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# State-of-the-art in Multimedia Databases

**Recent commercial software developments in terms of support for MM applications and limitations.**

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# MM Databases: Introduction

- Multimedia databases have to store numeric, image, video, audio, text, graphical, temporal, relational and categorical data.
- Attention in many application areas:
  - Medical information systems
  - Geographic information systems
  - E-commerce
  - Digital libraries
- We will draw attention on special purpose database files within the DC corporate group with regard to data mining databases.

# Overview

- Discussion of commercial multimedia databases:
  - historical development
  - **current architecture**
  - interfaces and plans for further developments for MM data
  - **general requirements for object-relational data management**
- Evaluation:
  - highlight pros and cons of **IBM DB2 V8, Oracle 9i**, SQL Server 2000, Informix V7.
  - Comparisons based on theoretical and practical aspects, concludes with case study

# Overview

- Challenges for state-of-the-art multimedia database implementations
  - open problems
  - special requirements for special data types
- Potentials of MM databases within DCX
  - **proposed system architecture**
  - **recommendations on the project management**

# Historical development

- Mid ‘80: Increasing popularity of *OO* programming languages (e.g. C++, Smalltalk, Java (later)).
- Begin ‘90: First prototypes of *OO* databases have come in the limelight.
- Mid ‘90: Vendors of *R* databases have responded to the new *OO* database products by creating hybrid products incorporating relational and *OO* functionality.
- 1997: The *OR* versions of Informix, Oracle, and DB2 followed.
- Future:
  - Object-oriented vendors will establish a powerful position in market.
  - Object-relational, too? (technical limitations and compromises)

# Multimedia standards

- Object-relational standards SQL99/SQL-3 (Database Lang):
  - object types
  - ORDBMS model(creating, managing, querying persist. *O* structures)
- Multimedia standards:
  - SQL/MM (SC32/WG4 SQL Multimedia and Application Packages)
    - SQL/MM Full Text (operators: contains, in_s_s_as, stem)
    - SQL/MM Still Image (operators: format conv., scaling)
  - SQLJ (Embedding of SQL in Java programs, store Java methods in DB)
  - MPEG-7 (multimedia content for audio, video, image)

# Current architecture vs. ORDM requirements: Basic types

| Basic type | SQL99 | DB2 | Oracle | SQL-Server | Informix |
|---|---|---|---|---|---|
| BOOLEAN | • | - | - | - | • |
| SMALLINT | • | • | • | •[1] | • |
| INTEGER | • | • | • | • | • |
| BIGINT | (SQL3) | • | NUMBER | • | INT8 |
| DECIMAL | • | • | • | - | • |
| NUMERIC | • | • | • | • | • |
| FLOAT | • | • | • | • | • |
| REAL | • | • | • | • | • |
| DOUBLE PRECISION | • | DOUBLE | • | - | • |
| CHAR | • | • | • | • | • |
| VARCHAR | • | • | • | • | • |
| CLOB | • | • | • | - | • |
| BLOB | • | • | • | • | • |
| BIT | - | - | - | - | - |
| BIT VARYING | - | - | - | - | - |
| DATE | • | • | • | - | • |
| TIME | - | • | - | - | - |
| TIMESTAMP | • | • | • | DATETIME | DATETIME |
| INTERVAL | • | - | • | - | • |
| XML | (SQL3) | XMLCLOB | XMLTYPE | • | - |

# Current architecture vs. ORDM requirements: Complete Data Model

| Object-Relational Data Model | DB2 | Oracle | SQL-Server | Informix |
|---|---|---|---|---|
| New additional basis data types for new application domains | ● | ● | ● | ● |
| Copies of basic data types with new type names | ● | ● | ● | ● |
| Data types for external data. | ● | ● | - | ● |
| Basic types variants (i.e. structured types) | ● | ● | - | -[1] |
| Collection types (List, Set, Multiset) | - | ●[2] | - | ●[3] |
| Reference types that objects can be referenced | ● | ● | - | - |
| Type hierarchies of objects | ● | ● | - | - |
| Type hierarchies of tables | ● | - | - | ● |
| Typed tables for typing complete data entries. | ● | ● | - | ● |
| User defined routines (functions) (UDR(F)) that can be registered in the DBMS and be used as operators for data types. | ● | ● | ● | ● |

# Current architecture vs. ORDM requirements

- Structured type example:

```
CREATE TYPE employee AS
  (name          CHAR(40),
   base_salary   DECIMAL(9,2))

METHOD getSalary() RETURNS DECIMAL(9,2)
```

# Current architecture vs. ORDM requirements

- Unstructured Image Data
  - different kinds like paintings, drawings, photographic pics, satellite images, architectural, facial ...
  - digital file formats like WAV, AU, GIF, JPG, MPEG with different compression and quality rates.
- Unstructured Text Data
  - string of arbitrary size, in linguistic terms containing words, sentences, paragraphs as logical units
  - in DB own internal representation format, converted from RTF, PDF, PS ...

# Current architecture vs. ORDM requirements

- DB2 multimedia technology (Extenders)
  - DB2 Text Extender (Text Information Extender, Net Search Extender)
    - Text search functions integrated into SQL
    - Incremental and asynchronous full-text index update
    - Supports char data types, UDFs, LOBs, and external files
    - Linguistic indexing/search for 22 languages
    - Boolean, wildcard, free-text and fuzzy search

# Current architecture vs. ORDM requirements

- DB2 multimedia technology (Extenders)
  - DB2 Image Extender
    - maintains image attributes such as size in bytes, format, height, width and number of colors
    - adds  CBR to SQL queries, color, texture, shape patterns as search criteria (18 UDFs)
    - format conversion, scaling, rotating, b/w image inversion, ...

# Current architecture vs. ORDM requirements

- Oracle multimedia technology (Cartridges)
  - Text Data Cartridge
    - functionality similar to DB2
    - support for over 160 different text file formats
      - ASCII, HTML, XML ...
      - Microsoft formats RTF, Word, PowerPoint, Access ...
      - PDF, WordPerfect, Lotus 1-2-3, MacWrite, dBase ...

```
Select p_id, p_name from p_information where

CONTAINS(p_description, ‘monitor’ NEAR ‘highresolution’) > 0
```

# Theoretical evaluation

- Comparison of **object-relational** and multimedia text features
  - DB2 offers a rich subset of the SQL standard, whereas the other databases comprise object-relational concepts not part of the standard.
  - Oracle supports user-defined orders for all types (defining own indexing structure for information retrieval. Build in: B-Tree indexes, bitmap indexes, partitioned indexes, function-based indexes, and domain indexes).
  - SQL Server 2000: very limited, not support for object types apart from build-in primitive types and formatted documents.
  - Informix has no object concept since neither object ID's (references) nor object methods exist.

# Theoretical evaluation

- Comparison of object-relational and **multimedia text features**

| Query expansion operator | DB2 | Oracle | SQL Server | Informix |
|---|---|---|---|---|
| *Fuzzy term matches* to include words that are spelled similarly to the query term. | • | • | - | • |
| *Taxonomy search* to include more specific or more general terms. | • | •[1] | - | - |
| *Proximity search to* test whether two words are close to each other, i.e. near positions. | • | • | • | • |
| *Related term matches* to expand the query by related terms defined in a thesaurus. | • | • | • | • |
| *Term replacement* to replace a term in a query with a preferred term defined in a thesaurus. Could also be used for synonym searches. | • | • | • | • |

# Theoretical evaluation

- Comparison of object-relational and **multimedia text features**

| Linguistic query expansion operator | DB2 | Oracle | SQL Server | Informix |
|---|---|---|---|---|
| *Stem match* to search for terms that have the same linguistic stem as the query term, e.g. runs->run, running ->run | ● | ● | ● | - |
| *Translation match* to search for translated terms in a different language, defined by a thesaurus. | - | ● | - | - |
| *Soundex match* to find phonetically similar words computed by the soundex algorithm. | ● | ● | ● | - |
| *Text summarization* Automatic summarization of documents based on key words and related sentences/paragraph (pseudo-semantic processing). | - | ● | - | - |
| *Theme search/extraction* Automatic extraction of the text theme that can then be searched for. | - | ● | - | - |
| *Decomposition match* to decompose complex words into their stems. | ● | ●[1] | - | - |

# Theoretical evaluation

- Comparison of object-relational and **multimedia image feat.**
  - Image Processing is discussed in terms of content-based image feature extraction (feature concepts and extraction methods).
  - Example: Oracle ORDImage type definition

| ORDImage Attribute | Data type | Purpose |
|---|---|---|
| source | ORDSource | Source storing data |
| mimetype | VARCHAR2(4000) | Mimetype of stored data e.g. tiff |
| height | INTEGER | Height in pixels |
| width | INTEGER | Width in pixels |
| contentLength | INTEGER | Size in bytes |
| fileFormat | VARCHAR2(4000) | File type e.g. *.tiff |
| contentFormat | VARCHAR2(4000) | Type of image e.g. grayscale |
| compressionFormat | VARCHAR2(4000) | Image compression format e.g. JPEG |

# Feature concepts

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# Extraction methods

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| | Concept level | Feature extraction method | DB2 | Oracle | Discovir |
|---|---|---|---|---|---|
| **Color global** | 1/2 | Global color histogram | • | • | • |
| | 1/2 | Global average color | • | - | • |
| | 2 | Color moment | - | - | • |
| | 2 | Color coherence vector | - | - | • |
| **Color local** | 3 | Local color histogram | - | • | • |
| | 3 | Local average color | • | - | - |
| **Texture global** | 2 | Homogeneity | - | - | • |
| | 2 | Entropy | - | - | • |
| | 2 | Probability | - | - | • |
| | 2 | inverse differential moment | - | - | • |
| | 2 | differential moment | - | - | • |
| | 2 | Contrast | • | - | - |
| | 2 | Edge direction | • | - | - |
| | 2 | Granularity/fineness | • | • | • |
| | 2 | Edge frequency | - | - | • |
| | 2 | Length of primitives/texture | - | - | • |
| **Texture local** | 3 | Locality of texture | - | • | - |
| **Shape global** | 2 | Geometric moment | - | - | • |
| | 2 | Eccentricity | - | - | • |
| | 2 | Invariant moment | - | - | • |
| | 2 | Legendre moment | - | - | • |
| | 2 | Zernike moment | - | - | • |
| | 2 | Edge direction histogram | - | - | • |
| | 2 | Color-based segmentation | - | • | - |
| **Shape local** | 3/4 | Locality of Shape | - | • | • |

# Theoretical evaluation: Conclusion

- (+) Principal multimedia capabilities can be certified to all discussed systems (all systems offer a kind of object-relational extension).
- (+) Standardization effort for multimedia features, the image and text processing support, the triggers, and the object-relational Java interface. In DB2, many parts of the SQL/MM standard are implemented.
- (+) Text processing capabilities of the databases are rather comparable.

- (-) Server 2000 supports only Windows, no support for any programming language except SQL.
- (-) No internal attribute changing methods (contradictory to *OO*).

# Practical Evaluation: Case study

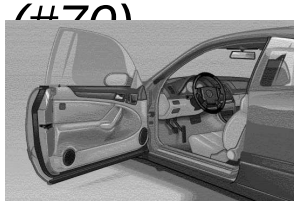
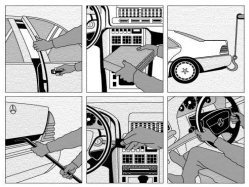
- Discussion of special task-oriented color, texture and shape extraction methods (image feature extraction and image retrieval capabilities).
- Data samples:
  - *DC Media service*:Mercedes-Benz passenger cars
  - *DC internal car image data asset*: entire cars, exhaust pipes, fuel pipes, interior equipment, etc.
  - *Cardetect*: gray-scale exterior car view imagery
  - *Rearcars*: rear car views and motorbikes

# Practical evaluation: Case study

- *DC Media service (#50)*


- *Cardetect (#30)*

- *DC internal car image data (#70)*

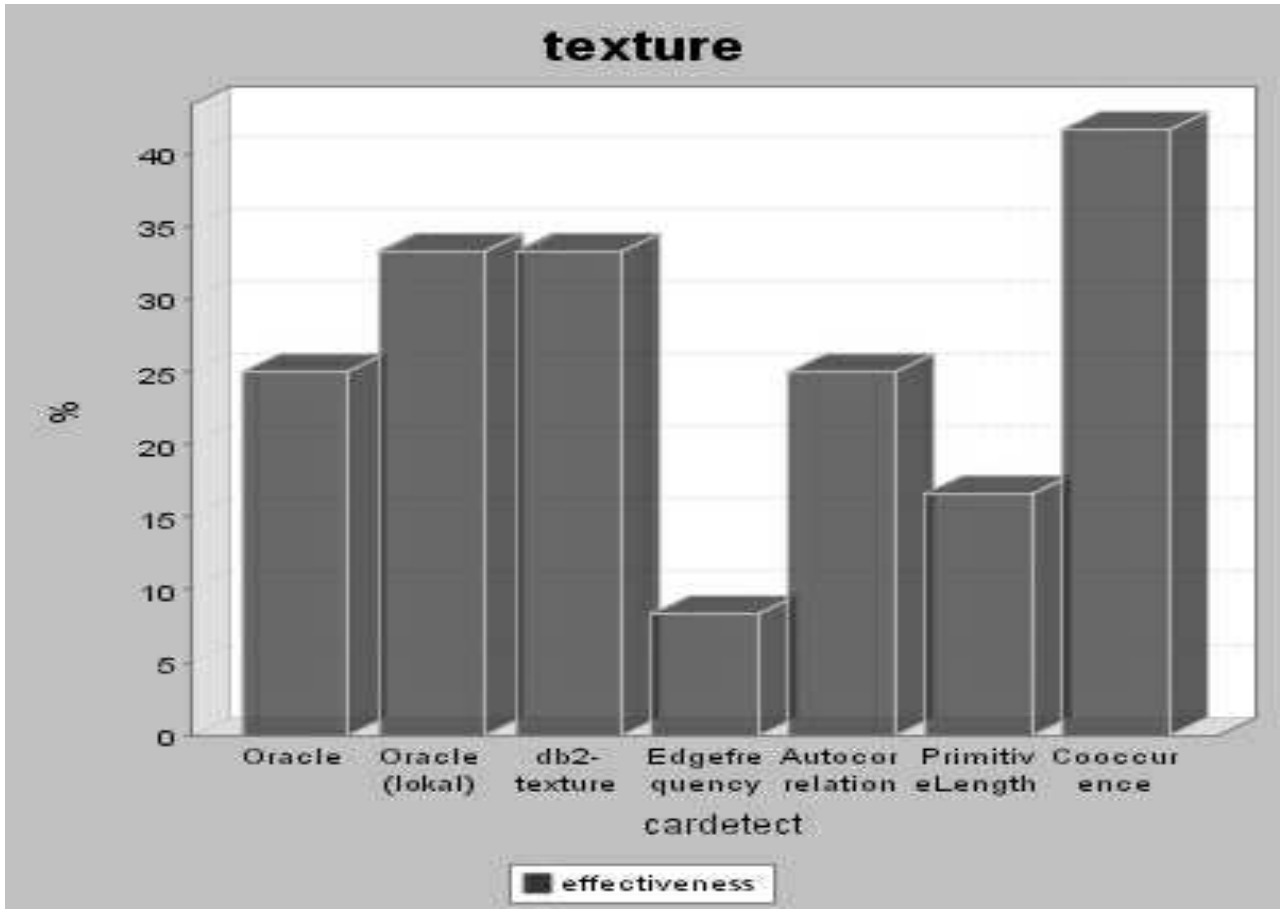



- Rear cars (#400)

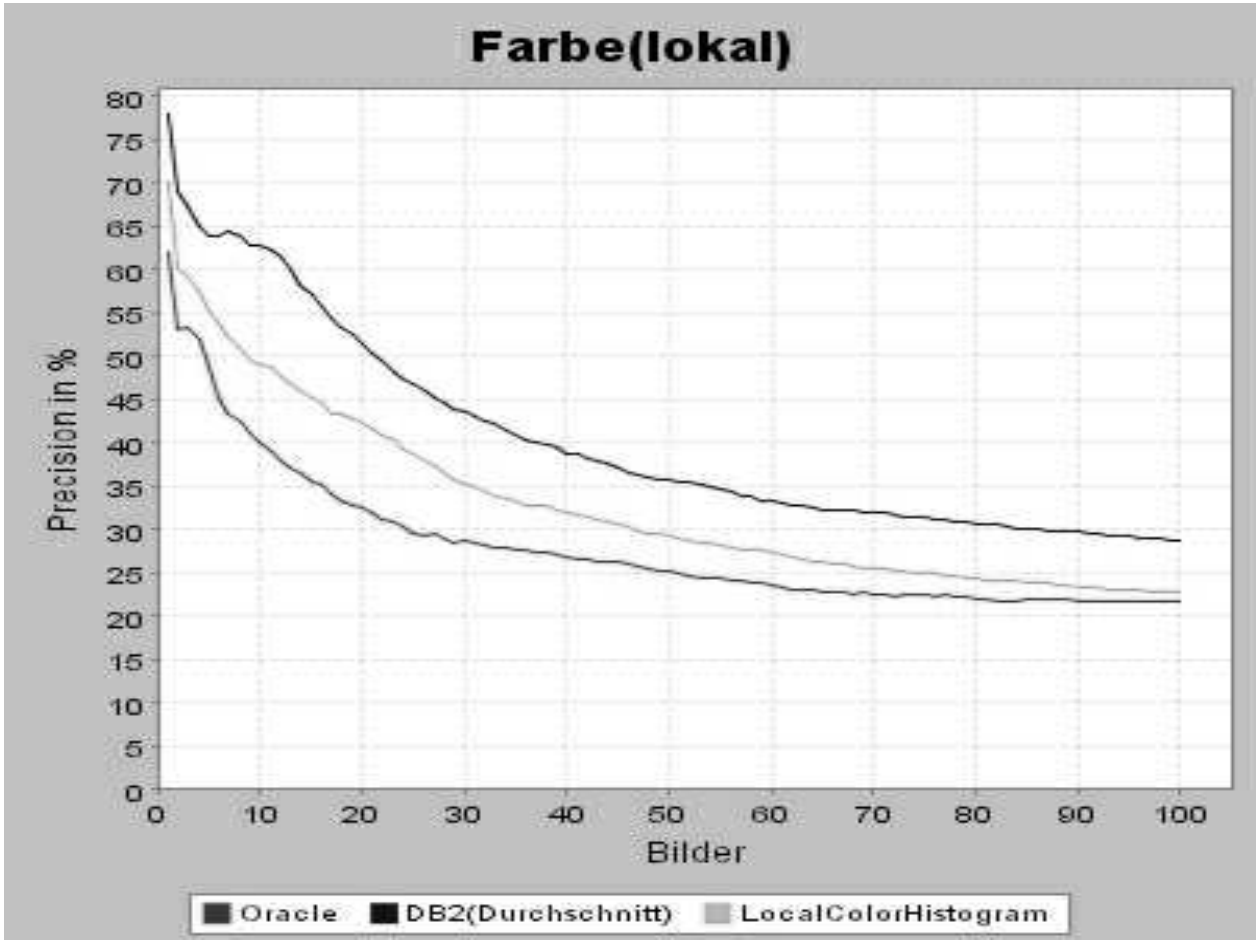

# Practical evaluation: Case study

- Evaluation measures (#8):
  - *Precision:* Precision measures the proportion of documents in the result set that are actually relevant.
  - *Recall:* Recall measures the proportion of all the relevant documents in the collection that are in the result set.
  - *Effectiveness:* This measure takes the relative order of retrieved documents into account.
  - ...

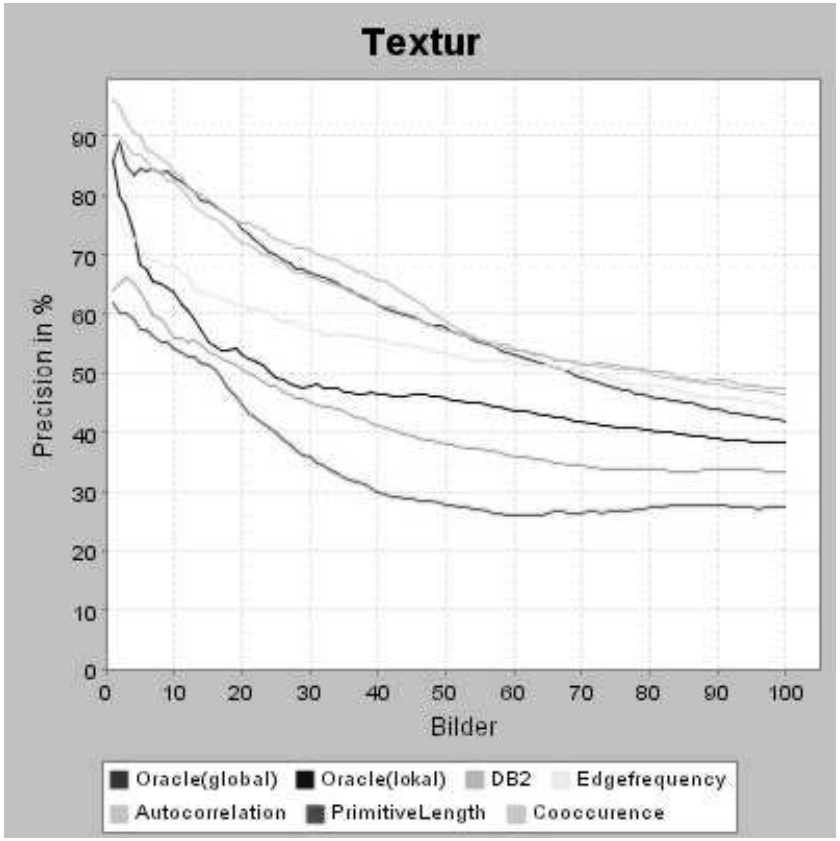
# Practical evaluation: Case study

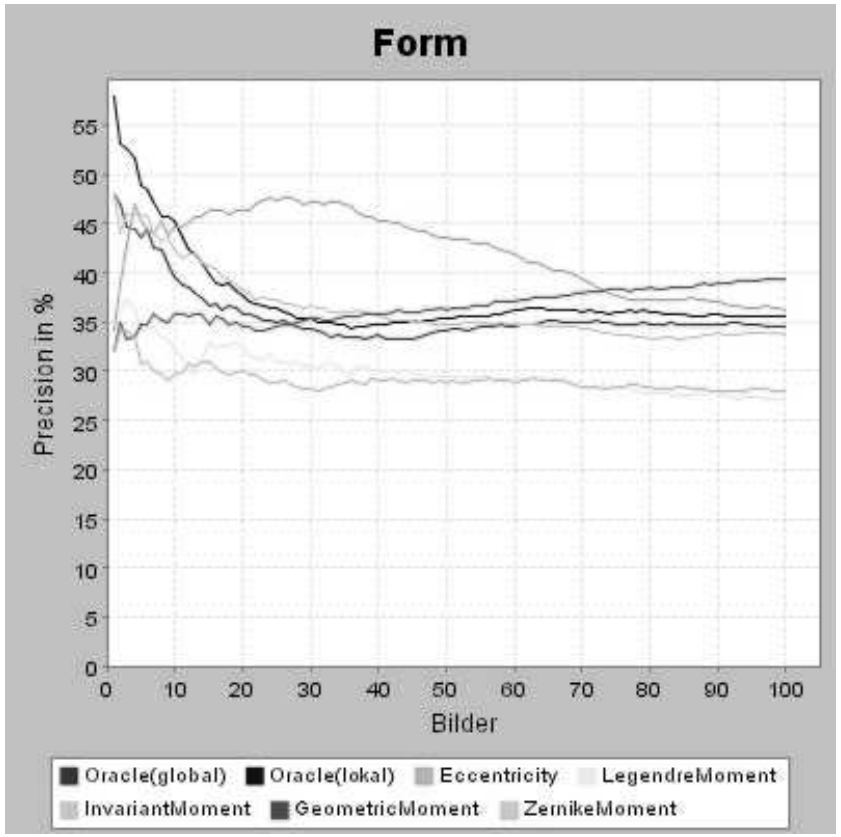


# Practical evaluation: Case study



# Practical evaluation: Case study



# Case study: Conclusion

- Oracle and DB2 image extraction features performed considerable well, whereat the *Discovir* features were always among the best, even better for measures of retrieval effectiveness.
- DB2 *LocalColor* feature performed most robust, in particular for noisy input. On the other hand, Oracle's shape features outperformed all other measures significantly on data without noise.
- Enhance DB2's feature extraction by *Discovir* shape features
- Black box fashion vs. transparent *Discovir* extraction features
  - computational and compositional aspects
  - source code is readable and freely adjustable

# Challenges for MM databases

- Special data types for media types
- **Feature extraction and selection**
  - extractable vs. perceptible vs. interpretable (semantic gap)
- Query system and language
- Similarity search
- Realtime retrieval

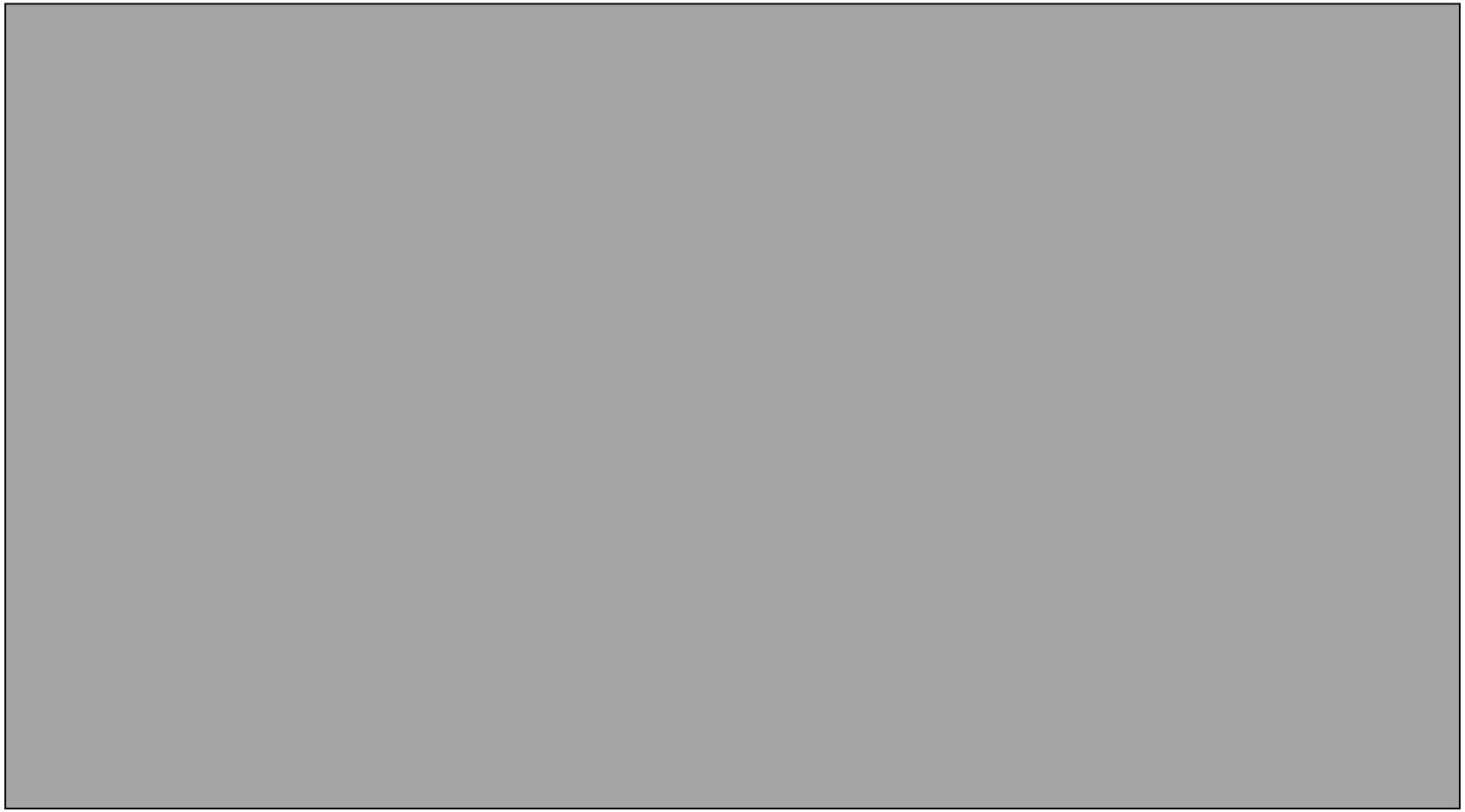
# Potentials of multimedia databases within DCX

- Differentiating advantage to companies not addressed the MM processing domain
  - Participate in standard activities (internal/external research and development)
  - Accommodate DC-specific requirements into new commercial releases
- Qualitative/quantitative benefit
  - Multimedia data analysis, e.g. data quality for pure data, image, text.
  - Central management strategy for different data sources of different media
  - Faster implementation through evaluated test scenarios and vendor tools comparison.

# Proposed DCX architecture

- Exploit commercial MM extensions before developing new
- Database commitments
  - Is it a single media application?
  - Is the user involved in capturing, editing, and manipulating the data?
  - Is the communication one-directional, only for retrieving data?
- Conceptual architecture commitments
  - Assumption: different related media types are stored together
  - rely on efficient storage of multimedia objects in Oracle/DB2
  - Multimedia object containing all types, and XML extracted

# Proposed DCX conceptual architecture



# Outlook

- Multimedia Mining:
  - Improve business processes in all fields where information of different media is relevant.
    - Customer Relationship Management
    - Quality assurance and innovative marketing
    - Competition analysis
    - Knowledge extraction from Internet portals, where **video, audio, text, image** and **speech data** are likewise represented as infinite multimedia source.

# Further Reading Material

- MultimediaDatabases, State-of-the-art report, Daniel Sonntag, RIC/AM, (2004).
- Analyse kommerzieller ORDB-Bild-Retrieval-Systeme, Diplomarbeit, Doreen Pittner, (2004).
- Image Databases, Search and Retrieval of Digital Imagery, edited by Vittorio Castelli and Lawrence D. Bergman (2003)
- Ingo Schmitt, Retrieval in Multimedia-Datenbanksystemen, Institut für Technische und Betriebliche Informationssysteme, Otto-von-Guericke-Universität Magdeburg, to appear (2004).