Information Quality in Integrated Information Systems

Institute for Infocomm Research, Singapore

15.3.2005

Felix Naumann

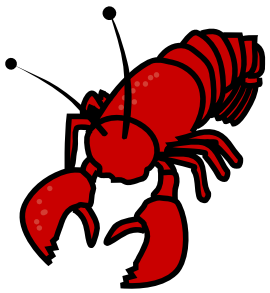
Humboldt-Universität zu Berlin

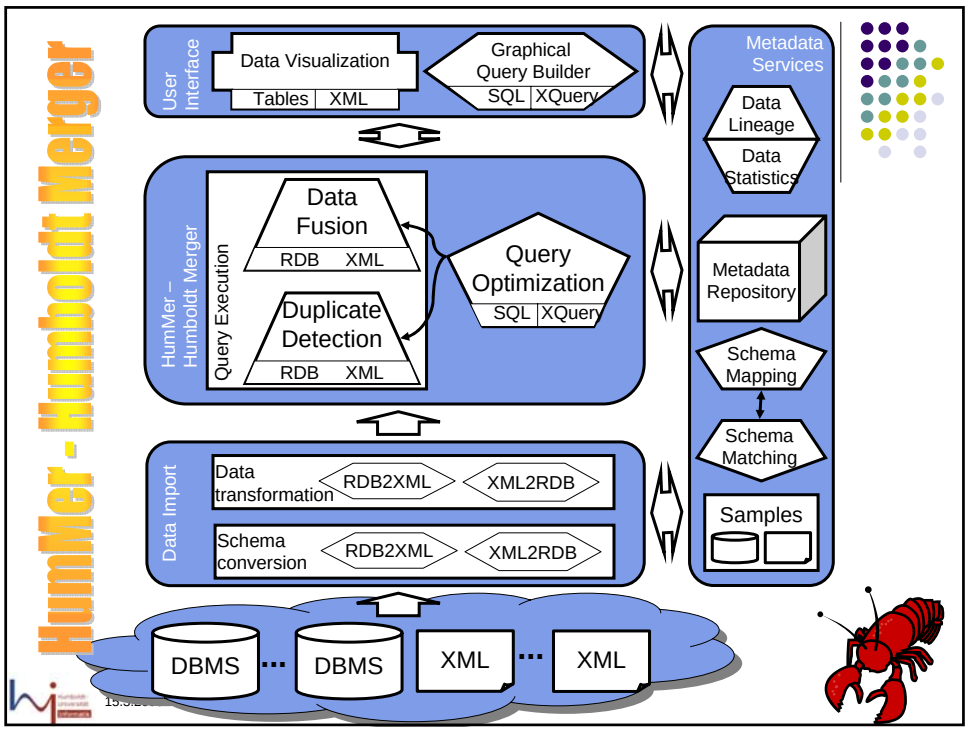
Humboldt-Universität zu Berlin

- Wilhelm and Alexander von Humboldt
- Unity of teaching and research
- Freedom and independence of sciences
- 29 Nobel prize winners
  - Mommsen, Hertz, Koch, Hahn, Planck, Einstein,...
- 38,000 students, (1200 computer sciences)
- 560 professors (12 + 10 computer sciences)

Research Group „Information Integration“

- Head: Felix Naumann (naumann@informatik.hu-berlin.de)
- PhD students
  - Jens Bleiholder (bleiho@informatik.hu-berlin.de)
    - Information fusion in relational data
  - Melanie Weis (mweis@informatik.hu-berlin.de)
    - Object identification in XML Data
- Affiliated PhD students
  - Armin Roth (aroth@informatik.hu-berlin.de)
    - Data quality in Peer-Data-Management-Systems
  - Alexander Bilke (bilke@cs.tu-berlin.de)
    - Schema Matching
- General Research Topics
  - Object identification
  - Information fusion
  - Optimization
  - Visualization
  - And IQ

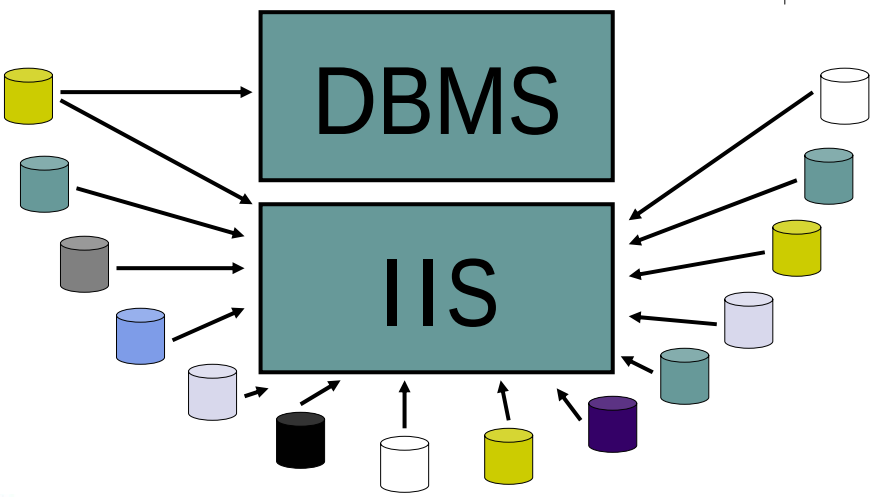




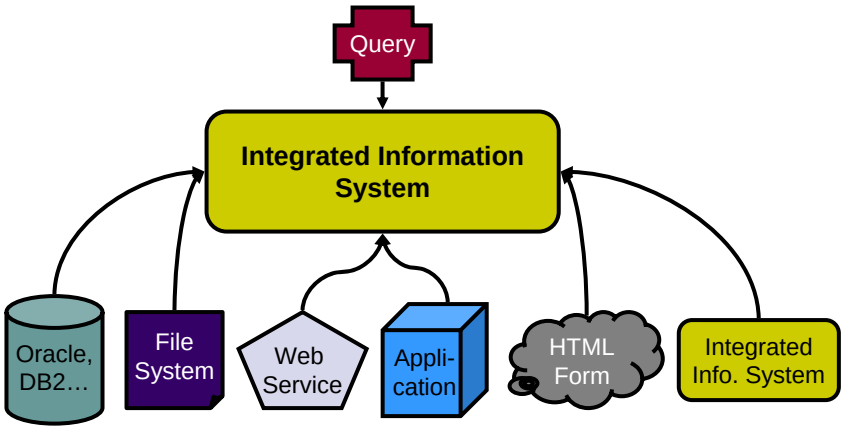
Outline

- Databases vs. Integrated Information systems
- Motivating Examples
- Components for IQ-driven query processing
  - IQ measure + IQ model
  - IQ-driven optimization – A new paradigm
  - IQ-driven integration
- Further topics for discussion

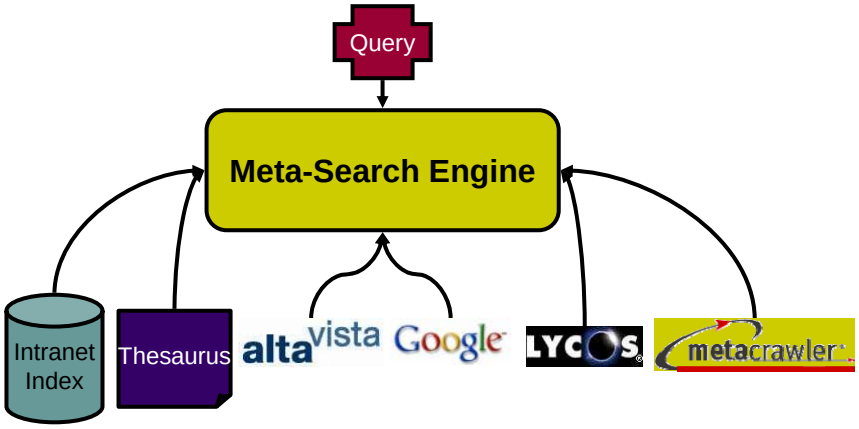
Database Management Systems vs. Integrated Information Systems



Integrated Information Systems

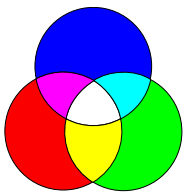


Integrated Search Engines



Redundancy

- Is good for you
  - More information
  - More detailed information
  - Verifiable information
  - Thus: INTEGRATE!



- But yields problems
  - More alternatives mean more complexity.
  - Technical and structural (and semantic) heterogeneity
  - Redundancy is only conceptual:
    - Object identity
    - Data conflicts
  - Mixed and low quality
  - New types of errors (duplicates)

DBMS vs. IIS

Single source	⟺	Multiple sources
Local	⟺	Distributed
Controlled	⟺	Autonomous
Structured	⟺	Semi-structured
Data	⟺	Information
short		text, images, tables
Professional user	⟺	Professional and casual user

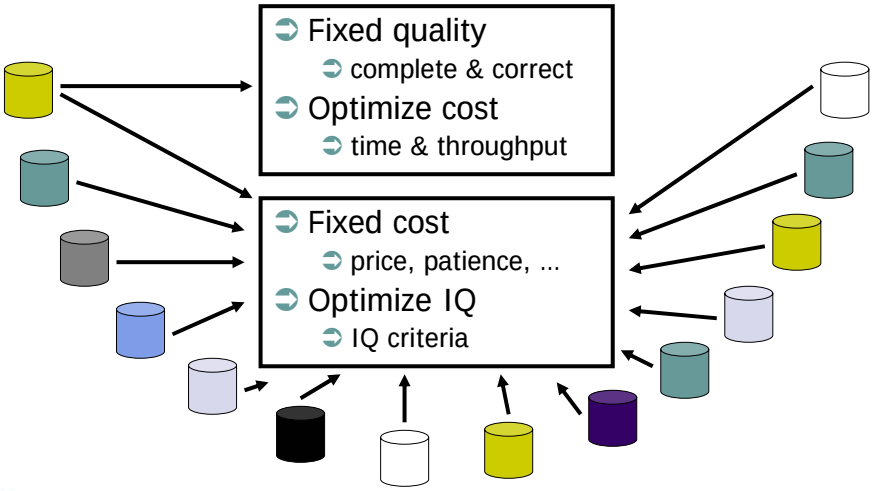
DBMS Quality vs. IIS Quality

Complete (assumed)	⟺	Incomplete
Accurate	⟺	Inaccurate
Trusted	⟺	Untrusted
Fast	⟺	Slow
Free	⟺	Possible cost

High expectations (guarantees) High quality

Low expectations (no guarantees) Low quality

Optimize IQ!



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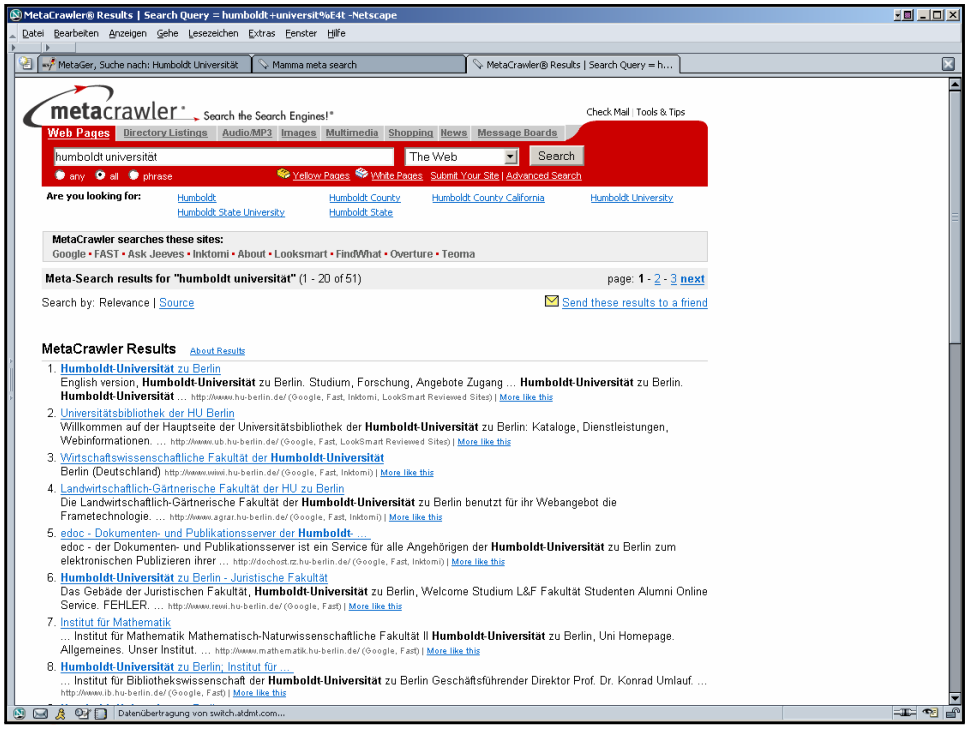
Motivating Examples

- Search
  - Meta Search Engines
- Data Fusion (Integration)
  - Data conflicts
  - Genome Databases
- Peer Data Management

Example: Meta Search Engines

- MetaGer
- Mamma
- MetaCrawler
  - Google: Title, Summary, Descr.,Category, URL, Size
  - Fast: Title, Summary, Descr., URL, Size
  - Inktomi: Title, Summary, URL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Yellow Pages
White Pages
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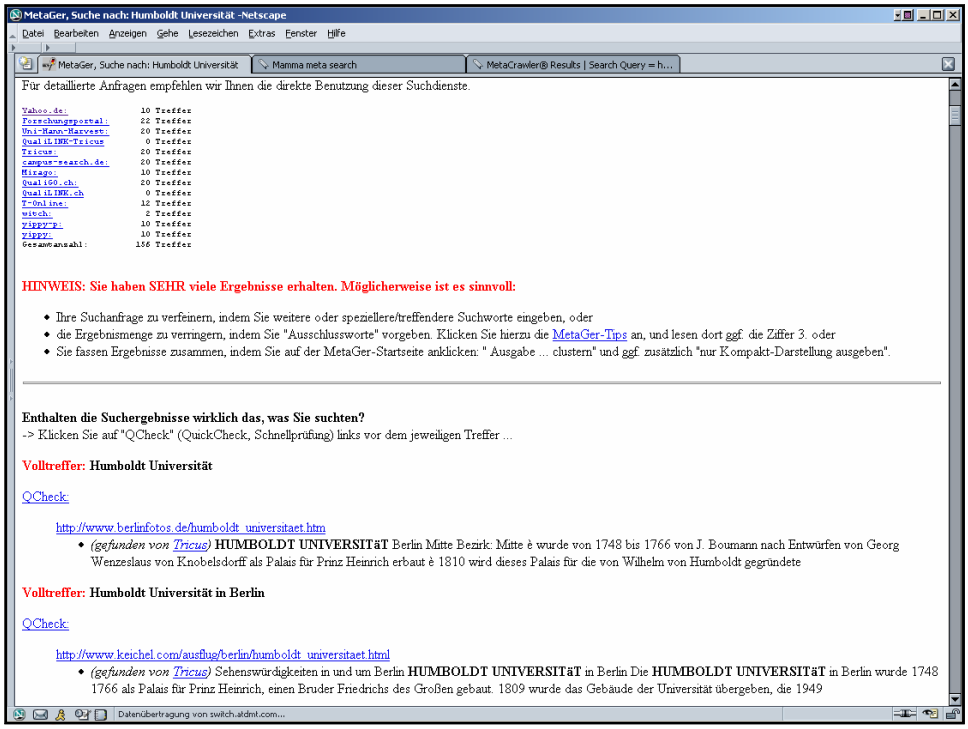
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die Ergebnismenge zu verringern, indem Sie "Ausschlussworte" vorgeben. Klicken Sie hierzu die MetaGer-Tips an, und lesen dort ggf. die Ziffer 3. oder
Sie fassen Ergebnisse zusammen, indem Sie auf der MetaGer-Startseite anklicken: " Ausgabe ... clustern" und ggf. zusätzlich "nur Kompakt-Darstellung ausgeben".
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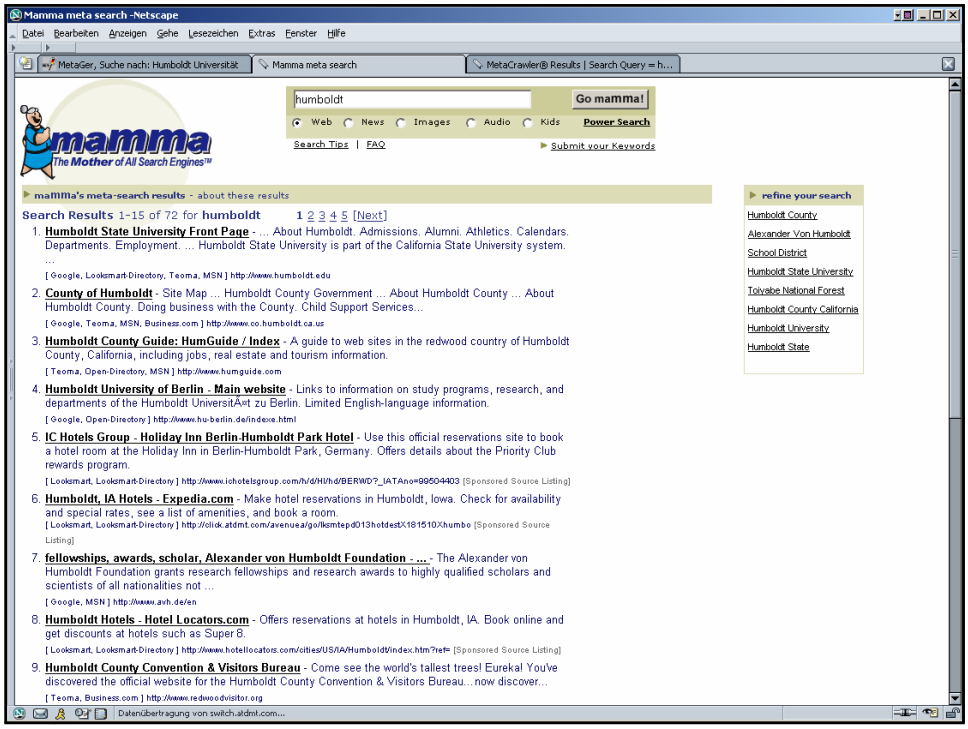
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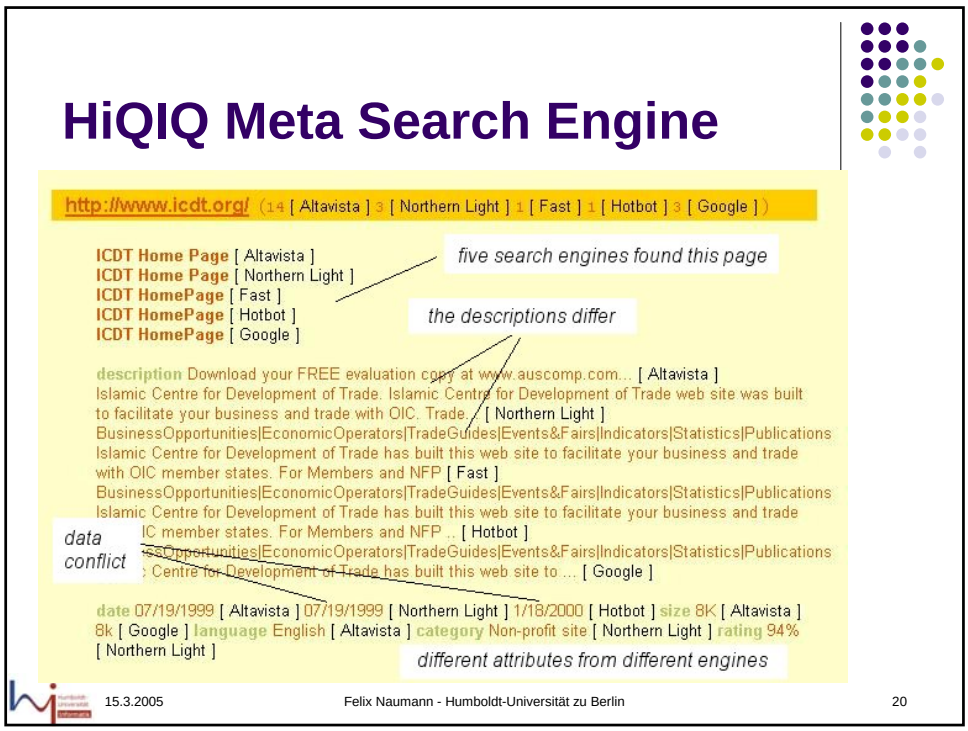
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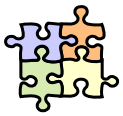
Motivating Examples

- Search
  - Meta Search Engines
- Data Fusion (Integration)
  - Data conflicts
  - Genome Databases
- Peer Data Management

Example: Data Fusion



Source 1 → a, b
Source 2 → a, b
=> a, b

a, b
a, -
=> a, b

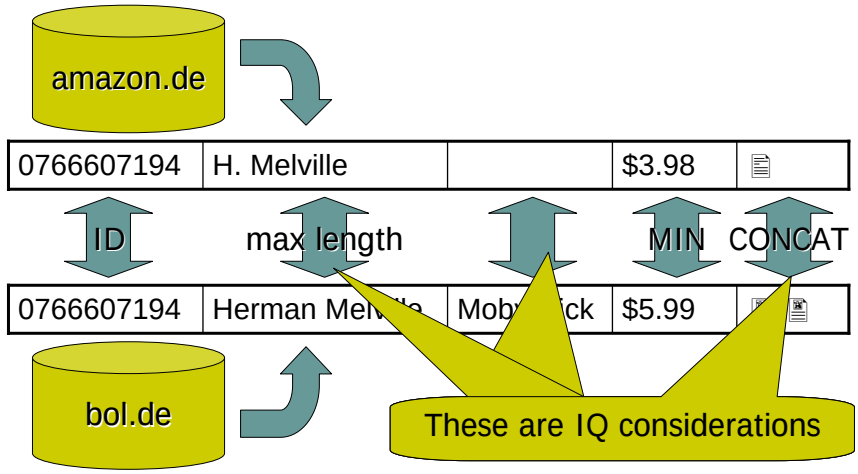
Meaning of null?

a, b
a, c
=> a, r(b,c)

Conflict-Resolution

a, -, d
a, c, -
=> a, c, d

Example: Data Fusion



Example: Data Fusion

- Genome Databases
  - Research labs produce many conceptually redundant results.
  - Quality of experimental results vary (poor IQ is intrinsic).
  - Quality of human (and machine) annotations vary.
  - Biologists are very opinionated about IQ of information sources.
  - ⇒ Perfect application for IQ-driven information integration

Example: Data Fusion

- Genome databases
  - Identification of redundancy very difficult (no standard representation)
  - No IQ metadata,
  - only human-readable annotation
  - (Some annotation on “methods used”)

RNA sequence entry from EMBL

Motivating Examples

- Search
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  - Information Retrieval
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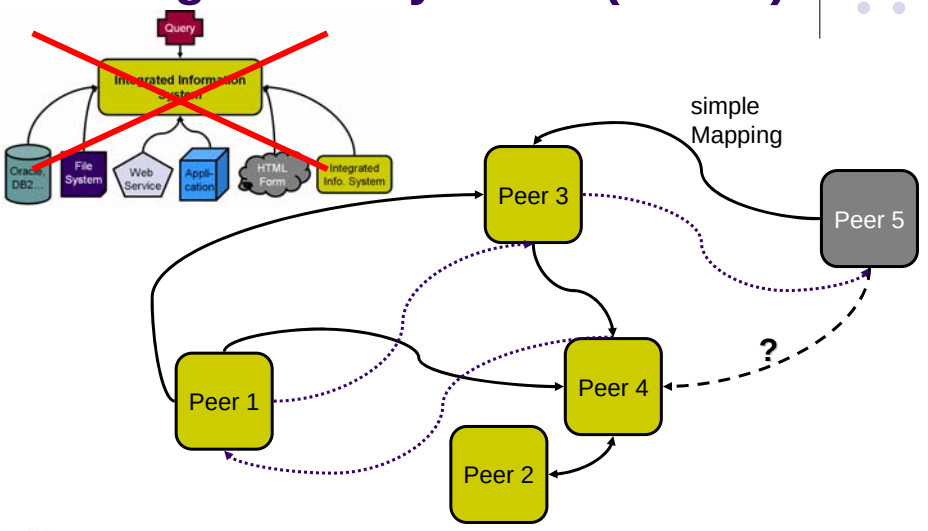
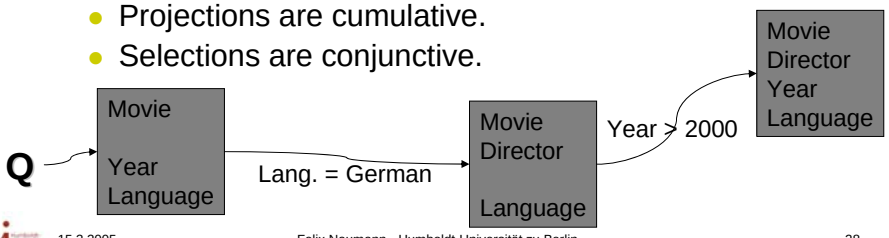
Example: Peer Data Management Systems (PDMS)



Work with Armin Roth, DaimlerChrysler

Example: Peer Data Management Systems (PDMS)

- IQ in PDMS
  - You don‘t know who is answering your query.
  - Mappings further degrade IQ:
    - Projections diminish density
    - Selections diminish completeness
  - Problem compounded along mapping paths:
    - Projections are cumulative.
    - Selections are conjunctive.



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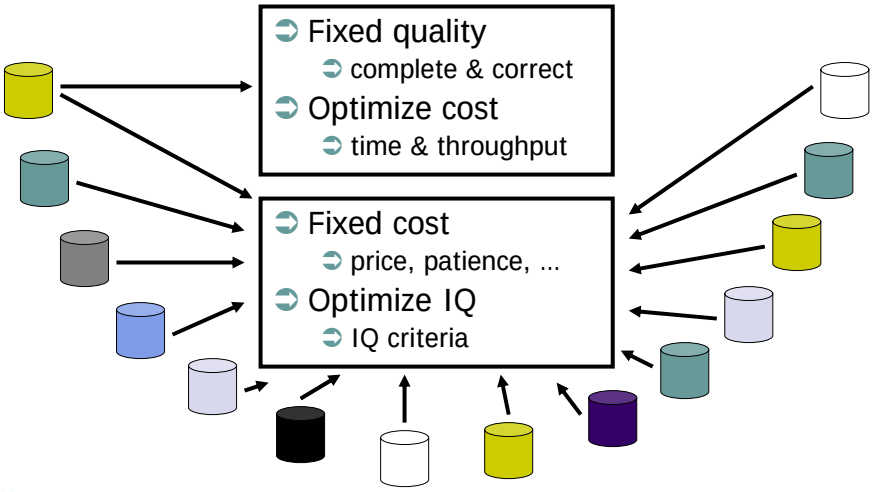
Optimize IQ!

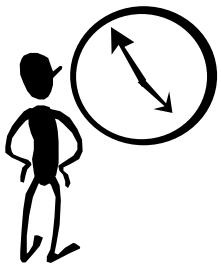


A New Optimization Paradigm – Changes

- Cost criteria ⟺ Quality criteria
- Cost model ⟺ Quality model
- Optimization algorithm ⟺ Optimization algorithm
- + Information integration

DB Cost Criteria

- Response time
- Execution time
- Latency
- Throughput
- Cardinality
- …



Assessed through system parameters and statistics.

IIS Quality Criteria

IQ :=

> ***"Even though quality cannot be defined, you know what it is."***
>
> **Robert Pirsig**

IIS Quality Criteria

IQ := {Understandability, Reputation, Reliability, Timeliness, Availability, Price, Conciseness Consistency, Coverage, Response time, Density, Completeness, Amount, Accuracy, Relevancy, ... }

IQ Criteria

- Accuracy
  - Definition:
    - Usually: Percentage of incorrect tuples
    - For integration: Percentage of incorrect data values
  - Assessment:
    - Domain and Constraint Testing
    - Lookup tables
    - Scientific measurements
    - Data-input experience
  - Improvement:
    - Often: Deletion
    - Better: “Data Scrubbing”
- Response Time
  - Definition:
    - Usually: Time until complete query result is received
    - For integration: Latency
  - Assessment:
    - “Cost Calibration”
    - Continuous assessment
  - Improvement:
    - Source selection
    - Classical optimization
    - Federated Optimization

IQ Criteria

- Completeness
  - Definition:
    - Coverage (extension): Number of real world objects represented
    - Density (intension): Number of attributes covered
      - NULL-values
  - Assessment:
    - Sampling
    - Existing Metadata
  - Improvement:
    - Source selection
    - “Best k” vs. “k best”
- Conciseness
  - Definition:
    - Extension: Number of real-world objects not represented doubly
    - Intension: Number of attributes not represented doubly
  - Assessment:
    - Duplicate detection
    - Schema Matching
  - Improvement:
    - Data Fusion

IIS Quality Criteria

IQ := {Understandability, Reputation, Reliability, Timeliness, Availability, Price, Conciseness Consistency, Coverage, Response time, Density, Completeness, Amount, Accuracy, Relevancy, ... **}**

Assessed in 3 classes...

IQ Assessment

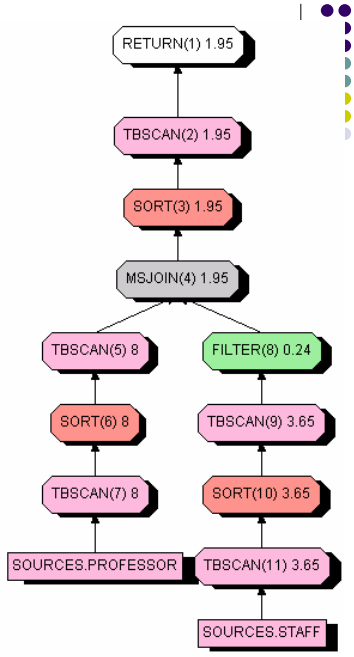
Information source:	S_1	S_2	S_3
Understandability	5	7	7
Reputation	5	5	7
Reliability	2	6	4
Age	30	30	2
Availability	99	99	60
Completeness	1	1	0.5
Response Time	0.2	0.2	0.2
Accuracy	99.9	99.9	99.8
Relevancy	60	80	90

- User
  - Questionnaires
- Information Source
  - Parsing
  - Metadata
- Query Process
  - Time Measurement

DB Cost Models

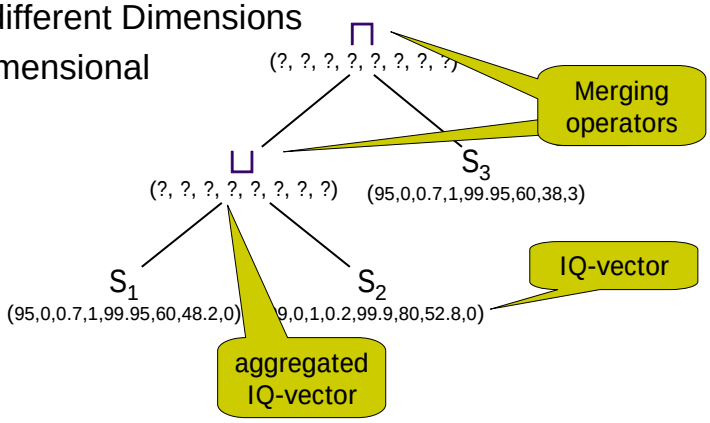
- Operators
  - + (add)
  - max
  - X (multiply)

Easy ;-)



IIS Quality Model

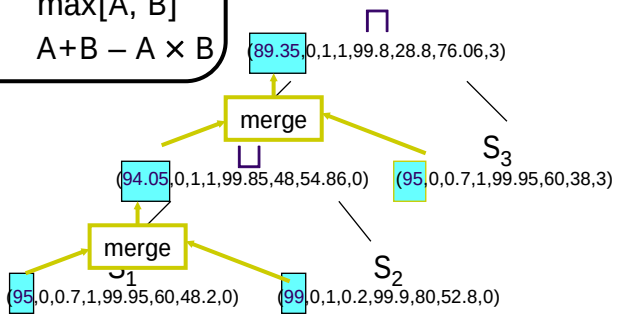
- 2 Problems
  - Many different Dimensions
  - Multidimensional



Merge IQ in many Dimensions

IQ Merge Functions

Availability:	A × B
Price:	A + B
Response Time:	max[A, B]
Coverage:	A+B – A × B



Multidimensional IQ

(89.35,0,1,1,99.8,28.8,76.06,3) > (82.35,0,2,1.5,95,32,71.77,2) ?

- IQ-criteria have
  - Different units
  - Different ranges
  - Different importance
- So...
  - convert
  - scale
  - weight

MADM methods:
SAW, TOPSIS, ELECTRE, AHP, DEA

Outline

- Databases vs. Integrated Information systems
- Motivating Examples
- Components for IQ-driven query processing
  - IQ measure + IQ model
  - IQ-driven optimization – A new paradigm
  - IQ-driven integration
- Further topics for discussion

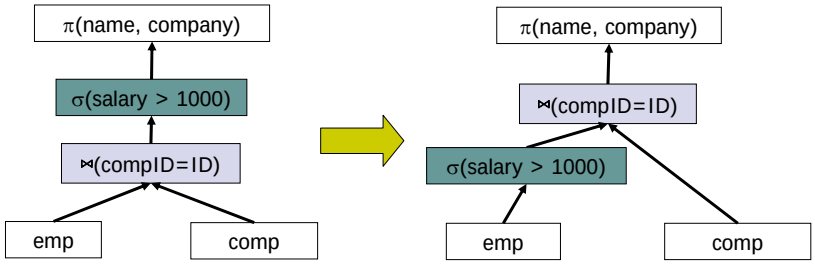
DB-type Optimization

- Goal
  - Minimize response time (single user)
  - Maximize throughput (multi-user)
- Restrictions
  - Complete
  - Correct (not just accurate: filter conditions…)

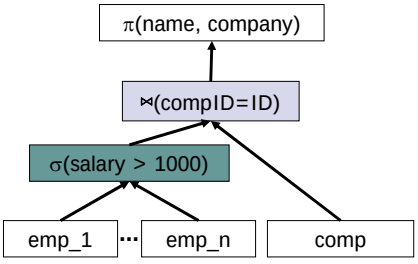
Find best plan!

DB-type Optimization

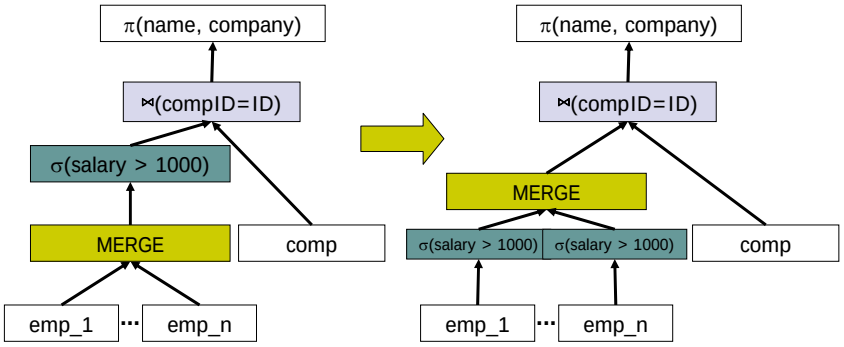
```
SELECT name, company FROM emp, comp
WHERE emp.compID = comp.ID AND emp.salary > 1000
```



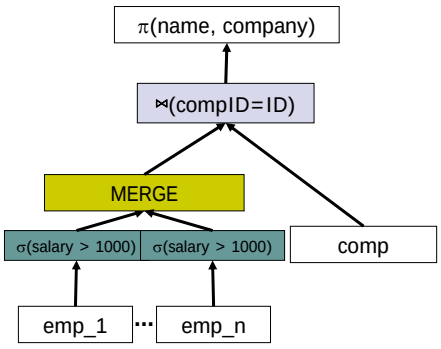
DB-type Optimization



Integration-type Optimization



Integration-type Optimization



- Change is efficient
- But:
  - Result can be incomplete.
  - Depending on “Merge function”
- Preferences? Quality!

IIS-type Optimization

- Goal
  - Maximize information quality
  - Maximize completeness
- Restrictions
  - Price
  - Bandwidth
  - Time (user patience)

Find *K* best sources – Find best *K* sources

IIS-type Optimization

- *K* best sources
  - (or *K* best conjunctive plans)
  - Simple IQ model, but
  - Sources may not complement each other
    - at tuple level (replication)
    - at attribute level
- Best *K* sources
  - (or best disjunctive normal form plan)
  - Finds optimal query result
  - Uses IQ merging

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Data Integration in DBMS

- UNION, UNION, UNION
- OUTER UNION,
- GROUP BY

- Cannot compute similarity.
  - For object identification
- Cannot deal with inconsistencies.
  - For conflict resolution

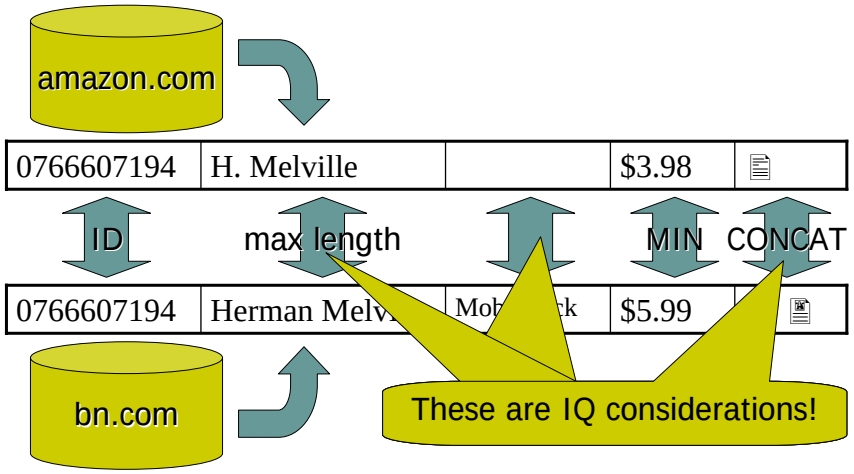
Information Integration in IS

- WHAT?
  - Problem: Identify different representations of same real-world object.
  - Solution: Object identification techniques
- HOW?
  - Problem: Merge conflicting data about same real-world object.
  - Solution: Conflict resolution techniques

Object Identification

- Also
  - Duplicate Detection
  - Record Linkage
  - Data Reconciliation/Consolidation
- Domain-specific
  - Address data
  - Microbiological data
  - …
- IQ weighting can help

Conflict Resolution



Conflict Resolution

- Numerical:
  SUM, AVG, MAX, MIN, …
- Non-numerical:
  MAXLENGTH, CONCAT, AnnCONCAT,…
- Special:
  RANDOM, COUNT, CHOOSE, **FAVOR**, **MaxIQ**,…
- Domain-specific
  …

Human specification of IQ

Automated specification of IQ

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Further topics for discussion

- One slide each on ongoing work:
  - IQ in Off-the-Shelf-DBMS
  - Detecting regular errors in DBMS using Data Mining
  - Duplicate detection in XML
  - Duplicate detection without a schema
  - Data Fusion – Completeness and Conciseness
  - 10th Int. Conference on Information Quality

IQ in Off-the-Shelf-DBMS

1. Most quality-critical data is stored in DBMS.
   - Data Warehouses
   - Web back-ends
2. DBMS are carefully designed to preserve high data quality.
   - Decades of development
   - ACID
3. Sometimes DBMS even improve data quality.
   - Aggregation
   - Integration

Work with Mary Roth, IBM

Detecting regular errors in DBMS using Data Mining

r_1

ID	ORG.	SEX	COLOR	SIZE
1	Frog	F	Green	20,4
2	Toad	F	Green	25,1
3	Newt	M	Grey	30,4
4	Frog	F	Blue	19,6
5	Toad	M	Blue	20,8
6	Newt	M	Grey	30,1
7	Newt	F	Grey	28,9
8	Frog	M	Green	20,3

r_2

ID	ORG.	SEX	COLOR	SIZE
1	Frog	W	Olive	20
2	Frog	W	Green	25,1
3	Newt	M	Grey-Spotted	30,4
4	Frog	W	Blue	19,6
5	Frog	M	Blue	20,8
6	Newt	M	Grey-Spotted	30,1
7	Newt	W	Grey&Yellow	28,9
8	Frog	M	Olive	20

r_m

			C[CORGANISM]			C[SEX]			C[COLOR]			C[SIZE]
ID	R_1.ORG	R_2.ORG	C_1	R_1.SEX	R_2.SEX	C_2	R_1.COLOR	R_2.COLOR	C_3	R_1.SIZE	R_2.SIZE	C_4
1	Frog	Frog	0	F	W	1	Green	Olive	1	20,4	20	1
2	Toad	Frog	1	F	W	1	Green	Green	0	25,1	25,1	0
3	Newt	Newt	0	M	M	0	Grey	Grey-Spotted	1	30,4	30,4	0
4	Frog	Frog	0	F	W	1	Blue	Blue	0	19,6	19,6	0
5	Toad	Frog	1	M	M	0	Blue	Blue	0	20,8	20,8	0
6	Newt	Newt	0	M	M	0	Grey	Grey-Spotted	1	30,1	30,1	0
7	Newt	Newt	0	F	W	1	Grey	Grey&Yellow	1	28,9	28,9	0
8	Frog	Frog	0	M	M	0	Green					

Work with Heiko Müller, Humboldt

Duplicate detection in XML

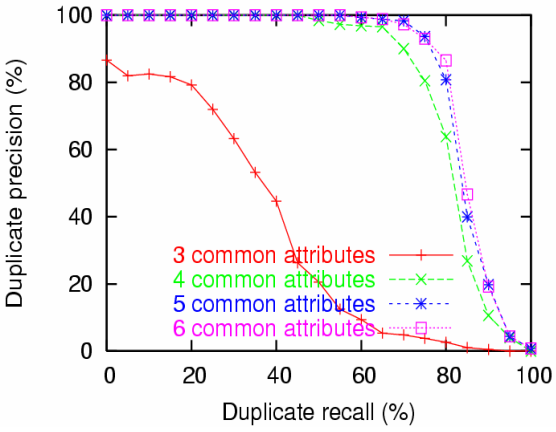
```
- <author>
    <name>Bernd Amann</name>
  - <publication>
      <title>XML Repository and Active Views Demonstration.</title>
      <year>1999</year>
    </publication>
  - <publication>
      <title>Active Views for Electronic Commerce.</title>
      <year>1999</year>
    </publication>
  </author>
- <author>
    <name>Sophie Cluet</name>
  - <publication>
      <title>XML Repository and Active Views Demonstration.</title>
      <year>1999</year>
    </publication>
  - <publication>
      <title>Active Views for Electronic Commerce.</title>
      <year>1999</year>
    </publication>
  - <publication>
      <title>Views in a Large Scale XML Repository.</title>
      <year>2001</year>
    </publication>
  </author>
```

- Compare <author>
  - With Subelements (<publication>)?
  - How deep?
- Compare <publication>
  - With siblings (<year>)?
  - Schema, or Data?
- In short: What is a duplicate?

Work with Melanie Weis, Humboldt

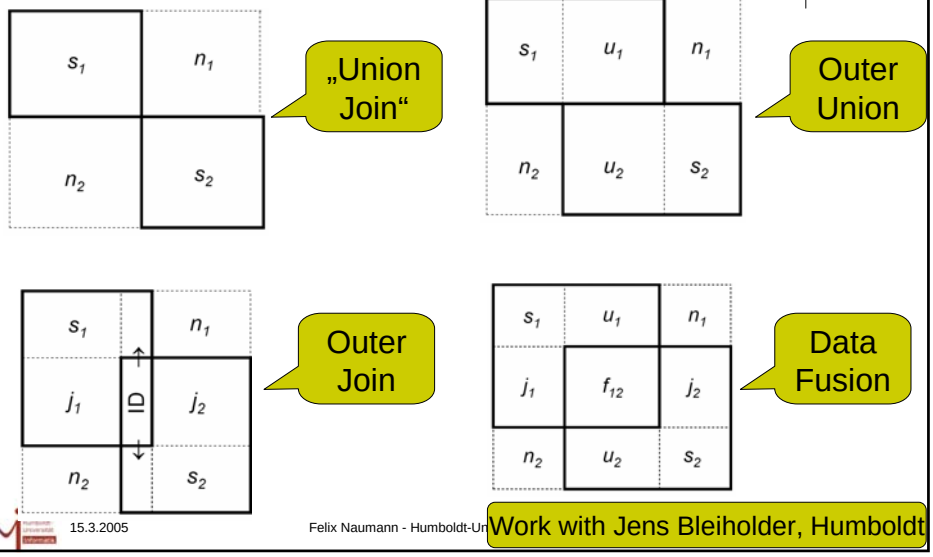
Duplicate detection without a schema

- Opaque attribute names
- Only some intensional overlap
- Similarity measure based on tokenization of tuple and TFIDF
- Whirl algorithm to efficiently find top duplicates



Work with Alexander Bilke, University of Technology Berlin

Data Fusion – Completeness and Conciseness



Work with Jens Bleiholder, Humboldt

CfP: 10th ICIQ

- International Conference on Information Quality
- Nov. 4 to 6 @ MIT in Cambridge
- Paper deadline: June 30 !
- Suggested topics:
  - IQ Concepts, Tools, Metrics, Measures, Models, and
  - Methodologies
  - IQ Policies and Standards
  - IQ Assessment
  - IQ Practices: Case Studies and Experience Reports
  - IQ Product Experience Reports
  - Cost/Benefit Analysis of IQ and IQ Improvement
  - Information Product Implementation, Delivery, and
  - Management
  - IQ in Databases, the Web, and e-Business
  - Data Warehouses and Data Mining
  - Corporate Household Data
  - IQ in Scientific Data Management
  - Data Cleansing and Reconciliation
  - IQ Education and Curriculum Development
  - Trust, Knowledge, and Society in the IQ Context
- Academic, research-in-progress, or practice-oriented paper.

Questions

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  - IQ-driven optimization – A new paradigm
  - IQ-driven integration

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