RELATIONAL ROOTS

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Papers Covered

- A Relational Model of Data for Large Shared Data Banks. E. F. Codd (1970)
  - A seminal paper on relational databases which caused a paradigm shift in the data models community.
- A History and Evaluation of System R. Donald D. Chamberlin et al (1981)
  - A paper about the experimental database system, System R, which implemented and demonstrated the feasibility and usability of relational models.

Background information

- Before the relational model, two major data models were competing:
  - Hierarchical

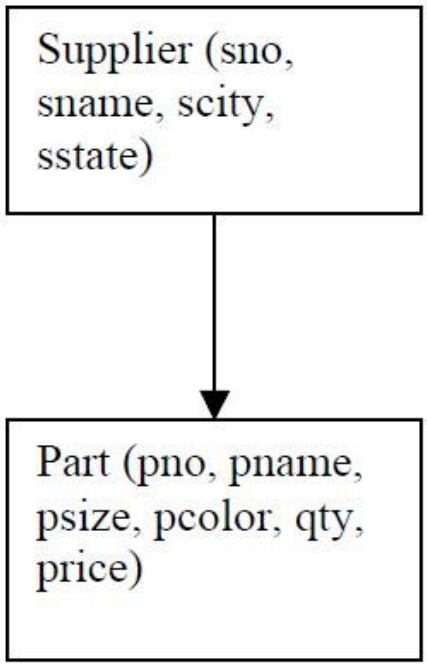


Figure taken from “What comes around goes around” (Stonebraker M, Hellerstein J.)

Background information

- Network/Graph

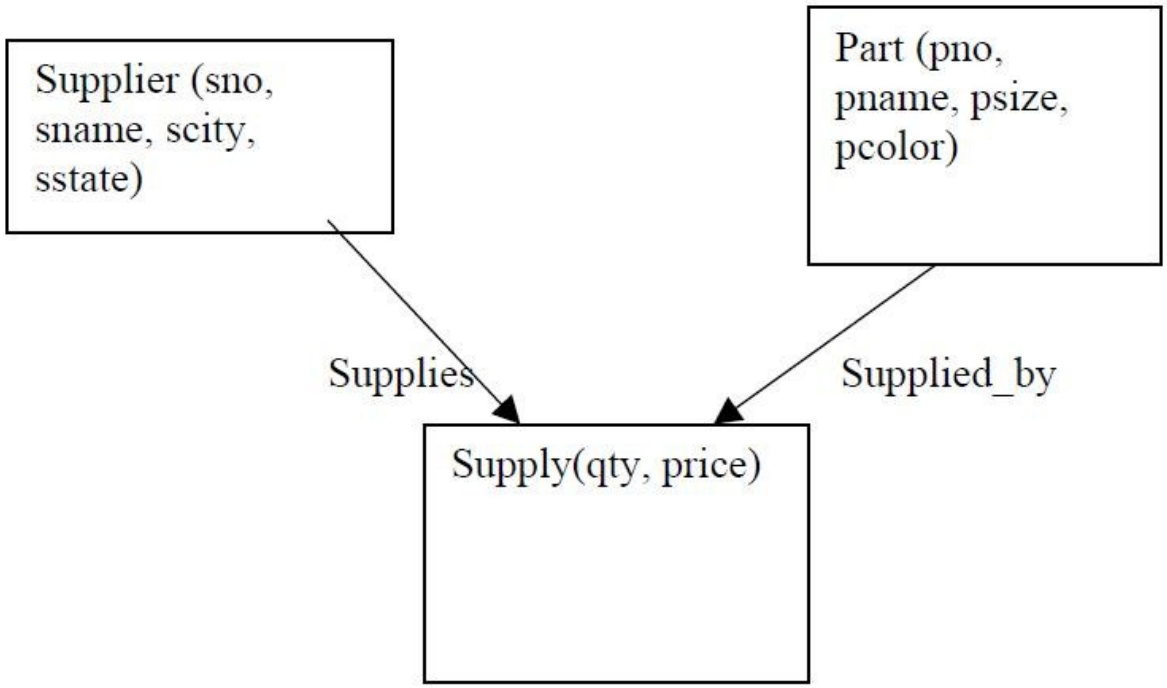


Figure taken from “What comes around goes around” (Stonebraker M, Hellerstein J.)

Background information

- Edgar Frank "Ted" Codd introduced the “Relational Model” in 1970 which sparked “The Great Debate” and eventually caused a paradigm shift.
- The relational model appeared to be superior in several aspects to the other competing models.

Motivations behind the model

- Provide a means of describing the data with its natural structure only. In other words, **data independence was a major goal**.
- Provide a foundation for high level data language that separates the application programs from the machine representation and organization of data.
- Permit a clearer evaluation of the scope and logical limitations of the present data systems.

Data Independency

- Data independency refers to making data applications immune from modifications in the definition and organization of the data it uses.
- Three principal kinds of physical data dependencies that needed to be removed:
  - Ordering Dependence
  - Indexing Dependence
  - Access Path Dependence

Physical Data Dependency: Ordering Dependence

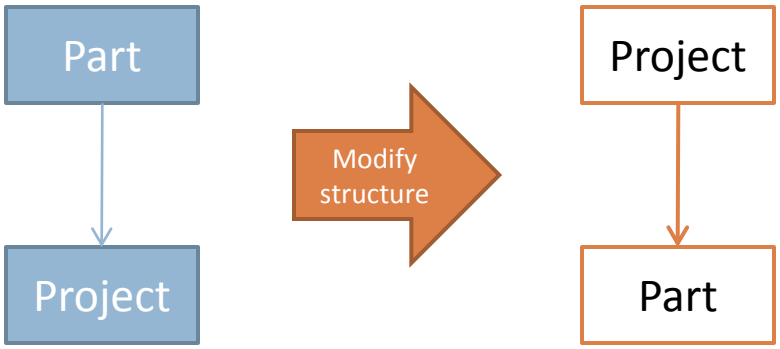
- Existing systems require or permit the elements to be ordered in a way that is closely related to how the hardware orders them.
  - Order of presentation vs. stored order
  - No clear distinction between these two types of orderings
- While it can be advantageous to have a stored ordering of a file, the system will likely fail to operate correctly if the ordering needs to be replaced.

Physical Data Dependency: Indexing Dependence

- Indices are performance-oriented components of the data which improve the speed of particular queries.
- On a system which is consistently changing, the need to create and destroy indices at any particular time will be necessary:
- “Can application programs and terminal activities remain invariant as indices come and go?”

Physical Data Dependency: Access Path Dependence

- An access path describes how to actually access the data (bits) on disk.
- Existing data systems provide users with complicated tree-structured or network models of the data
  - If the structure of these models were changed, the application programs would fail.



The Relational Model

- Everything can be represented as a relation
  - Relation = Set = Table
- Relations have domains (attributes)
  - Domains may have the same name

Discussion: Leaky Abstraction

- A major goal of the relational model was to ensure that users do not need to know about indices to write queries. Though users do not *need* to know about indices, changing them can have serious performance impact, leaving users puzzled. Has independence of indices really been achieved?

Benefits of the Relational Model

- In other models, the initial design of the system was very important:
  - For example, hierarchical model, the hierarchy had to be decided on ahead of time. Who is the parent of who? Who is the child of?
- With the relational model, because everything is represented as a relation it is no longer critical that all the relationships are decided at the initial design.

Benefits of the Relational Model

- With other models, if indices existed, then querying required knowing they existed and the removal of them make problems for applications using the data.
- With the relational model, indices could be created and dropped readily to enhance the system performance without having any real drastic effects

Benefits of the Relational Model

- With other models, a structural change in the representation of the data meant that applications that used this data needed to be modified.
- With the relational model, a structural change doesn't have such a drastic effect. Modifications of SQL queries are simpler.

Discussion: Second chance to Tree structured data model?

- Once the relational model made it to the market, people flocked to it and previous models were almost forgotten about.
- Was it possible that the success of relational databases killed off any interest in making tree-structured data easier to work with?

Normal Form

- Simple domains (columns) have elements which are atomic values. A simple two-dimensional array can be used to stored this data.
- If the domain is non-simple, then a more complicated data structure is necessary.
- To eliminate these non-simple domains, Codd presents a technique called normalization.
  - This is not to be confused with the modern notion of normalization which is used to maintain the database integrity.

Operators

- Introduced to allow the ability to derive relations from other relations.
- Codd suggested four different operators:
  - Permutation (not used today)
  - Projection (used today)
  - Join (used today)
  - Composition and Restriction (not used today)

Summary of Codd's paper

- An introduction to the concept of relational databases which caused a paradigm shift.
- We use many of Codd's ideas today, but not everything "made it":
  - "…Codd was originally a mathematician…his DML proposals were rigorous and formal, but not necessarily easy for mere mortals to understand" (What Comes Around Goes around)
  - Duplicate domain names
  - Original concept of normalization
  - Some operators

A final note on Codd's Paper

- Paper was published in Communications of the ACM
  - A leading publisher for Computer Science and IT fields.
  - Accepted very technical papers back in Codd's period, but not so much anymore.

Discussion: The Paper Structure

- Codd's paper is mathematically rigorous but doesn't have implementation or evaluation; and doesn't meet the requirement of conferences today. What does it say about the metrics today? Are we impeding the chances of paradigm change?

System R

- An experimental project to implement a relational database management system.
- One of the first relational database systems to be implemented.

Three phases of the project

- Phase Zero: An Initial Prototype
  - Designed to be a quick implementation of a subset of the functions. Intended to be thrown away.
- Phase One: Construction of a Multiuser Prototype
  - Re-design of the phase zero prototype with concurrent access and some new features.
- Phase Two: Evaluation
  - Review of the work done and some enhancements

Phase Zero: An Initial Prototype

- No concurrent access was implemented yet. Only single-user access was concerned.
- Supported the “subquery” SQL command, but not the “join” command.
  - A query was capable of searching through several tables to find the desired results, however the final results had to be from only one table.

Phase Zero: XRM

- XRM was used as the relational access method

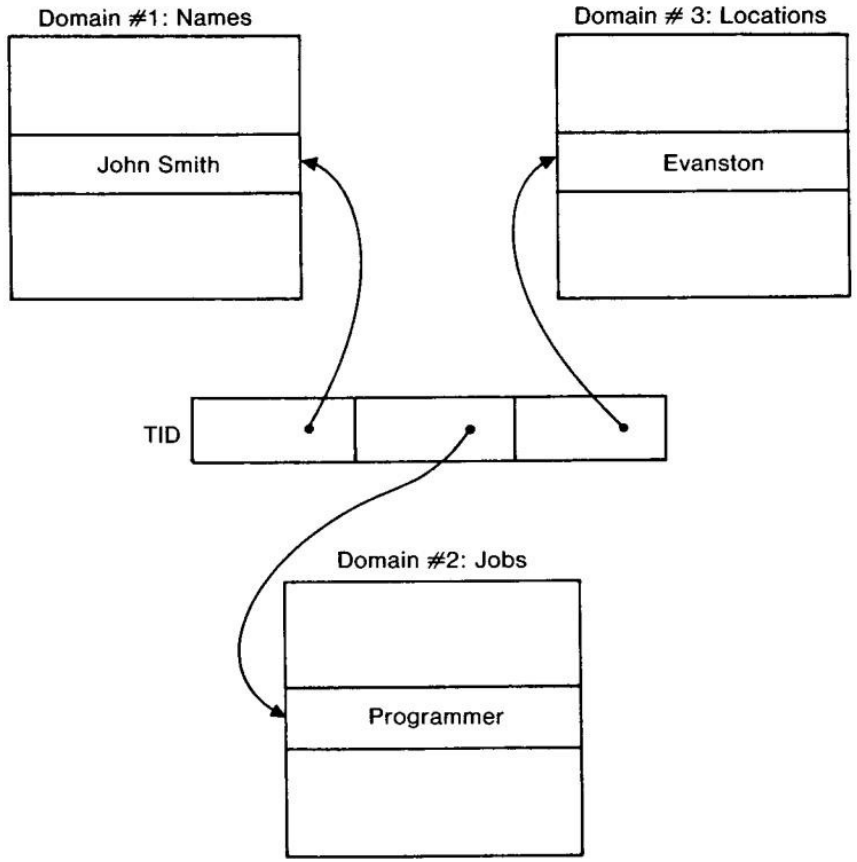


Fig. 2. XRM Storage Structure.

- Relations were stored as tuples with a unique TID associated with each one.
- Tuple didn't store any data itself, but contained pointers to "domains" that actually stored the data.
- Inversions could be used to find TIDs of tuples that contained a given domain value.

Phase Zero: Optimization

- Designing an optimizer to efficient run SQL queries on top of XRM was the most challenging part.
- Optimizer tried to minimize the number of tuples retrieved
  - Extensive usage of “inversions” was used
  - Didn’t take into account the “hidden costs” being the costs of creating and manipulating the TID lists, fetching those tuples, and then using the pointers to finally fetch the data.
- “A better measure of cost would have been measure of I/Os”
  - Storing the data values separate from the tuples led to many I/O requests to retrieve the data.

Discussion: Why Prototype???

- They first implemented a Phase 0 prototype, which is currently the norm (i.e. to implement a prototype).
- What benefits were truly obtained by having a prototype phase? Indeed much was learned about the limitations of XRM, but this was already identified as it was defined as single user,
- So was it a "waste" of time to go through work of creating this phase if it was always meant to be abandoned?

Phase One: Construction of a Multiuser Prototype

- Scraped phase zero, but learned from evaluating it.
- The Research Storage System, RSS, replaced the XRM as the relational access method.
- Implemented concurrent access with a locking subsystem
- Implemented a recovery subsystem
- Implemented a security system with view and authorization subsystems.

Phase One: Optimization

- The RSS access method was more efficient
- Didn’t rely on manipulating TID lists, but scanned each table in the query using any available index that exists to find the desired results.
- The choice of the access path is entirely up to the optimizer and was abstracted from the user.

Phase One: Optimization of the “Join” Method.

- Nested Loop Join vs. Sort-Merge Join
- Depending on the circumstance, one is optimal.
- The optimizer will consider all paths and choose the path which has the lowest predicted cost

Discussion: Joins!!! DUH!

- It is interesting that the benefits of joins were finally recognized upon user feedback during phase 0 and then implemented in Phase 1.
- Why did they not implement it from the beginning if this concept was introduced by Codd?

Phase One: Security System

- Quite primitive with simply GRANT, REVOKE, and RESOURCE commands to users of the system to allow them manage the tables of the database.

Phase One: Recovery Subsystem

- Implemented solutions for:
  - Media failure (hard disk died)
    - Image dump and database log of “before” and “after” changes
  - System failure (information in main memory lost)
    - Log and usage of “shadow pages”
  - Transaction failure (query didn’t finish)
    - Log

Phase One: Locking Subsystem

- Originally proposed a predicate locking concept where tuples were locked based on a domain value.
  - Product = Aircraft
- Settled on a hierarchy locking concept with “intention” and “exclusion” locks.

Phase Two: Evaluation

- At this point, the response to System R had been excellent.
  - "…ease of installation, a high-level user language, and an ability to rapidly reconfigure the database."
- SQL was demonstrated as a feasible and highly usable language for querying the data.

Phase Two: SQL

- The high level language to query the data was primarily successful:
  - Replaced Codd's initially proposed Data Manipulation Language concept which was far too convoluted.
- Praised for the uniformity of the syntax regardless of the environment.
- Users suggested improvements:
  - EXISTS
  - LIKES
  - PREPARE AND EXECUTE

Discussion: EASY SQL… ahhh

- System R developed a usable high-level SQL language to allow easy user interaction including ad hoc queries.
- Has the success of relational database models been due to the simplicity of SQL?

Summary of System R

- The success of System R essentially proved that Codd's idea were possible to implement.
- It showed that many of the problems that plagued old systems, could actually be solved by the relational model.
- Similar to Codd, they didn't get everything right at first:
  - XRM access path method
  - Shadow pages for recovery
  - Predicate locking

Discussion: Have you been “relationalized”?

- Relational model has been around for such a long time with such a widespread penetration into almost all data storage market that Database experts, administrators and aspirants alike have "relationalized" their design approach.
  - Can we break out of the shackles of relational model and think some different and better paradigm?
  - “How have our application been molded from a relational model? What could we have done better if a graph or hierarchical model provided data independence?”

Thanks for listening! Any Questions?