Integrating Theory and Practice for Scientific Data Sharing

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http://www.cis.upenn.edu/~zives/orchestra/

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

Proposition 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!
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

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

[Ives+05]
The CDSS “Pipeline” (One Peer’s Perspective)

Updates from other peers

ΔP_{other} → m
Translate through mappings with provenance

σ
Apply trust policies using data + provenance

ΔP_c → Local curation
Resolve conflicts

Candidate updates

ΔP_f
Final updates for peer

Candidates from other peers

ΔP_{other} → m
Translate through mappings with provenance

σ
Apply trust policies using data + provenance

ΔP_c → Local curation
Resolve conflicts

Candidate updates

ΔP_f
Final updates for peer

Curate data

* [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:

\[(\Delta P^c_c, \Delta P^f_f) \rightarrow (\Delta P^c, \Delta P^f)\]
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)
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?