The PrInt Model

Disciplina de Procedência de Dados e
Data Warehousing

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Outline

- Motivation
- The PrInt Model
  - Theoretical basis
  - Architecture
  - Operations

Research Issue

- Motivation
  - there are a crescent number of integration applications in which updates on heterogeneous sources are not allowed

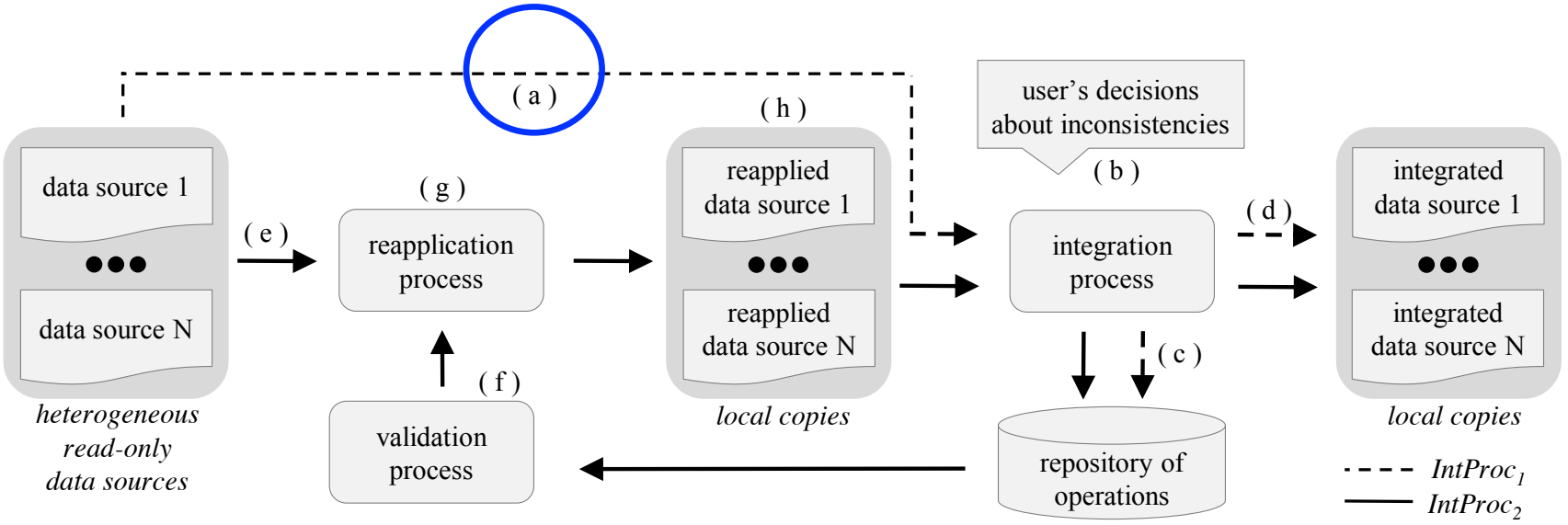
How to avoid decision retaking by tracking actions about integration decisions and automatically reapplying them in subsequent integration processes?

The PrInt Model

Provenance model to support integration processes

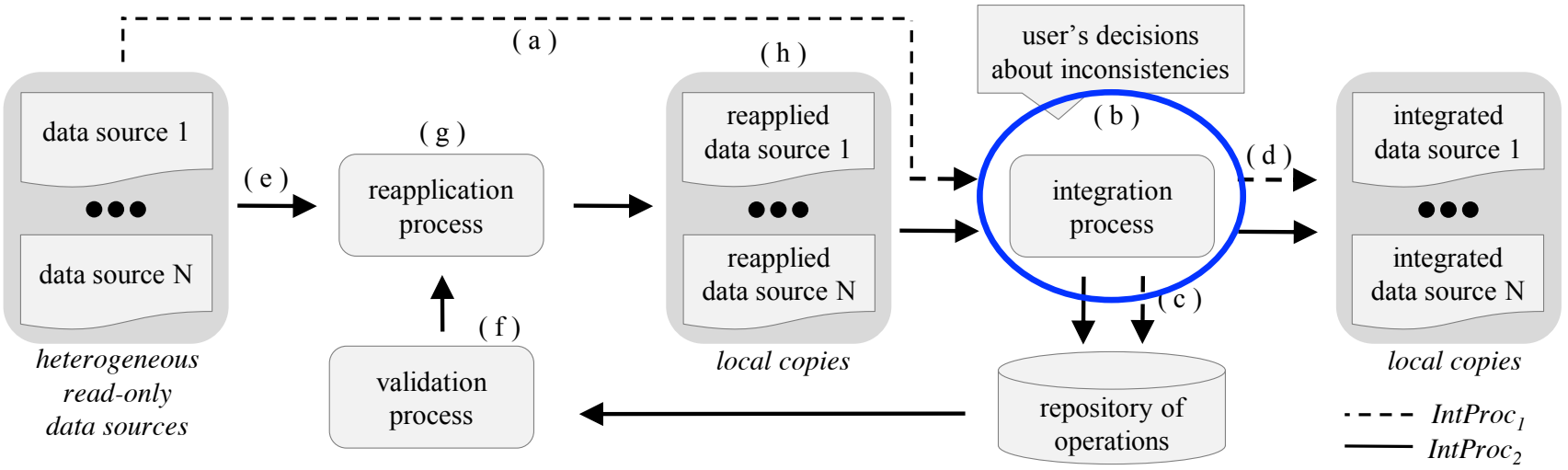
- Theoretical basis
  - it incorporates data provenance to improve the integration process
    - set of metadata that allows for the identification of sources and transformations applied to data
  - it focuses on instance level integration
  - it is applied to integration processes where the sources are read-only
  - it provides a strict reproduction of decisions among distinct integration processes

Architecture



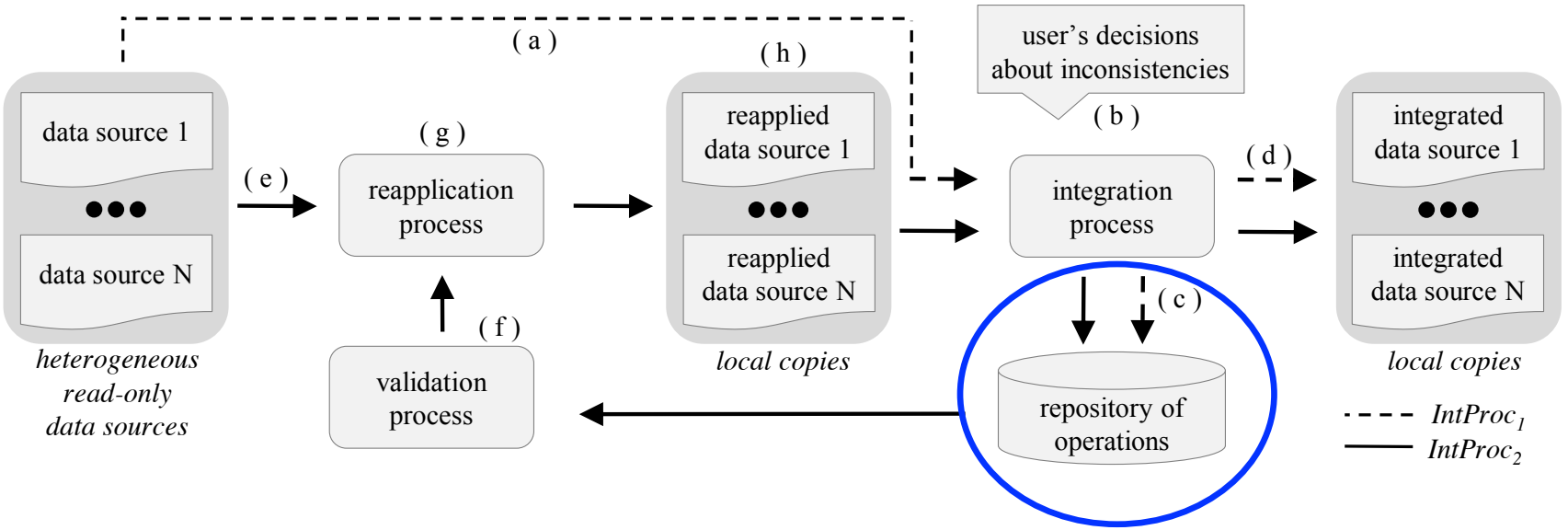
- Integration scenario
  - a) a first integration process, $IntProc_1$, is executed by receiving as input several sources

Architecture



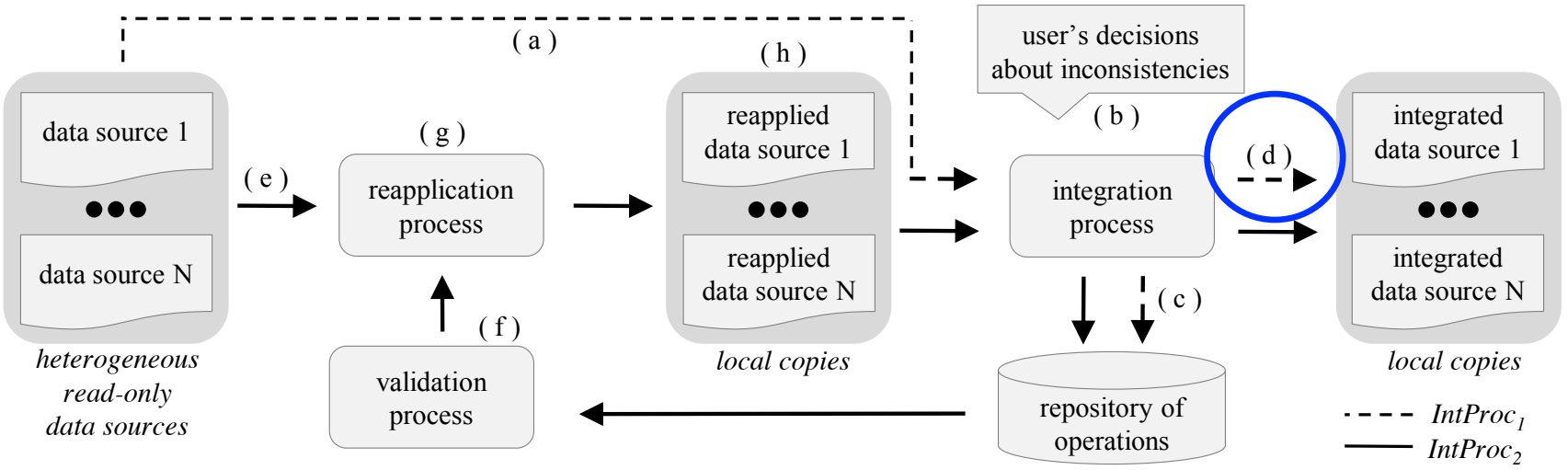
- Integration scenario
  - b) inconsistencies are solved

Architecture



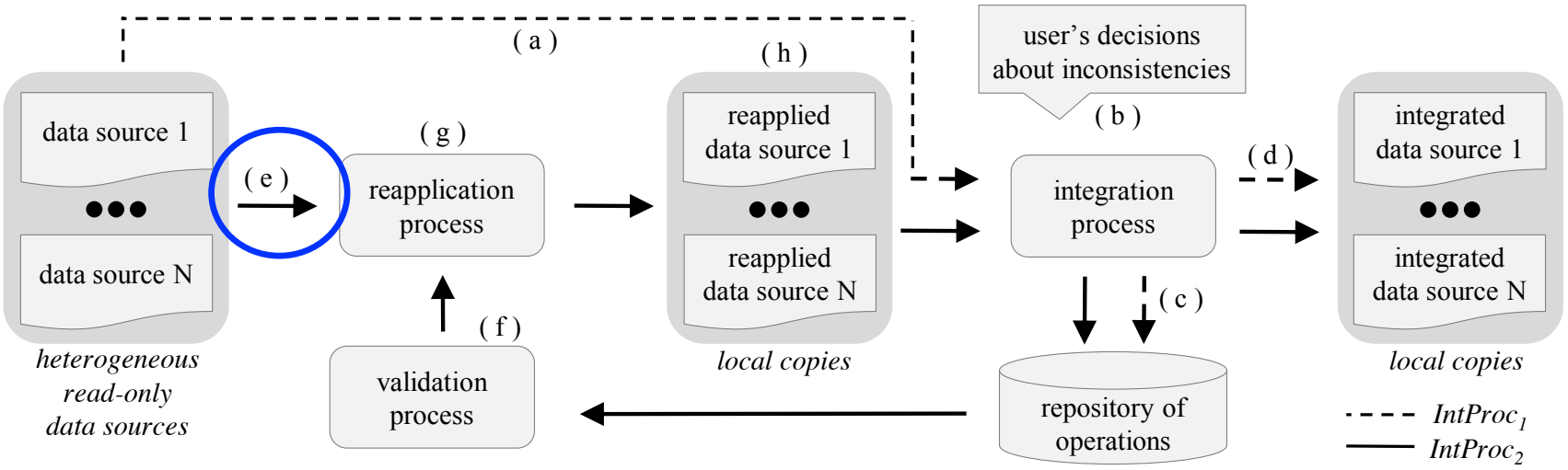
- Integration scenario
  - c) decisions are stored as operations in a repository

Architecture



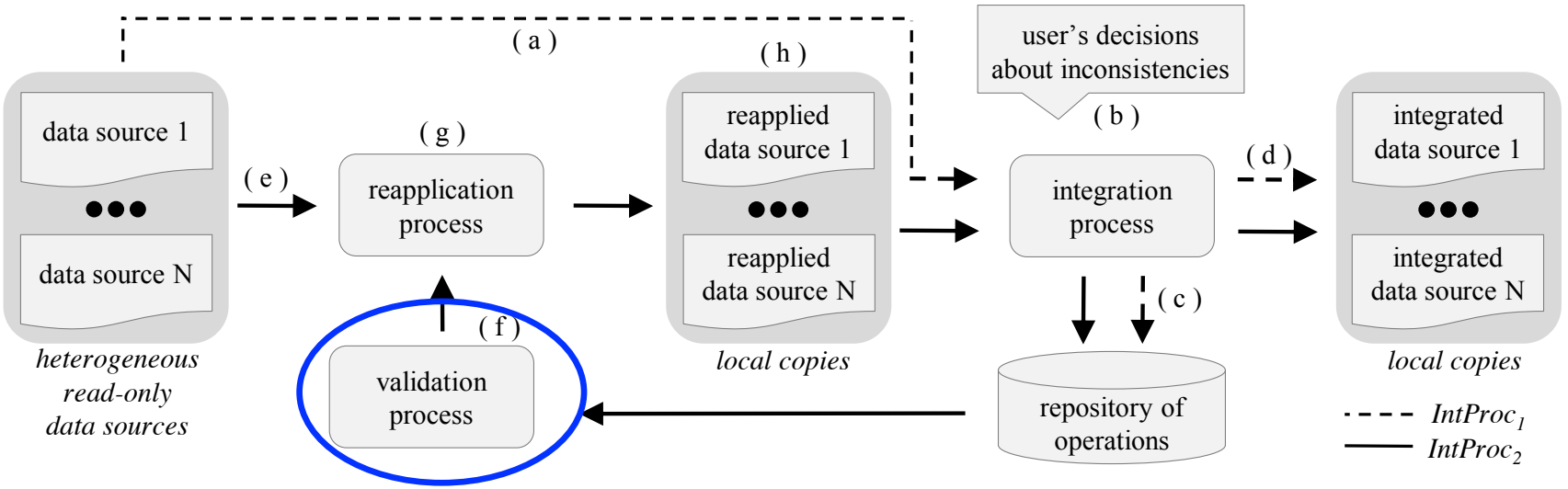
- Integration scenario
  - d) consistent copies of sources are locally stored as read-only copies

Architecture



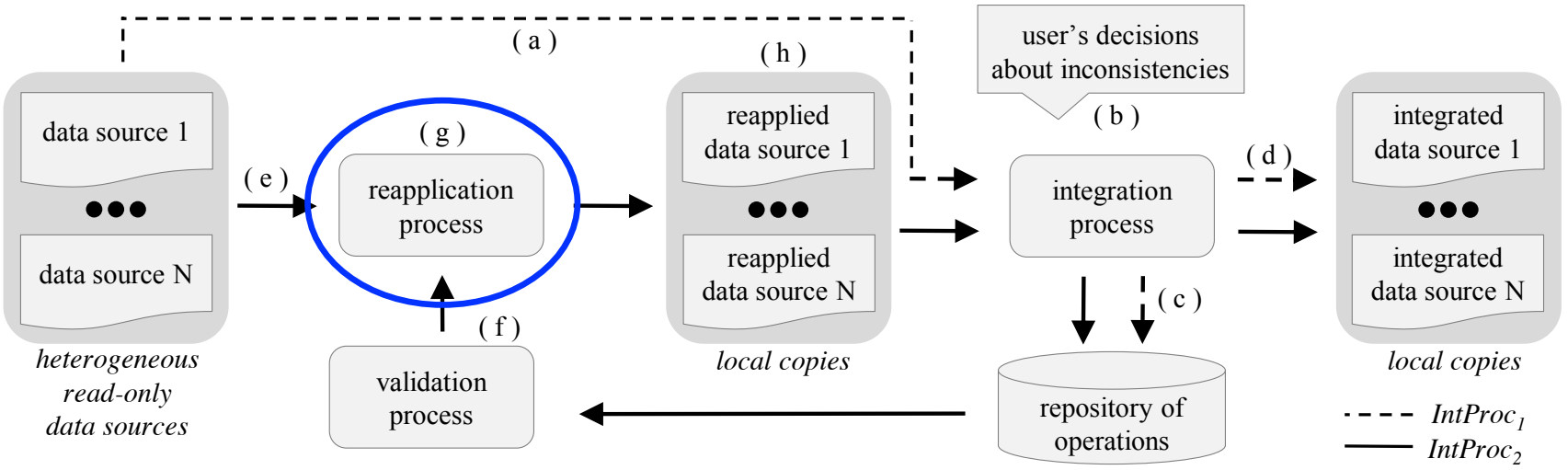
- Integration scenario
  - e) a second integration process, $IntProc_2$, is started

Architecture



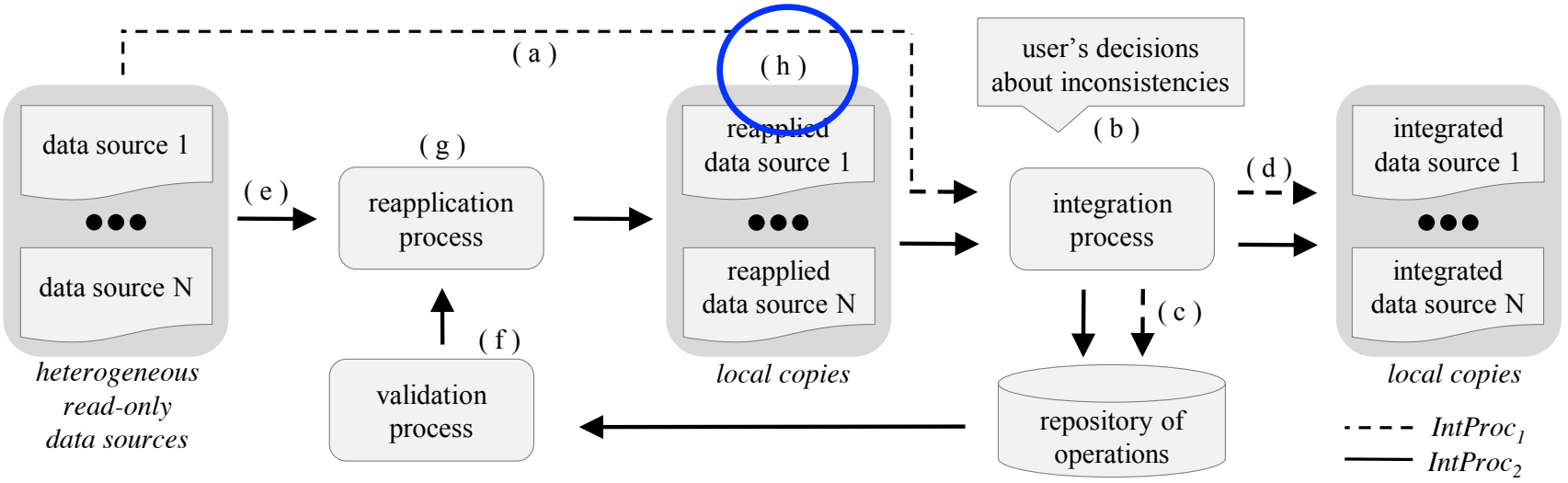
- Integration scenario
  - f) before reapplying the operations, PrInt validates the repository of operations

Architecture



- Integration scenario
  - g) PrInt reapplies all valid operations, thus reproducing integration decisions taken in $IntProc_1$

Architecture

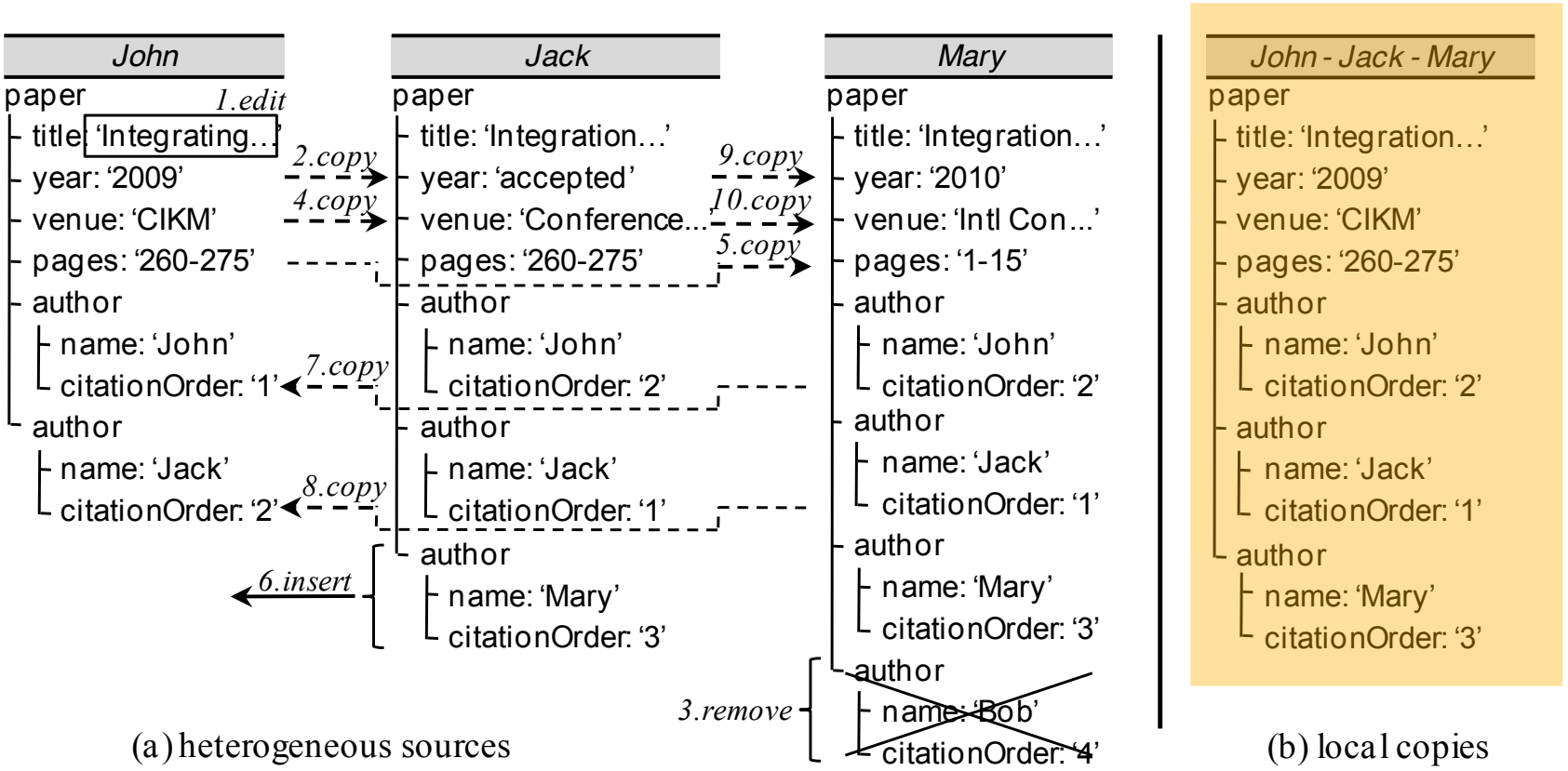


- Integration scenario
  - h) intervention for solving inconsistencies in $IntProc_2$ are limited to those new inconsistencies originated from source updates since $IntProc_1$

Main Characteristics

- Storage of integration decisions in a repository
  - based on operations of edit, copy, insert and remove
  - management of transitive and overlapping operations
- Validation and reapplication of operations
  - the VRT method

Example of Data Integration



(a) heterogeneous sources

(b) local copies

Repository of Operations

id	op	origin	target	objKey	objAtt	originValue	targetValue
1	ed	null	John	title=Integrating...	title	Integration...	Integrating...
2	cp	John	Jack	title=Integration...	year	2009	accepted
3	ed	null	Mary	title=Integration.../name=Bob	citationOrder	null	4
4	rm	null	Mary	title=Integration.../name=Bob	null	null	null
5	cp	John	Jack	title=Integration...	venue	Conference...	CIKM
6	cp	John	Mary	title=Integration…	pages	260-275	1-15
7	in	Jack	John	title=Integration…/name=Mary	null	null	null
8	cp	Jack	John	title=Integration…/name=Mary	citationOrder	3	null
9	cp	Mary	John	title=Integration…/name=John	citationOrder	2	1
10	cp	Mary	John	title=Integration…/name=Jack	citationOrder	1	2
11	cp	Jack	Mary	title=Integration...	year	2009	2010
12	cp	Jack	Mary	title=Integration…	venue	Conference...	Intl Con…

Repository of Operations

an integer that identifies an operation

id	op	origin	target	objKey	objAtt	originValue	targetValue
1	ed	null	John	title=Integrating...	title	Integration...	Integrating...
2	cp	John	Jack	title=Integration...	year	2009	accepted
3	ed	null	Mary	title=Integration.../name=Bob	citationOrder	null	4
4	rm	null	Mary	title=Integration.../name=Bob	null	null	null
5	cp	John	Jack	title=Integration...	venue	Conference...	CIKM
6	cp	John	Mary	title=Integration…	pages	260-275	1-15
7	in	Jack	John	title=Integration…/name=Mary	null	null	null
8	cp	Jack	John	title=Integration…/name=Mary	citationOrder	3	null
9	cp	Mary	John	title=Integration…/name=John	citationOrder	2	1
10	cp	Mary	John	title=Integration…/name=Jack	citationOrder	1	2
11	cp	Jack	Mary	title=Integration...	year	2009	2010
12	cp	Jack	Mary	title=Integration…	venue	Conference...	Intl Con…

Repository of Operations

the type of the operation

id	op	origin	target	objKey	objAtt	originValue	targetValue
1	ed	null	John	title=Integrating...	title	Integration...	Integrating...
2	cp	John	Jack	title=Integration...	year	2009	accepted
3	ed	null	Mary	title=Integration.../name=Bob	citationOrder	null	4
4	rm	null	Mary	title=Integration.../name=Bob	null	null	null
5	cp	John	Jack	title=Integration...	venue	Conference...	CIKM
6	cp	John	Mary	title=Integration…	pages	260-275	1-15
7	in	Jack	John	title=Integration…/name=Mary	null	null	null
8	cp	Jack	John	title=Integration…/name=Mary	citationOrder	3	null
9	cp	Mary	John	title=Integration…/name=John	citationOrder	2	1
10	cp	Mary	John	title=Integration…/name=Jack	citationOrder	1	2
11	cp	Jack	Mary	title=Integration...	year	2009	2010
12	cp	Jack	Mary	title=Integration…	venue	Conference...	Intl Con…

Repository of Operations

source that provides the value

id	op	origin	target	objKey	objAtt	originValue	targetValue
1	ed	null	John	title=Integrating...	title	Integration...	Integrating...
2	cp	John	Jack	title=Integration...	year	2009	accepted
3	ed	null	Mary	title=Integration.../name=Bob	citationOrder	null	4
4	rm	null	Mary	title=Integration.../name=Bob	null	null	null
5	cp	John	Jack	title=Integration...	venue	Conference...	CIKM
6	cp	John	Mary	title=Integration…	pages	260-275	1-15
7	in	Jack	John	title=Integration…/name=Mary	null	null	null
8	cp	Jack	John	title=Integration…/name=Mary	citationOrder	3	null
9	cp	Mary	John	title=Integration…/name=John	citationOrder	2	1
10	cp	Mary	John	title=Integration…/name=Jack	citationOrder	1	2
11	cp	Jack	Mary	title=Integration...	year	2009	2010
12	cp	Jack	Mary	title=Integration…	venue	Conference...	Intl Con…

Repository of Operations

source that is the target of the operation

id	op	origin	target	objKey	objAtt	originValue	targetValue
1	ed	null	John	title=Integrating...	title	Integration...	Integrating...
2	cp	John	Jack	title=Integration...	year	2009	accepted
3	ed	null	Mary	title=Integration.../name=Bob	citationOrder	null	4
4	rm	null	Mary	title=Integration.../name=Bob	null	null	null
5	cp	John	Jack	title=Integration...	venue	Conference...	CIKM
6	cp	John	Mary	title=Integration…	pages	260-275	1-15
7	in	Jack	John	title=Integration…/name=Mary	null	null	null
8	cp	Jack	John	title=Integration…/name=Mary	citationOrder	3	null
9	cp	Mary	John	title=Integration…/name=John	citationOrder	2	1
10	cp	Mary	John	title=Integration…/name=Jack	citationOrder	1	2
11	cp	Jack	Mary	title=Integration...	year	2009	2010
12	cp	Jack	Mary	title=Integration…	venue	Conference...	Intl Con…

Repository of Operations

values of key attributes of the object

id	op	origin	target	objKey	objAtt	originValue	targetValue
1	ed	null	John	title=Integrating...	title	Integration...	Integrating...
2	cp	John	Jack	title=Integration...	year	2009	accepted
3	ed	null	Mary	title=Integration.../name=Bob	citationOrder	null	4
4	rm	null	Mary	title=Integration.../name=Bob	null	null	null
5	cp	John	Jack	title=Integration...	venue	Conference...	CIKM
6	cp	John	Mary	title=Integration…	pages	260-275	1-15
7	in	Jack	John	title=Integration…/name=Mary	null	null	null
8	cp	Jack	John	title=Integration…/name=Mary	citationOrder	3	null
9	cp	Mary	John	title=Integration…/name=John	citationOrder	2	1
10	cp	Mary	John	title=Integration…/name=Jack	citationOrder	1	2
11	cp	Jack	Mary	title=Integration...	year	2009	2010
12	cp	Jack	Mary	title=Integration…	venue	Conference...	Intl Con…

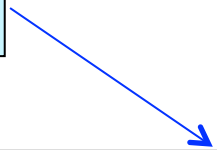
Repository of Operations

attribute name involved in the operation

id	op	origin	target	objKey	objAtt	originValue	targetValue
1	ed	null	John	title=Integrating...	title	Integration...	Integrating...
2	cp	John	Jack	title=Integration...	year	2009	accepted
3	ed	null	Mary	title=Integration.../name=Bob	citationOrder	null	4
4	rm	null	Mary	title=Integration.../name=Bob	null	null	null
5	cp	John	Jack	title=Integration...	venue	Conference...	CIKM
6	cp	John	Mary	title=Integration…	pages	260-275	1-15
7	in	Jack	John	title=Integration…/name=Mary	null	null	null
8	cp	Jack	John	title=Integration…/name=Mary	citationOrder	3	null
9	cp	Mary	John	title=Integration…/name=John	citationOrder	2	1
10	cp	Mary	John	title=Integration…/name=Jack	citationOrder	1	2
11	cp	Jack	Mary	title=Integration...	year	2009	2010
12	cp	Jack	Mary	title=Integration…	venue	Conference...	Intl Con…

Repository of Operations

origin's attribute value



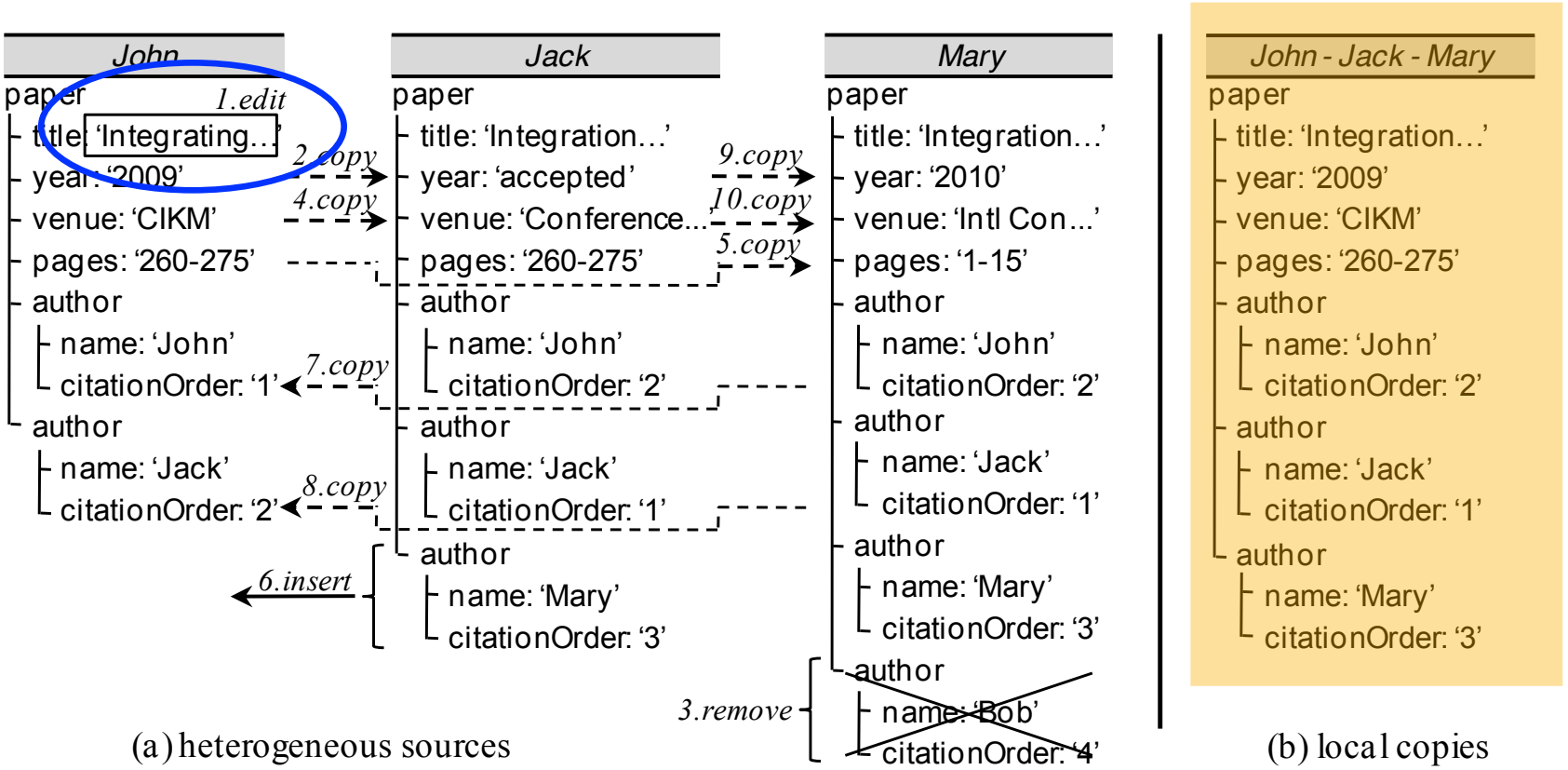
id	op	origin	target	objKey	objAtt	originValue	targetValue
1	ed	null	John	title=Integrating...	title	Integration...	Integrating...
2	cp	John	Jack	title=Integration...	year	2009	accepted
3	ed	null	Mary	title=Integration.../name=Bob	citationOrder	null	4
4	rm	null	Mary	title=Integration.../name=Bob	null	null	null
5	cp	John	Jack	title=Integration...	venue	Conference...	CIKM
6	cp	John	Mary	title=Integration…	pages	260-275	1-15
7	in	Jack	John	title=Integration…/name=Mary	null	null	null
8	cp	Jack	John	title=Integration…/name=Mary	citationOrder	3	null
9	cp	Mary	John	title=Integration…/name=John	citationOrder	2	1
10	cp	Mary	John	title=Integration…/name=Jack	citationOrder	1	2
11	cp	Jack	Mary	title=Integration...	year	2009	2010
12	cp	Jack	Mary	title=Integration…	venue	Conference...	Intl Con…

Repository of Operations

original target's attribute value

id	op	origin	target	objKey	objAtt	originValue	targetValue
1	ed	null	John	title=Integrating...	title	Integration...	Integrating...
2	cp	John	Jack	title=Integration...	year	2009	accepted
3	ed	null	Mary	title=Integration.../name=Bob	citationOrder	null	4
4	rm	null	Mary	title=Integration.../name=Bob	null	null	null
5	cp	John	Jack	title=Integration...	venue	Conference...	CIKM
6	cp	John	Mary	title=Integration…	pages	260-275	1-15
7	in	Jack	John	title=Integration…/name=Mary	null	null	null
8	cp	Jack	John	title=Integration…/name=Mary	citationOrder	3	null
9	cp	Mary	John	title=Integration…/name=John	citationOrder	2	1
10	cp	Mary	John	title=Integration…/name=Jack	citationOrder	1	2
11	cp	Jack	Mary	title=Integration...	year	2009	2010
12	cp	Jack	Mary	title=Integration…	venue	Conference...	Intl Con…

Example of Data Integration



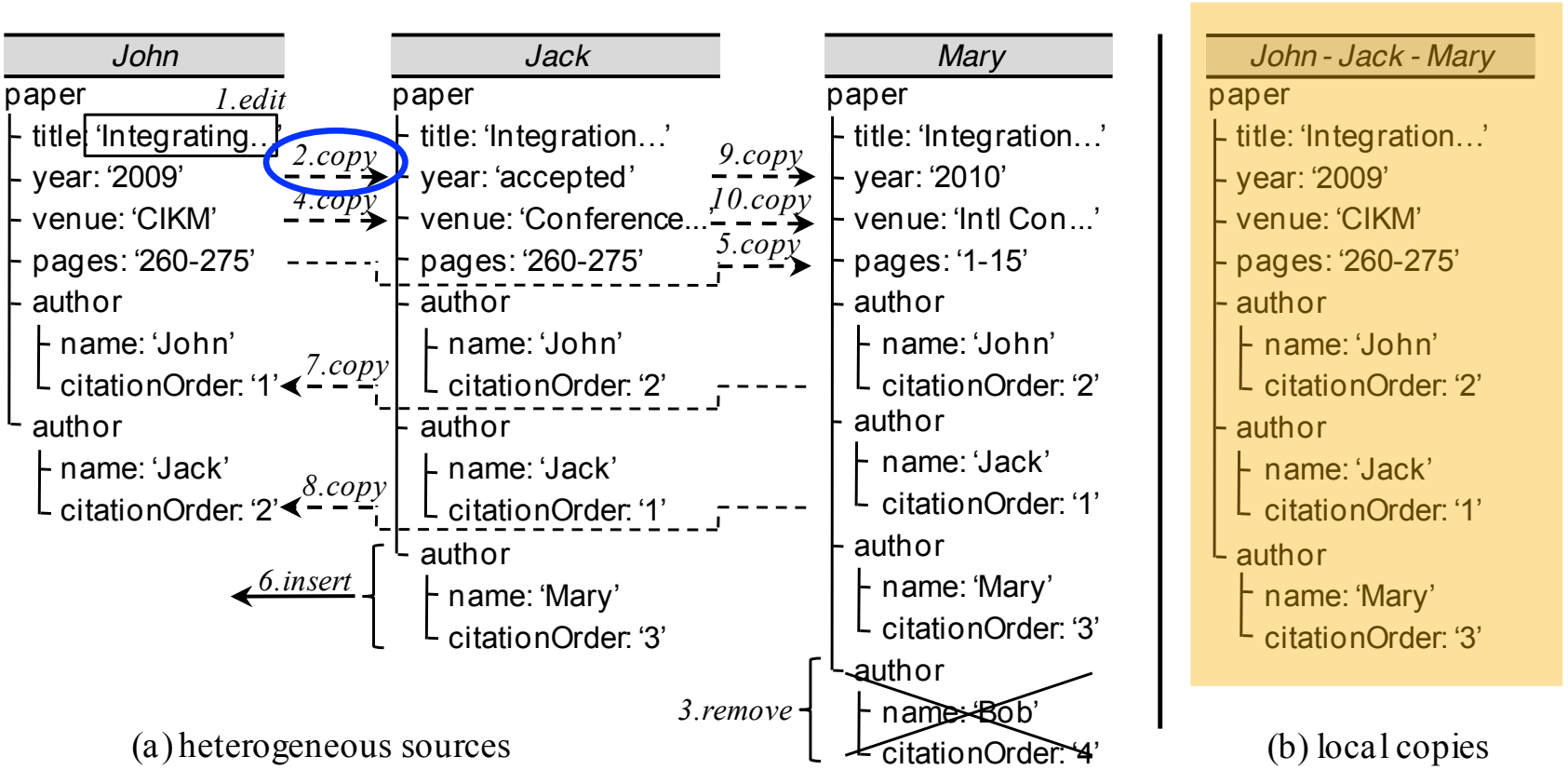
the value of paper's title for John is edited from 'Integrating...' to 'Integration...'

Well-defined Edit Operation

id	op	origin	target	objKey	objAtt	originValue	targetValue
1	ed	null	John	title=Integrating...	title	Integration...	Integrating...
2	cp	John	Jack	title=Integration...	year	2009	accepted
3	ed	null	Mary	title=Integration.../name=Bob	citationOrder	null	4
4	rm	null	Mary	title=Integration.../name=Bob	null	null	null
5	cp	John	Jack	title=Integration...	venue	Conference...	CIKM
6	cp	John	Mary	title=Integration…	pages	260-275	1-15
7	in	Jack	John	title=Integration…/name=Mary	null	null	null
8	cp	Jack	John	title=Integration…/name=Mary	citationOrder	3	null
9	cp	Mary	John	title=Integration…/name=John	citationOrder	2	1
10	cp	Mary	John	title=Integration…/name=Jack	citationOrder	1	2
11	cp	Jack	Mary	title=Integration...	year	2009	2010
12	cp	Jack	Mary	title=Integration…	venue	Conference...	Intl Con…

- *originValue* is the value obtained from input
- *origin* is set to null to indicate an external action
- *originValue* and *targetValue* should have different values

Example of Data Integration



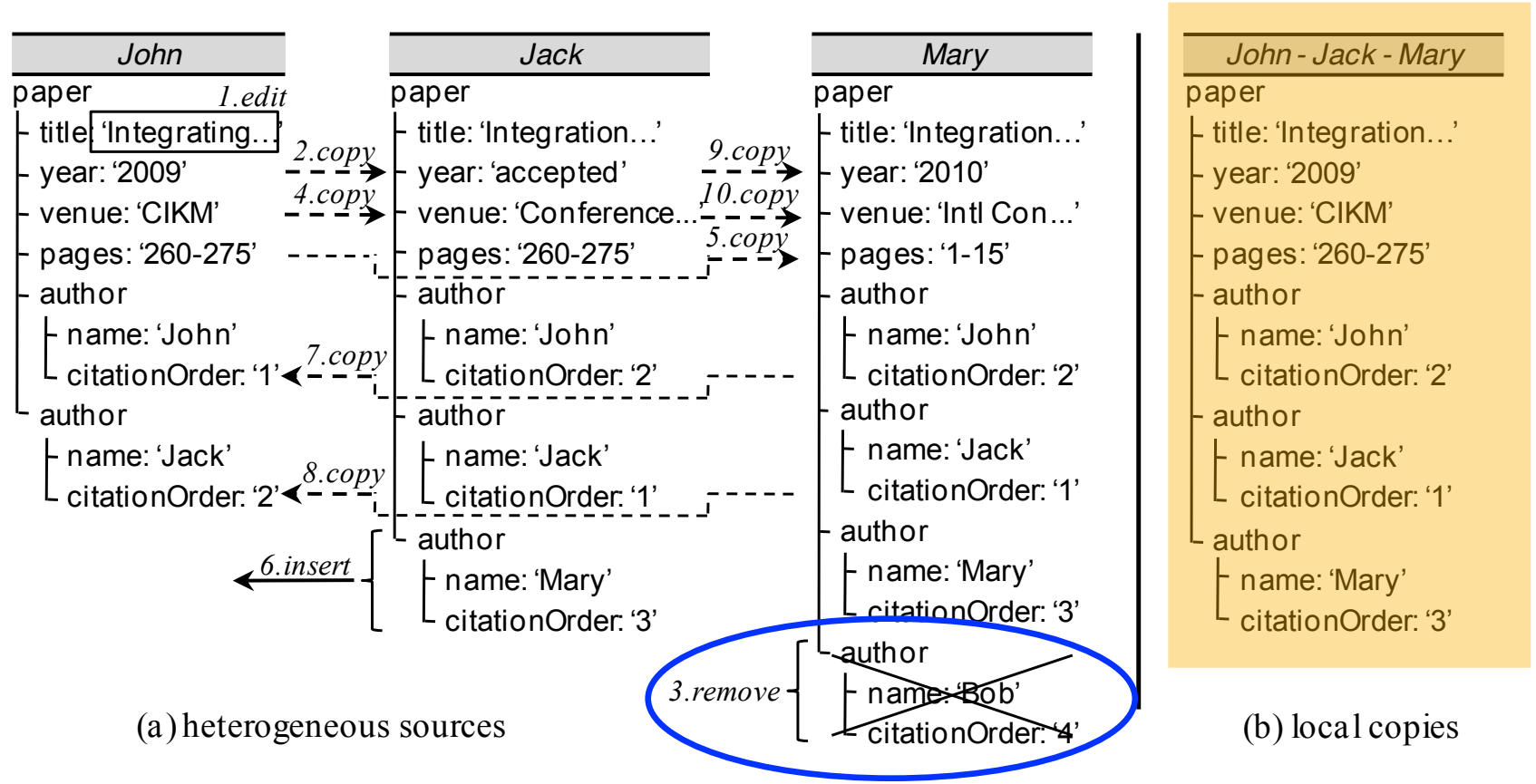
paper's year is copied from John to Jack

Well-defined Copy Operation

id	op	origin	target	objKey	objAtt	originValue	targetValue
1	ed	null	John	title=Integrating...	title	Integration...	Integrating...
2	cp	John	Jack	title=Integration...	year	2009	accepted
3	ed	null	Mary	title=Integration.../name=Bob	citationOrder	null	4
4	rm	null	Mary	title=Integration.../name=Bob	null	null	null
5	cp	John	Jack	title=Integration...	venue	Conference...	CIKM
6	cp	John	Mary	title=Integration…	pages	260-275	1-15
7	in	Jack	John	title=Integration…/name=Mary	null	null	null
8	cp	Jack	John	title=Integration…/name=Mary	citationOrder	3	null
9	cp	Mary	John	title=Integration…/name=John	citationOrder	2	1
10	cp	Mary	John	title=Integration…/name=Jack	citationOrder	1	2
11	cp	Jack	Mary	title=Integration...	year	2009	2010
12	cp	Jack	Mary	title=Integration…	venue	Conference...	Intl Con…

- *originValue* and *targetValue* should have different values

Example of Data Integration



(a) heterogeneous sources

(b) local copies

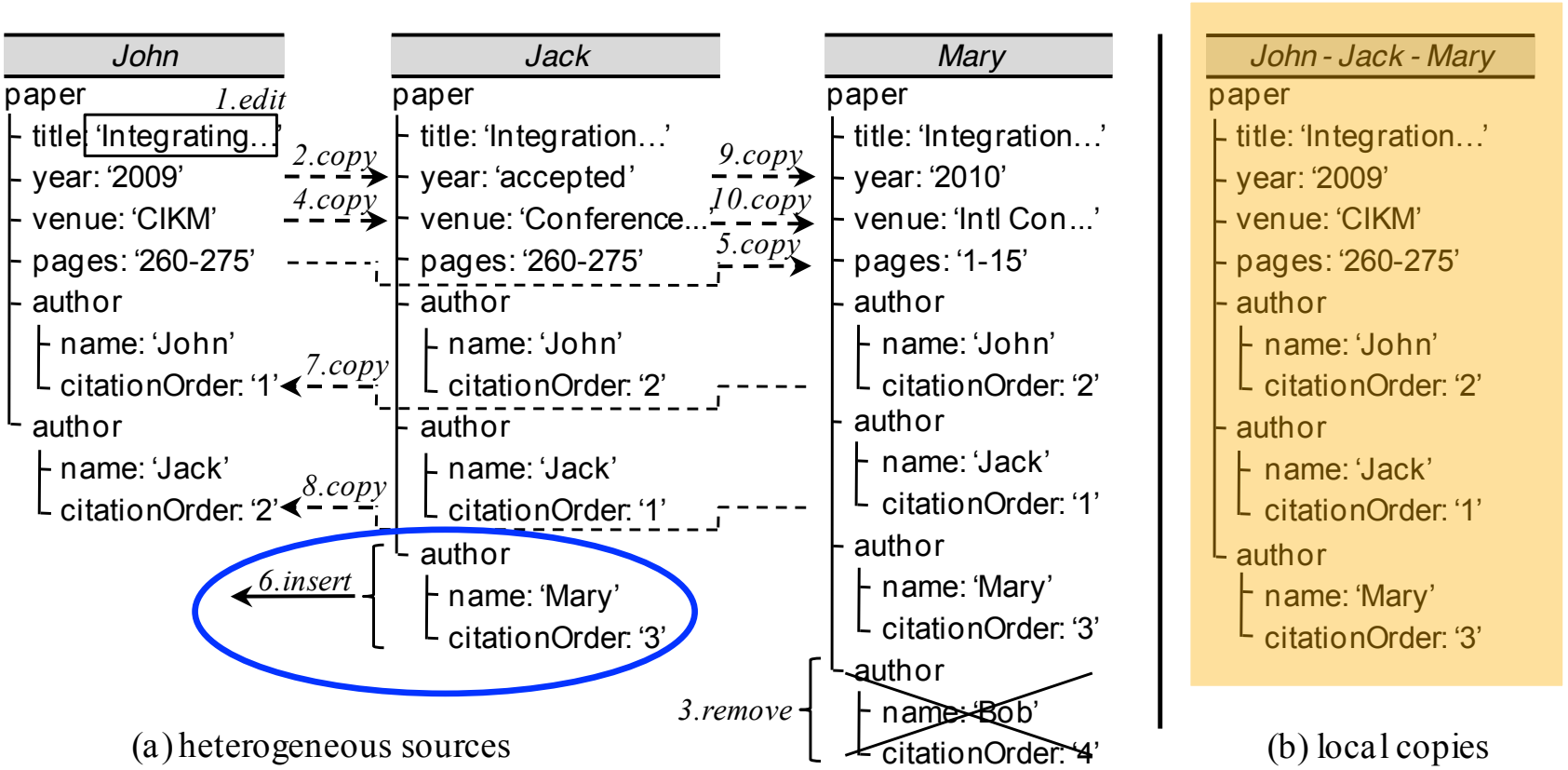
author 'Bob' is removed from Mary

Well-defined Remove Operation

id	op	origin	target	objKey	objAtt	originValue	targetValue
1	ed	null	John	title=Integrating...	title	Integration...	Integrating...
2	cp	John	Jack	title=Integration...	year	2009	accepted
3	ed	null	Mary	title=Integration.../name=Bob	citationOrder	null	4
4	rm	null	Mary	title=Integration.../name=Bob	null	null	null
5	cp	John	Jack	title=Integration...	venue	Conference...	CIKM
6	cp	John	Mary	title=Integration…	pages	260-275	1-15
7	in	Jack	John	title=Integration…/name=Mary	null	null	null
8	cp	Jack	John	title=Integration…/name=Mary	citationOrder	3	null
9	cp	Mary	John	title=Integration…/name=John	citationOrder	2	1
10	cp	Mary	John	title=Integration…/name=Jack	citationOrder	1	2
11	cp	Jack	Mary	title=Integration...	year	2009	2010
12	cp	Jack	Mary	title=Integration…	venue	Conference...	Intl Con…

- mapped to a remove operation and several edit operations
- *origin, objAtt, originValue* and *targetValue* are set to null

Example of Data Integration



author 'Mary' from Jack is inserted into John

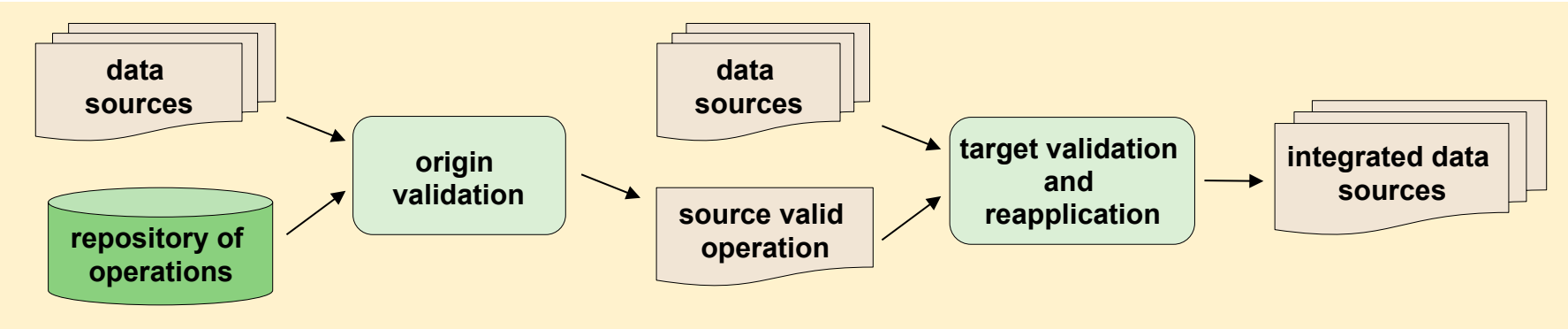
Well-defined Insert Operation

id	op	origin	target	objKey	objAtt	originValue	targetValue
1	ed	null	John	title=Integrating...	title	Integration...	Integrating...
2	cp	John	Jack	title=Integration...	year	2009	accepted
3	ed	null	Mary	title=Integration.../name=Bob	citationOrder	null	4
4	rm	null	Mary	title=Integration.../name=Bob	null	null	null
5	cp	John	Jack	title=Integration...	venue	Conference...	CIKM
6	cp	John	Mary	title=Integration…	pages	260-275	1-15
7	in	Jack	John	title=Integration…/name=Mary	null	null	null
8	cp	Jack	John	title=Integration…/name=Mary	citationOrder	3	null
9	cp	Mary	John	title=Integration…/name=John	citationOrder	2	1
10	cp	Mary	John	title=Integration…/name=Jack	citationOrder	1	2
11	cp	Jack	Mary	title=Integration...	year	2009	2010
12	cp	Jack	Mary	title=Integration…	venue	Conference...	Intl Con…

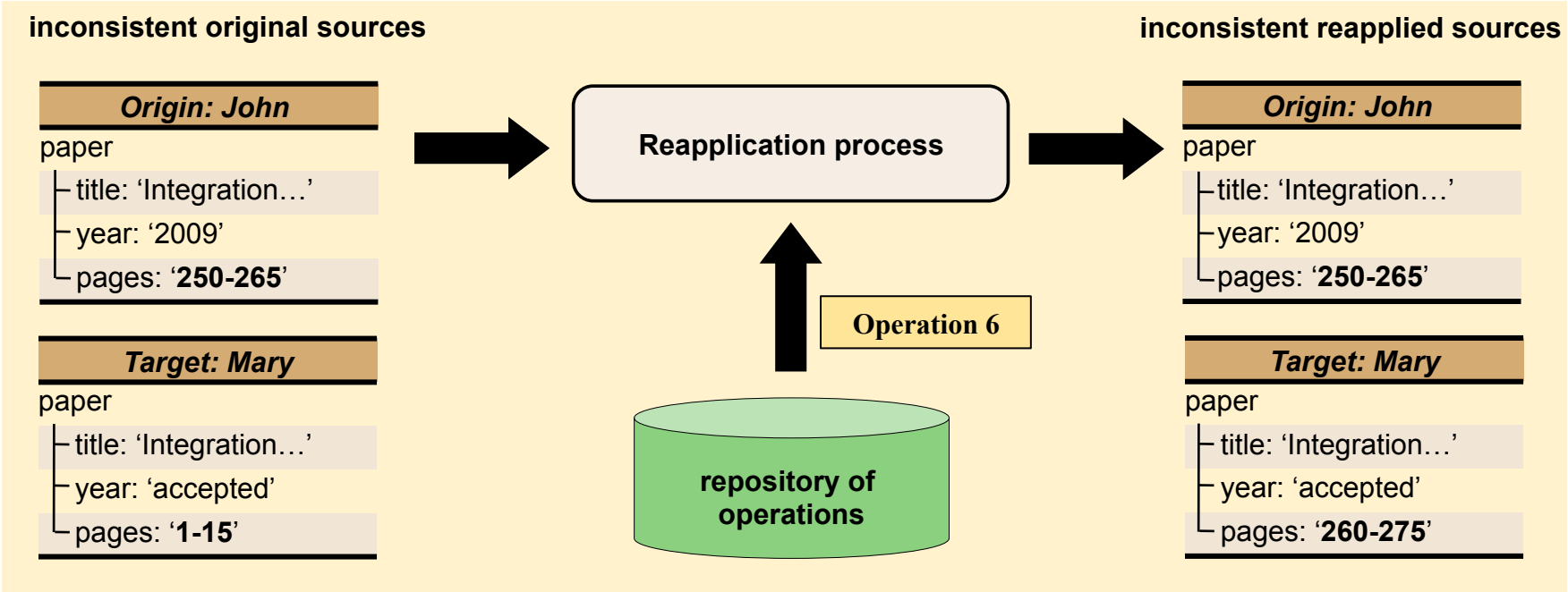
- mapped to an insert operation and several copy operations
- *objAtt, originValue* and *targetValue* are set to null

The VRT Method

- Validation and reapplication of operations
  - validation of both origin and target
    - checking if they still store the same value on the data item involved
  - reapplication of all valid operations

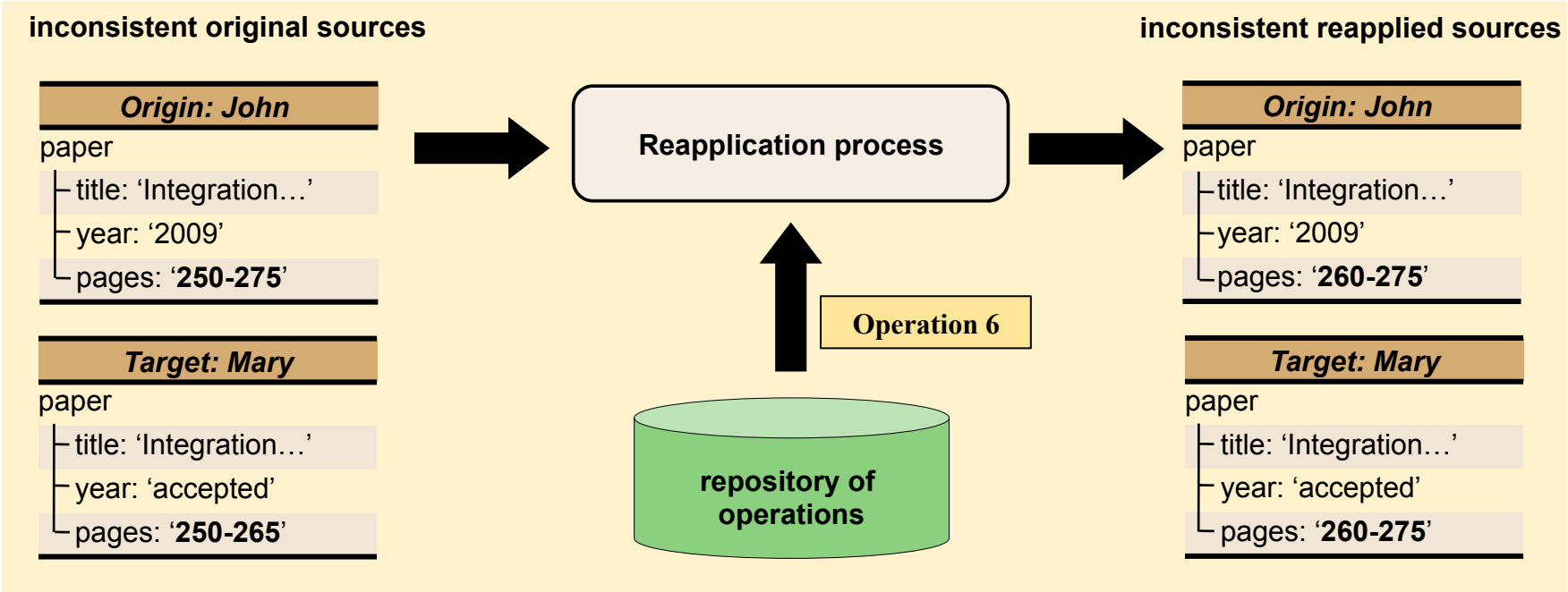


Origin has changed



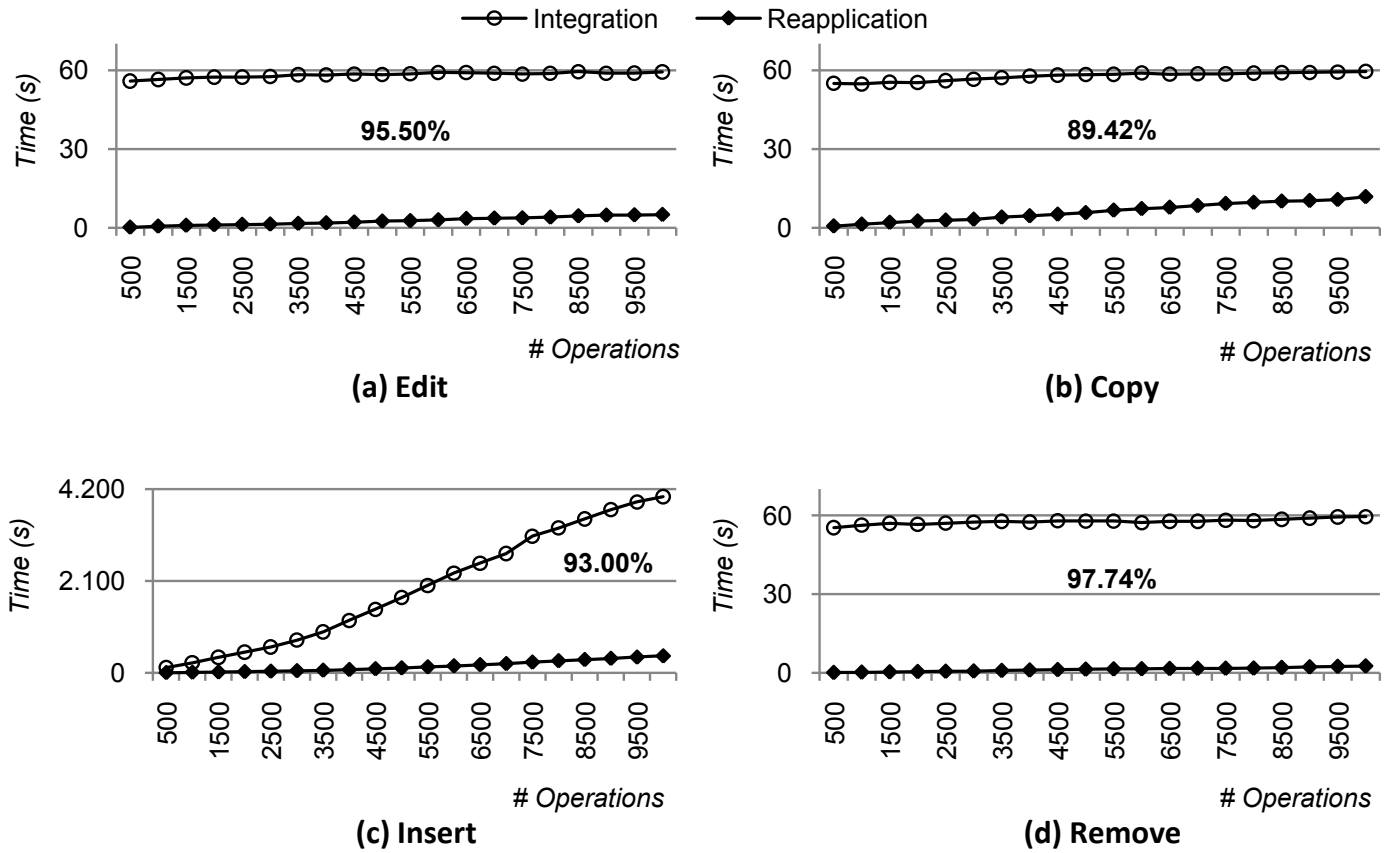
- Origin validation
  - if origin changes, reapplication of operation 6 leads to inconsistent sources

Target has changed



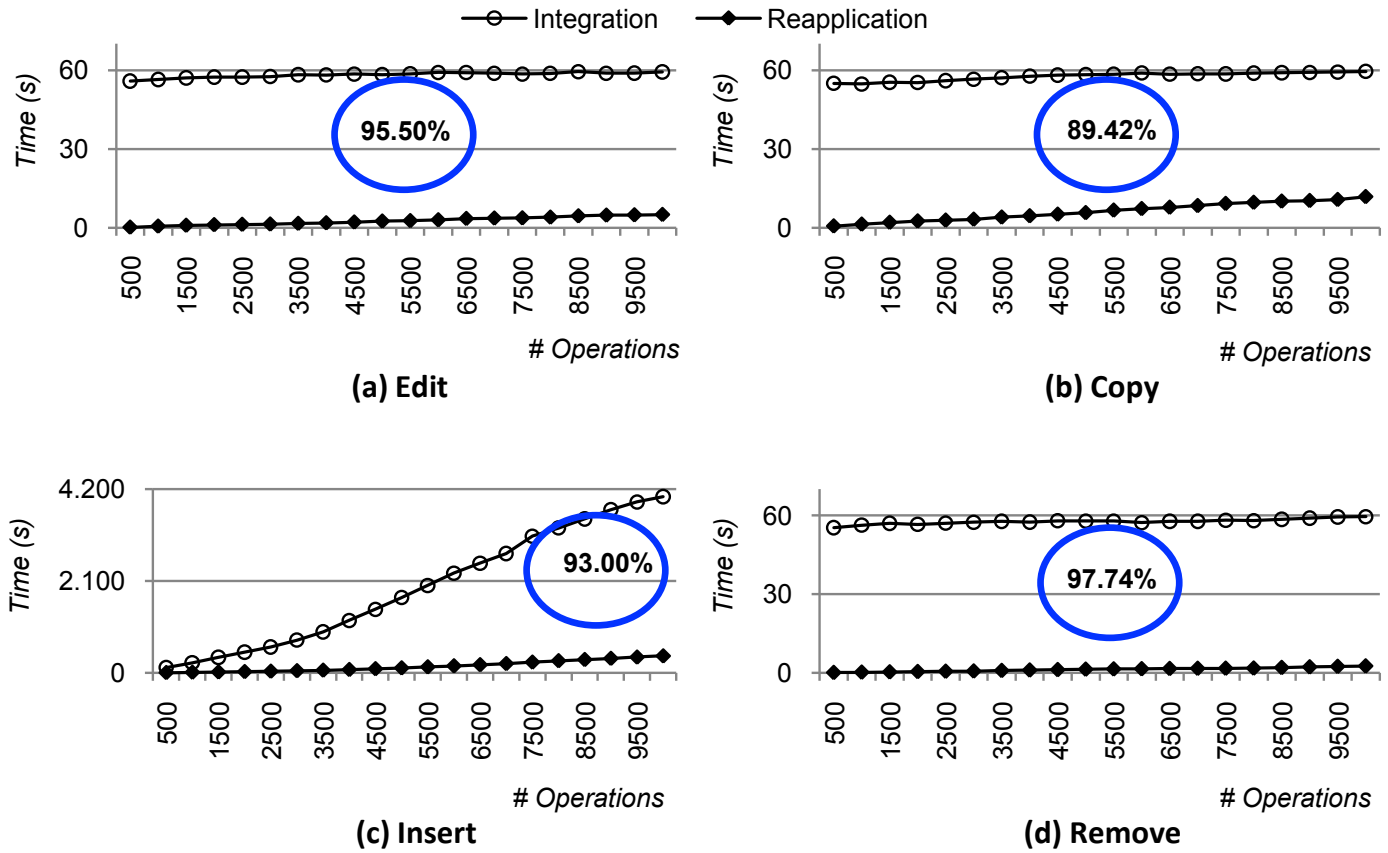
- Target validation
  - if target changes, reapplication of operation 6 leads to consistent sources, but the new value of the target is overwritten without consent

Cost of Reapplication



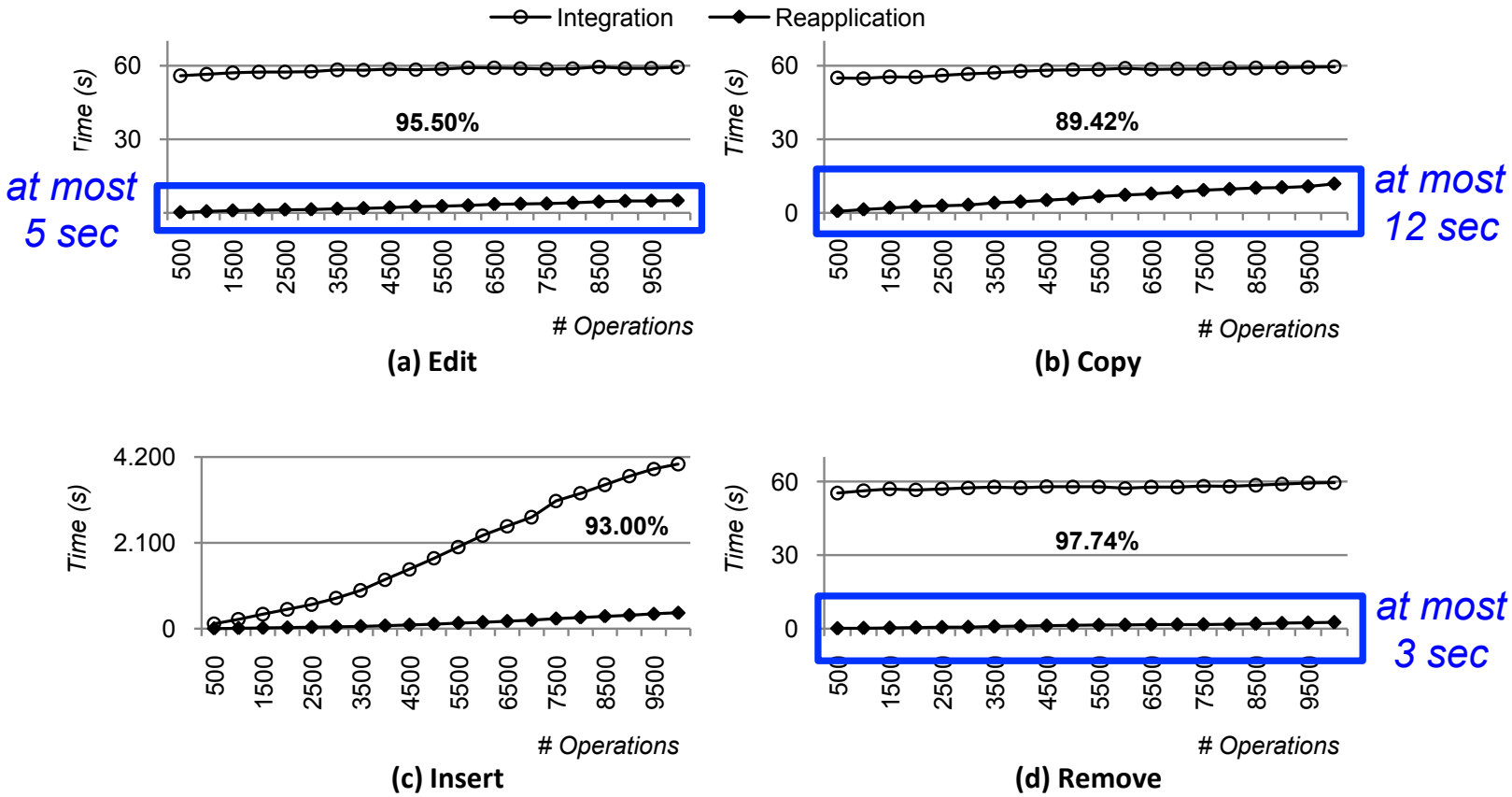
Scalability: 30 sources; from 500 to 10,000 operations

Cost of Reapplication



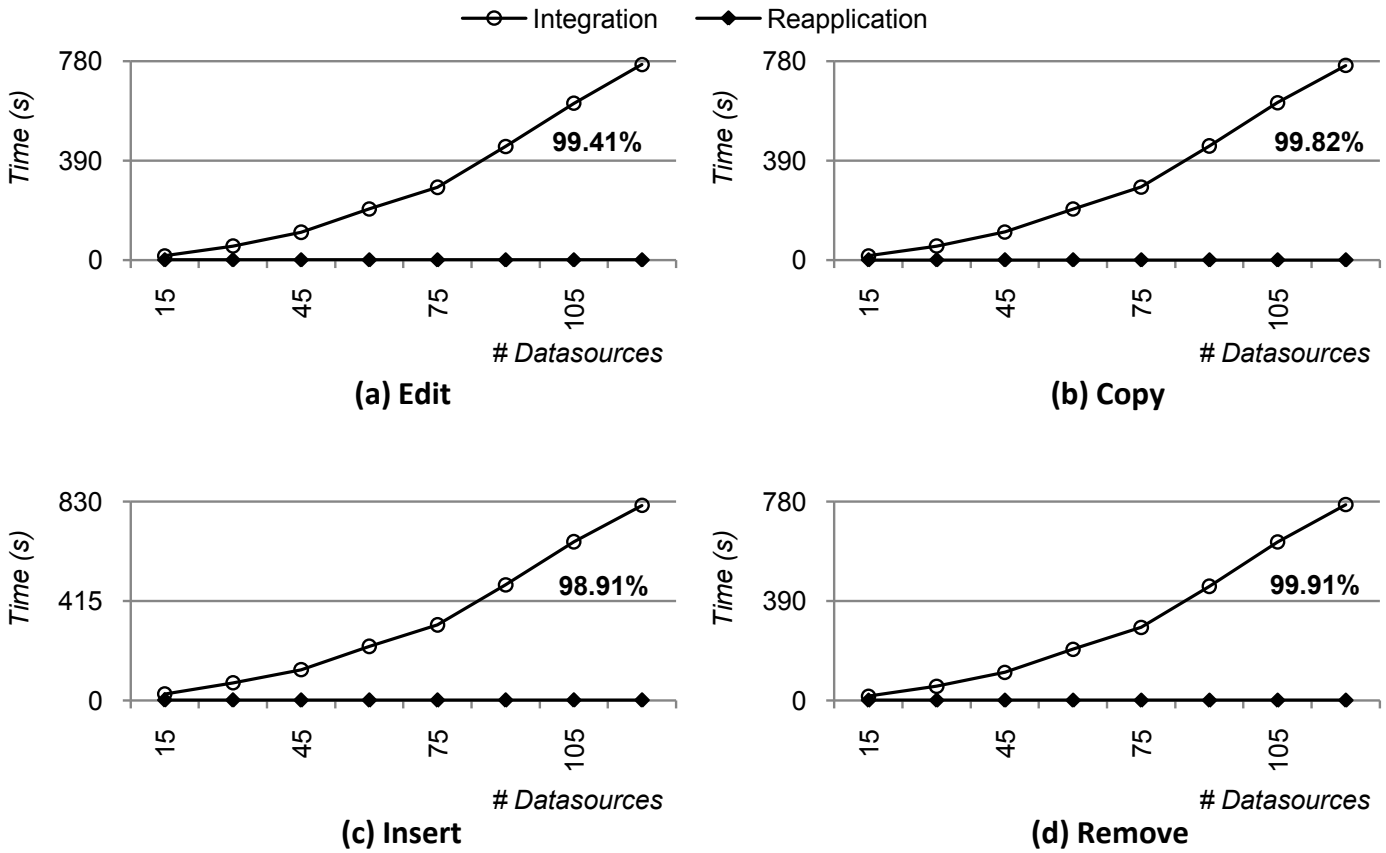
remarkable performance gains

Cost of Reapplication



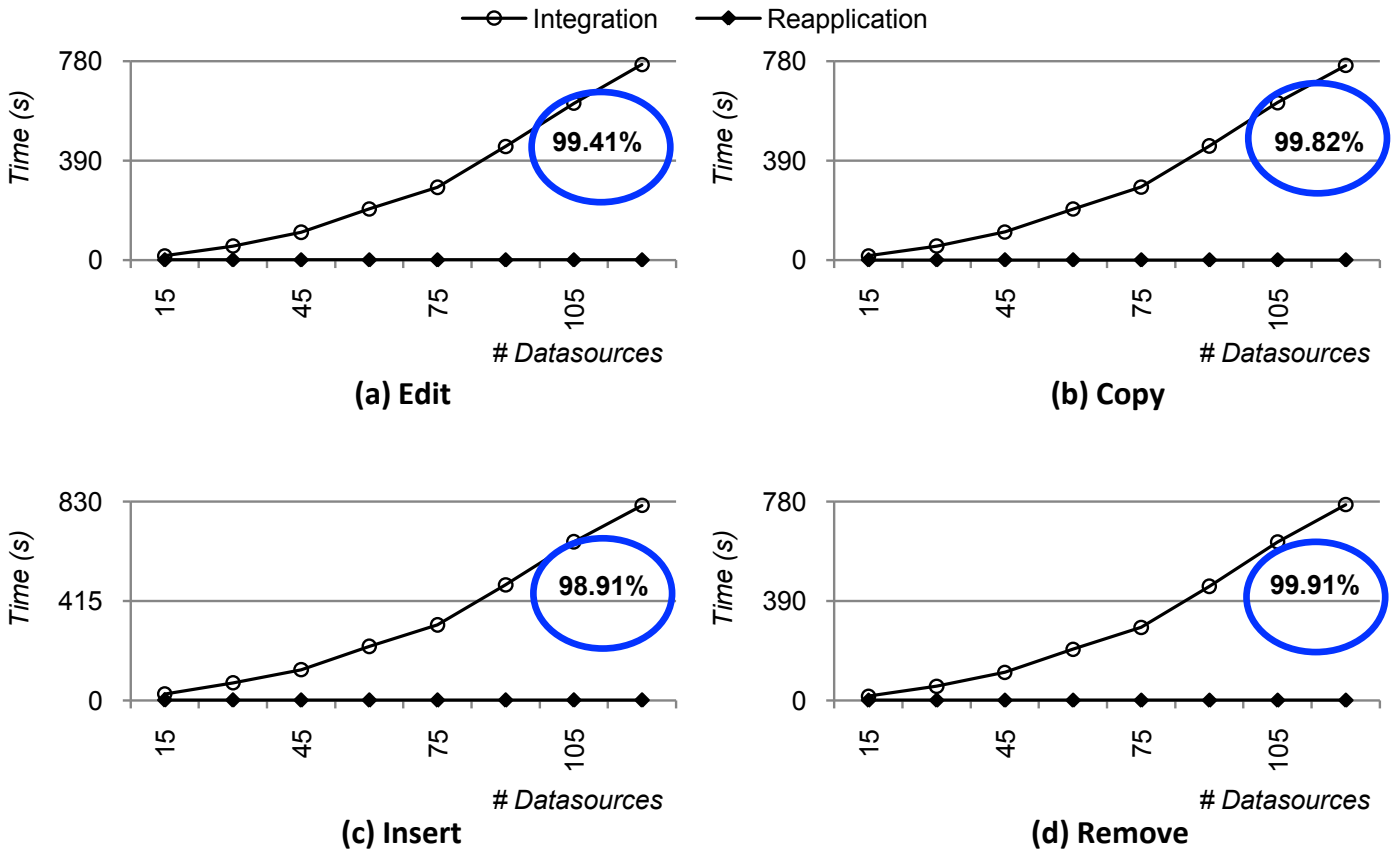
time spent was nearly constant

Cost of Reapplication



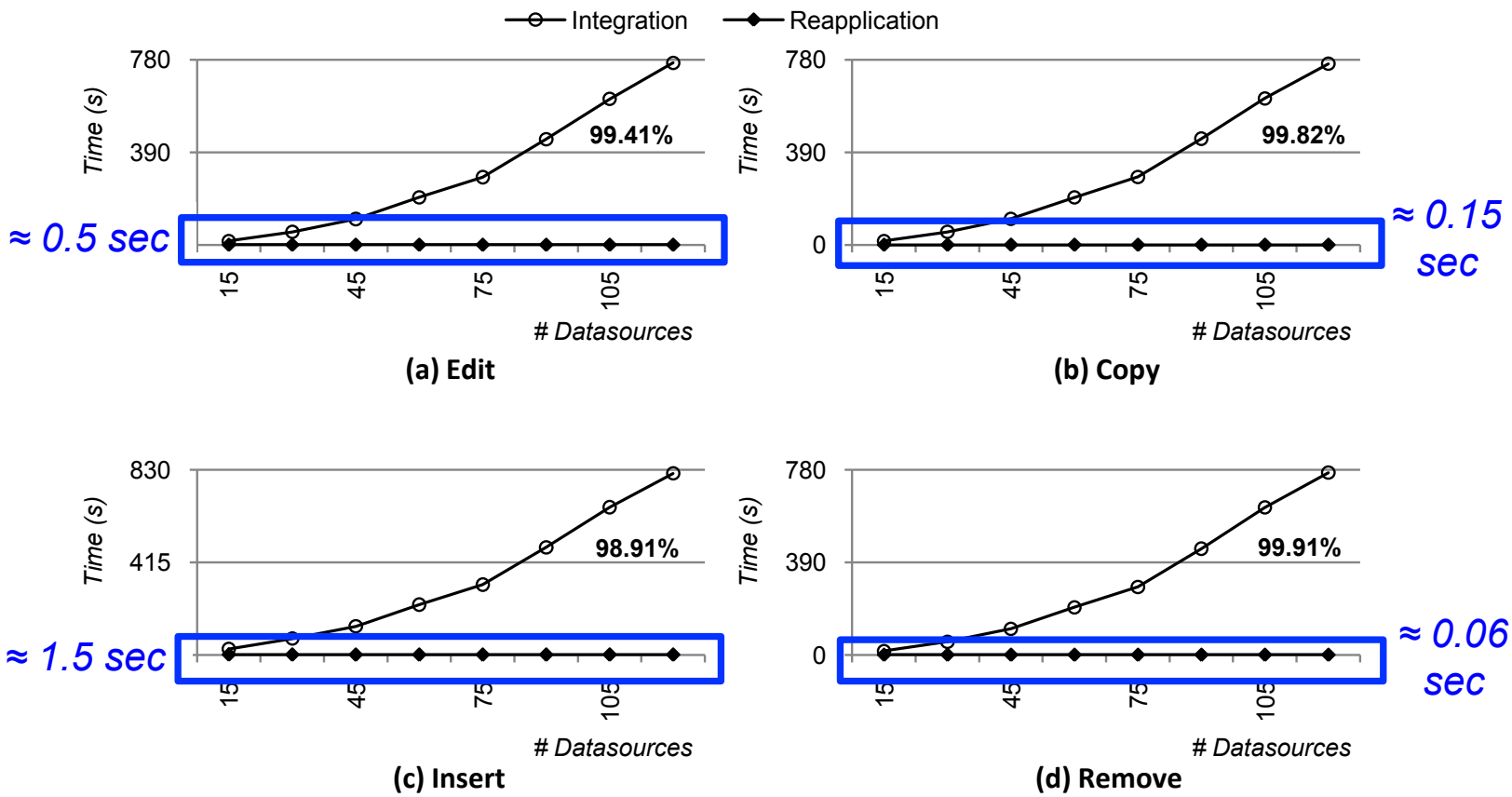
Scalability: 120 operations; from 15 to 120 sources

Cost of Reapplication



remarkable performance gains

Cost of Reapplication



time spent was nearly constant

Time Spent by Real Users

# user	time spent (sec)	# actions	# operations	# *edit*	# *copy*	# *insert*	# *remove*
01	1,021	53	361	136	190	25	10
02	1,300	49	616	204	361	45	6
03	1,040	48	420	160	225	27	8
04	1,055	47	243	88	130	18	7
05	859	51	616	115	449	47	5
06	1,246	49	749	296	391	51	11
07	1,151	55	185	35	135	13	2
08	860	45	106	33	73	0	0
09	1,158	53	91	14	74	3	0
10	948	53	92	17	67	7	1

integration of only 4 sources

The PrInt Model

- Eliminates decision retaking
- Introduces advantages to the integration process
  - it avoids that conflicting decisions about the same inconsistency be taken in different integration processes
  - it also improves the performance of the integration process as only new inconsistencies should be solved from source modified data