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Chapter 8 – Data Models for Media Objects

Overview

- Requirements and general approach
  - support for large media objects
  - media object types
  - data and relationship modeling
- (Object-) Relational DBMS
  - LOBs vs. external storage
  - user-defined types and routines
  - SQL/MM
- Object-oriented DBMS

Support for Multimedia Data Types

Main aspects regarding data model support

1. Support for managing large media objects
   - managing large data objects inside DBMS
   - file-based storage of media objects
     - managed by file system or DBMS?
   - only as "infrastructure", not sufficient!
2. Introduction of new data types
   - TEXT, GRAPHICS, IMAGE, SOUND, VIDEO
   - including applicable operations
     - "abstract data type" (ADT)
3. Inclusion in existing data models
   - relational
   - object-relational
   - object-oriented

➥ Usage of existing modeling constructs and query languages

Basic Data Types

integer / real / float
- operations:
  + , – , * , / , ... : integer × integer → integer
  = , ≠ , ≤ , ≥ , ... : integer × integer → boolean

char
- operations:
  conversion to/from integer, output (print), ...

boolean / bit
- operations:
  and, or, ...

i.e., types are defined through supported operations!

Composite Types / Type Constructors

("generic" or "parameterized" types)

- listOf *Typ (min, max)*
  - operations:
    determine length, access elements, concatenate, sublist, …
  - examples:
    byte = listOf boolean (8,8)
    string = listOf char (0,*)
  - canonical continuation of all element-level operations:
    List3 := List1 * List2
    pairwise, element-by-element operation
- setOf *Typ (min, max)*
  - operations :
    element count, for each, union, difference, add/remove element, ...

Text Data Type

- Applicable operations (in Java notation):
  - read access:

```
interface Text {
  public int length ();
  public int alphabet ();
              // 0 == ISO Latin-1, …
  public int alphabetSize ();
  public int language ();
    // 0 == English, 1 == German, …
  public char charAt (int n);
  public byte [ ] getASCII ();
  public byte [ ] getEBCDIC ();
  public String getUnicode ();   … }
```

  - with whitespace, end of line:

```
public byte [ ] word (int wordNo);
public byte [ ] line (int lineNo);
public int wordCount ();
public int lineCount ();
```

  - complete text (e.g., print, display):

```
public boolean print (Printer p);
public boolean display (Window w);
```

  - modification (preserving consistency):

```
public void replaceLine
  (int lineNo, byte [ ] newLine);
public void insertLine
  (int lineNo, byte [ ] newLine);
public void concatenate (Text t2);
```

- General problem: procedure or function?
  - procedure performs updates directly (see above example)
  - function returns new object/value:

```
public Text replaceLine
  (int lineNo, byte [] newLine);
```

Text (2)

- Create:

```
class TextClass implements Text {
  public TextClass (
            int length,
            int charLength,
            int code,  // 0 == ASCII, 1 == EBCDIC, …
            int formatter,  // 0 == none, 1 == PostScript, …
            byte endOfLine,
            byte [ ] characters
  ) { … };
  …
}
```

or in a specific context:

```
  public TextClass (String filename) { … };
```

- Similar model/interfaces for image, audio, video

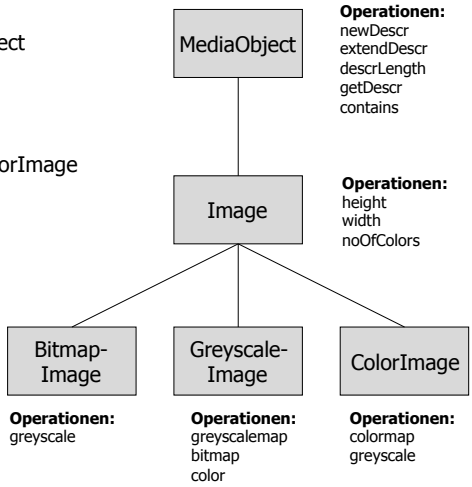
Description Data and Comparisons

- Content description
  - dependent component, constituents of the media object
  - requires additional operations
    - add, extend
    - read length, content
    - content search (over description)
  - Example: Image

```
interface Image {
  …
  public void newDescr (String descr);
  public void extendDescr (String descr);
  public int descrLength ();
  public String getDescr ();
  public boolean contains (String query);
}
```

Generalization

- Building a generalization hierarchy
  - generic operations defined in MediaObject supertype
  - refinement of media object types
- Example: Image
  - specialization as Bitmap, Greyscale, ColorImage
  - operations for conversion
- Additional aspects
  - disjointness, completeness
  - subtype-specific constructors
- Other, application-oriented refinements possible



Object-Relational DBMS

- Major development to extend relational DBMS to introduce object-oriented concepts into the relational data model and query language
- Main concepts
  - support for large objects and external data
  - composite data types (row types, collection types)
  - user-defined data types
    - distinct types: strong typing
    - structured data types for complex, nested data structures
    - type hierarchies with inheritance
    - typed table hierarchies
      - restricted notion of object identity
  - user-defined routines
    - stored procedures, user-defined functions, methods for structured types
    - overloading, overriding, dynamic binding
    - implementation using procedural SQL (PSM) or external programming language
- Standardized: SQL:1999, SQL:2003
- Systems: (University-)Ingres (1984), Postgres, Starburst, Illustra/Informix, DB2, Oracle

Large Object Data Types

- LOBs store strings of up to gigabytes
  - maintained directly in the database
- There are 2 LOB data types
  - BLOB - Binary Large Object
  - CLOB - Character Large Object
- LOB size can be specified at column definition time (in terms of KB, MB, GB)

```
CREATE TABLE Booktable
    (title      VARCHAR(200),
    book_id     INTEGER,
    summary     CLOB(32K),
    book_text   CLOB(20M),
    movie       BLOB(2G))
```

- Internally, LOBs are usually stored in a separate storage space
  - i.e., out-of-line storage
- LOBs may be retrieved, inserted, updated like any other type
  - excluded from some operations
- Functions that support LOBs
  - CONCATENATION string1 || string2
  - SUBSTRING (string FROM start FOR length)
  - LENGTH (expression)
  - POSITION (search-string IN source-string)
  - NULLIF/COALESCE
  - TRIM
  - OVERLAY
  - Cast
  - LIKE predicate

LOBs and Application Programs

- LOBs may be unmanageable in application programs
  - huge amounts of storage may be needed to buffer their values
  - applications may want to deal with LOBS a piece at a time
- LOB locators
  - 4-byte value stored in a host variable that a program can use to refer to a LOB value
    - LOB still resides in the SQL server
    - a locator may be used anywhere a LOB value can be used
  - allows application to work with LOBs a piece at a time
- Example:

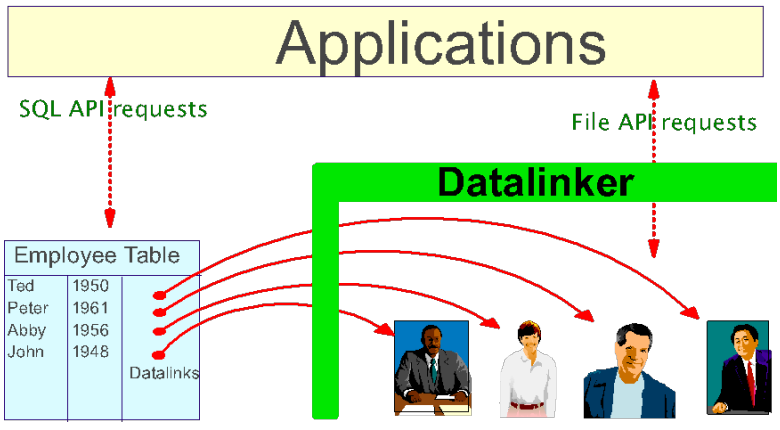
```
EXEC SQL BEGIN DECLARE SECTION;
    SQL TYPE IS BLOB AS LOCATOR
        movie_loc;
EXEC SQL END DECLARE SECTION;

EXEC SQL
      SELECT movie
      INTO :movie_loc
      FROM BOOKTABLE
    WHERE title = 'Moby Dick'
```

Locators on LOB Expressions

- Locators may also represent LOB expressions
  - a LOB expression is any expression that refers to a LOB column or results in a LOB data type
    - may include LOB functions
  - may even reference other locators
- Implementation
  - "smart LOB" support will avoid unnecessary operations/copies on LOBs
  - only store a "recipe" (i.e., script of operations)
  - materialize only if required
    - e.g., :Chapt1Loc is used in UPDATE, INSERT, or retrieved into memory buffer
- Example: *select chaper 1 into locator*

```
SELECT
  SUBSTRING(book_text,
  POSITION('Chapter 1' IN book_text),
  POSITION('Chapter 2' IN book_text)
                -
  POSITION('Chapter 1' IN book_text))
FROM Booktable
INTO :Chapt1Loc
WHERE title = 'Moby Dick';
```


Managing External Data: Datalinks



DataLinks in SQL/MED

- Goal
  - preserve external storage, manipulation of files
  - synchronize integrity control, recovery, and access control of files and associated SQL data
- Concepts
  - datalink is an instance of the DATALINK data type
    - references a file (URL) that is not stored by the SQL server, but maintained by an external file manager
  - datalink options (per column)
    - define the amount of management and control the SQL server has over the datalink values of a column
      - integrity, read/write access, recovery
    - specifies the semantics of link/unlink behavior
  - datalinker
    - implementation-dependent
    - implements a number of mechanisms for guaranteeing datalink properties such as integrity control, recovery, access control

Functions and Operations

- New SQL functions for datalinks
  - constructor: DLVALUE, ...
  - (components of) URLs: DLURLCOMPLETE, …
- SQL statements (examples)
  - insert (“link”)

```
INSERT INTO Movies (Title, Minutes, Movie)
   VALUES ('My Life', 126,
   DLVALUE('http://my.server.de/movies/mylife.avi'))
```

  - select (incl. URL access token)

```
SELECT Title, DLURLCOMPLETE(Movie)
   FROM Movies
   WHERE Title LIKE '%Life%'
```

Data Link Options

- Link control (NO, FILE)
  - NO LINK CONTROL
    - URL-Format of datalink
    - no further control, file is not "linked"
  - FILE LINK CONTROL
    - file is "linked", file has to exist!
    - level of control can be specified using further options
- Integrity control option (ALL, SELECTIVE, NONE)
  - INTEGRITY ALL
    - linked files cannot be deleted or renamed
  - INTEGRITY SELECTIVE
    - linked files can only be deleted or modified using file manager operations, if no datalinker is installed
  - INTEGRITY NONE
    - referenced files can be deleted or modified using file manager operations
      - not compatible with FILE LINK CONTROL

Data Link Options (continued)

- Read permission option (FS, DB)
  - READ PERMISSION FS
    - read access is determined by file manager
  - READ PERMISSION DB
    - read access is controlled by SQL server, based on access privileges to the datalink value
    - involves read access tokens
      - encoded into the URL by the SQL server
      - verified by external file manager/data linker
- Write permission option(FS, ADMIN, BLOCKED)
  - WRITE PERMISSION FS
    - write access controlled by file manager
  - WRITE PERMISSION BLOCKED
    - linked files cannot be modified
  - WRITE PERMISSION ADMIN [NOT] REQUIRING TOKEN FOR UPDATE
    - write access governed by SQL server (and datalinker)
      - requires READ PERMISSION DB
    - involves write access token for modifying file content
      - may have to be presented to the SQL server again

Functions and Operations (continued)

- "Update-in-place"

  SELECT Title, **DLURLCOMPLETEWRITE**(Movie)
  INTO :t, :url ...

  open using URL, modify ...

  UPDATE Movies SET Movie = **DLNEWCOPY**(:url, 1)
  WHERE Title = :t

- DLNEWCOPY
  - indicates to the SQL server that the file content has changed and should be managed appropriately
  - alternative: DLPREVIOUSCOPY – file content may have changed, but the application is not interested in keeping the changes, original file is restored

Data Link Options (continued)

- RECOVERY YES/NO
  - indicates whether SQL server coordinates recovery (jointly with datalinker) or not
- Unlink option (RESTORE, DELETE, NONE)
  - ON UNLINK RESTORE
    - original properties (ownership, permissions) restored as well
  - ON UNLINK DELETE
    - file is deleted when unlinked
  - ON UNLINK NONE
    - ownership and permissions are not restored
- SQL statement (example)
  - "Unlink/Replace"

    UPDATE Movies SET Movie =
    DLVALUE('http://my.newserver.de/mylife.avi')
    WHERE Title = 'My Life'

    RESTORE or DELETE for ".../movies/mylife.avi"

Valid Combinations

Integrity	Read permission	Write permission	Recovery	Unlink
ALL	FS	FS	NO	NONE
ALL	FS	BLOCKED	NO	RESTORE
ALL	FS	BLOCKED	YES	RESTORE
ALL	DB	BLOCKED	NO	RESTORE
ALL	DB	BLOCKED	NO	DELETE
ALL	DB	BLOCKED	YES	RESTORE
ALL	DB	BLOCKED	YES	DELETE
ALL	DB	ADMIN	NO	RESTORE
ALL	DB	ADMIN	NO	DELETE
ALL	DB	ADMIN	YES	RESTORE
ALL	DB	ADMIN	YES	DELETE
SELECTIVE	FS	FS	NO	NONE

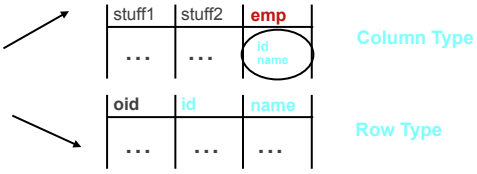
User-defined Types: Key Features

- New functionality
  - Users can indefinitely increase the set of provided types
  - Users can indefinitely increase the set of operations on types and extend SQL to automate complex operations/calculations
- Flexibility
  - Users can specify any semantics and behavior for a new type
- Consistency
  - Strong typing insures that functions are applied on correct types
- Encapsulation
  - Applications do not depend on the internal representation of the type
- Performance
  - Potential to integrate types and functions into the DBMS as "first class citizens"

User-defined Structured Types (ST)

- User-defined, complex data types
  - definition of state (attributes) and behavior
  - can be used as data type wherever predefined data types can be used
    - type of domains or columns in tables
    - attribute type of other structured types
    - type of parameters of functions, methods, and procedures
    - type of SQL variables
  - strong typing
- Structured Types can be used to define typed tables
  - types and functions for rows of tables
    - for modeling entities with relationships & behavior
  - explicit object identifier column to support flavor of "object identity"

```
CREATE TYPE employee AS
(id      INTEGER,
name  VARCHAR (20))
```



Creating and Using Structured Types

- Create structured type:

```
CREATE TYPE address AS (
    street      CHAR (30),
    city        CHAR (20),
    state       CHAR (2),
    zip         INTEGER) NOT FINAL
```

- Create table using type for column:

```
CREATE TABLE properties(
    price       DECIMAL(9,2),
    owner       VARCHAR (50),
    addr        address)
```

- Insert structured values using the NEW operator
  - Invokes (system-supplied or user-defined) constructor function

```
INSERT INTO properties
    VALUES (... , NEW address, ...)
```

- Access attributes using dot-notation

```
SELECT p.addr.street, p.addr.city,
    p.addr.state, p.addr.zip
FROM properties p
WHERE price < 100000
```

- Update attributes

```
UPDATE properties
SET addr.city = 'Los Angeles'
WHERE addr.city = 'LA'
```

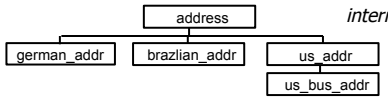
Type Hierarchies and Value Substitutability

- Create type hierarchy:

```
CREATE TYPE german_addr UNDER address
    (family_name VARCHAR(30) ) NOT FINAL
CREATE TYPE brazilian_addr UNDER address
    (neighborhood VARCHAR(30) ) NOT FINAL
CREATE TYPE us_addr UNDER address
    (area_code INTEGER, phone INTEGER) NOT
    FINAL
CREATE TYPE us_bus_addr UNDER us_address
    (bus_area_code INTEGER, bus_phone
    INTEGER) NOT FINAL
```

- Each row can have a column value of a different subtype!

```
INSERT INTO properties (price, owner, location)
    VALUES (100000, 'Mr.S.White', NEW us_addr
    ('1654 Heath Road', 'Heath', 'OH', 45394, ..))
INSERT INTO properties (price, owner, location)
    VALUES (400000, 'Mr.W.Green', NEW
    brazilian_addr ('245 Cons. Xavier da Costa',
    'Rio de Janeiro', ..., 'Copacabana') )
INSERT INTO properties (price, owner, location)
    VALUES (150000, 'Mrs.D.Black', NEW
    german_addr ('305 Kurt-Schumacher
    Strasse', 'Kaiserslautern', 'Schwarz') )
```



internal type tags

price	owner	location
100000	Mr.S.White	<us_addr> '1654 Heath Road', ...
400000	Mr.W.Green	<brazilian_addr> '245 Cons. Xavier ...
150000	Mrs.D.Black	<german_addr> '305 Kurt-Schumacher ...

Routines: Procedures, Functions and Methods

- Procedure

```
CREATE PROCEDURE getPropertiesCloseTo
      (IN     addr      VARCHAR(50),
       IN     distance  INTEGER,
       OUT    results   INTEGER) ...
```

  - invoked exclusively using the SQL CALL statement

```
CALL getPropertiesCloseTo ('1234 Cherry
Lane ...', 50, :number);
```

  - may return additional results in form of result sets

- Functions

```
CREATE FUNCTION distance
    (loc1 address, loc2 address)
    RETURNS INTEGER ...;
```

  - invoked in an expressions within other SQL statements (e.g., a SELECT or UPDATE statement) using function invocation syntax

```
SELECT price, addr, distance(addr, NEW
address('1234 Cherry Lane', ...)) AS dist
FROM properties
ORDER BY dist
```

- Methods
  - are regarded as a "special kind of function", associated with structured types

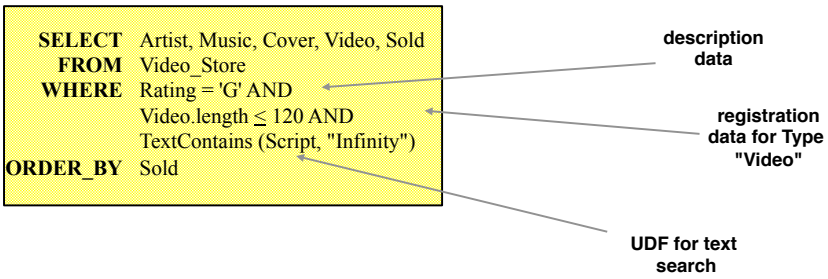
```
CREATE TYPE address AS (
    street      CHAR (30),
    city        CHAR (20),
    state       CHAR (2),
    zip         INTEGER)
    METHOD longitude()
        RETURNS DECIMAL(5, 2)
    METHOD latitude() RETURNS DECIMAL(5, 2)
    ... ;
CREATE METHOD longitude () FOR address
    BEGIN ... END;
CREATE METHOD latitude () FOR address
    BEGIN ... END;
```

  - invocation similar to function, but using method invocation syntax

```
SELECT price, addr, addr.longitude(),
addr.latitude()
FROM properties
```

Combined Search Using UDTs/UDFs

- User-defined types can be for representing media object types
  - user-defined functions or methods for content search predicates
- Query may range over "traditional" and multimedia data at the same time



Methods That Modify Object State

- In OO-programming
  - a method that wants to modify the state of its object simply assigns new values to an attribute
  - changes are reflected in the identical object
- In SQL
  - value-based operations
    - expressions (including method invocations) always return (copies of) values
    - persistent data can only be updated by the respective DML operations (e.g., UPDATE), assigning the results of expressions to the columns to be modified
  - a method will always operate on a copy of a complex value (i.e., instance of a structured type)
    - modification of state as a pure side-effect of a method is not possible
  - modifying the object state will require an UPDATE statement
    - method returns a modified copy of the original complex value
    - separate UPDATE replaces old value with the new copy

SQL Collection Types

- Two kinds of collection types
  - Array (with optional maximum length)
  - Multiset
- Collections are typed
  - all elements are instances of the specified element type
  - any element type admissible (including user-defined types and collection types)
- Construction of collections
  - by enumeration
  - by query
- UNNESTing of collections to access elements
- Manipulation of collections
  - general: cardinality
  - arrays: element access, concatenation
  - multisets: turn singleton into element, turn into set (eliminate duplicates), multi-set union, intersection, difference
- Multiset predicates (member, submultiset, is a set)
- Collections can be compared, assigned, cast

Working with Collection Types and Values

- Example (for multisets):

```
CREATE TABLE properties ( …,
   owners VARCHAR(50) MULTISET, …)
```

- Constructing multisets
  - by enumeration
  - by query

```
UPDATE properties
SET owners = MULTISET
      (SELECT name
       FROM people WHERE …)
WHERE …
```

- Using multisets as table references (UNNEST)

```
SELECT p.price, p.addr.print(), o.name
FROM properties p,
       UNNEST(p.owners) AS o(name)
WHERE o.name LIKE %Schmidt%
```

SQL/MM – an SQL-Standard for Media Objects

- Media objects and operations are used in many applications
- ORDBMS extensibility concepts can be used to define media object types
- Extensions can be provided in "packages"
  - easier management (installation, upgrade, removal) and reuse (package can use another package)
- Proprietary packages offered for numerous ORDBMS products
  - Informix: Excalibur Text Search DataBlade, Excalibur Image DataBlade, Informix Video Foundation Data-Blade Module
  - DB2: Image Extender, Audio Extender, Video Extender, Text Extender
  - Oracle: Visual Information Retrieval (VIR) Cartridge, ConText Cartridge, InterMedia
- Standardization, based on SQL:1999, SQL:2003:
  - common "language"
  - portability of applications
  - data exchange

SQL/MM Overview

- Refers to SQL-Standard, but stand-alone
  - SQL: ISO/IEC 9075, SQL/MM: ISO/IEC 13249
  - full name: *SQL Multimedia and Application Packages*
- Consists of multiple parts
  - Part 1: SQL/MM **Framework** (2000)
  - Part 2: SQL/MM **Full Text** (2000)
  - Part 3: SQL/MM **Spatial** (2000)
  - Part 5: SQL/MM **Still Image** (2001)
  - …
- Part 1 provides overview, conformance details
- Every other part
  - represents a "package" for specific type of media data
  - contains UDTs, methods, functions based on SQL:1999

SQL/MM Full Text

- Version as of December 2001
- specifies
  - UDT **FullText** for text data and
  - UDT **FT_Pattern** for search patterns
- FullText:
  - four search methods
    - two method pairs, each pair differing only regarding search parameter type: character string or pattern if type FT_Pattern (Overloading)
    - Contains methods: boolean search ⇒ result: true/falsen
    - Rank methods: ranking ⇒ result: implementation-defined value of type REAL
  - two constructors
    - character string
    - character string, language
  - function FullText_to_Character two produce character string from FullText value
- Language can be defined for FullText and some of the search patterns
  - used for language-specific processing during text preprocessing (see chapter 3)

UDT Definitions

```
create type FullText as (
    Contents character
    varying(FT_MaxTextLength),
    Language character
    varying(FT_MaxLanguageLength),
    ...
    )
method Contains (pattern FT_Pattern) returns
    integer
method Contains (
    pattern character
    varying(FT_MaxPatternLength)
    ) returns integer
method Rank (pattern FT_Pattern)
    returns double precision
method Rank ...
```

```
method FullText (
    String character
    varying(FT_MaxTextLength)
    ) returns FullText
method FullText (
    String ... ,
    Language character
    varying(FT_MaxLanguageLength)
    ) returns FullText;
create cast (FullText as
    character varying(FT_MaxTextLength)
    with FullText_to_Character);
create type FT_Pattern as
    character varying(FT_MaxPatternLength);
```

- FT_Pattern values have to comply with BNF of pattern language
- Search semantics "constrained" by a set of rules

Search Patterns for Contains and Rank

- Text example
  aText: "This paragraph introduces the SQL/MM standard. This standard defines types and routines for media objects."
- Single word

```
aText.Contains (' "paragraph" ') = 1
```

- Sets of words
  - wildcards

```
aText.Contains (' "media_" ') = 0
```

  - thesaurus-based extension

```
aText.Contains ('
   thesaurus "CompSci"
   expand synonym term of "norm"
') = 1
```


Search Patterns for Contains and Rank (2)

- Context pattern

```
aText.Contains ('
   ("paragraph") near "standard" within 0 sentences in order
') = 1
```

- Concept pattern

```
aText.Contains ('
   is about "International Standard for Fulltext Search"
') = 1
```

- Single phrase, combination of word/phrase search, arbitrary patterns using boolean operators (|, &, NOT)
- Example query:

```
select * from myDocs
  where Doc.Rank(' "standard" ') > 0.8
```

SQL/MM Spatial

- Version as of December 2001 (581 pages)
- Corresponds to graphics media type
- Specifies UDTs for
  - 2D data (point, line, polygon)
  - collections thereof
- Defines routines
  - manipulation, search, comparison of spatial data
  - conversion among UDTs and character/binary representations
- Geometry objects (ST_Geometry) are associated with **SRIDs** (spatial reference system identifiers) that identify a spatial reference system
  - based on well-known reference systems
    - geographic coordinate system (long/lat)
    - projection coordinate systems: X, Y
    - geo-centric coordinate system: X, Y, Z

SQL/MM Spatial: Types

- 0-dim: ST_Point
- 1-dim: ST_Curve
  - subtypes differ in the interpolation between element points
  - **ST_LineString**: linear interpolation
  - **ST_CircularString**: circular interpolation
  - **ST_CompoundString**: mix of both
- 2-dim: ST_Surface
  - **ST_CurvePolygon**: 1 external + n internal ST_Compound-String boundaries
  - **ST_Polygon**: only ST_LineString boundary
- collection objects
  - same reference system for all elements
  - **ST_MultiPoint**
  - **ST_MultiCurve, ST_MultiLineString**
  - **ST_MultiSurface, ST_MultiPolygon**

SQL/MM Spatial Methods

- ST_Geometry methods:
  - intersection (sets of points), difference, union
  - distance
  - tests (contains, overlaps, touches, crosses, …)
  - determine reference system
- additional methods on subtypes
  - ST_Curve: length
  - ST_Surface: area, perimeter

SQL/MM Still Image

- Version as of December 2001
- Specifies
  - UDT **SI_StillImage** for image data,
  - UDT **SI_Feature** for image features
  - UDT **SI_FeatureList** for lists of features
- SI_StillImage:
  - internal representation is revealed (⇨ no format independence)
  - two constructors (BLOB, BLOB + format)
  - two mutator (modification) methods: BLOB replacement + forma change
  - two observer (read) methods for generating thumbnail images

SQL/MM Still Image: UDT SI_StillImage

```
create type SI_StillImage as (
    SI_content binary large
    object(SI_MaxContLength),
    SI_contentLength integer,
    SI_format character varying(8),
    SI_height integer,
    SI_width integer,
    ...
    )
```

- SI_content:
  - also contains registration data (header fields, color map, etc.)
  - "container" for the complete image
- SI_format:
  - built-in formats (DBS can read and change format, extract properties and features)
  - user-defined formats

```
method SI_StillImage (
    content binary large
    object(SI_MaxContLength)
    ) returns SI_StillImage
method SI_StillImage (
    content binary large
    object(SI_MaxContLength),
    format character varying(...)
    ) returns SI_StillImage
method SI_setContent (
    content binary large
    object(SI_MaxContLength)
    ) returns SI_StillImage
method SI_changeFormat (
    targetFormat character varying( ... )
    ) returns SI_StillImage
```


SQL/MM Still Image: Features

- Types SI_Feature has the following subtypes (also see chapter 4):
  - **SI_AverageColor**: single color for complete image
  - **SI_ColorHistogram**: percentages for groups of colors
  - **SI_PositionalColor**: grid segments with average segment color
  - **SI_Texture**: texture information
- Features have a methods SI_Score for
  - computing the distance of an image to the feature, and
  - returning a REAL value in the range 0 to 1
- Subtypes of SI_Feature have functions for performing feature extraction
- Instances of SI_AverageColor and SI_ColorHistogram can also be constructed explicitly using literal values

SQL/MM Still Image: UDTs for Features

```
create type SI_Feature
    method SI_Score (image SI_StillImage)
    returns double precision
create type SI_AverageColor under SI_Feature
    as (SI_AverageColorSpec SI_Color)
    method SI_AverageColor (
            RedValue integer,
            GreenValue integer,
            BlueValue integer
    ) returns SI_AverageColor
create function SI_AverageColor (image
    SI_StillImage) returns SI_AverageColor
```

- List of feature-value-pairs
  - SI_Score returns weighted average:

```
self.SI_Features[1].SI_Score(img) * self.SI_Weights[1]
+ self.SI_Features[2].SI_Score(img) * self.SI_Weights[2]
+ ...
/ (self.SI_Weights[1] + self.SI_Weights[2] + ... )
```

```
create type SI_FeatureList as (
    SI_Features SI_Feature
            array[SI_MaxFeatureNumber],
    SI_Weights double precision
            array[SI_MaxFeatureNumber])
method SI_FeatureList (firstFeature SI_Feature,
    weight double precision)
    returns SI_FeatureList
method SI_Append (feature SI_Feature,
    weight double precision)
    returns SI_FeatureList
```

- Example:

```
select * from Logos
where
  SI_FeatureList (
    SI_Texture (SI_StillImage(:bspLogo)), 0.8).
        SI_Append (
    SI_ColorHistogram
            (SI_StillImage(:bspLogo)), 0.2).
  SI_Score (Logo) > 0.7
```


SQL/MM – Closing Remarks

- Three parts standardized: FullText, Spatial, Still Image
  - no ongoing standardization work for video, audio
- Some inconsistencies (*Rank* for FullText, *Score* for StillImage)
- No full generalization pursued
  - MM_Object type with media object subtypes?
- Questions
  - are vendors implementing the standard?
  - how big are the differences compared to existing vendor packages?

Object-Relational Schema

- Text, Image, …are possible atomic domains, i.e. attributes can be of type Text, Image, …
- Example:
  - Employee (EmpNo integer, … , Photo image , Fingerprint image)
  - Inmate (I-Nr integer, … , Front image, Side image)
  - Car (Make varchar(50), Year integer, … , Photo image, EngineSound audio)
- 1:1-relationship, attribute relationship

1:N Relationship Involving Media Objects

- Alternative 1: based on foreign key
  - use separate relation (1NF) for variable number of texts, images, etc. per entity

```
Patient (Name       varchar(100),
         … ,
         Picture    image)
XRay (PName         varchar(100),
      Date          date,
      Position      varchar(30),
      BodyPart      varchar(40),
      Picture       image)
```

  - PName is a primary key component, i.e., XRays only for known patients
- Access:
  - to retrieve patient data with patient x-rays: requires join operation
- Alternative 2: using collection types, structured types

```
Patient (Name varchar(100),
         … ,
         Picture  image
         XRays    XRay MULTISET)
CREATE TYPE XRay
        (Date        date,
         Position    varchar(30),
         BodyPart    varchar(40),
         Picture     image)
```

  - Again, XRays without a patient cannot exist
- Access:
  - to work with individual images: requires UNNEST

N:M-Relationships

- Example: picture may show more than one entity: relatione for images, relationship

```
Horse            (Name          varchar(50),
                  Age           integer)
RacePhoto        (Archivenr     integer,
                  Date          date,
                  Location      varchar(80),
                  Picture       image)
Is_depicted_on   (Horsename     varchar(50),
                  Archivenr     integer,
                  Position      varchar(10))
```

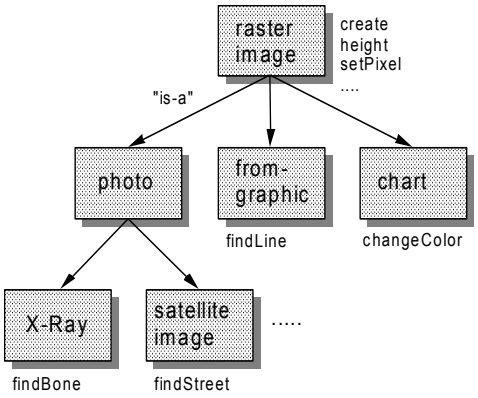
  - Photos are separate entities, i.e., they can be stored without an association to a subject (here: horses)
- Access:
  - two (usually expensive) join operations
- Alternative approach for binary relationships: use collection types
  - e.g., multiset of archive numbers, multiset of horses

Summary for Object-Relational DBMS

- LOBs vs. file-based storage (datalinks)
  - management of large amounts of (raw) data
    - datalinks preserve file-based access, but allow gradual control/management by DBMS
  - no media object type semantics, operations
- User-defined, structured types
  - important concept for defining media object types (structure and behavior)
  - enablement for SQL/MM standardized types
- Relationships
  - different types of relationships (1 : 1, 1 : N, N : M) between MM objects and entities can be represented
  - Media objects can be represented as attributes or entities
    - may be complicated if different types of entities are involved (ship, car, airplane, …) may require multiple relationship tables
- Advantages
  - stable, proven environment
    - smooth learning curve, upward compatibility

Object-oriented DBMS Extensions

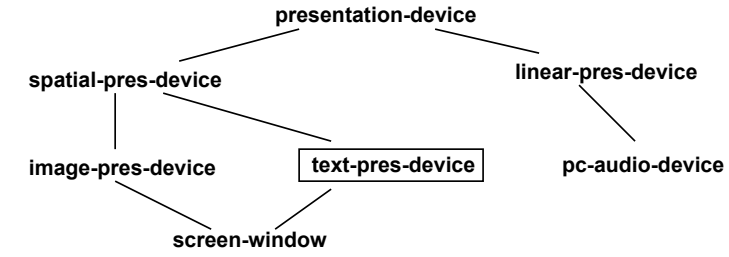
- MM data objects are instances of classes
- Class hierarchy and inheritance
  - simplified data modeling
  - more integrity control
  - inheritance, specialization, overriding
- Applications
  - may pursue definition of subclasses (extensibility)
  - "benefit" from MM methods available in the MM classes



Example: ORION

- Overview:
  - MCC (Austin, Texas)
  - since 1985: development of a Multimedia-DBMS
  - early decision for fully object-oriented architecture
  - prototype implementation in Common LISP on Symbolics and SUN, commercial product (ITASCA), but little traction
- Multimedia Information Manager (MIM)
  - packages of classes and methods ("class library" under ORION)
  - extensible: developers can provide subclasses for special formats
- Unique approach:
  - even devices (I/O, storage) modeled as objects

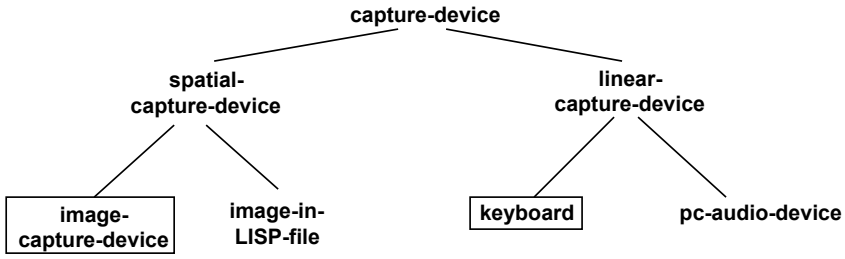
Output Devices



Note: framed classes are not part of the MIM product, but represent possible user extensions

- Instances of classes in the hierarchy also describe
  - presentation position on the device (e.g., position on screen)
  - which part of the MM object is presented
- There may be multiple instances representing the same physical device
  - "presentation formats" for media objects

Input Devices

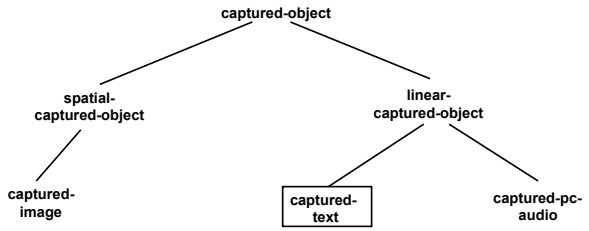


- Instances are again more than specific devices:
  - which part of the MM object is captures
  - device configuration

Input and Output Devices – More Details

- spatial-pres-device
  - attributes: **upper-left-x**, **upper-left-y**, **width**, **height**
  - (section of MM object)
- screen-window (subclass of spatial-pres-device)
  - attributes: **win-upper-left-x**, **win-upper-left-y**, **win-width**, **win-height**
  - (area on the screen)
  - methods: **present**, **capture**, **persistent-pres**
- spatial-capture-device
  - attributes: **upper-left-x**, **upper-left-y**, **width**, **height**
- image-capture-device (subclass of spatial-capture-device)
  - attributes: **cam-width**, **cam-height**, **bits-per-pixel**
  - methods: **capture**

Stored Objects



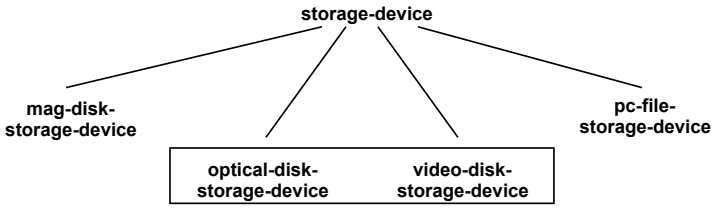
- Attributes of captured-object:

storage-object:	refers to instance of class *storage-device*
logical-measure:	elementary unit for raw data from user perspective, e.g., seconds for audio, frame for video
phys-logic-ratio:	bytes per second, etc.

- Attributes of spatial-captured-object:
  - width
  - height
  - row-major: row/column storage
  - bits-per-pixel

  (registration data)

Storage Devices



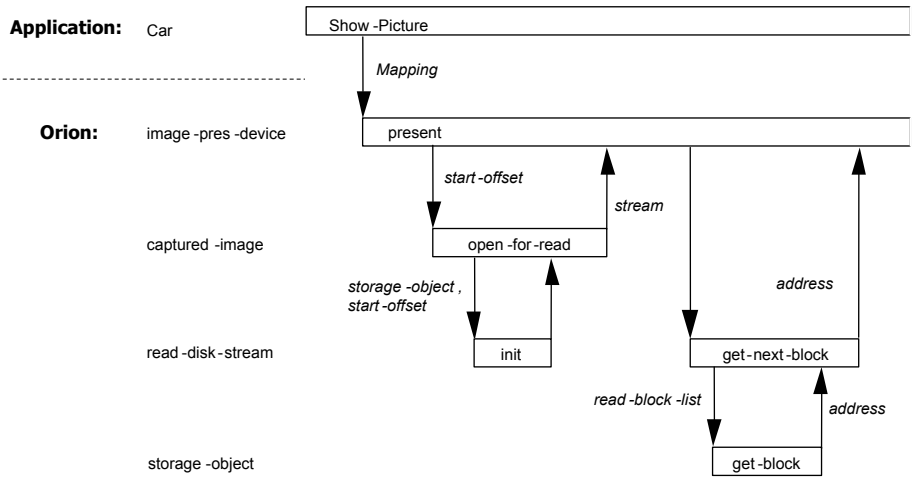
- Decribe only storage aspects used by MM objects
- Attributes of mag-disk-storage-device:
  - **block-list:** block number of all physical blocks occupied by MM objects
  - **allocated-block-list:** blocks actually allocated (see versions)
  - **min-object-size-in-disk-pages:** number of blocks to be added when MM object has to grow
  - **seg-id:** disc segment hosting new blocks

Input/Output Streams

- Instances represent a read or write operation
  - generated dynamically
- Attribute of disk-stream:
  - **storage-object:** references an instance of **storage-device**
- Attribute of read-disk-stream:
  - **read-block-list:** cursor; next block to read for the MM objects

(similar for write-disk-stream)

Details of Output Operation (Example)



Summary for Object-Oriented DBMS

- Complete proposal for a MMDBS
- Application developer extends system by adding new subclasses
- Open questions:
  - Is the class hierarchy adequate? Methods?
    - e.g., classification of MM objects as 1D (linear) and 2D (spatial)
    - why not visual vs. acoustic
    - or time-dependent vs. static?
  - many alternatives:
    - device x : show image Y
    - image y : present on device X
    - evaluation criteria?
  - Is differentiation of magnetic vs. optical disc required?
    - more abstract: random access memory, sequential storage, write-once-storage, …
  - Search?