Database Technology Evolution III: Knowledge Graphs and Linked Data

MALCOLM CROWE, FRITZ LAUX

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Malcolm Crowe

University of the West of Scotland
Email: malcolm.crowe@uws.ac.uk

- Malcolm Crowe is an Emeritus Professor at the University of the West of Scotland, where he worked from 1972 (when it was Paisley College of Technology) until 2018.
- He gained a D.Phil. in Mathematics at the University of Oxford in 1979.
- He was appointed head of the Department of Computing in 1985. His funded research projects before 2001 were on Programming Languages and Cooperative Work.
- Since 2001 he has worked steadily on PyrrhoDBMS to explore optimistic technologies for relational databases and this work led to involvement in DBTech, and a series of papers and other contributions at IARIA conferences with Fritz Laux, Martti Laiho, and others.
- Prof. Crowe has recently been appointed an IARIA Fellow.

Prof. Dr. Fritz Laux

(Retired), Reutlingen University
Email: fritz.laux@reutlingen-university.de

- Prof. Dr. Fritz Laux was professor (now emeritus) for Database and Information Systems at Reutlingen University from 1986 - 2015. He holds an MSc (Diplom) and PhD (Dr. rer. nat.) in Mathematics.
- His current research interests include
  - Information modeling and data integration
  - Transaction management and optimistic concurrency control
  - Business intelligence and knowledge discovery
- He contributed papers to DBKDA and PATTERNS conferences that received DBKDA 2009 and DBKDA 2010 Best Paper Awards. He is a panellist, keynote speaker, and member of the DBKDA advisory board.
- Prof. Laux is a founding member of DBTech.net (http://www.dbtechnet.org/), an initiative of European universities and IT-companies to set up a transnational collaboration scheme for Database teaching. Together with colleagues from 5 European countries he has conducted projects supported by the European Union on state-of-the-art database teaching.
- He is a member of the ACM and the German Computer Society (Gesellschaft für Informatik).

Linked Data and Databases

- Everyone's data today is stored online
- Using vast databases: Google, Meta etc
  - The "Semantic Web" [1]
- Your PC also has its own/your local data
- Data can be accessed using database queries
- Results can be text, tables, images etc
- And links to more data, other databases
- All of this gives us today's world wide web of information systems and knowledge [2]

Knowledge and Links

- Information links to more information
- “China’s lunar probe has landed”
- Web pages such as news feeds, Wikipedia have clickable links
- For navigating through the knowledge web
- Or you can look up things using search
- Eventually it involves database technology

Database technology

- Supports durable storage of data
- Data can be shared subject to security
- Data is organised for efficient retrieval
- In tables and indexes (since 1970s)
- Or knowledge graphs [3]
  - Nodes are knowledge items such as words or objects
  - Edges link nodes (e.g., is, has,..)
- Or both? [4]

Database Management System

- There are thousands of DBMS today
- All shapes and sizes: company accounts, catalogues, health data, address books, shopping lists
- Few people buy a DBMS directly
  - Usually part of a larger service
- Many information workers simply use the systems
  - Applications access DBMS behind the scenes
- But someone has chosen the DBMS

Choosing a DBMS

- Data organised in tables (relations)
  - Start with creating tables
    - Homogeneous data structures
    - Oracle: declare everything before use
- Data coming from complex structures
  - Start with documents, indexed somehow
    - MongoDB: no schema
- Knowledge graphs and linked data
  - Focus on links between knowledge items
    - Neo4J: easy to get started

Industry standards

- Good practice: what people can expect
- Interoperability: enables links between data systems
- Reliability: keep things simple
- International Standards Organization
  - Internet Society, W3C, etc
- ISO9075: Database Language SQL
- ISO39075: Database Language GQL

Efficiency and structure

- Trade-offs
  - Structure vs content
    - Greater precision assists indexing
    - Many ways of indexing..
  - Precision vs clarity
    - Sharing across countries, cultures
    - Metadata to assist sharing
  - Accessibility vs security
  - Transactions vs inconsistency
- How up-to-date? Archiving old stuff?

Research areas

- Keen to find the best way of ..
  - Designing usable systems
  - Keeping ideas as clear as possible
  - Covering many use cases
- New application areas, use cases
  - Can we find more useful models
- This talk is part of a series looking at
  - Underlying principles
  - Practical implementation
  - Evolution of new standard: GQL

- Is SQL + GQL possible?

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Relational vs Graph databases

- Seem different in concept and scale
- Linked data mean joins of relations
  - Graph DBMS are better at following links
- Chains of links important in business
  - Transfers, logistics, components, supply chain, timelines, epidemics
- Last year we reported on extending SQL to handle graphs, we continue this today
- But GQL is new and still under discussion
  - No implementations yet of the GQL standard
  - Changes to GQL are already under discussion

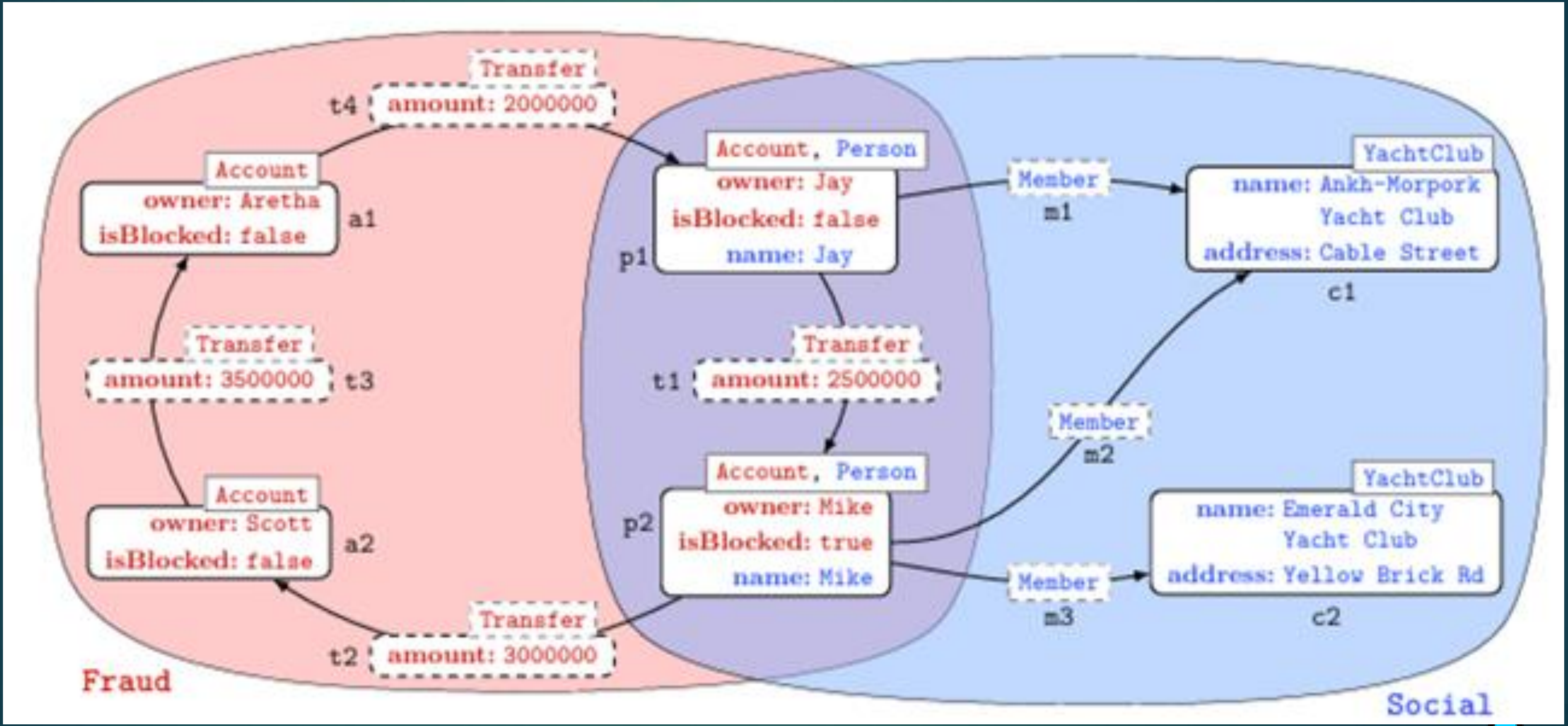
SQL+GQL can work

- ISO39075 leaves this possibility open
  - Syntax is designed to be compatible
  - Though reserved words etc are different
- Last year we showed graph creation and graph queries in PyrrhoDBMS [5]
  - Files are append-only transaction logs
  - Objects defining positions do not change
    - Position can be used for indexing, replaces keys
  - Optimistic concurrency control validation
  - Mixing of schema and data changes
  - Full range of SQL features: triggers, types etc

- The Yacht Club example

The Yacht Club example [6]

- Motivated by combination of 2 graphs



Building this example

- Can be done in just a few steps
  - 3 statements for schema and graph type
  - 1 statement to build all the nodes and edges
- But it is not completely GQL compliant
- GQL has “closed” and “open” graphs ☹
  - Closed = predefined, unchangeable
  - Open = typeless, like Mongo docs
- GQL nodes can have a set of labels
  - But cannot be in more than one graph
  - (We could put everything in one graph..)

- The graph types

Graph types in GQL

```
create schema /yc;

create graph type /yc/Social {node Person {name string},
    node YachtClub {name string,address string},
    directed edge "Member" connecting (Person->YachtClub)};
create graph /yc/Fraud ANY;
```

- This shows a closed graph for Social and an open graph for Fraud
- This allows us to add undeclared types Account, Transfer

- The insert statement

Inserting the yacht club nodes

```
insert (a2 :Account{owner:'Scott',isBlocked:false})
-[:Transfer{amount:350000}]->
(:Account{owner:'Aretha',isBlocked:false})
-[:Transfer{amount:2000000}]->
(p1 :Person&Account{owner:'Jay',name:'Jay',isBlocked:false})
-[:"Member"]->(:YachtClub {name:'Ankh-Morpork Yacht
Club',address: 'Cable Street'})
<-[:"Member"]-(p2 :Person&Account {owner:'Mike',name:'Mike',
isBlocked:true})
-[:"Member"]->(:YachtClub{name:'Emerald City Yacht
Club',address:'Yellow Brick Road'}),
(p1)-[:Transfer{amount:2500000}]->
(p2)-[:Transfer{amount:3000000}]->(a2);
```

A tiny knowledge graph [7]

t1 = (:John :masterFrom :DauphineUni),

t2 = (:John :phdFrom :DauphineUni),

t3 = (:masterFrom $<_{sp}$:degreeFrom),

t4 = (:phdFrom $<_{sp}$:degreeFrom)

- This paper is about “implies” relationships between edge types and saturation
- If GQL had INSERT SCHEMA this could be

```
INSERT (:John)-[:masterFrom]->(:DauphineUni);

INSERT (:John)-[:phdFrom]->(:DauphineUni);
INSERT SCHEMA [:masterFrom=>:DegreeFrom];
INSERT SCHEMA [:phdFrom=>:DegreeFrom];
```

GQL and linked data

- Combining graphs from different sources
  - Big use case, as in Social+Fraud above
  - We looked at view-mediated big data [8]
    - Query remote system, don’t import data
  - No concept yet of views in GQL
    - Viewed graph? Virtual links?
- Directory paths in CREATE statements do not extend to network links/HTTP
  - But they look promising
- More work is needed on sharing of data between graphs

Current state and conclusion

- Pyrrho DBMS demonstrates that GQL features can be added to an SQL implementation
- Lightweight and efficient for links
- Can it become GQL-compliant?
- GQL is designed for several business cases
- How will it be extended for knowledge graphs and linked data?

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