Week 13: Data Warehousing

Warehousing

- Growing industry: $8 billion in 1998
- Range from desktop to huge:
  - Walmart: 900-CPU, 2,700 disk, 23TB Teradata system
- Lots of buzzwords, hype
  - slice & dice, rollup, MOLAP, pivot, ...

Outline

- What is a data warehouse?
- Why a warehouse?
- Models & operations
- Implementing a warehouse
- Future directions

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What is a Warehouse?

- Collection of diverse data
  - subject oriented
  - aimed at executive, decision maker
  - often a copy of operational data
  - with value-added data (e.g., summaries, history)
  - integrated
  - time-varying
  - non-volatile

more

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What is a Warehouse?

- Collection of tools
  - gathering data
  - cleansing, integrating, ...
  - querying, reporting, analysis
  - data mining
  - monitoring, administering warehouse

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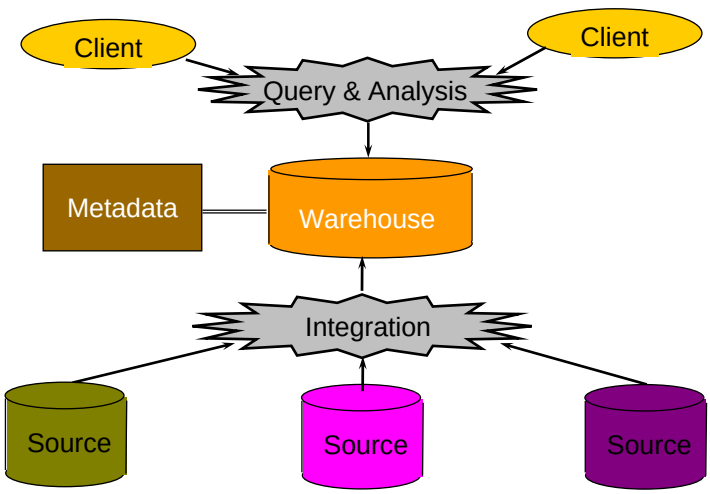
Warehouse Architecture



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Motivating Examples

- Forecasting
- Comparing performance of units
- Monitoring, detecting fraud
- Visualization

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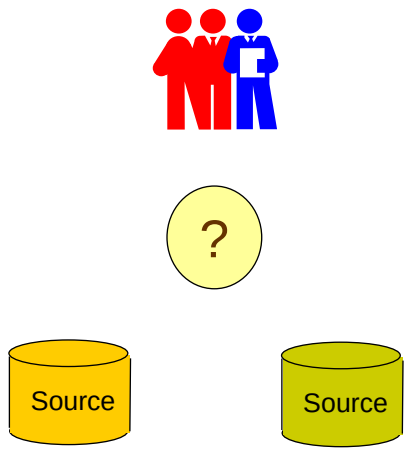
Why a Warehouse?

- Two Approaches:
  - Query-Driven (Lazy)
  - Warehouse (Eager)



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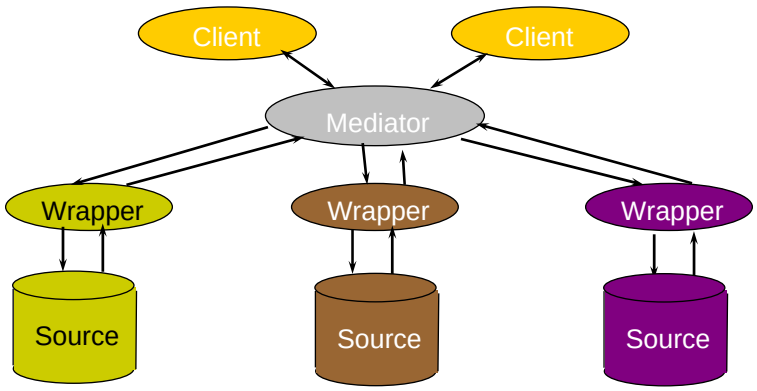
Query-Driven Approach



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Advantages of Warehousing

- High query performance
- Queries not visible outside warehouse
- Local processing at sources unaffected
- Can operate when sources unavailable
- Can query data not stored in a DBMS
- Extra information at warehouse
  - Modify, summarize (store aggregates)
  - Add historical information

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Advantages of Query-Driven

- No need to copy data
  - less storage
  - no need to purchase data
- More up-to-date data
- Query needs can be unknown
- Only query interface needed at sources
- May be less draining on sources

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OLTP vs. OLAP

- OLTP: On Line Transaction Processing
  - Describes processing at operational sites
- OLAP: On Line Analytical Processing
  - Describes processing at warehouse

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OLTP vs. OLAP

OLTP

- Mostly updates
- Many small transactions
- Mb-Tb of data
- Raw data
- Clerical users
- Up-to-date data
- Consistency, recoverability critical

OLAP

- Mostly reads
- Queries long, complex
- Gb-Tb of data
- Summarized, consolidated data
- Decision-makers, analysts as users

Data Marts

- Smaller warehouses
- Spans part of organization
  - e.g., marketing (customers, products, sales)
- Do not require enterprise-wide consensus
  - but long term integration problems?

Warehouse Models & Operators

- Data Models
  - relations
  - stars & snowflakes
  - cubes
- Operators
  - slice & dice
  - roll-up, drill down
  - pivoting
  - other

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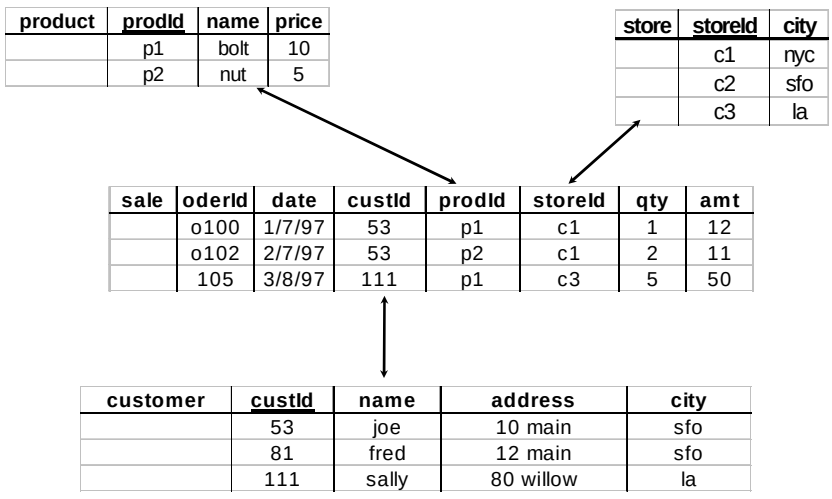
Star



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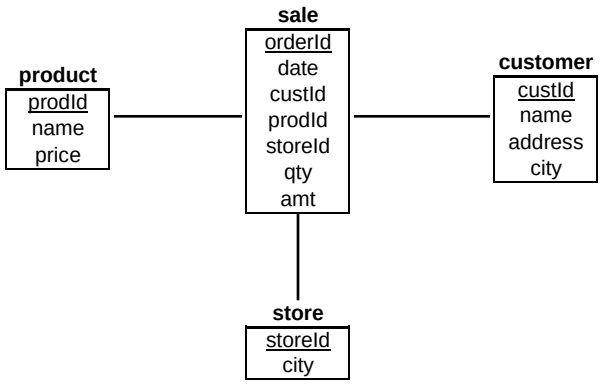
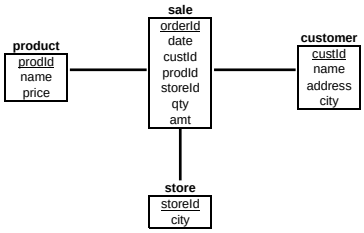
Star Schema

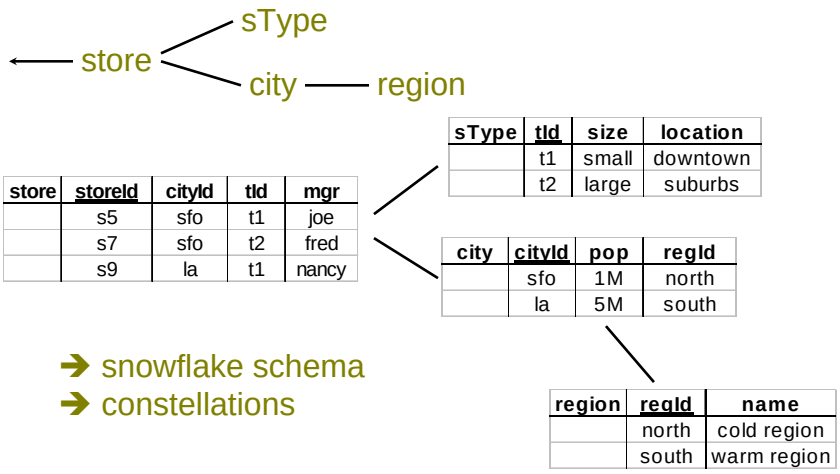


Terms

- Fact table
- Dimension tables
- Measures



Dimension Hierarchies



store	storeId	cityId	tId	mgr
	s5	sfo	t1	joe
	s7	sfo	t2	fred
	s9	la	t1	nancy

sType	tId	size	location
	t1	small	downtown
	t2	large	suburbs

city	cityId	pop	regId
	sfo	1M	north
	la	5M	south

region	regId	name
	north	cold region
	south	warm region

➔ snowflake schema
➔ constellations

Cube

Fact table view:

sale	prodId	storeId	amt
	p1	c1	12
	p2	c1	11
	p1	c3	50
	p2	c2	8

Multi-dimensional cube:

	c1	c2	c3
p1	12		50
p2	11	8	

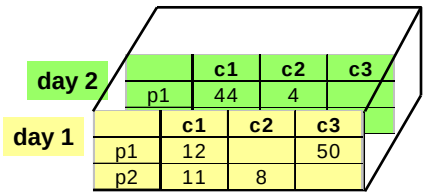
dimensions = 2

3-D Cube

Fact table view:

sale	prodId	storeId	date	amt
	p1	c1	1	12
	p2	c1	1	11
	p1	c3	1	50
	p2	c2	1	8
	p1	c1	2	44
	p1	c2	2	4

Multi-dimensional cube:



dimensions = 3

ROLAP vs. MOLAP

- ROLAP:
  Relational On-Line Analytical Processing
- MOLAP:
  Multi-Dimensional On-Line Analytical Processing

Aggregates

- Add up amounts for day 1
- In SQL: SELECT sum(amt) FROM SALE
  WHERE date = 1

sale	prodId	storeId	date	amt
	p1	c1	1	12
	p2	c1	1	11
	p1	c3	1	50
	p2	c2	1	8
	p1	c1	2	44
	p1	c2	2	4

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Aggregates

- Add up amounts by day
- In SQL: SELECT date, sum(amt) FROM SALE
  GROUP BY date

sale	prodId	storeId	date	amt
	p1	c1	1	12
	p2	c1	1	11
	p1	c3	1	50
	p2	c2	1	8
	p1	c1	2	44
	p1	c2	2	4

ans	date	sum
	1	81
	2	48

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Another Example

- Add up amounts by day, product
- In SQL: SELECT date, sum(amt) FROM SALE GROUP BY date, prodId

sale	prodId	storeId	date	amt
	p1	c1	1	12
	p2	c1	1	11
	p1	c3	1	50
	p2	c2	1	8
	p1	c1	2	44
	p1	c2	2	4

sale	prodId	date	amt
	p1	1	62
	p2	1	19
	p1	2	48

rollup →

← drill-down

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Aggregates

- Operators: sum, count, max, min, median, ave
- "Having" clause
- Using dimension hierarchy
  - average by region (within store)
  - maximum by month (within date)

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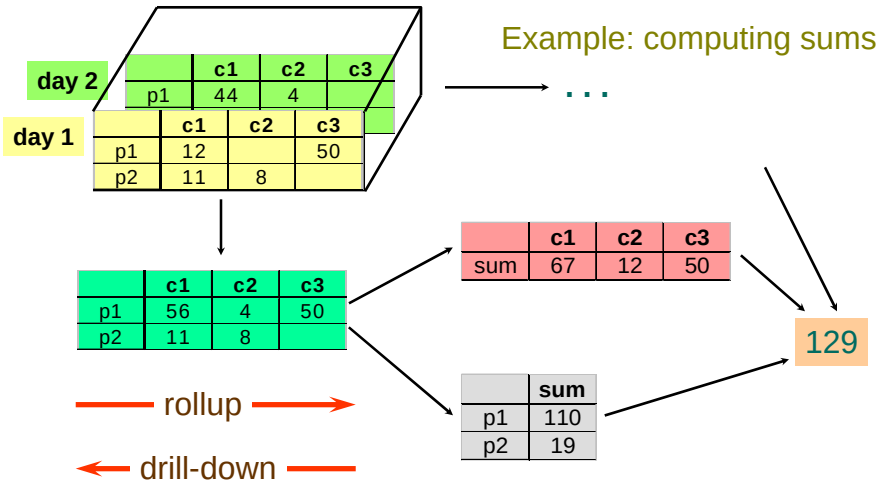
Cube Aggregation



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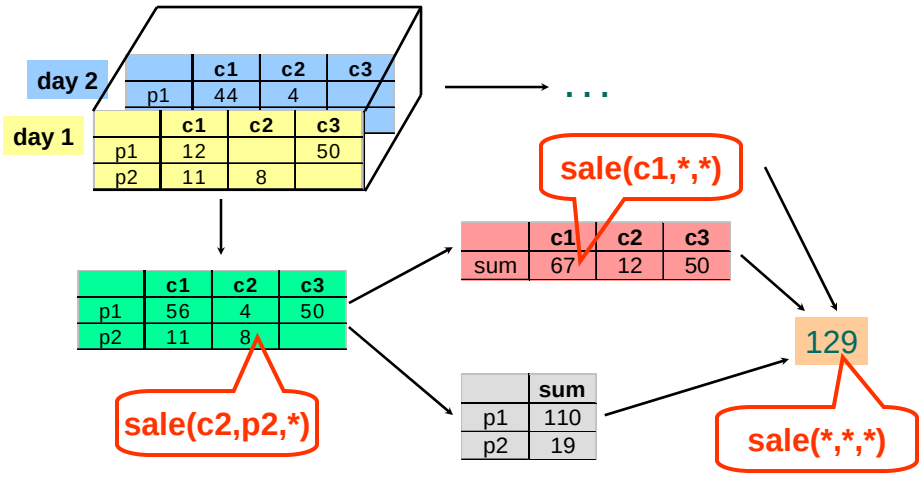
Cube Operators



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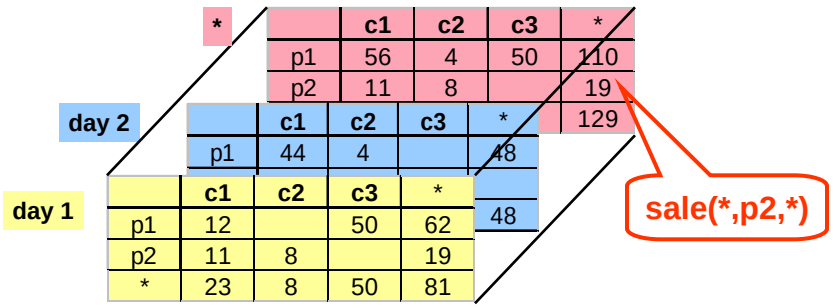
Extended Cube



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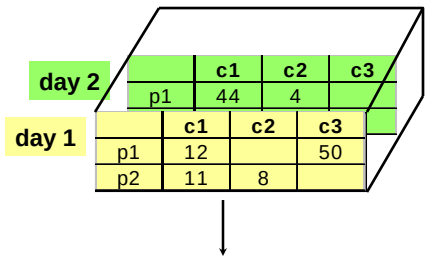
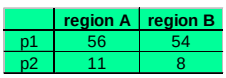
Aggregation Using Hierarchies





(customer c1 in Region A;
customers c2, c3 in Region B)

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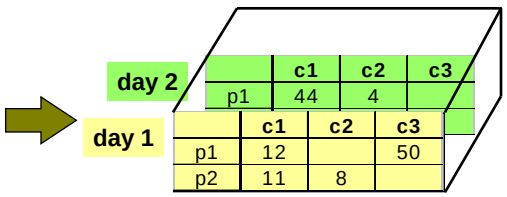
Pivoting

Fact table view:

sale	prodId	storeId	date	amt
	p1	c1	1	12
	p2	c1	1	11
	p1	c3	1	50
	p2	c2	1	8
	p1	c1	2	44
	p1	c2	2	4

Multi-dimensional cube:



	c1	c2	c3
p1	56	4	50
p2	11	8	

Query & Analysis Tools

- Query Building
- Report Writers (comparisons, growth, graphs,…)
- Spreadsheet Systems
- Web Interfaces
- Data Mining

Other Operations

- Time functions
  - e.g., time average
- Computed Attributes
  - e.g., commission = sales * rate
- Text Queries
  - e.g., find documents with words X AND B
  - e.g., rank documents by frequency of words X, Y, Z

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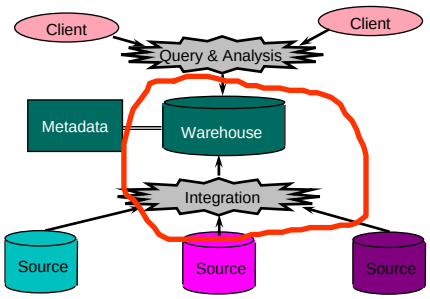
Integration

- Data Cleaning
- Data Loading
- Derived Data



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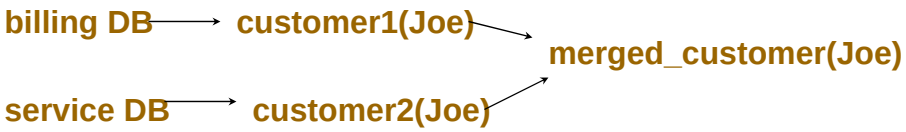
Data Cleaning

- Migration (e.g., yen ⇨ dollars)
- Scrubbing: use domain-specific knowledge (e.g., social security numbers)
- Fusion (e.g., mail list, customer merging)



- Auditing: discover rules & relationships (like data mining)

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Loading Data

- Incremental vs. refresh
- Off-line vs. on-line
- Frequency of loading
  - At night, 1x a week/month, continuously
- Parallel/Partitioned load

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Derived Data

- Derived Warehouse Data
  - indexes
  - aggregates
  - materialized views (next slide)
- When to update derived data?
- Incremental vs. refresh

Materialized Views

- Define new warehouse relations using SQL expressions

sale	prodId	storeId	date	amt
	p1	c1	1	12
	p2	c1	1	11
	p1	c3	1	50
	p2	c2	1	8
	p1	c1	2	44
	p1	c2	2	4

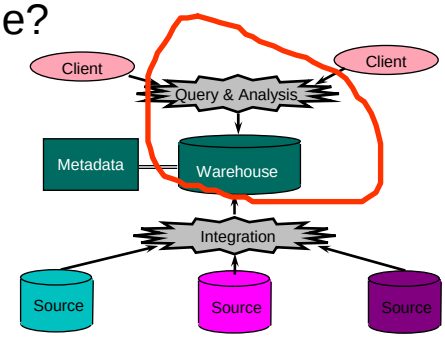
product	id	name	price
	p1	bolt	10
	p2	nut	5

joinTb	prodId	name	price	storeId	date	amt
	p1	bolt	10	c1	1	12
	p2	nut	5	c1	1	11
	p1	bolt	10	c3	1	50
	p2	nut	5	c2	1	8
	p1	bolt	10	c1	2	44
	p1	bolt	10	c2	2	4

does not exist at any source

Processing

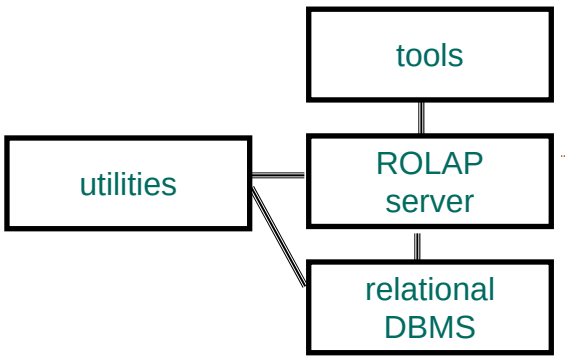
- ROLAP servers vs. MOLAP servers
- Index Structures
- What to Materialize?
- Algorithms



ROLAP Server

- Relational OLAP Server

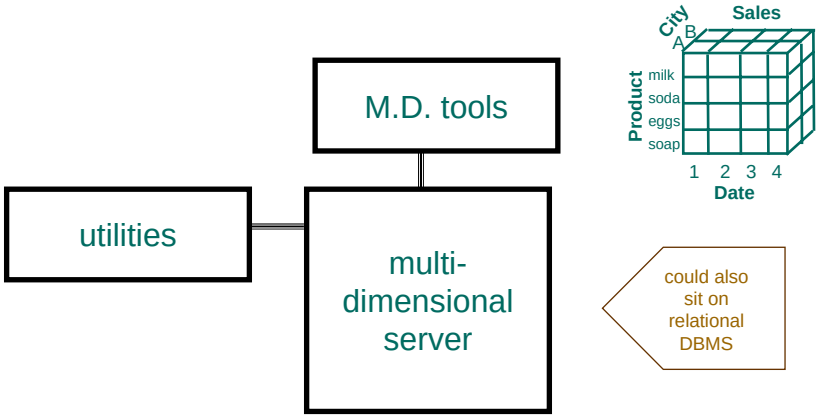
sale	prodId	date	sum
	p1	1	62
	p2	1	19
	p1	2	48



Special indices, tuning;
Schema is “denormalized”

MOLAP Server

- Multi-Dimensional OLAP Server



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Index Structures

- Traditional Access Methods
  - B-trees, hash tables, R-trees, grids, …
- Popular in Warehouses
  - inverted lists
  - bit map indexes
  - join indexes
  - text indexes

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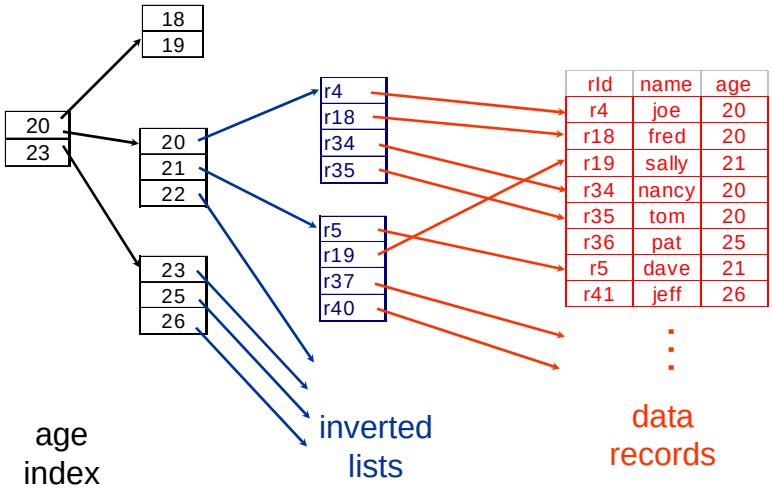
Inverted Lists

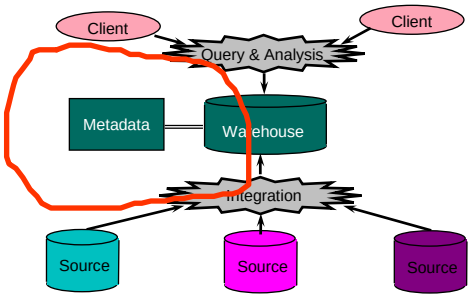


Using Inverted Lists

- Query:
  - Get people with age = 20 and name = “fred”
- List for age = 20: r4, r18, r34, r35
- List for name = “fred”: r18, r52
- Answer is intersection: r18

Managing

- Metadata
- Warehouse Design
- Tools



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Metadata

- Administrative
  - definition of sources, tools, ...
  - schemas, dimension hierarchies, …
  - rules for extraction, cleaning, …
  - refresh, purging policies
  - user profiles, access control, ...

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Metadata

- Business
  - business terms & definition
  - data ownership, charging
- Operational
  - data lineage
  - data currency (e.g., active, archived, purged)
  - use stats, error reports, audit trails

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Design

- What data is needed?
- Where does it come from?
- How to clean data?
- How to represent in warehouse (schema)?
- What to summarize?
- What to materialize?
- What to index?

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Tools

- Development
  - design & edit: schemas, views, scripts, rules, queries, reports
- Planning & Analysis
  - what-if scenarios (schema changes, refresh rates), capacity planning
- Warehouse Management
  - performance monitoring, usage patterns, exception reporting
- System & Network Management
  - measure traffic (sources, warehouse, clients)
- Workflow Management
  - "reliable scripts" for cleaning & analyzing data

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Current State of Industry

- Extraction and integration done off-line
  - Usually in large, time-consuming, batches
- Everything copied at warehouse
  - Not selective about what is stored
  - Query benefit vs storage & update cost
- Query optimization aimed at OLTP
  - High throughput instead of fast response
  - Process whole query before displaying anything

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Future Directions

- Better performance
- Larger warehouses
- Easier to use
- What are companies & research labs working on?

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Research (1)

- Incremental Maintenance
- Data Consistency
- Data Expiration
- Recovery
- Data Quality
- Error Handling

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Research (2)

- Rapid Monitor Construction
- Temporal Warehouses
- Materialization & Index Selection
- Data Fusion
- Data Mining
- Integration of Text & Relational Data

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Conclusions

- Massive amounts of data and complexity of queries will push limits of current warehouses
- Need better systems:
  - easier to use
  - provide quality information

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