ProDIS

Provenance for Data-Intensive Systems

ProDIS: Provenance for Data-Intensive Systems

- Databases, Data Mining, Data Science…
- Highly complex logic, Big Data

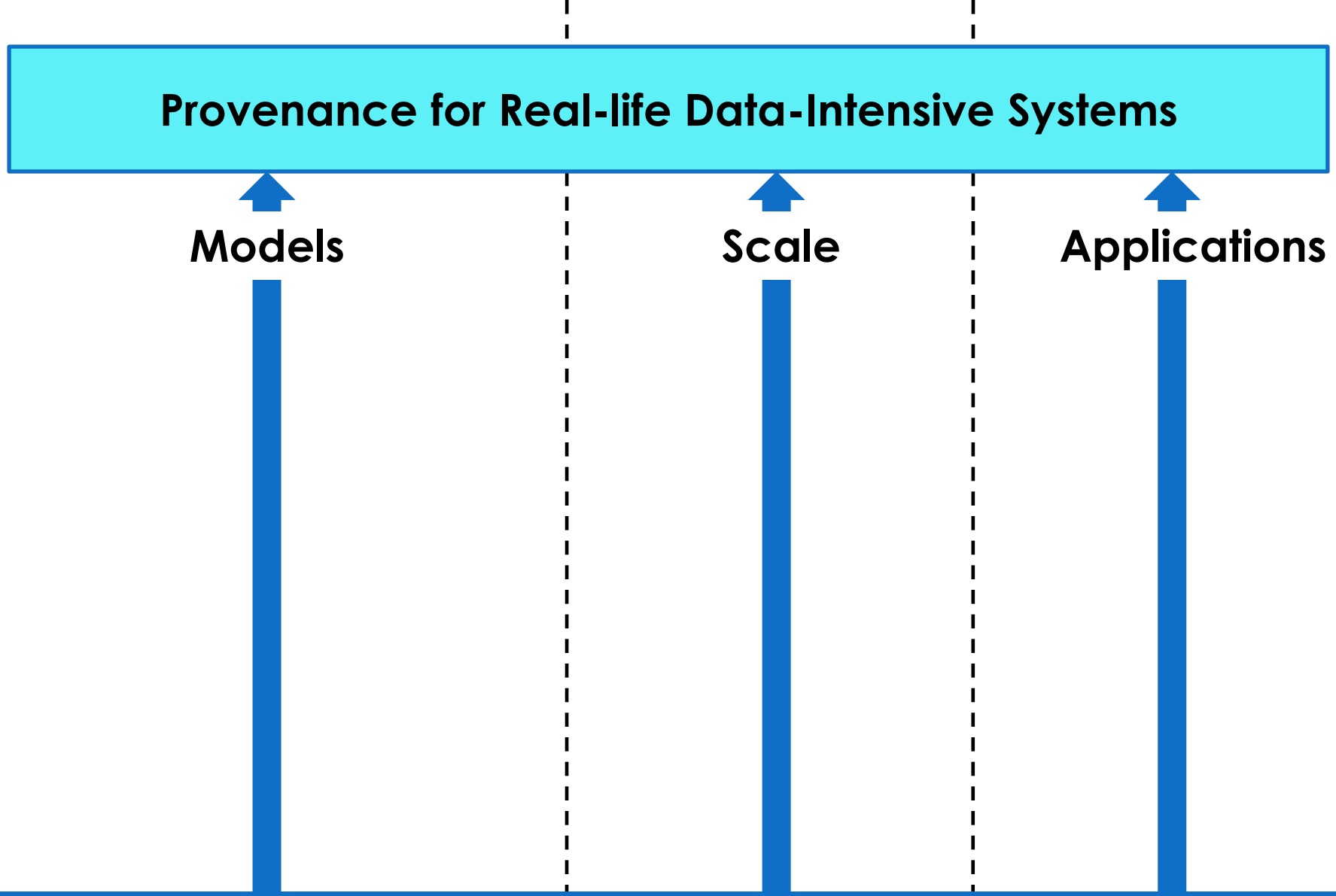
Provenance of output is typically unknown

- Why, what if, what data was used, can we trust?...
- Without answers to these questions, results may be useless/harmful
  - Medical recommendations, loan request rejections..

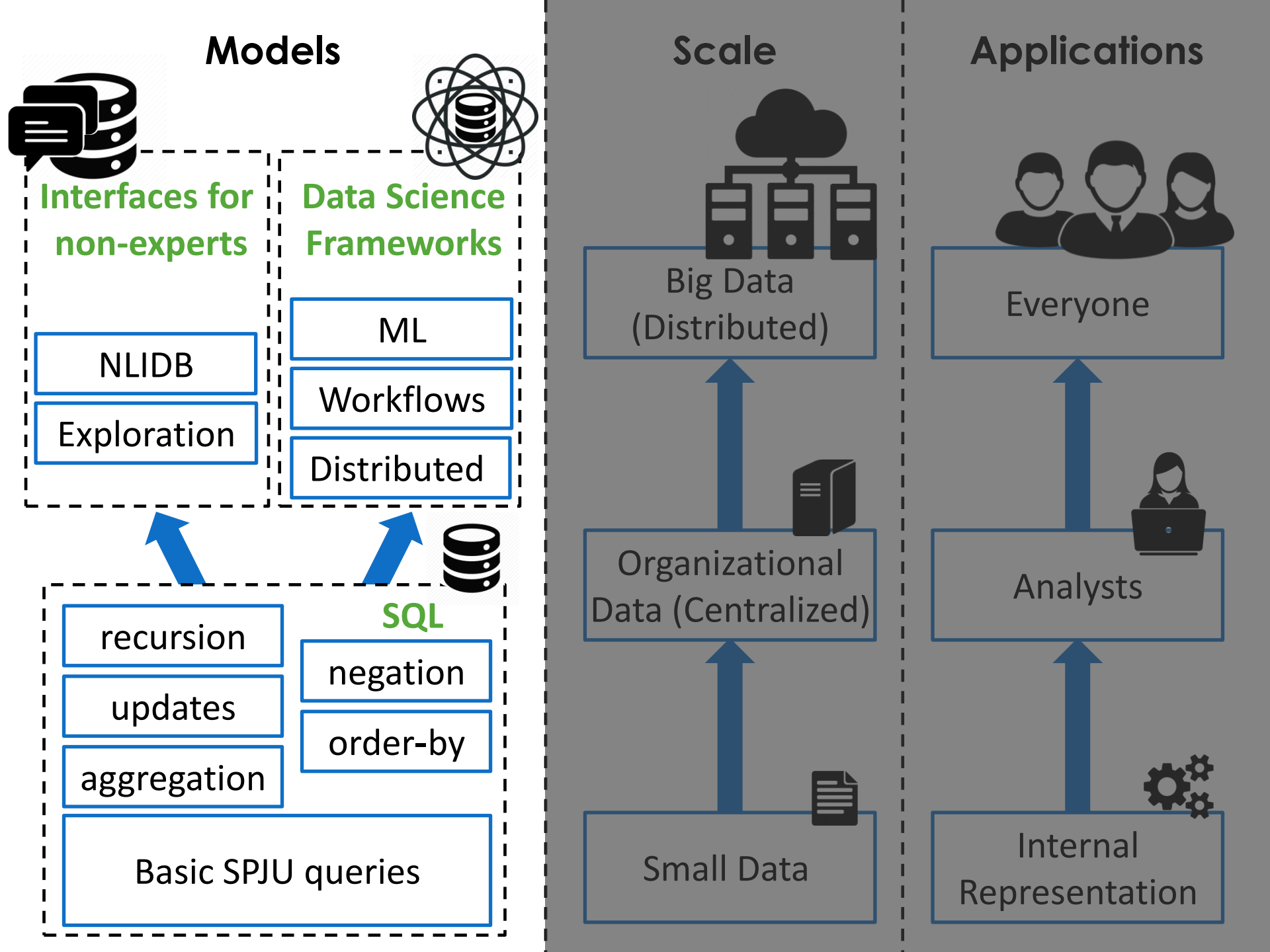
Imagine a world where computation results are
accounted for and explained

Systems would be transparent and controllable,
and the results credible and reusable

Provenance for Real-life Data-Intensive Systems



Data Provenance: theory and algorithms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Applications
Interfaces for non-experts
Data Science Frameworks
NLIDB
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ML
Workflows
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Basic SPJU queries
Big Data (Distributed)
Organizational Data (Centralized)
Small Data
Everyone
Analysts
Internal Representation

Models

"Return customers with overdraft events after 2006"

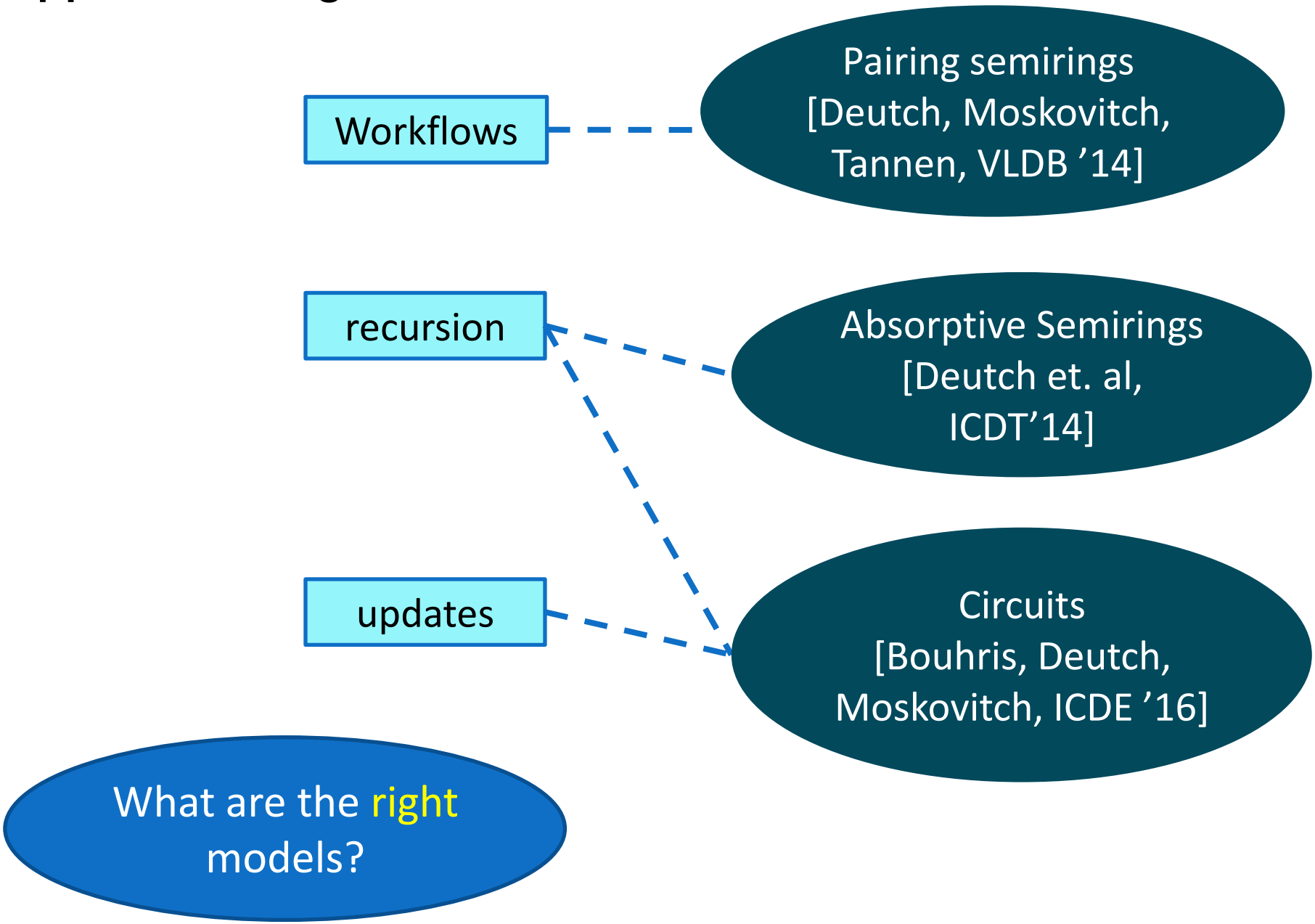
eventid	sum	type	due	Prov
1	50000	overdraft	2012	p1
2	400000	mortgage	2014	p2
3	2000000	overdraft	2010	p3

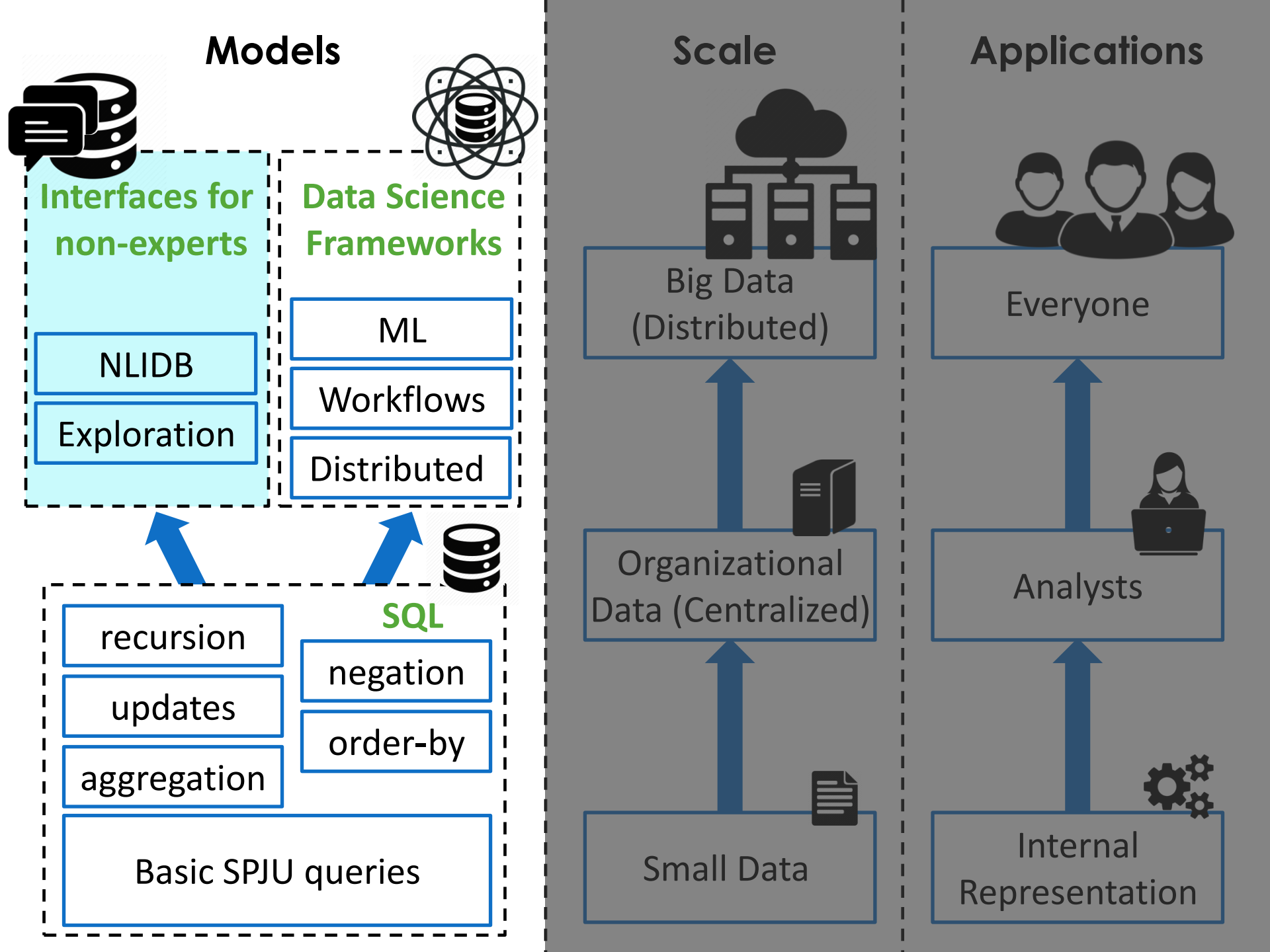
custname	eventid	prov
Smith	1	c1
Smith	3	c2
Roth	2	c3

custname	prov
Smith	p1·c1+p3·c2

[Green et. al, PODS 2007]

Models
Approach I: Algebraic Provenance

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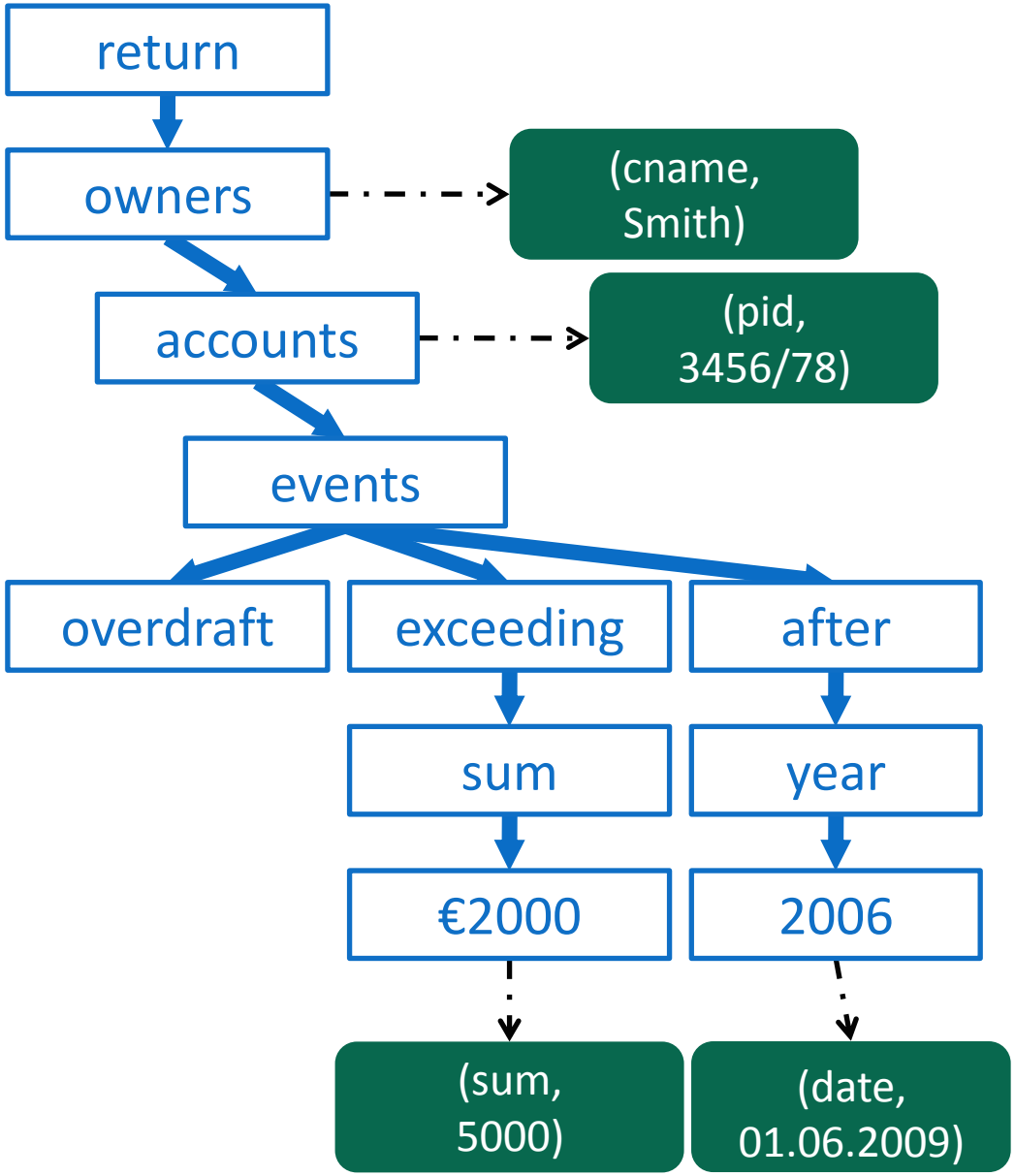
Models
Approach II: Interaction-Based Provenance

NLIDB

"Return owners of accounts with overdraft events exceeding a sum of €2000 after the year 2006"

...

"Why is 'Smith' an answer?"



[Deutch, Frost, Gilad, VLDB '17 best paper]

Models
Approach II: Interaction-Based Provenance

Data Science Frameworks

ML

Workflows

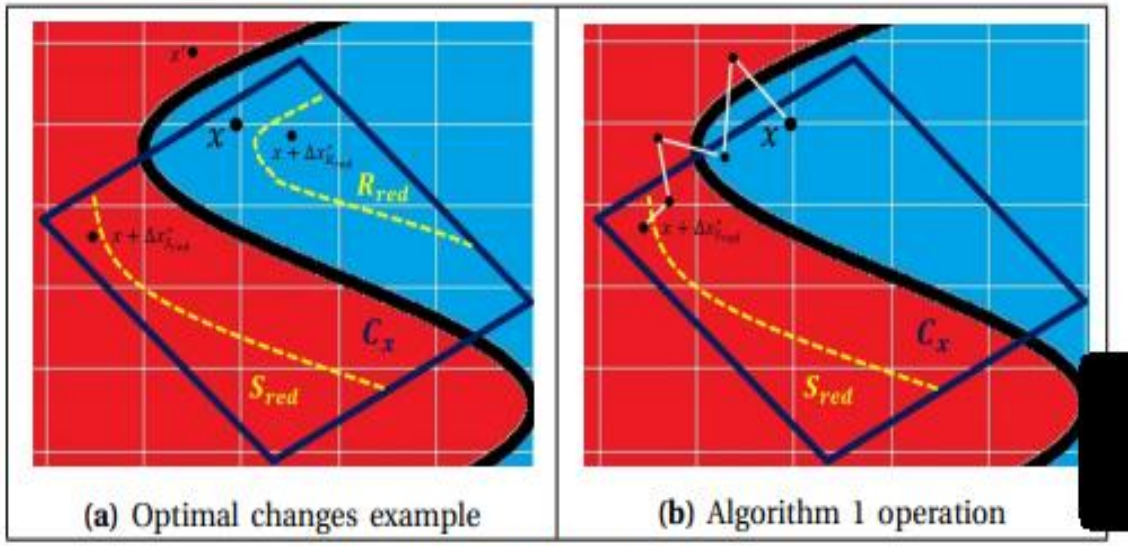
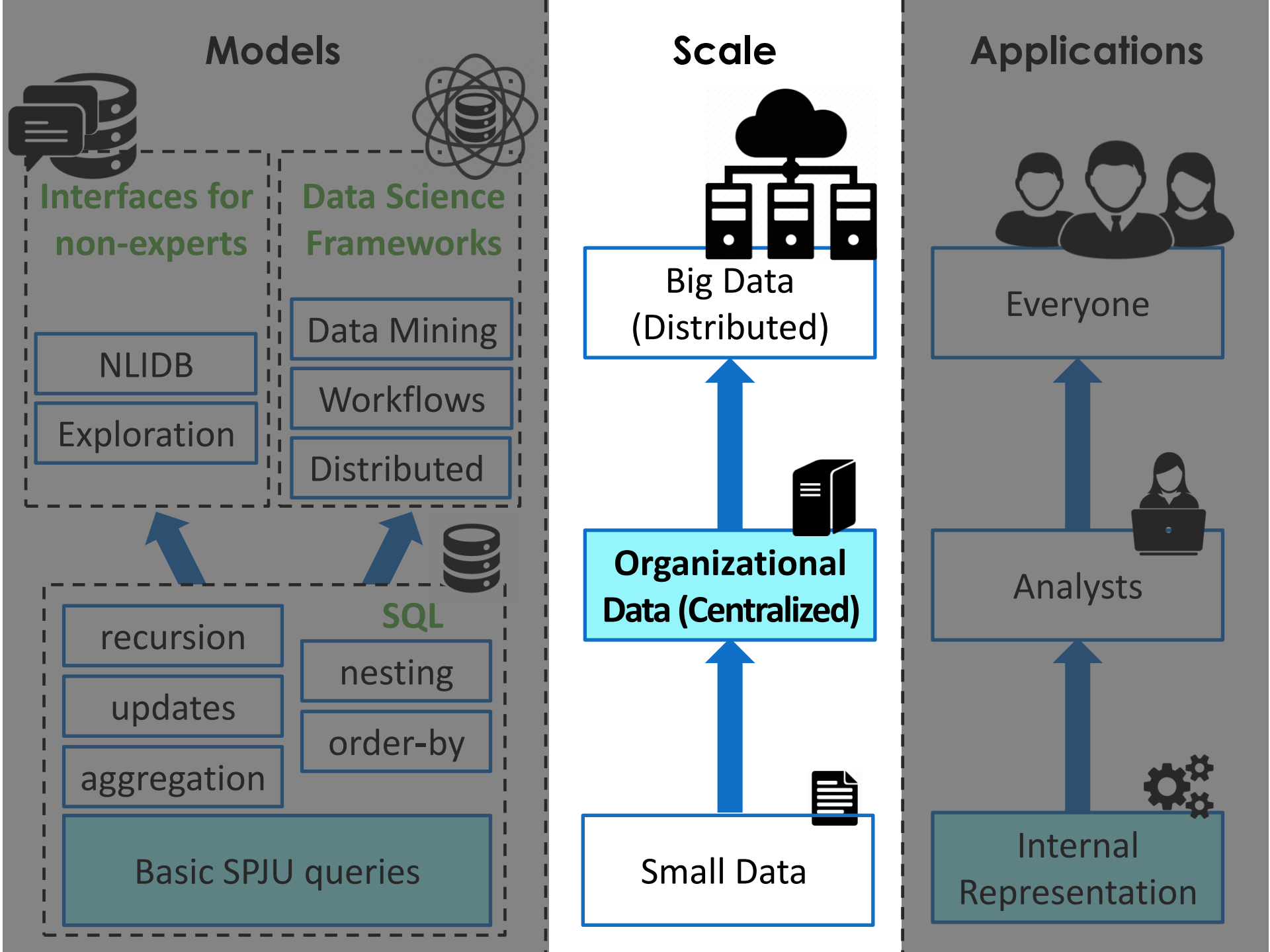


Figure 2: Optimal changes

Integrity Constraint	Formula Example	Project Constraint
Domain	$\forall t \in R, t.v_i \in [a, b]$	$v_i \geq a \wedge v_i \leq b$
Check	$\forall t \in R, t.v_i \leq t.v_j$	$v_i - v_j \leq 0$
CFD	$\forall t \in R, t.v_i = V_1 \rightarrow t.v_j = V_2$	$v_i \neq V_1 \vee v_j = V_2$
Unary Denial	$\forall t \in R, \neg(\bigwedge_{i=1}^{k} t.v_i = V_i)$	$\bigvee_{i=1}^{k} v_i \neq V_i$

D.Deutch and N.Frost, **Constraints-based Explanations of Classifications**, ICDE 2019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```
SELECT Customer.cname
FROM Customer, Ownership, Product,
Assoc, Event, DebtEvent, Currency
WHERE Customer.cid = Ownership.cid
AND Ownership.pid = Product.pid
AND Product.type LIKE '%account'
AND Product.pid=Assoc.pid AND
Assoc.eid=Event.eid AND
Event.date > '01.01.2007' AND
Event.eid = DebtEvent.eid
DebtEvent.sum > 2000
```

"Return owners of accounts with overdraft events exceeding a sum of €2000 after the year 2006"

Organizational Data (Centralized)

Basic SPJU queries

Internal Representation

cname	prov
Smith	C0123·01325·P85335·A821 ·E23874·DE23874·CU2+ C0123·01325·P85335·A43 ·E9873·DE9873·CU2+ …
Jones	C8432·012387·P1248 ·E2384·DE2384·CU …

"Return owners of accounts with overdraft events exceeding a sum of €2000 after the year 2006"

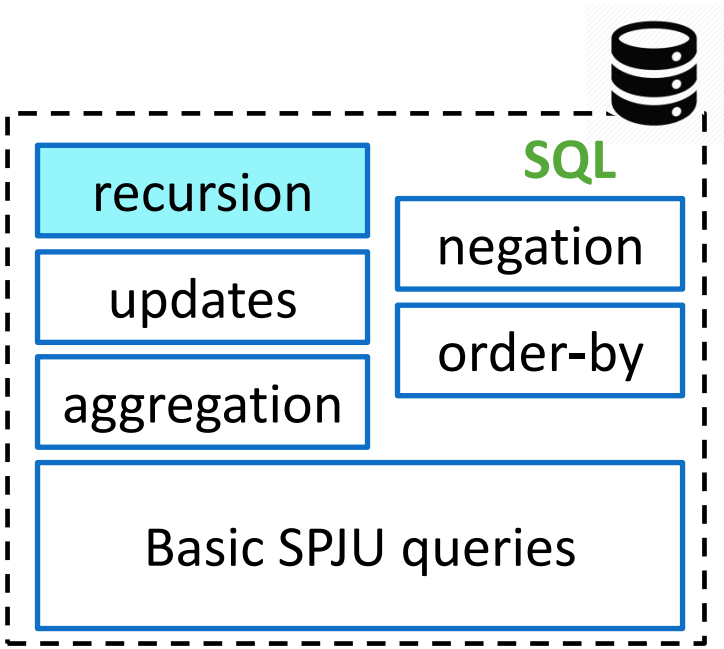
PTIME but practically inefficient

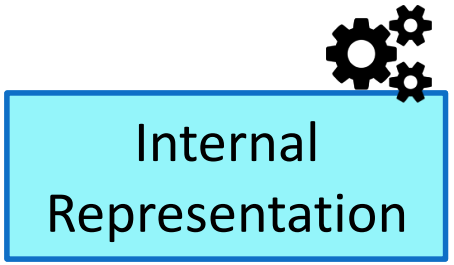
Organizational Data (Centralized)

Basic SPJU queries

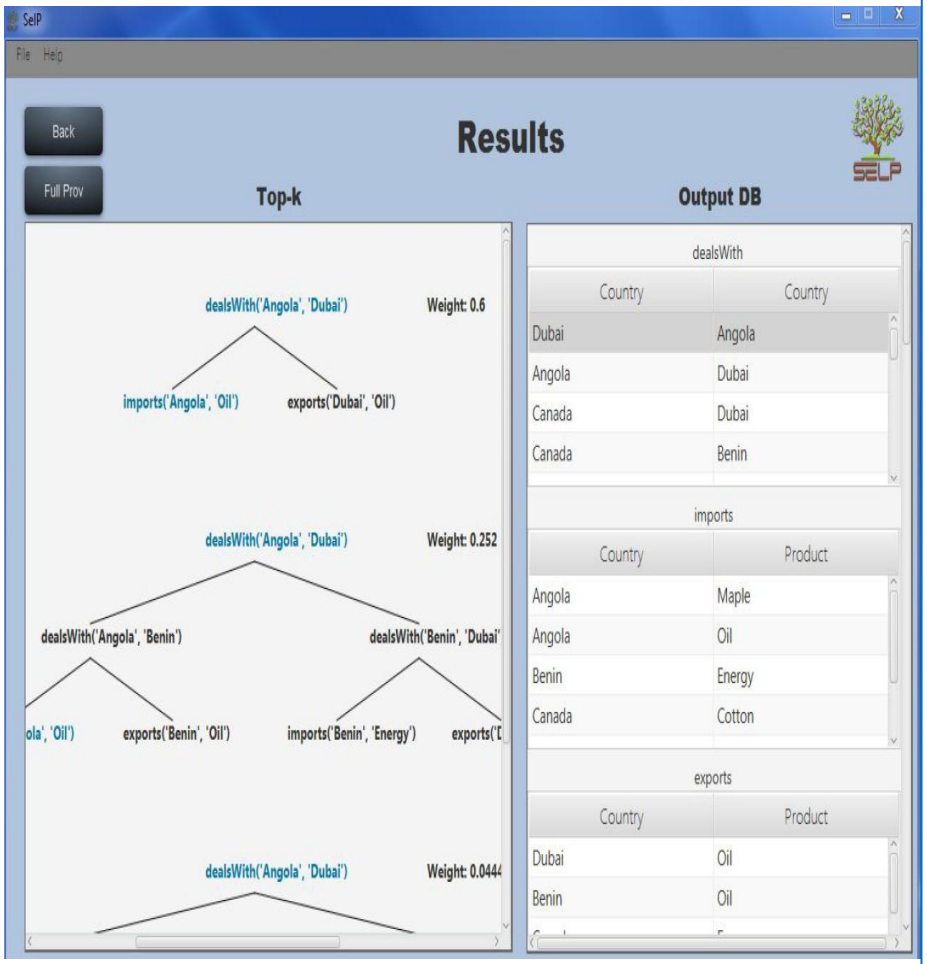
Internal Representation

Super-polynomial lower bound for datalog [Deutch et. al, ICDT ’14]





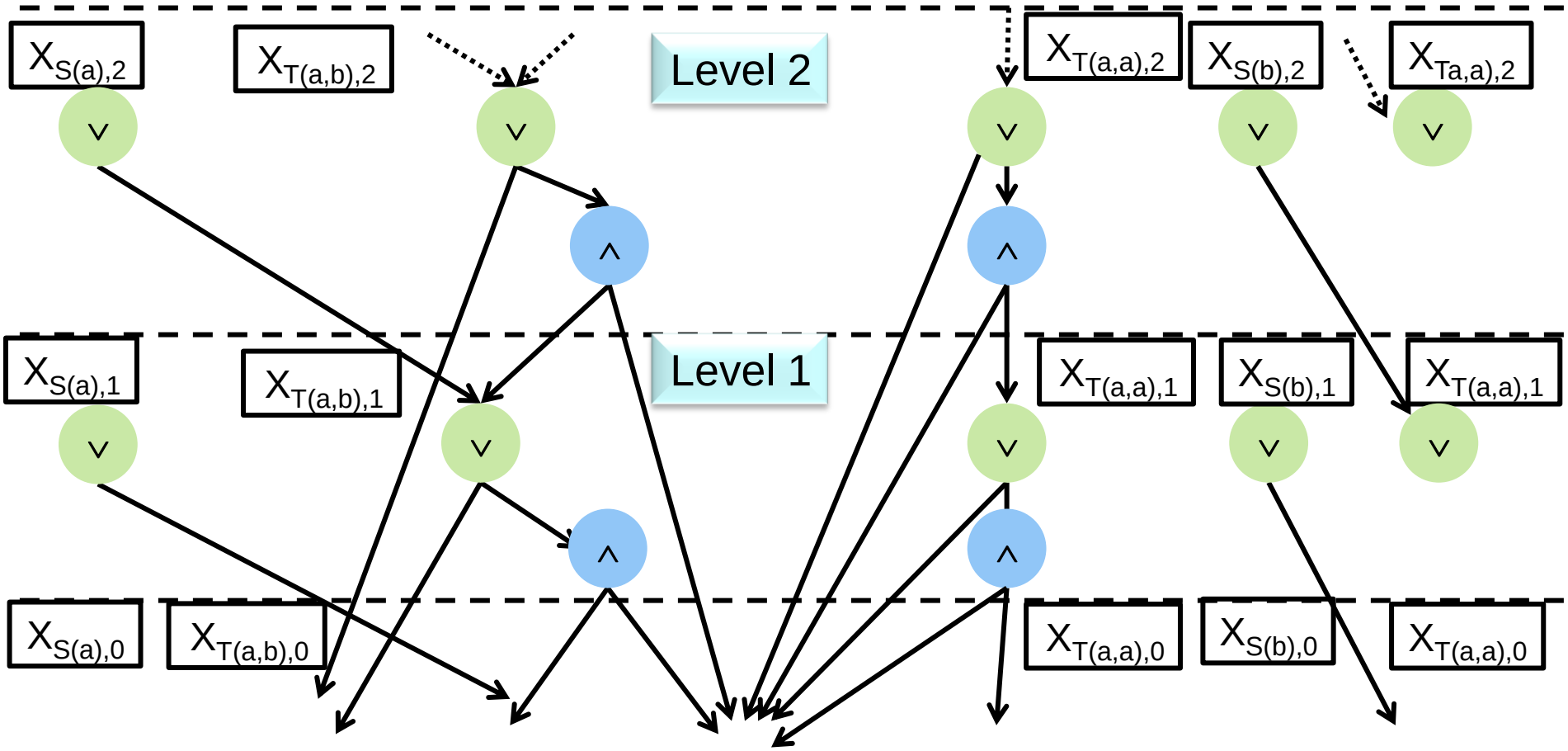
Scalable Provenance Solutions
Approach I: Selective Provenance Tracking



[Deutch, Gilad, Moskovitch, VLDB ’15, VLDB Journal ‘18]

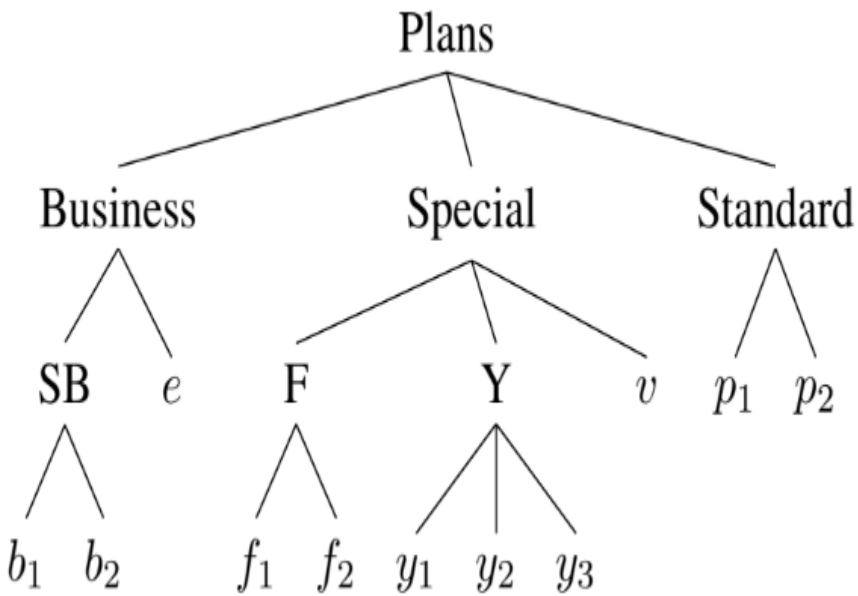
[Bouhris, Deutch, Moskovitch, ICDE ‘16]

Scalable Provenance Solutions
Approach II: Summarization



[Deutch et. al, **Provenance for Datalog Circuits**, ICDT '14]

Scalable Provenance Solutions
Approach III: Abstraction



[Deutch,Moskovitch, Rinetzky,
Hypothetical Reasoning Via Provenance Abstraction, SIGMOD '19]

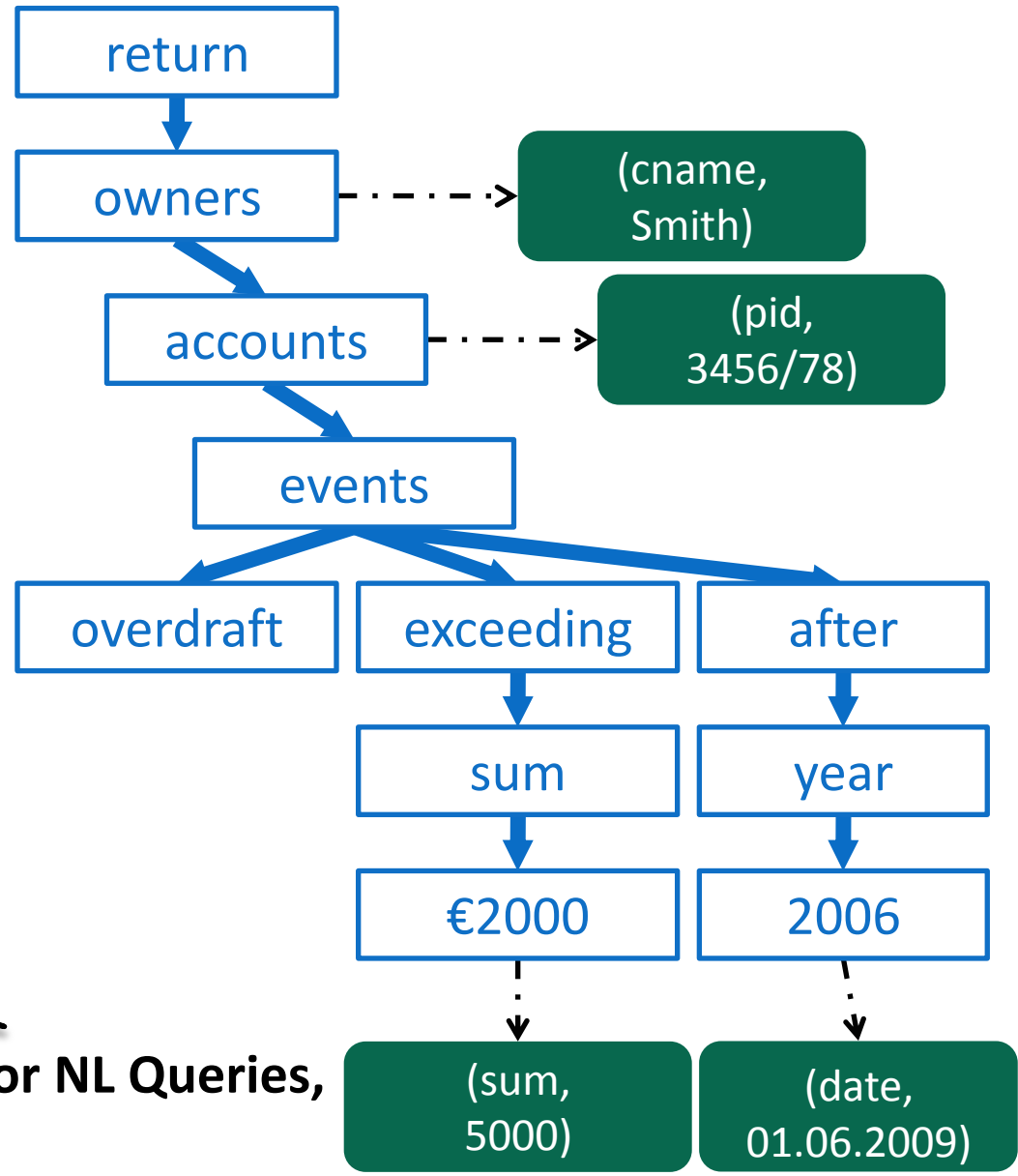
Scalable Provenance Solutions
Approach IV: Interaction Based

"Return owners of accounts with overdraft events exceeding a sum of €2000 after the year 2006"

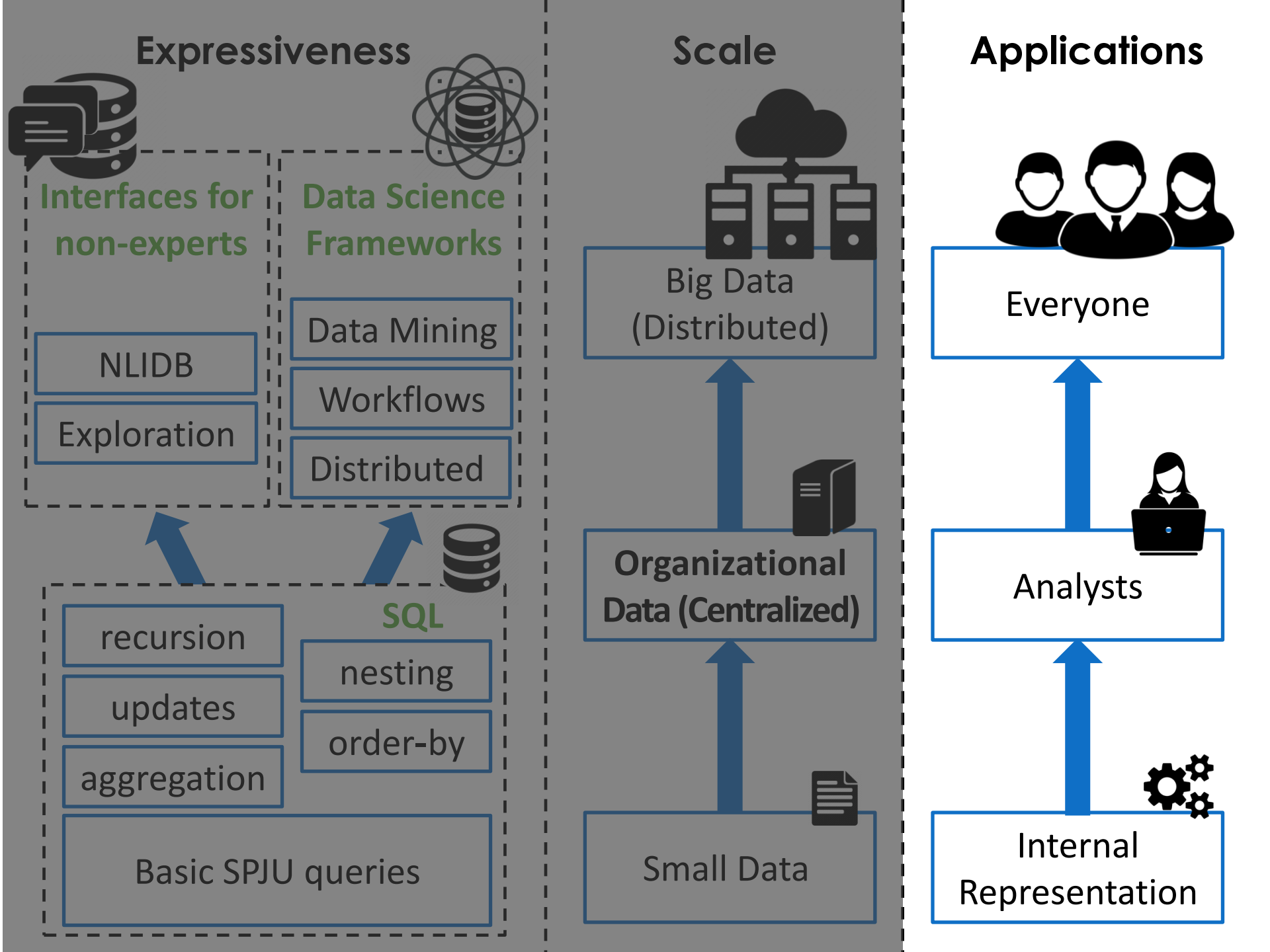
...

"Why is 'Smith' an answer?"

"Smith is the owner of 3 accounts with 13 overdraft events of a total sum of €30000 in 01.02.2009-01.05.2010"



[Deutch, Frost, Gilad, **Provenance for NL Queries,** VLDB '17 best paper]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Provenance Applications

"Why is 'Smith' an answer?"

"On what sources is the 'Smith' answer based on?"

"Smith is the owner of 3 accounts with 13 overdraft events of a total sum of €30000 in 01.02.2009-01.05.2010"

"Citibank combined with American Express and independently BNP Paribas combined with Visa "

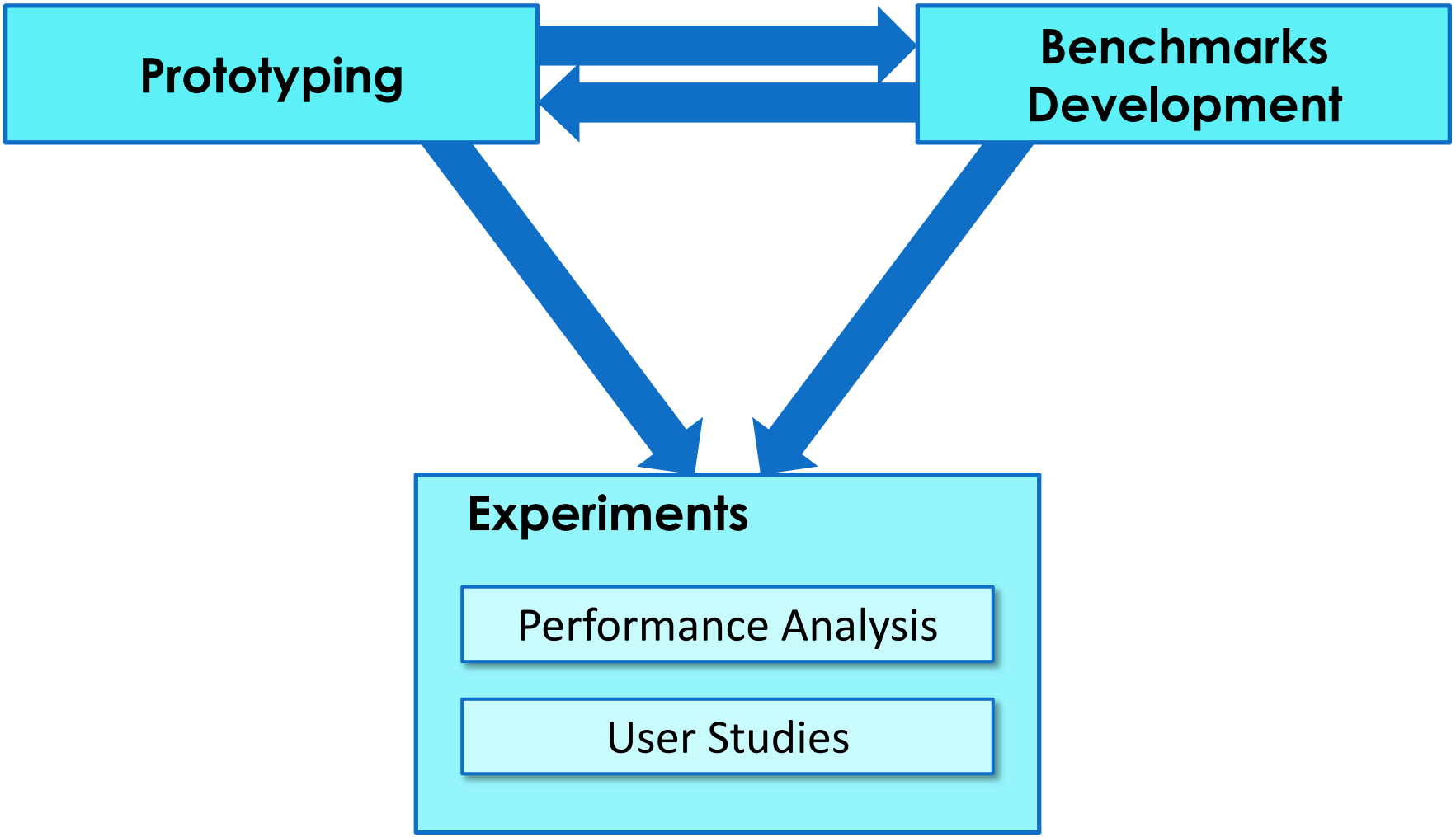
"How could 'Smith' Become a non-answer?"

"What if a particular overdraft event of 'Smith' is excused?"

"Remove overdraft event of date 01.04.2009 of sum €10000 "

"'Smith' would still be an answer"

Implementation and Evaluation



Vision: a world where computation results are **accounted for and explained**

Essence of computation
• why • what if • trust • …

Provenance for Real-life Data-Intensive Systems

Models | **Scale** | **Applications**

Data Provenance: theory and algorithms