Integrating Theory and Practice for Scientific Data Sharing

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Funded by NSF IIS-0477972, 0513778, 0629846
http://www.cis.upenn.edu/~zives/orchestra/

InfInt Workshop

2 October 2007

We Haven't Built a Channel from Theory ➔ Practice in Academia

Proposition 1

Conjecture 1

Theory gets mapped to practice if(f):

1. It provides a **solution** to problems difficult to solve using alternative strategies
2. A **system** implements the theory in a non-commercial setting first
3. The system is applied and **evaluated** in real(istic) settings

Let's Consider Sharing among Large Numbers of Scientific DBs

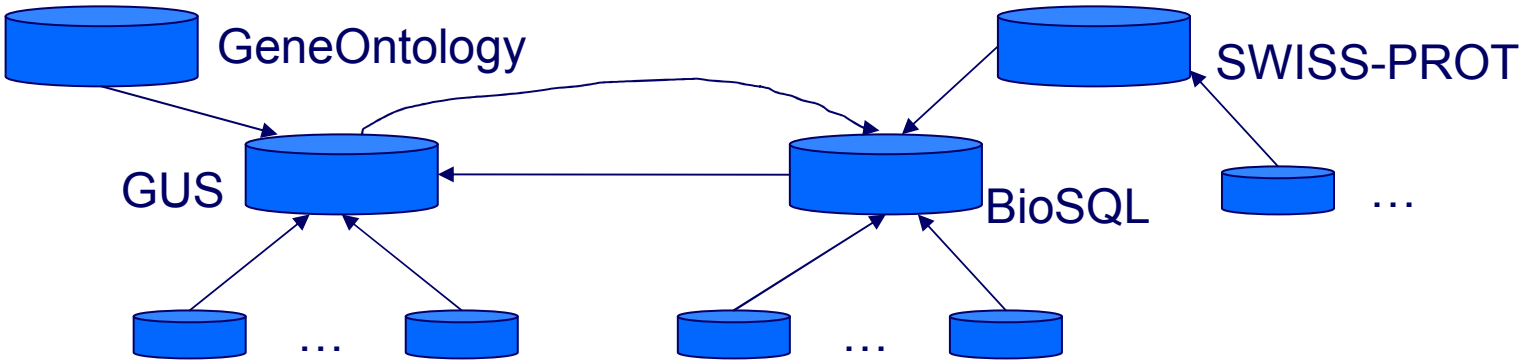
Scientific data sharing is a great domain for data integration research:

- Data and schemas publicly available – **much to share**
- Great **diversity**, overlap
- Many efforts to bring the data together
- Huge potential (scientific) payoff, eager users
  - Often best-effort is sufficient – much exploratory work

➢It provides an eager user community, real problems that we can get access to. It also gives lessons that transfer to other areas.

- But we currently do a very poor job of supporting it!

Scientific Data Sharing Today (Life Sciences, e.g., Genomics)



- Many labs produce raw data and analyze / curate it
- Large community / organization warehouses (e.g., SWISS-PROT, GenBank, FlyBase, …) **standardize some data**
- But there's a lot of overlapping and complementary info among warehouses – sites **import others' data**
- Almost all based on Perl, Python scripts as "mappings"!

➢ Why aren't they using declarative mappings and tools?

Many Unfulfilled Scientific Data Sharing Desiderata

Autonomy and **local control** of data are critical

- Control which data is imported / integrated
- Modify any data, even data from elsewhere!

Many different **points of view** !!!

- Disagreements about data, mappings, schemas...
- Which sources are trusted / distrusted

Data **provenance** tracking

Support frequent **updates**, to data, schemas, mappings

➢ Data integration & exchange don't provide a unified solution

Conventional Data Integration Architectures Don't Work Here

The traditional virtual integration model is too controlled:

- Global standardization, strictly hierarchical

  Doesn't scale, especially to diverse user bases or evolving domains

- Assumes globally consistent view of data is possible and desirable

Data exchange [Fagin+03] is one-time only

Peer data management (e.g., Hyperion, Piazza, [Bernstein+02], [Calvanese+04], peer data exchange, …) helps somewhat:

- Supports many schemas for many different needs
- Can incrementally add schemas, mappings
- But what about changes to the data? Disagreements among sites? Curation of imported data? Control over what data is imported?

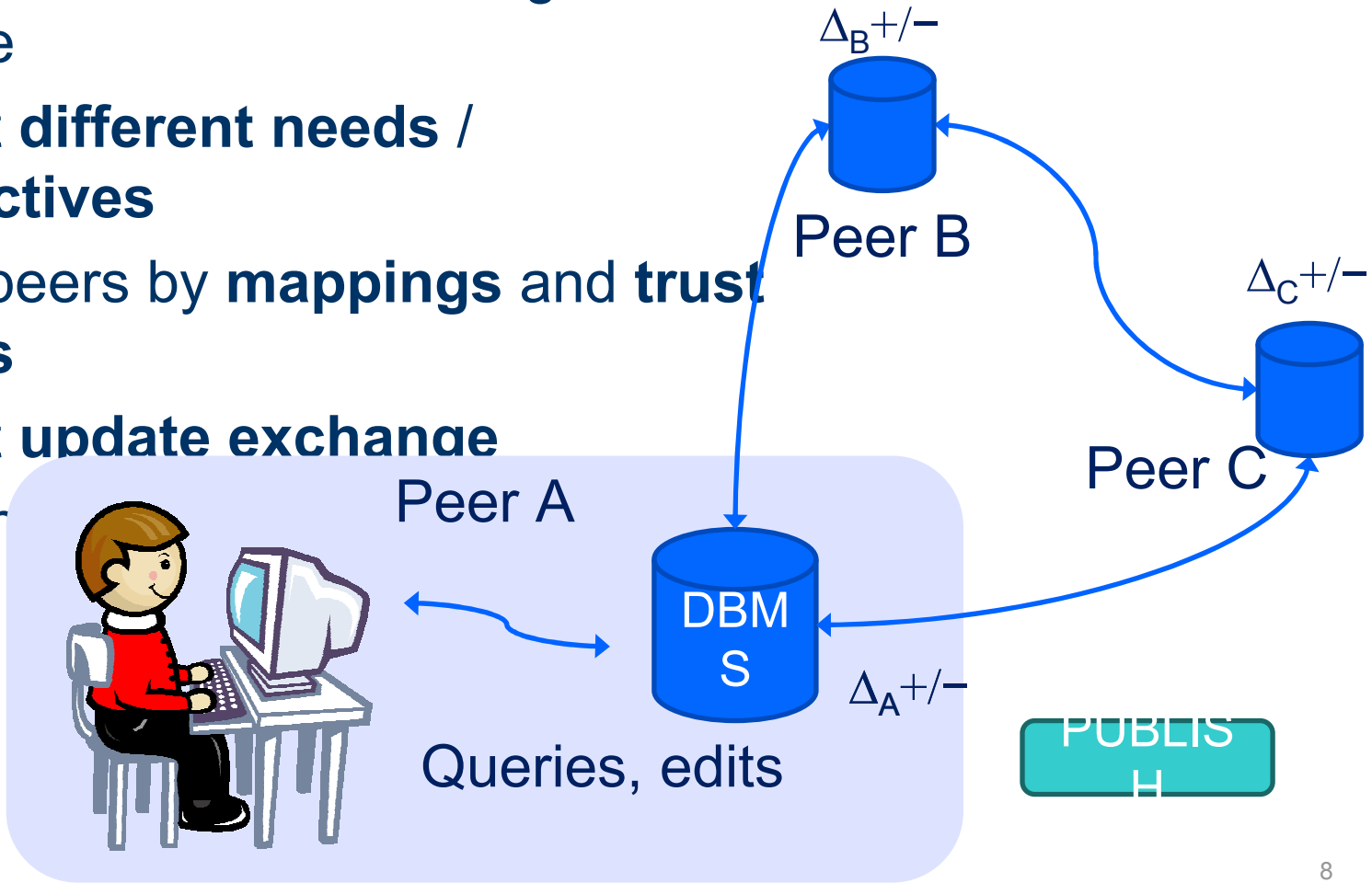
Much as semi-structured data
made it easier to handle occasionally irregular
information, we need a more
flexible, **dynamic, incremental** scheme for
integrating / sharing structured data!

… we have been defining its theory and
implementation, in a system called
ORCHESTRA…

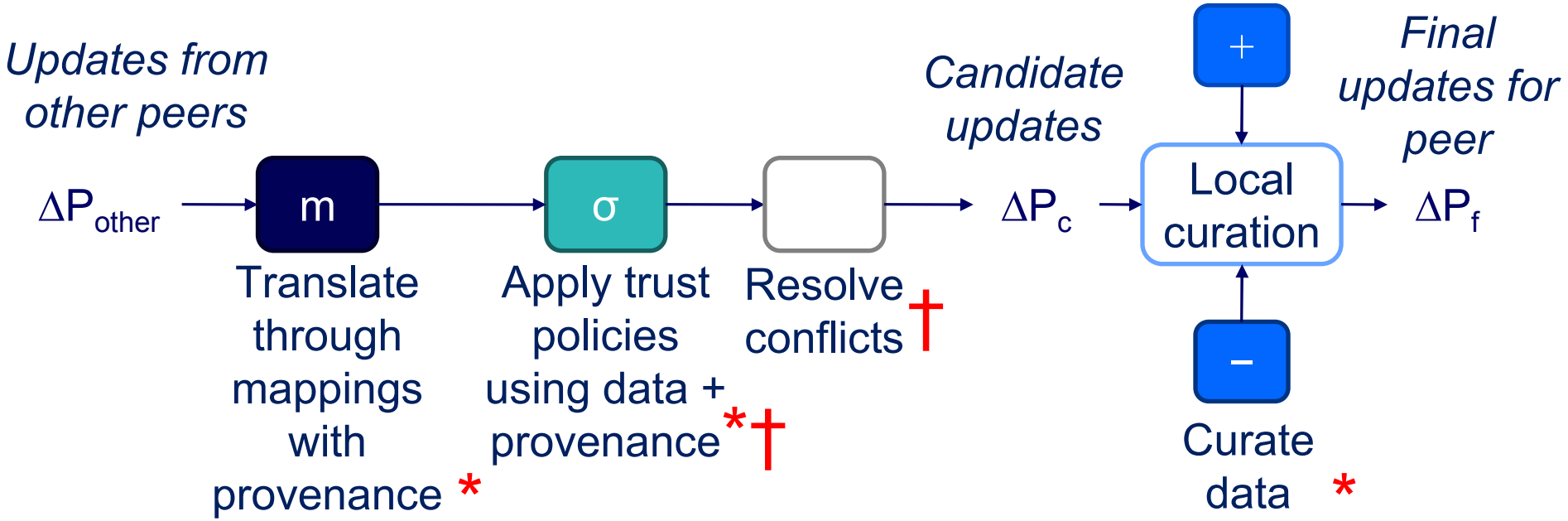
The Collaborative Data Sharing System (CDSS): Loosely Coupled, Highly Dynamic

[Ives+05]

- Give peers **full control** using local instance
- Support **different needs / perspectives**
- Relate peers by **mappings** and **trust policies**
- Support **update exchange**
- Maintain



The CDSS "Pipeline" (One Peer's Perspective)



* [Green+07]

† [TaylorIves06]

Technical Overview – Roadmap

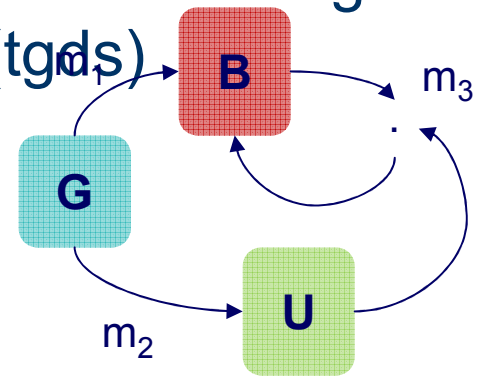
Update exchange in a CDSS:

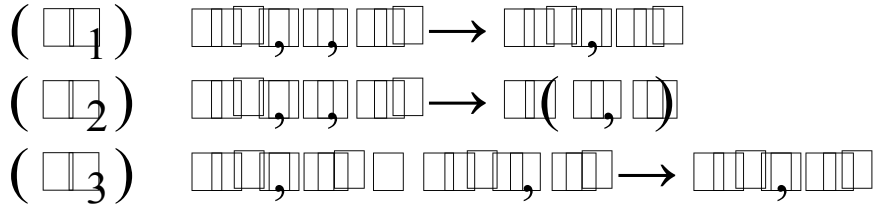
- **Schema mappings**
- Tracking of **data provenance**
- **Incremental propagation** of updates
- Provenance-based **trust policies**
- **Local curation** via insertions / deletions

Brief overview of prototype (ORCHESTRA)

Mappings and updates

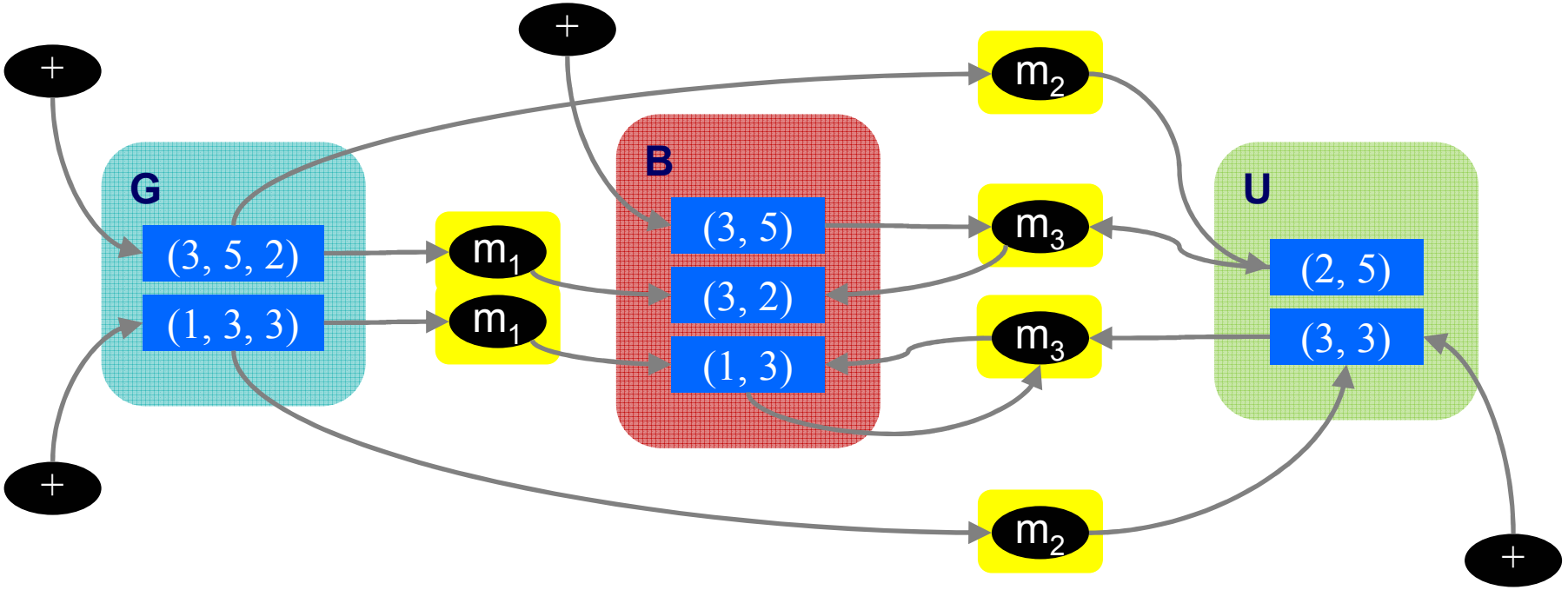
- CDSS setting: set of peers; set of declarative mappings (tgds)

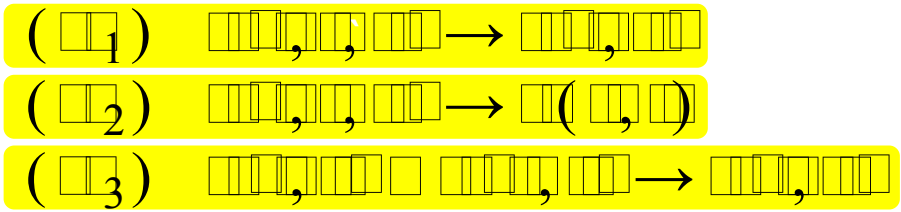




- Given: setting, base data, updates
- Goal: local instance at each peer cf. **data exchange** paradigm [Fagin+03]
  - **Universal solution** yields the "**certain answers**" to queries
  - Can be computed using the **chase**
- Our contribution: how to do it **incrementally**, with **provenance**...

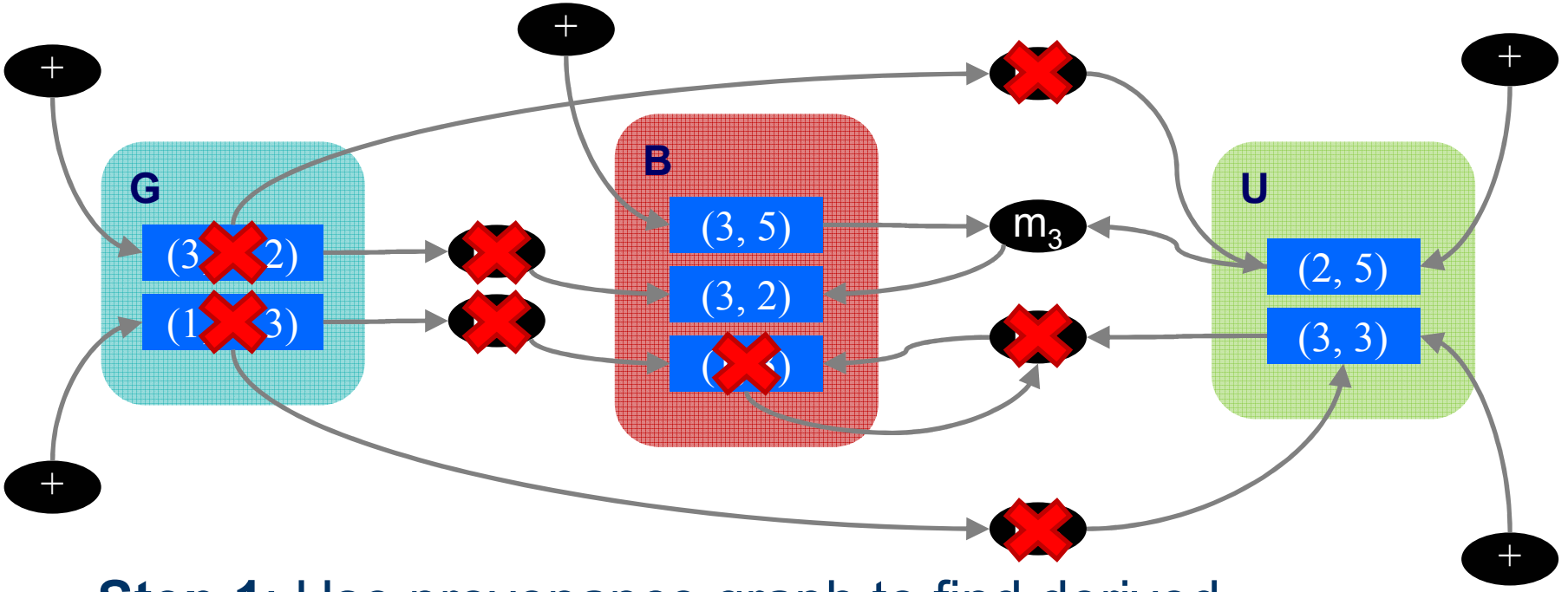
Incremental insertion





This graph represents the provenance information that ORCHESTRA maintains
(see also [Green+07])

Incremental deletion that supports recursion



- **Step 1**: Use provenance graph to find derived tuples which can also be deleted
- **Step 2**: Test other affected tuples for derivability from base insertions, and delete any not derivable
- **Step 3**: Repeat

Trust policies (not every update should be propagated)

Updates can be **filtered automatically** based on **provenance** and **content**

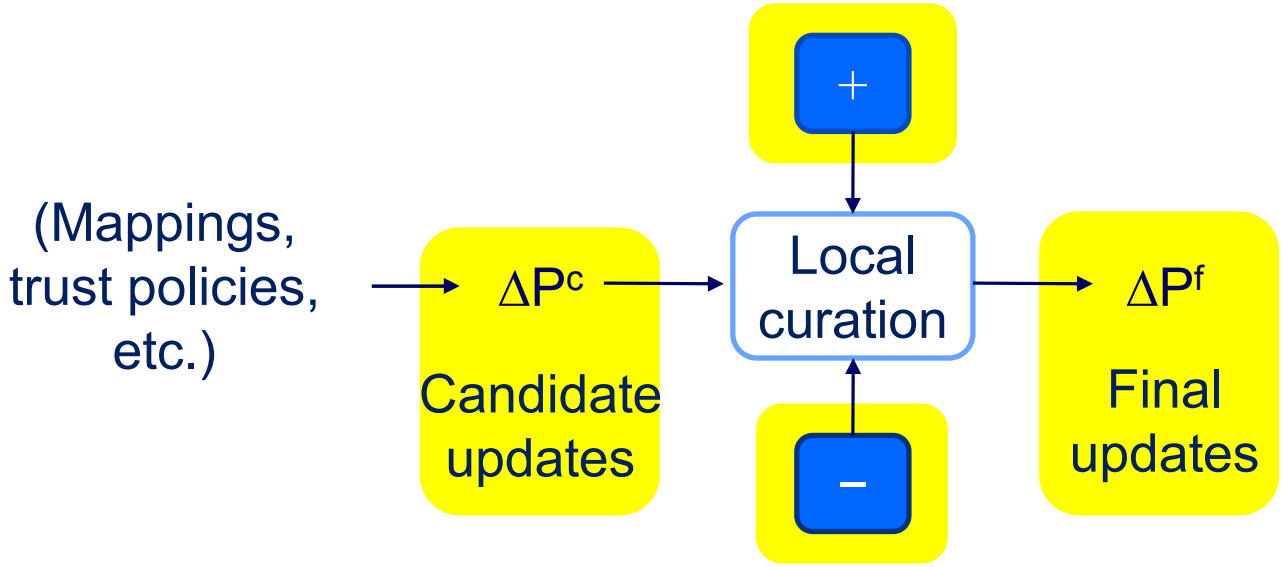
"Peer A:

- distrusts any tuple U(i,n) that came from Peer B and has value n = 3
- trusts any tuple that came from Peer C
- distrusts any tuple U(i,n) that came from mapping m4 if n = 2"

Local curation: user can **also manually** accept/reject **updates,** or introduce new ones...

Local curations

Extra tables for local **insertions** and **deletions**:



Contribution: conforms to data exchange paradigm by using **internal mappings** with local **insertions/deletions**:

$(\square_2)$ $\square_{\square}(\square, \square, \square) \rightarrow \square(\square, \square)$ $\square$

$(\square_2')$ $\square_{\square}(\square, \square, \square) \rightarrow \square(\square, \square)$

$(\square_{\square^+})$ $\square^+(\square, \square) \rightarrow \square(\square, \square)$

$(\square_{\square^-})$ $\square_{\square}(\square, \square) \wedge \neg \square^-(\square, \square) \rightarrow \square(\square, \square)$

Prototype implementation

- **Middleware** layer on top of clients' relational DBMSs
- Auxiliary tables store provenance info
- Mappings converted to **datalog rules** (as in Clio)
  - Uses either a commercial DBMS engine
    - Datalog fixpoints in Java and SQL (only linear recursion in vendor SQL)
    - Labeled nulls supported via encoding scheme; Skolem UDFs
  - Or our own engine (with custom fixpoint, labeled null types)
- 30,000 lines of Java code (growing rapidly)

  Performance validated experimentally in [Green+07]

  Demoed at SIGMOD, DILS this year

➢ Targeting open-source release in 2008

Related work

- **Peer data management systems** Piazza [Halevy+03, 04], Hyperion [Kementsietsidis+04], [Bernstein+02], [Calvanese+04], ...
- **Data exchange** [Haas+99, Miller+00, Popa+02, Fagin+03], **peer data exchange** [Fuxman+05]
- **Provenance** / **lineage** [CuiWidom01], [Buneman+01], Trio [Widom+05], Spider [ChiticariuTan06], [Green+07], ...
- **Incremental maintenance** [Blakeley+86], many others incl. commercial systems; for recursive case, [GuptaMumick95] …
- DRed ("delete and re-derive") computes **superset** of deletions, then corrects if needed
- We use provenance to compute **exact** set of deletions

The ORCHESTRA System: A Platform for Data Integration / Exchange

ORCHESTRA implements the CDSS architecture:

- Supports update exchange over tgd / GLAV mappings
  - Will also support certain-answers query answering over virtual schemas
- Tracks provenance (using *provenance semirings* [Green+07])
- Supports site-specific trust conditions, conflict resolution, local curation

Academia needs at least one "PostgreSQL of data integration"

- Postgres was very helpful in connecting research → real apps!
- We are making our prototype available by request
- Open-source release planned for 2008

With bio collaborators: build applications for phylogeny (pPOD), genomics/proteomics (SHARQ)

Discussion: Some Questions and Possible Ideas for Future Work

- Collaborative data sharing for science must support at least:
  - Loose sync of autonomous schemas, instances; possible conflicts
  - Mappings (schema, entity, …)
  - Trust / authority, related to provenance
  - Local curation (and cleansing)
- … Are there other aspects? Does business need these capabilities, or is science different? Other apps?
- Data cleaning vs. conflicts vs. trust?
- Trust aggregation: ideas from social networks, PageRank, …
- Probabilistic / ranked data or mappings? Keywords?
- Data exploration?