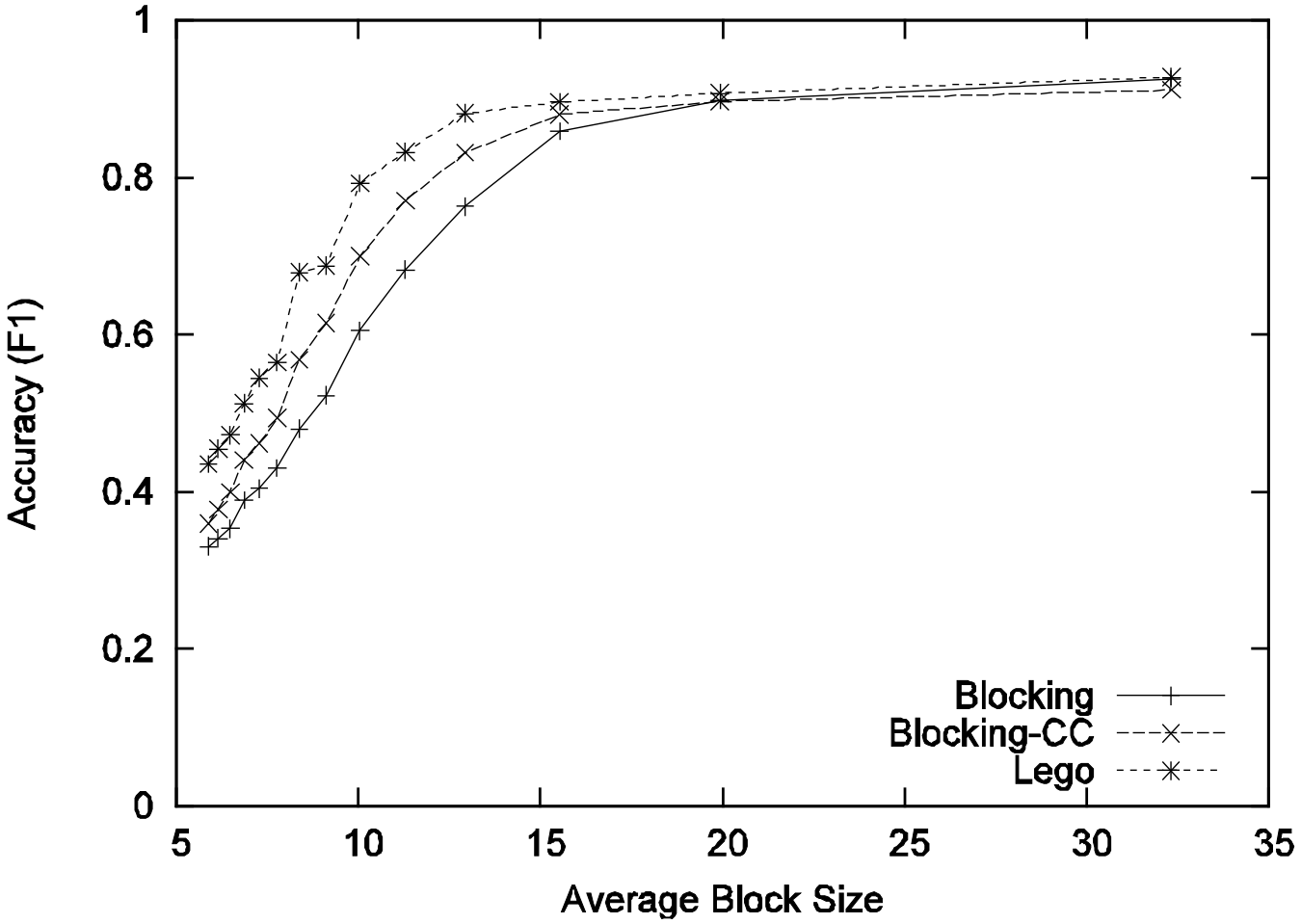


Solution: Propagate Matches

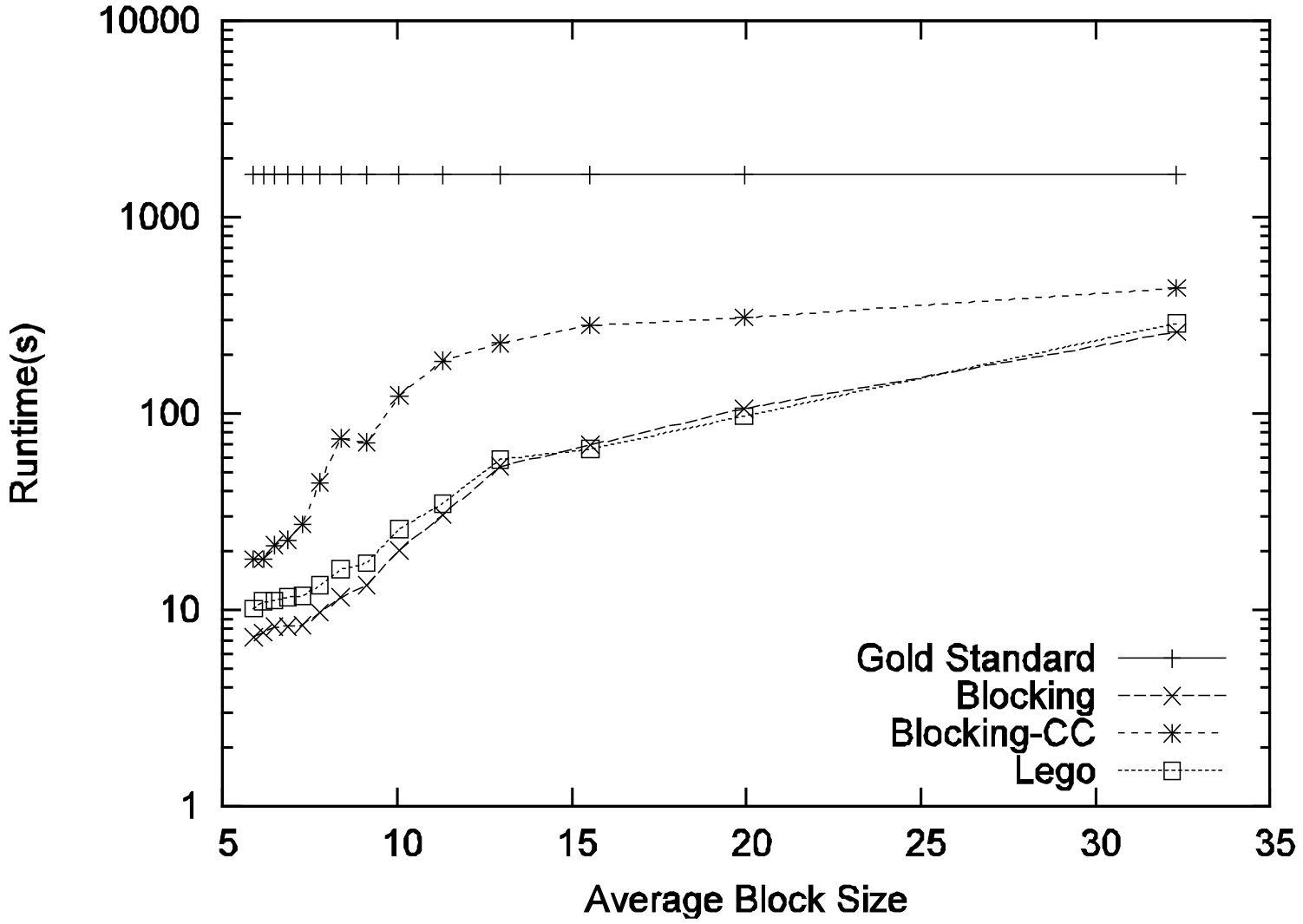
What We Have Done

- Formal Model for Iterative Blocking
  - based on generic “core” ER algorithm
- Two Algorithms:
  - Lego: in memory
  - Duplo: disk based
- Experiments

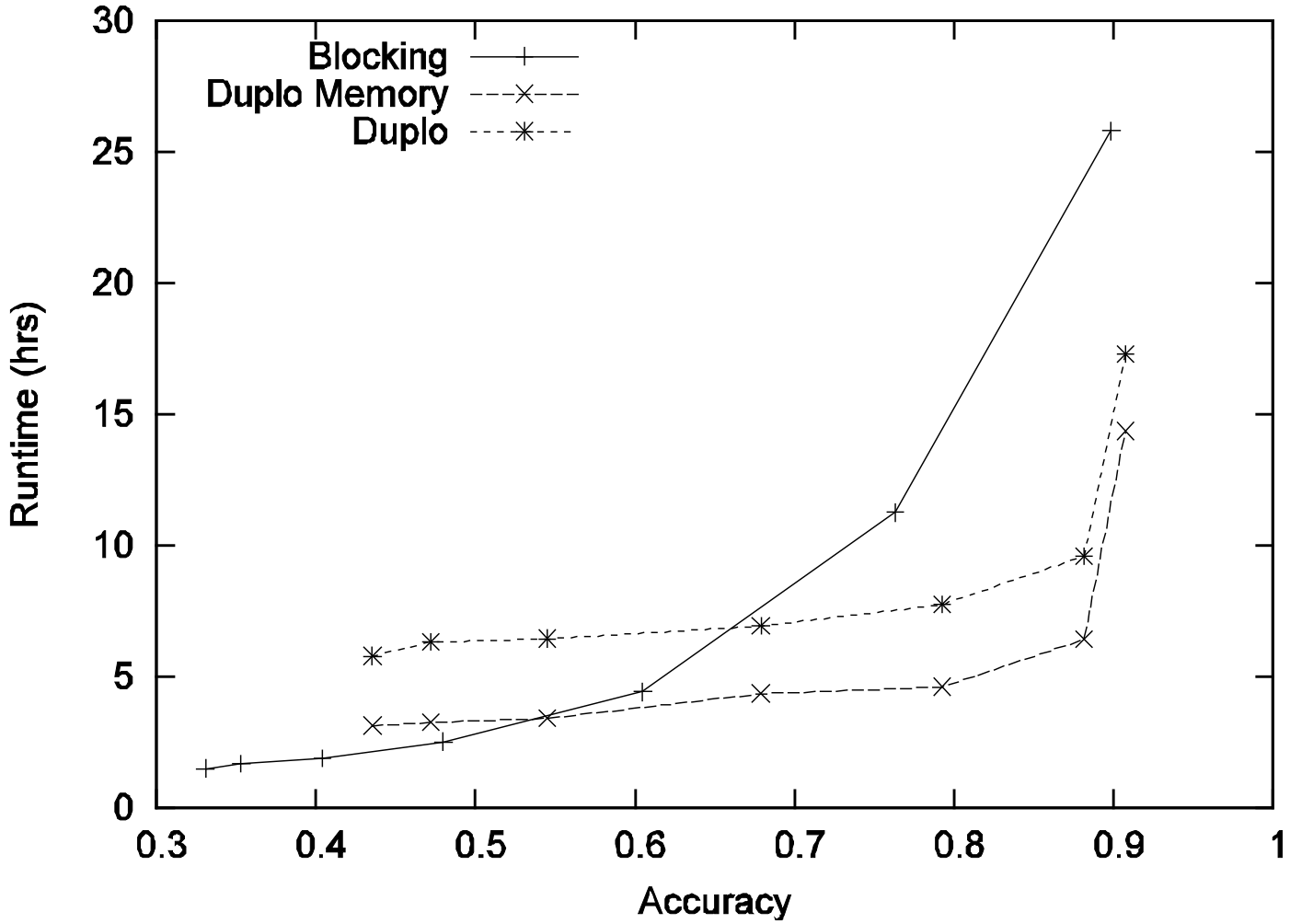
Sample Results: Accuracy



Sample Results: Run Time



Accuracy vs Run Time



Conclusion

- ER is old and important problem
- Critical for gluing components

Thanks.