MINISTÉRIO DA CIÊNCIA E TECNOLOGIA
INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

Oracle Spatial – Geometry and GeoRaster

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CAP 349 – Bancos de Dados Geográficos (07/08/2013)

Disponível em: http://wiki.dpi.inpe.br/doku.php?id=cap349

Oracle Spatial

- Oracle Spatial is an integrated set of functions and procedures that enables spatial data (vector and raster) to be stored, accessed, and analyzed in an Oracle database.
- Comercial system
- Current version: 11g
- http://www.oracle.com/index.html

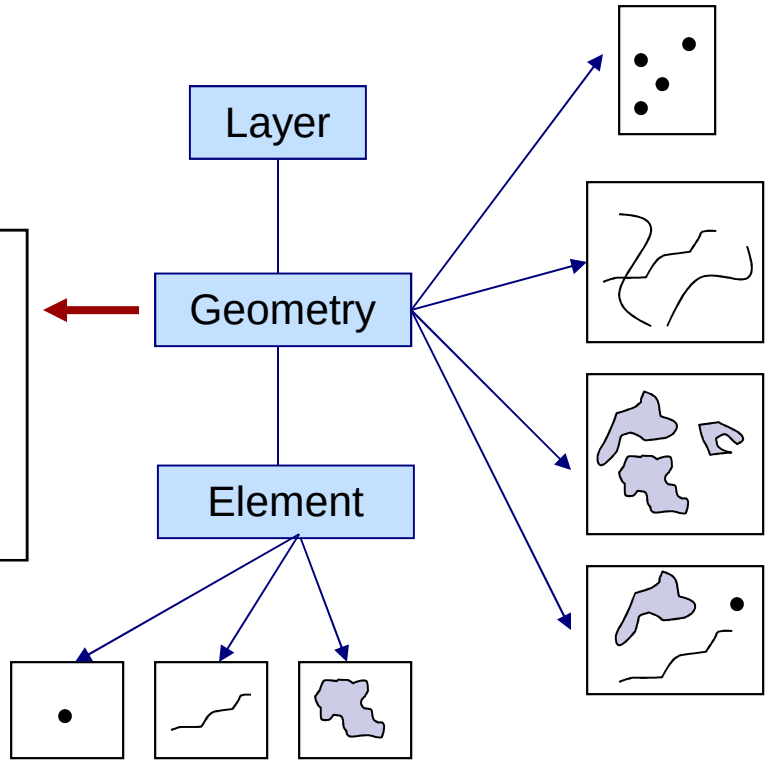
Oracle Spatial provides

- A schema (MDSYS) that prescribes the storage, syntax, and semantics of geometric and raster data types
- A spatial indexing mechanism
- Operators, functions, and procedures for performing area-of-interest queries, spatial join queries, and other spatial analysis operations
- Topology data model for working with data about nodes, edges, and faces in a topology
- Network data model for representing capabilities or objects that are modeled as nodes and links in a network
- GeoRaster, a feature that lets you store, index, query, analyze, and deliver GeoRaster data, that is, raster image and gridded data and its associated metadata

Oracle Spatial – Vector Data

- Tipos de dados geométricos.
- Operadores e funções espaciais.
- Métodos de Acesso Espacial:
  - R-Tree e QuadTree

```
CREATE TYPE SDO_GEOMETRY AS OBJECT (
SDO_GTYPE          NUMBER,
SDO_SRID           NUMBER,
SDO_POINT          SDO_POINT_TYPE,
SDO_ELEM_INFO      SDO_ELEM_INFO_ARRAY,
SDO_ORDINATES      SDO_ORDINATE_ARRAY);
```



Oracle Spatial – SDO_GEOMETRY

- Criação de tabelas com tipos de dados espaciais:

```
CREATE TABLE distritossp
( cod              NUMBER(32),
  sigla            VARCHAR(10),
  denominacao      VARCHAR(50),
  spatial_data     MDSYS.SDO_GEOMETRY
  PRIMARY KEY (cod)
);
```

Oracle Spatial – Metadata Tables

MDSYS.CS_SRS

SC_NAME	VARCHAR2(68)
SRID	NUMBER(38)
AUTH_SRID	NUMBER(38)
AUTH_NAME	VARCHAR2(256)
WKTEXT	VARCHAR2(2046)
SC_BOUDS	SDO_GEOMETRY

USER_SDO_GEOM_METADATA

TABLE_NAME	VARCHAR2(32)
COLUMN_NAME	VARCHAR2(32)
DIMINFO	SDO_DIM_ARRAY
SRID	NUMBER

USER_SDO_INDEX_INFO

SDO_INDEX_OWNER	VARCHAR2(32)
INDEX_NAME	VARCHAR2(32)
TABLE_NAME	VARCHAR2(32)
COLUMN_NAME	VARCHAR2(32)
SDO_INDEX_TYPE	VARCHAR2(32)
SDO_INDEX_TABLE	VARCHAR2(32)
SDO_INDEX_STATUS	VARCHAR2(32)

Oracle Spatial – Examples

- Inserindo dados em tabelas com tipos de dados espaciais:

```
INSERT INTO distritossp (cod, sigla,
denominacao, spatial_data)
VALUES (1, 'VMR', 'VILA MARIA'
MDSYS.SDO_GEOMETRY(2003, NULL, NULL,
MDSYS.SDO_ELEM_INFO_ARRAY( 1, 1003, 1 ),
MDSYS.SDO_ORDINATE_ARRAY(6,10, 10,1, 14,10,
10,14, 6,10)))
```

Oracle Spatial – Examples

- Indexando uma coluna espacial (R-Tree):

```
CREATE INDEX distritossp_IDX
ON distritossp(SPATIAL_DATA)
INDEXTYPE IS MDSYS.SPATIAL_INDEX
```

- Funções para trabalhar com os índices:

```
SDO_TUNE.QUALITY_DEGRADATION
ALTER INDEX REBUILD
```

Oracle Spatial – Spatial Query

- Operadores:
  - Usados na cláusula WHERE de uma consulta SQL
  - Utilizam indexação espacial

Operadores	Descrição
`SDO_FILTER`	Implementa o primeiro filtro do modelo de consulta (baseado nos MBR)
`SDO_RELATE (SDO_TOUCH, SDO_ON, SDO_INSIDE)`	Avalia se as geometrias possuem uma determinada relação topológica
`SDO_WITHIN_DISTANCE`	Verifica se duas geometrias estão dentro de uma determinada distância.
`SDO_NN`	Identifica os n vizinhos mais próximos de uma geometria

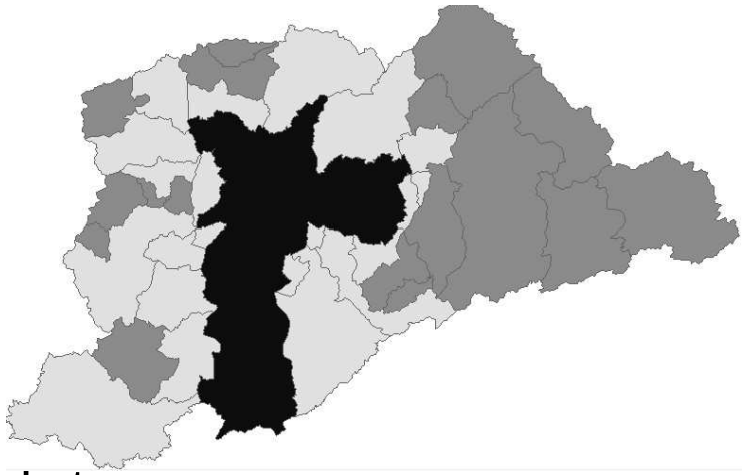
Oracle Spatial – Spatial Query

- Funções:
  - Definidas como subprogramas PL/SQL
  - Usados na cláusula WHERE ou em SUBCONSULTAS
  - Podem ser utilizadas sobre colunas espaciais não indexadas

Funções	Descrição
`SDO_INTERSECTION, SDO_UNION SDO_DIFFERENCE, SDO_XOR`	Operações de conjunto
`SDO_BUFFER, SDO_CENTROID, SDO_CONVEXHULL`	Operações que geram novas geometrias
`SDO_AREA, SDO_ LENGTH, SDO_DISTANCE`	Operações métricas

Oracle Spatial – Examples

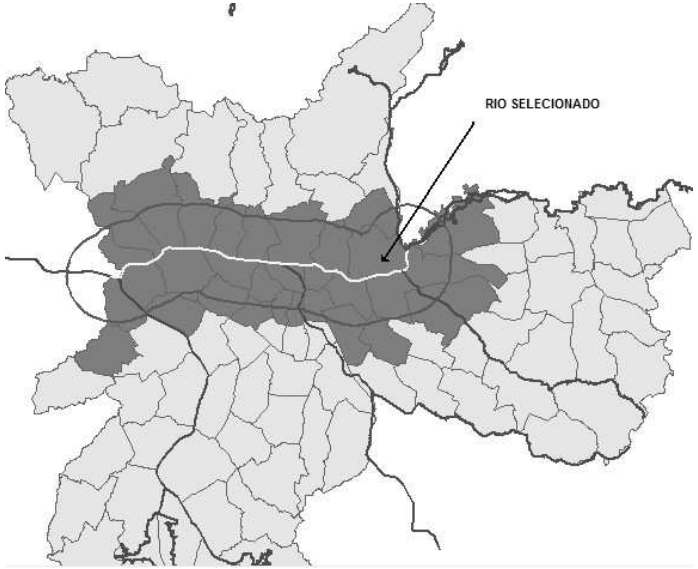
- “Recuperar o nome de todos os municípios da grande São Paulo que são vizinhos ao município de São Paulo”.



```
SELECT d2.nomemunicp
FROM  grande_sp d1,
       grande_sp d2
WHERE SDO_TOUCH (d1.spatial_data,
                 d2.spatial_data) = 'TRUE'
AND (d2.nomemunicp <> 'SAO PAULO')
AND (d1.nomemunicp = 'SAO PAULO')
```

Oracle Spatial – Examples

- “Recuperar todos os distritos que estão num raio de 3Km de um determinado rio”

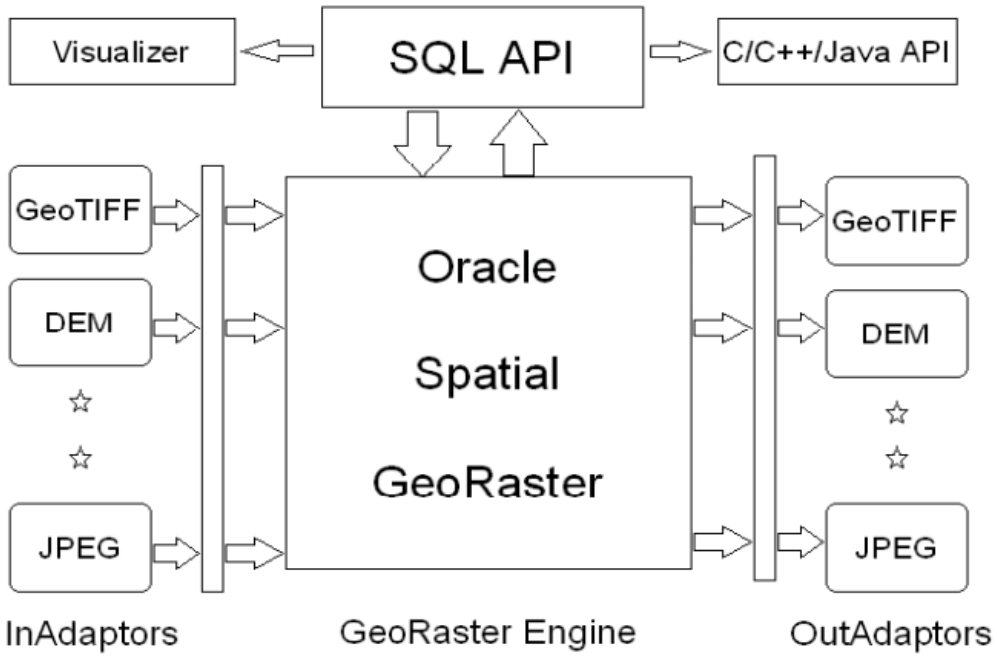



```
SELECT di.deno
FROM   sp_distritos di,
       sp_drenagem dr,
       user_sdo_geom_metadata m,
WHERE
   SDO_RELATE (di.spatial_data,
   SDO_BUFFER (dr.spatial_data, m.diminfo, 3000),
   'mask=INSIDE+TOUCH+OVERLAPBDYINTERSECT') = 'TRUE'
AND m.table_name = 'sp_drenagem'
AND m.column_name = 'spatial_data'
AND dr.object_id = '59';
```

Oracle Spatial – Raster Data

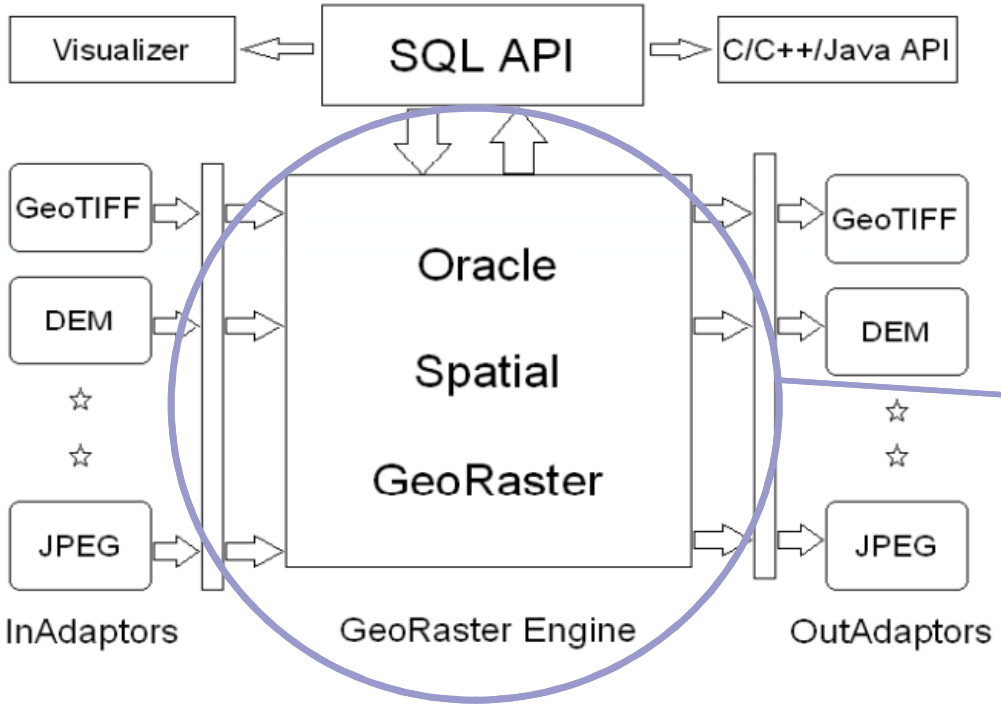
- GeoRaster is a feature of Oracle Spatial that lets you store, index, query, analyze, and deliver raster data and its associated metadata.

Oracle GeoRaster – Architecture



Five components to support the storage and use of raster data in Oracle Database:

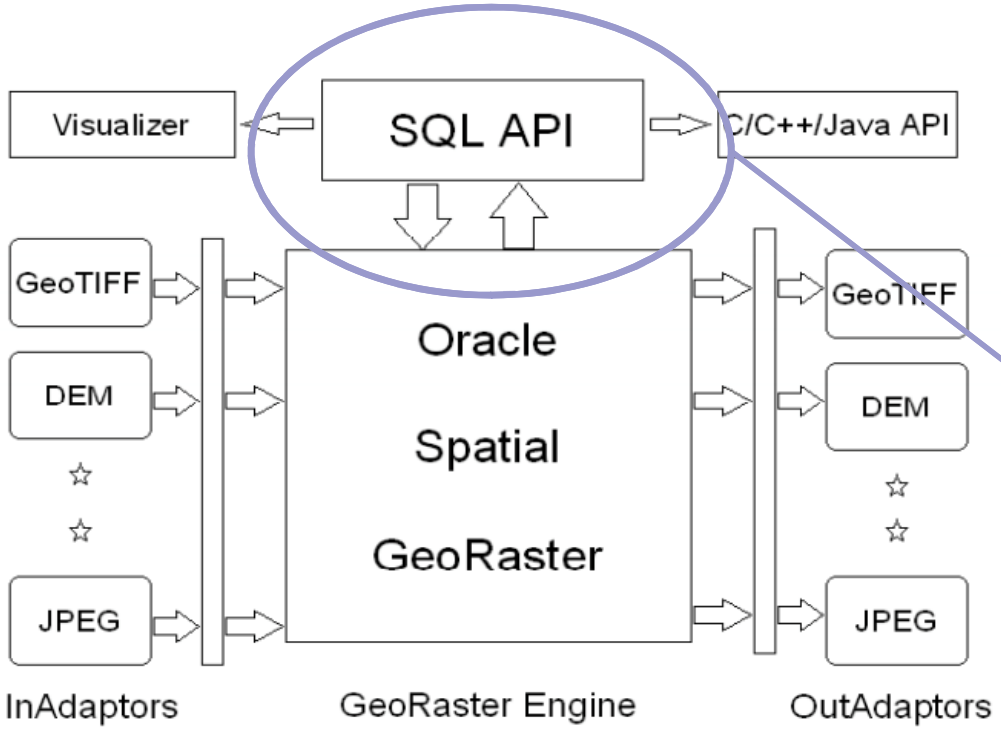
Oracle GeoRaster – Architecture



Five components to support the storage and use of raster data in Oracle Database:

GeoRaster Engine: provides the native GeoRaster object type and GeoRaster functionality including raster data and metadata indexing, update, query and manipulations.

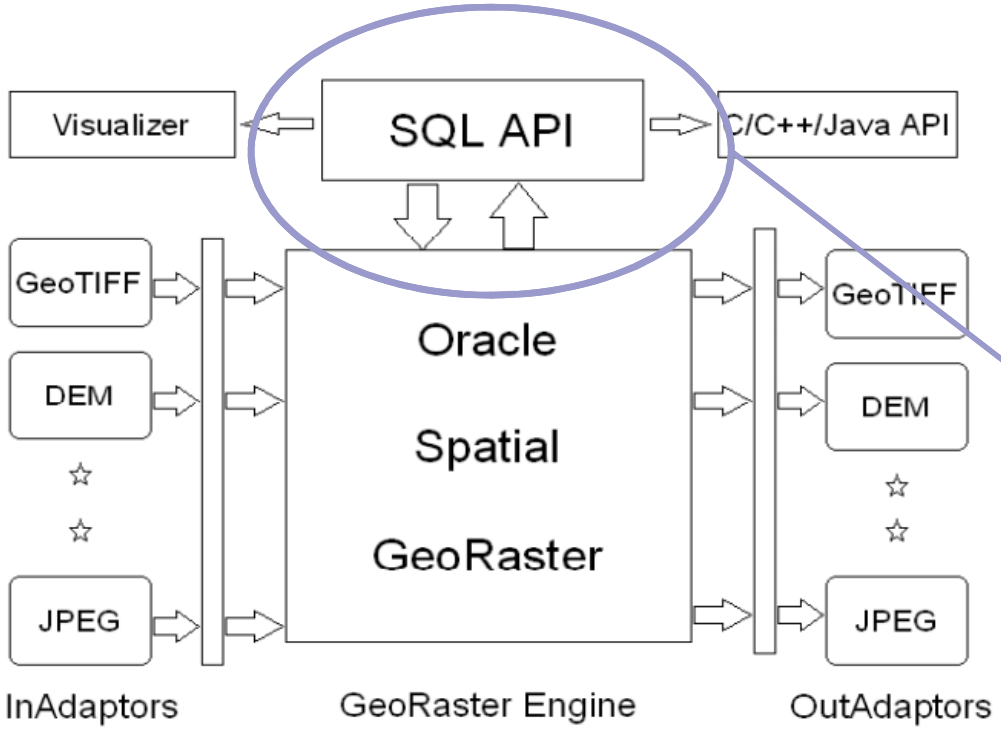
Oracle GeoRaster – Architecture



Five components to support the storage and use of raster data in Oracle Database:

SQL API : standard SQL access to the raster and grid-based data in GeoRaster databases.

Oracle GeoRaster – Architecture



Five components to support the storage and use of raster data in Oracle Database:

SQL API : standard SQL access to the raster and grid-based data in GeoRaster databases.

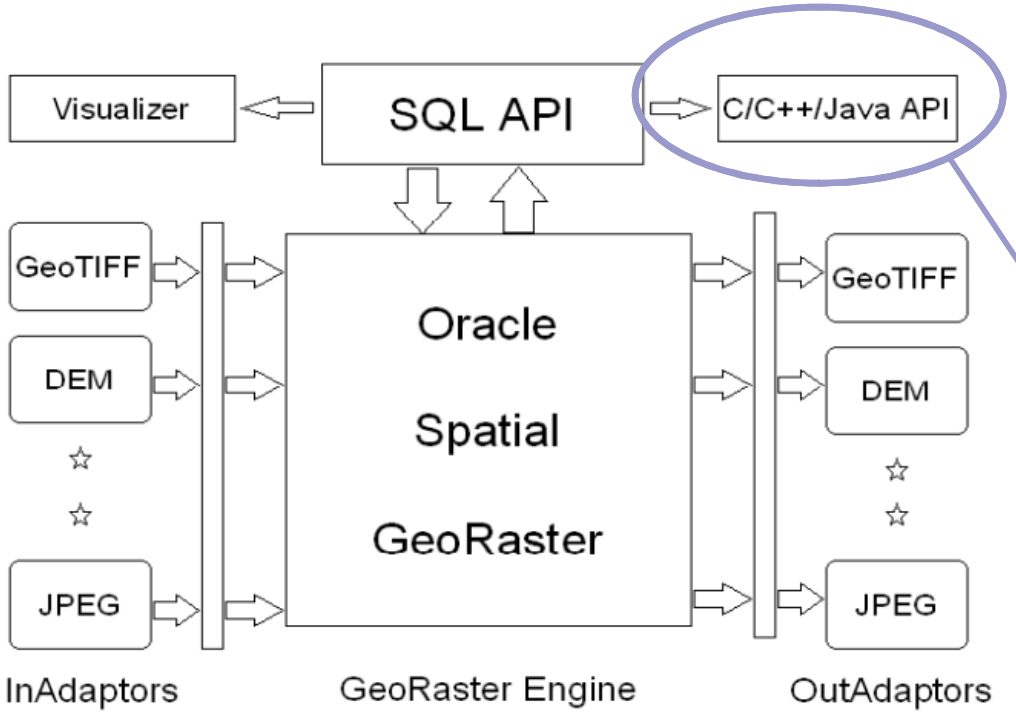
Three PL/SQL packages:

(1) MDSYS.SDO_GEOR: for creating, modifying, and retrieving GeoRaster objects

(2) MDSYS.SDO_GEOR_UTL: for utility operations related to GeoRaster

(3) MDSYS.SDO_GEOR_ADMIN: for administrative operations related to GeoRaster

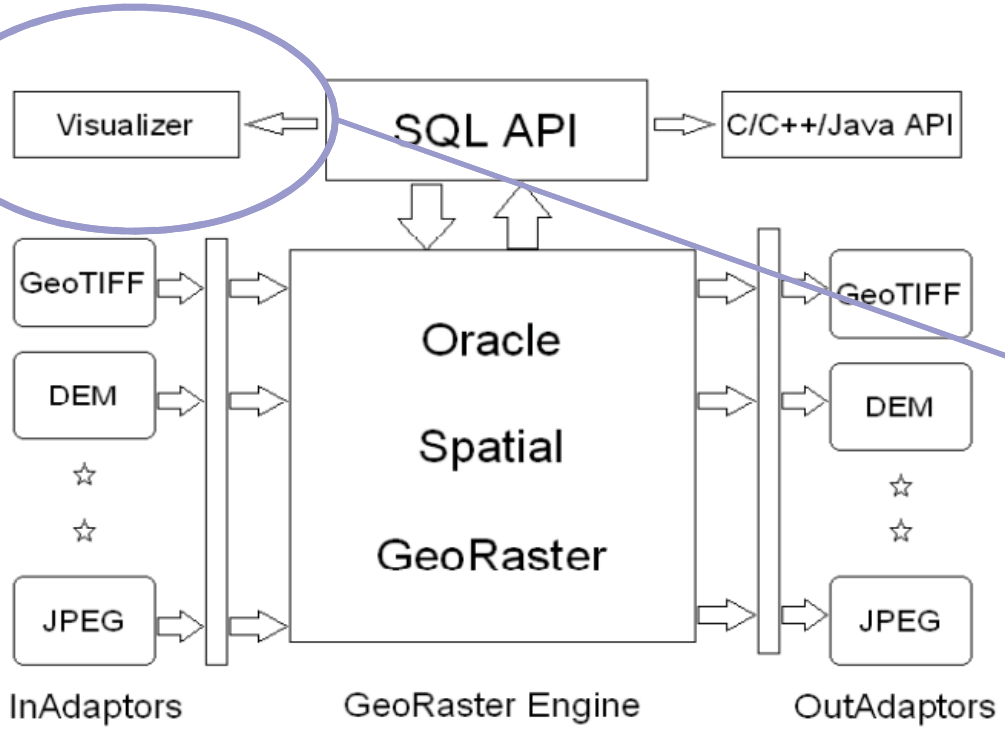
Oracle GeoRaster – Architecture



Five components to support the storage and use of raster data in Oracle Database:

C/C++/Java – Java, OCI, and OCCI : access to the raster and grid based data in GeoRaster with or without calling the GeoRaster SQL API.

Oracle GeoRaster – Architecture



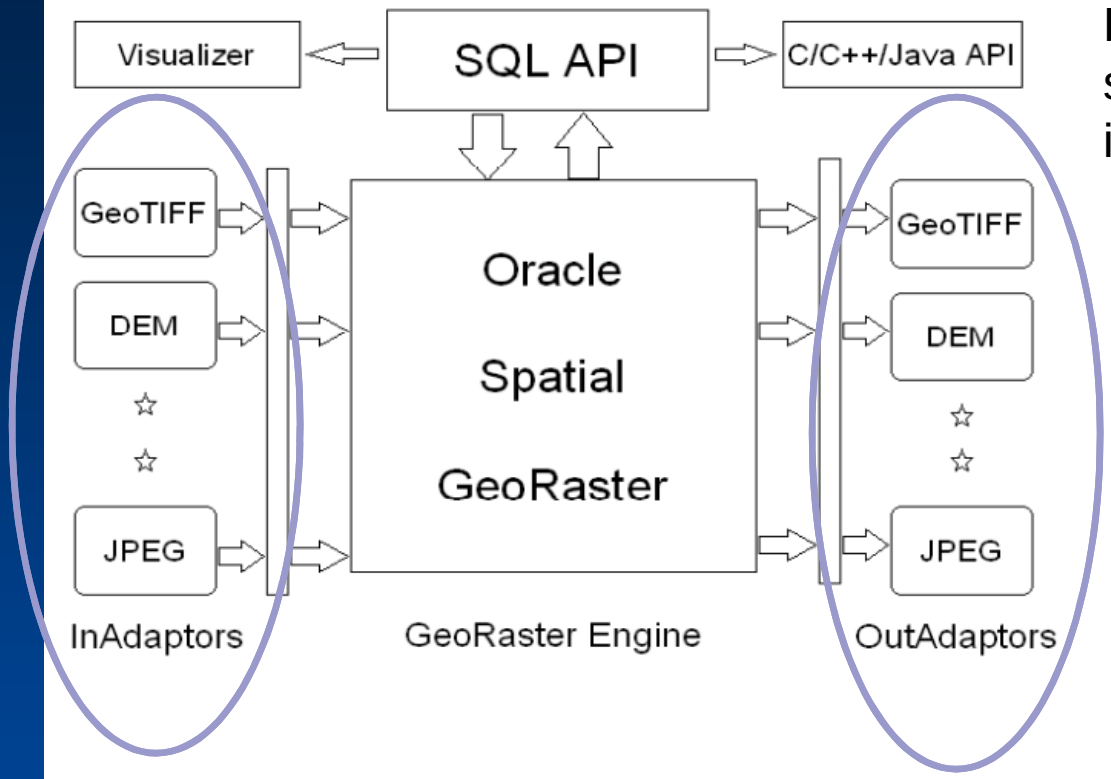
Five components to support the storage and use of raster data in Oracle Database:

Viewing Tools: A variety of third party visualization and analysis tools:

(1) Oracle Fusion Middleware MapViewer;

(2) GeoRaster Viewer: a standalone viewer comes with the Oracle GeoRaster installation and can be used as a development or DBA tool.

Oracle GeoRaster – Architecture

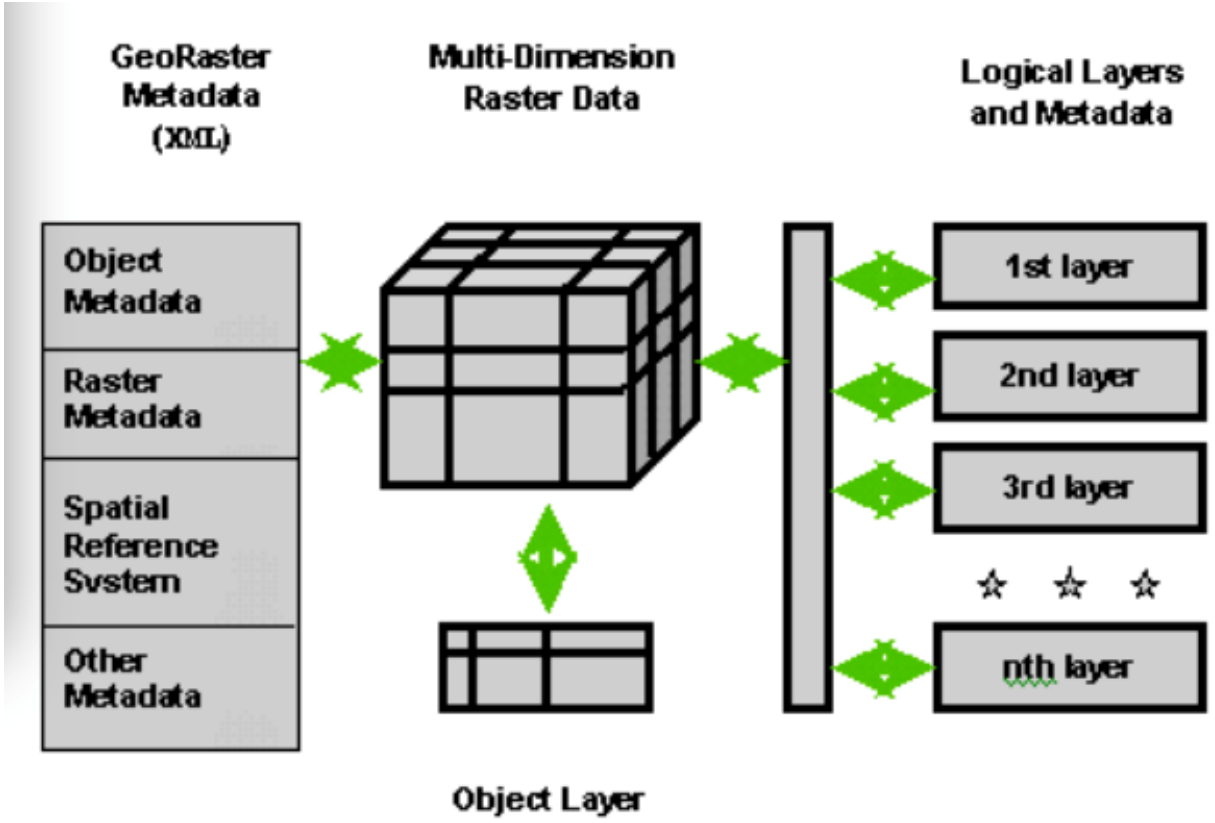


Five components to support the storage and use of raster data in Oracle Database:

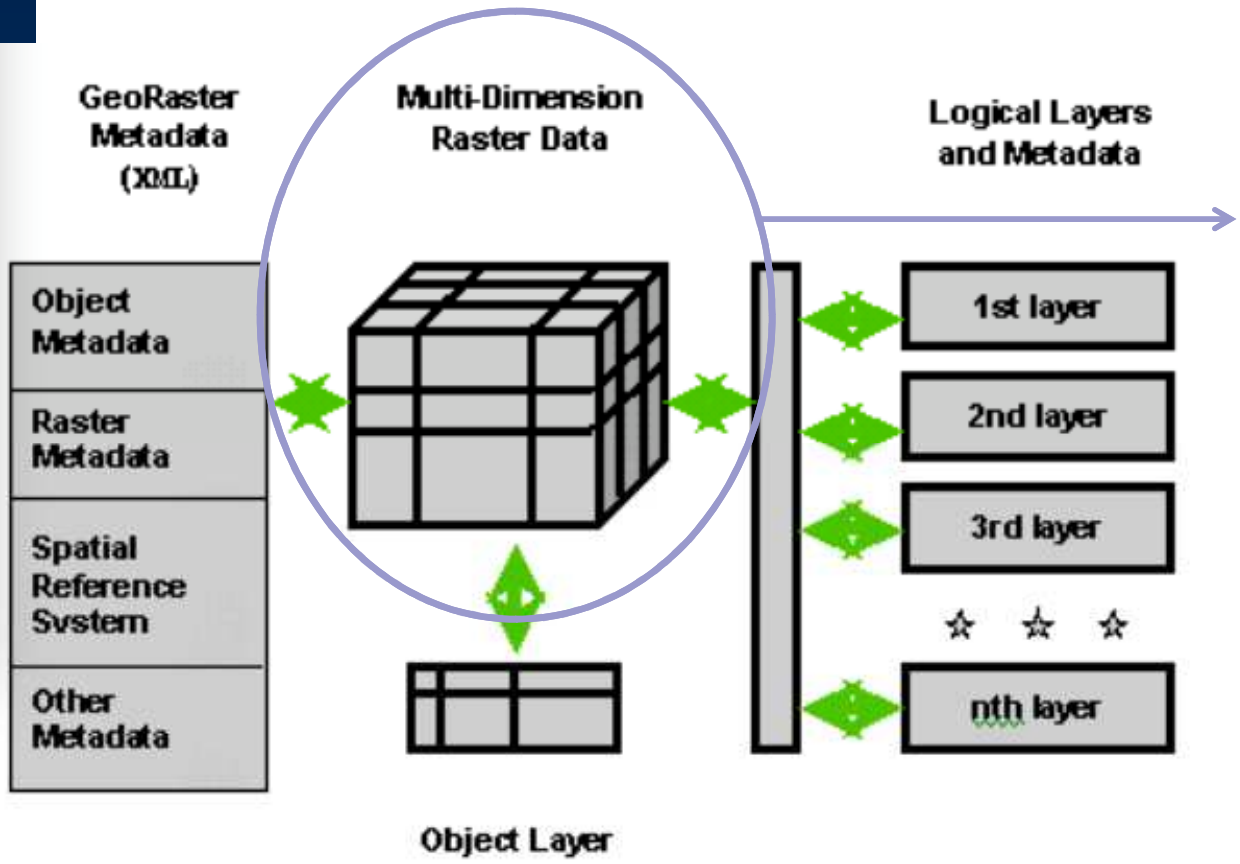
Input and Output [data] adapters: Facilitate loading and unloading raster data between well-known image file formats and GeoRaster. A variety of third party ETL tools now support loading and unloading GeoRaster data. GeoRaster also provides limited importing and exporting capability on six standard image file formats through both the server-side SQL API and the client-side Java tool.

GeoRaster – Logical Data Model

Oracle defines *georaster* object as a multidimensional matrix of cells (raster) and a set of metadata. It is logically layered.



GeoRaster – Logical Data Model

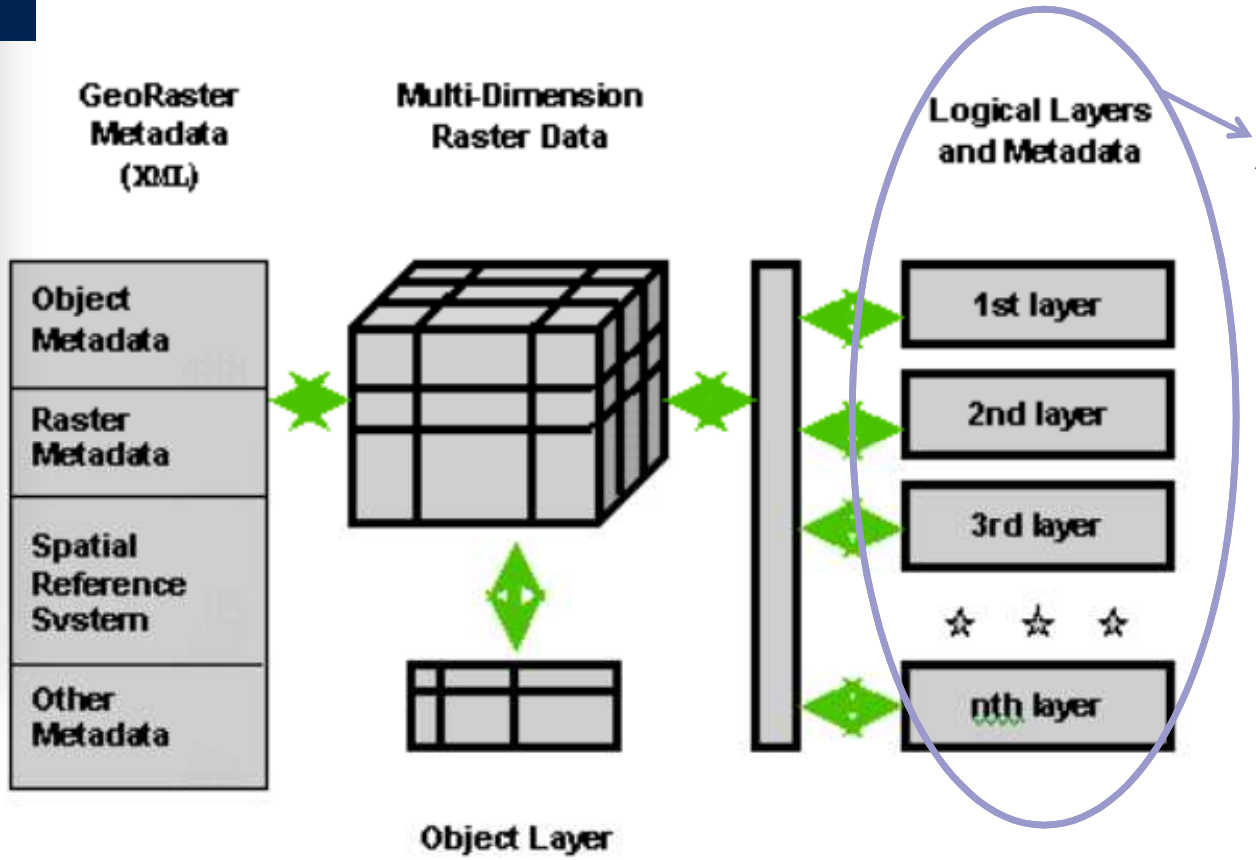


Raster: a **multidimensional** matrix of raster cells. Each cell is one element of the matrix, and its value is called the cell value. The matrix has a number of dimensions, a cell depth, and a size for each dimension.

It can be **blocked** for optimal storage, retrieval and processing.

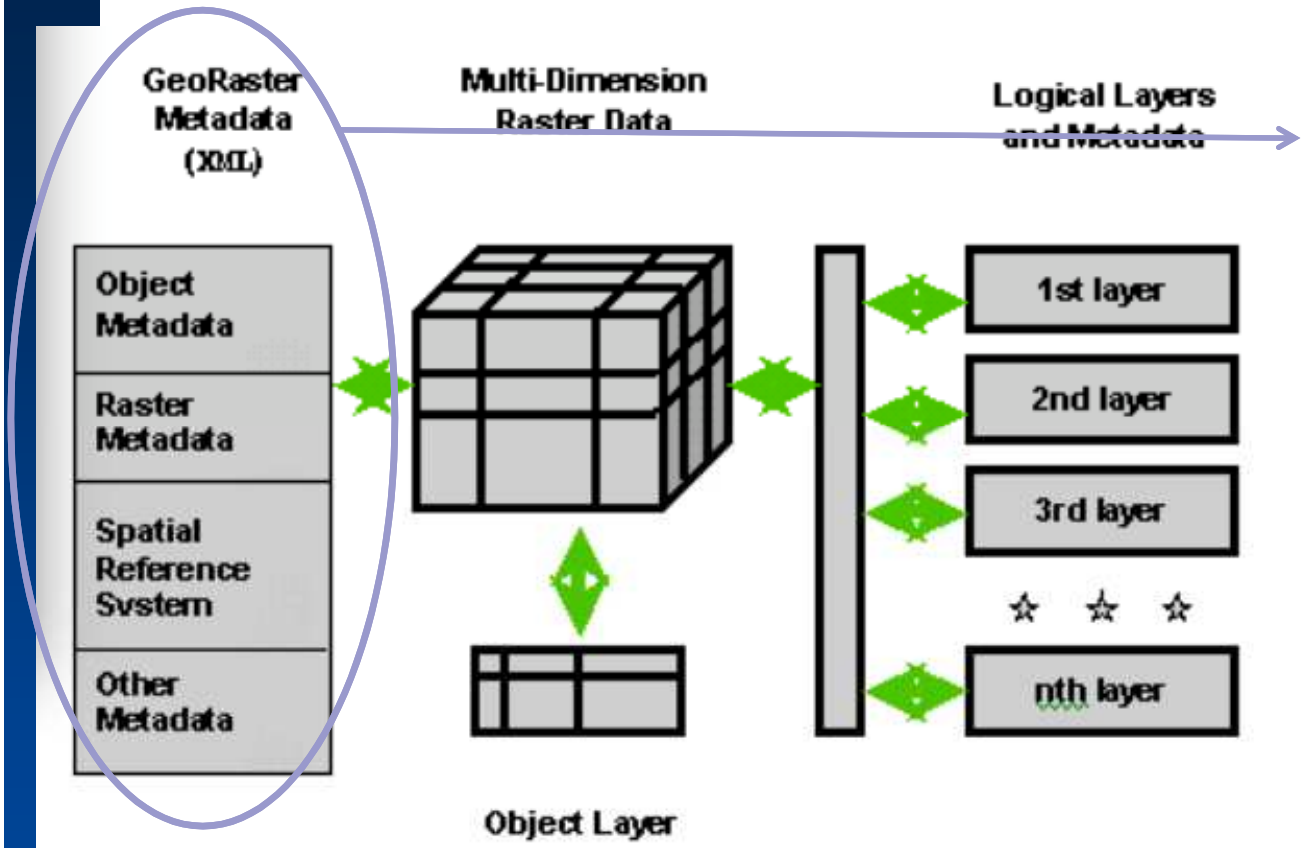
Pyramids (generalized, lower-resolution versions of the image – useful for fast retrieval in web applications) of the core raster data can be generated, stored and processed the same way.

GeoRaster – Logical Data Model



A georaster object is logically **layered**. The core data is called the **object layer** or layer 0, and consists of one or more logical layers (or sublayers).

GeoRaster – Logical Data Model



GeoRaster metadata:

(1) Object information (cell depth, blocking size, compression, info about pyramids, …)

(2) Raster information

(3) Spatial reference system information

(4) Date and time (temporal reference system) information

(5) Spectral (band reference system) information

(6) Layer information for each layer (RGB colormap, grayscale lookup table, statistics, NODATA values, value ranges, …)

GeoRaster Engine

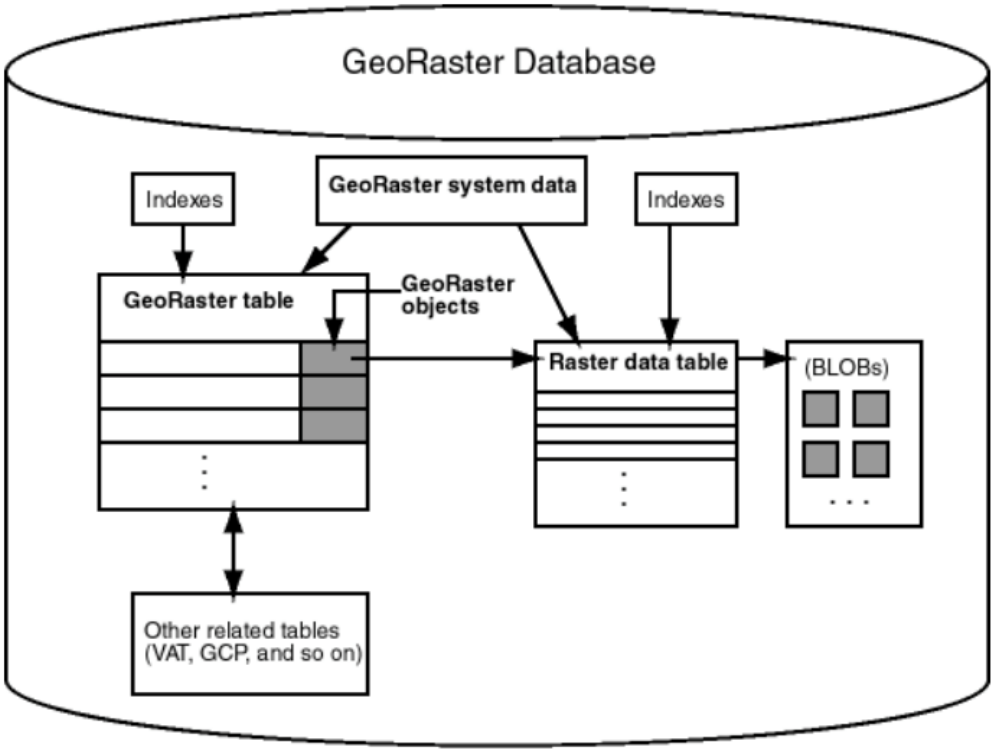
Physically, the GeoRaster data model is embodied as:

(1) two native data types: SDO_GEORASTER and SDO_RASTER

(2) an object-relational schema inside Oracle ORDBMS.

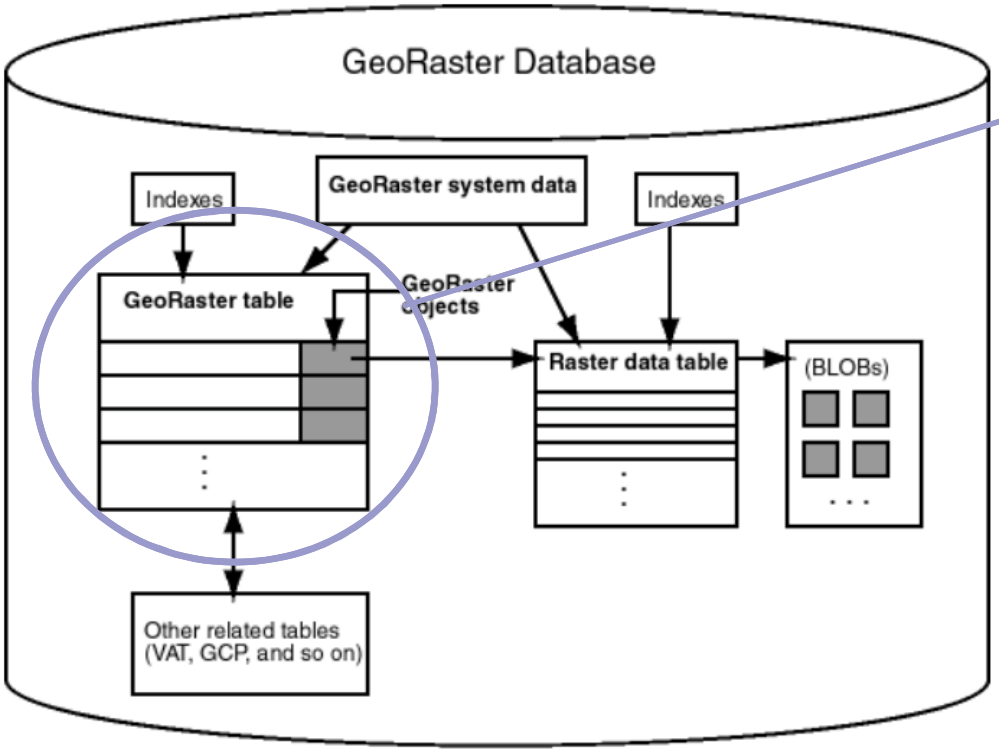
GeoRaster – Database Schema

Schema designed to store and manage raster data inside the database.



GeoRaster – Database Schema

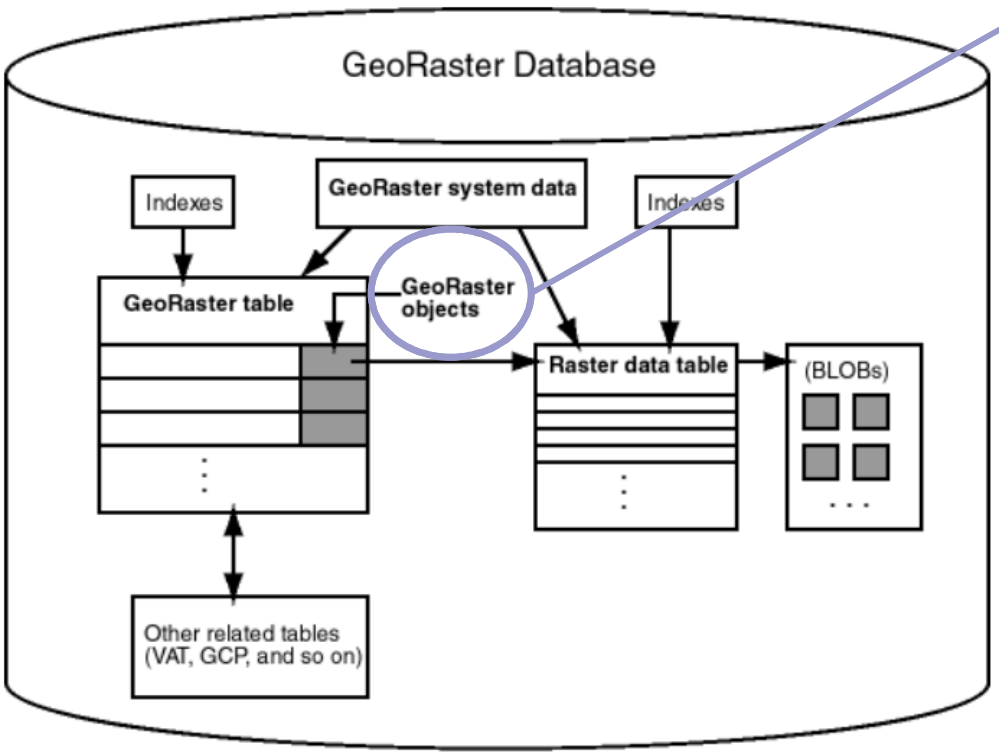
Schema designed to store and manage raster data inside the database.



GeoRaster table: A GeoRaster table is any user-defined table, which has at least one data column of type SDO_GEORASTER.

GeoRaster – Database Schema

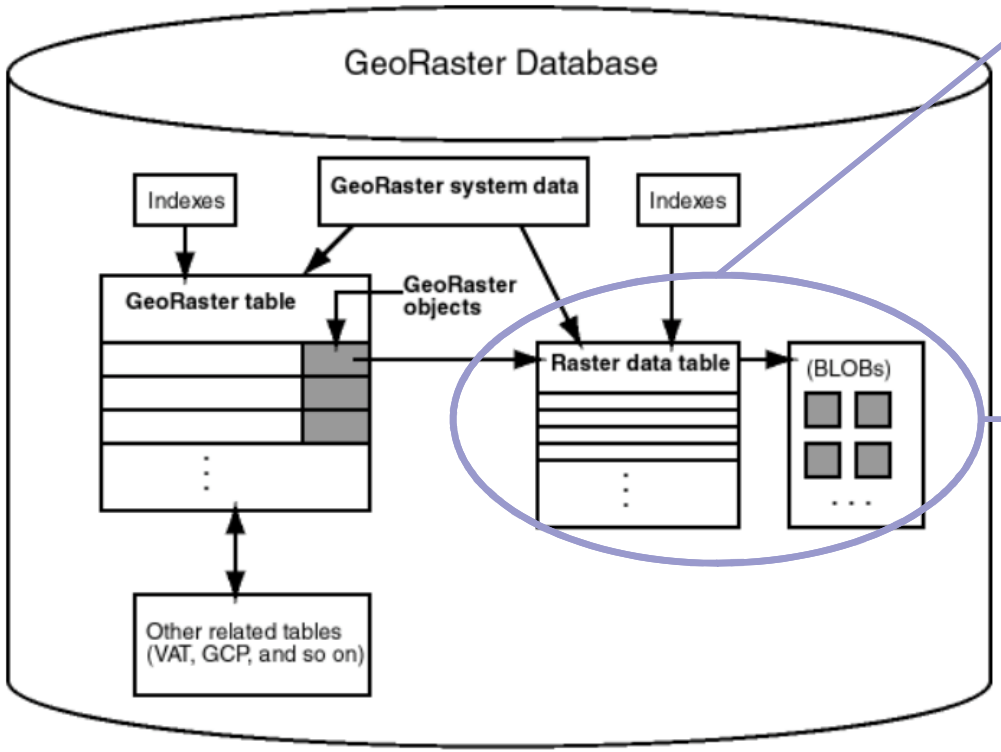
Schema designed to store and manage raster data inside the database.



SDO_GEORASTER Object: include metadata and information about *how* to retrieve the raster data stored in another user-defined table called a *Raster Data Table*.

GeoRaster – Database Schema

Schema designed to store and manage raster data inside the database.

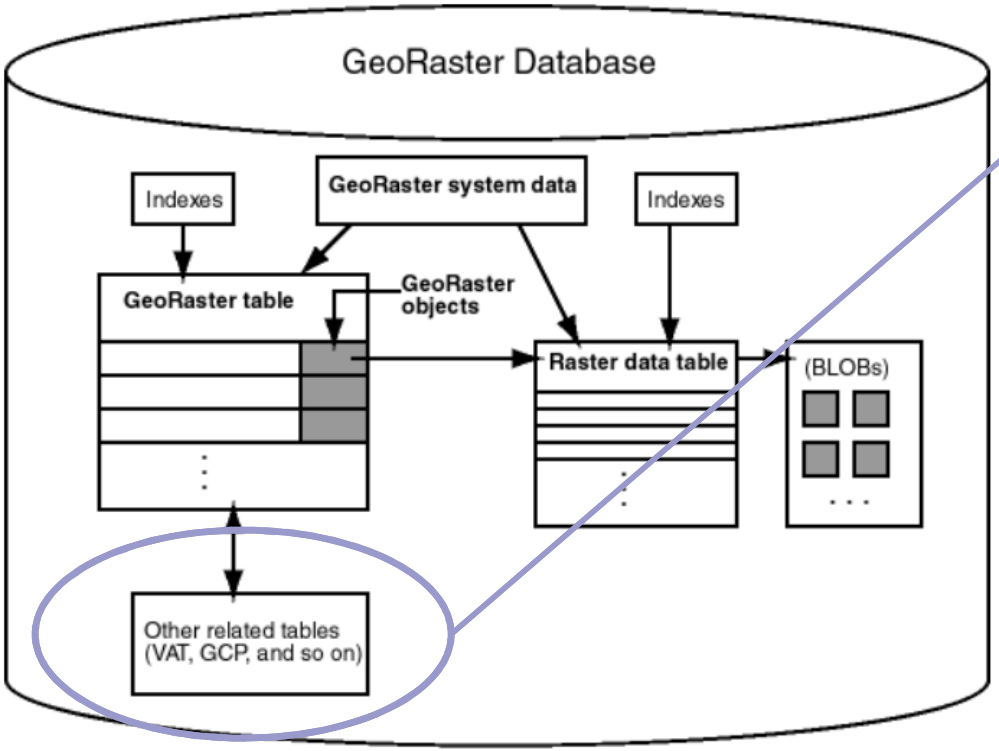


Raster data table: user-defined table which is an object table of type SDO_RASTER.

SDO_RASTER Object: includes a BLOB column called RASTERBLOCK, which stores the real raster blocks.

GeoRaster – Database Schema

Schema designed to store and manage raster data inside the database.



Other information associated with the GeoRaster objects can be stored in separate columns or tables, such as a Value Attribute Table (VAT).

SDO_GEORASTER Object

Native data type: each image or raster grid is stored as a single object of this native type.

```
CREATE TYPE sdo_georaster AS OBJECT (
        rasterType NUMBER,
        spatialExtent SDO_GEOMETRY,
        rasterDataTable VARCHAR2(32),
        rasterID NUMBER,
        metadata XMLType);
```

SDO_GEORASTER Object

Native data type: each image or raster grid is stored as a single object of this native type.

```
SQL> describe mdsys.sdo_georaster
 Name                                      Null?    Type
 ----------------------------------------- -------- --------------------
 RASTERTYPE                                         NUMBER
 SPATIALEXTENT                                      MDSYS.SDO_GEOMETRY
 RASTERDATATABLE                                    VARCHAR2(32)
 RASTERID                                           NUMBER
 METADATA                                           XMLTYPE
```

SDO_GEORASTER Object

Native data type: each image or raster grid is stored as a single object of this native type.

```
SQL> describe mdsys.sdo_georaster
 Name                                      Null?    Type
 ----------------------------------------- -------- --------------------
 RASTERTYPE                                         NUMBER
 SPATIALEXTENT                                      MDSYS.SDO_GEOMETRY
 RASTERDATATABLE                                    VARCHAR2(32)
 RASTERID                                           NUMBER
 METADATA                                           XMLTYPE
```

RasterType: contains dimensionality information and the data type that can be extended

SpatialExtent: spatial extent of the raster. GeoRaster uses R-Tree to index them.

RasterDataTable: the table name where the raster is physically stored.

RasterId: the index of the raster in the *Raster Data Table*.

Metadata: XML document (Oracle XML Type data type) according to the GeoRaster metadata XML schema defined by GeoRaster

SDO_GEORASTER Object: RasterType

5-digit number in the format [**d**][**b**][**t**][**gt**], where:

[**d**] identifies the number of spatial dimensions. Must be 2 for the current release.

[**b**] indicates band or layer information: 0 means one band or layer; 1 means one or more than one band or layer.

[**t**] is reserved for future use and should be specified as 0 (zero).

[**gt**] identifies the 2-digit GeoRaster type:

00	Reserved for Oracle use.
01	Any GeoRaster type. This is the only value supported for the current release.
02-50	Reserved for Oracle use.
51-99	Reserved for customer use in future releases.

SDO_GEORASTER Object: RasterType

For example, a RasterType value of 20001 means:

Two-dimensional data

One band (layer)

Any GeoRaster type

SDO_RASTER Object

Native type: each block of the image or raster grid (of a SDO_GEORASTER object) is stored as a single object of this type.

```
CREATE TYPE sdo_raster AS OBJECT (
        rasterID NUMBER,
        pyramidLevel NUMBER,
        bandBlockNumber NUMBER,
        rowBlockNumber NUMBER,
        columnBlockNumber NUMBER,
        blockMBR SDO_GEOMETRY,
        rasterBlock BLOB);
```

SDO_RASTER Object

Native type: each block of the image or raster grid (of a SDO_GEORASTER object) is stored as a single object of this type.

```
SQL> describe mdsys.sdo_raster
 Name                                      Null?    Type
 ----------------------------------------- -------- --------------------
 RASTERID                                           NUMBER
 PYRAMIDLEVEL                                       NUMBER
 BANDBLOCKNUMBER                                    NUMBER
 ROWBLOCKNUMBER                                     NUMBER
 COLUMNBLOCKNUMBER                                  NUMBER
 BLOCKMBR                                           MDSYS.SDO_GEOMETRY
 RASTERBLOCK                                        BLOB
```

SDO_RASTER Object

Native type: each block of the image or raster grid (of a SDO_GEORASTER object) is stored as a single object of this type.

```
SQL> describe mdsys.sdo_raster
 Name                                      Null?    Type
 ----------------------------------------- -------- --------------------
 RASTERID                                           NUMBER
 PYRAMIDLEVEL                                       NUMBER
 BANDBLOCKNUMBER                                    NUMBER
 ROWBLOCKNUMBER                                     NUMBER
 COLUMNBLOCKNUMBER                                  NUMBER
 BLOCKMBR                                           MDSYS.SDO_GEOMETRY
 RASTERBLOCK                                        BLOB
```

RasterId: the raster id

PyramidLevel: the pyramid level of this block

BandBlockNumber: the band block number

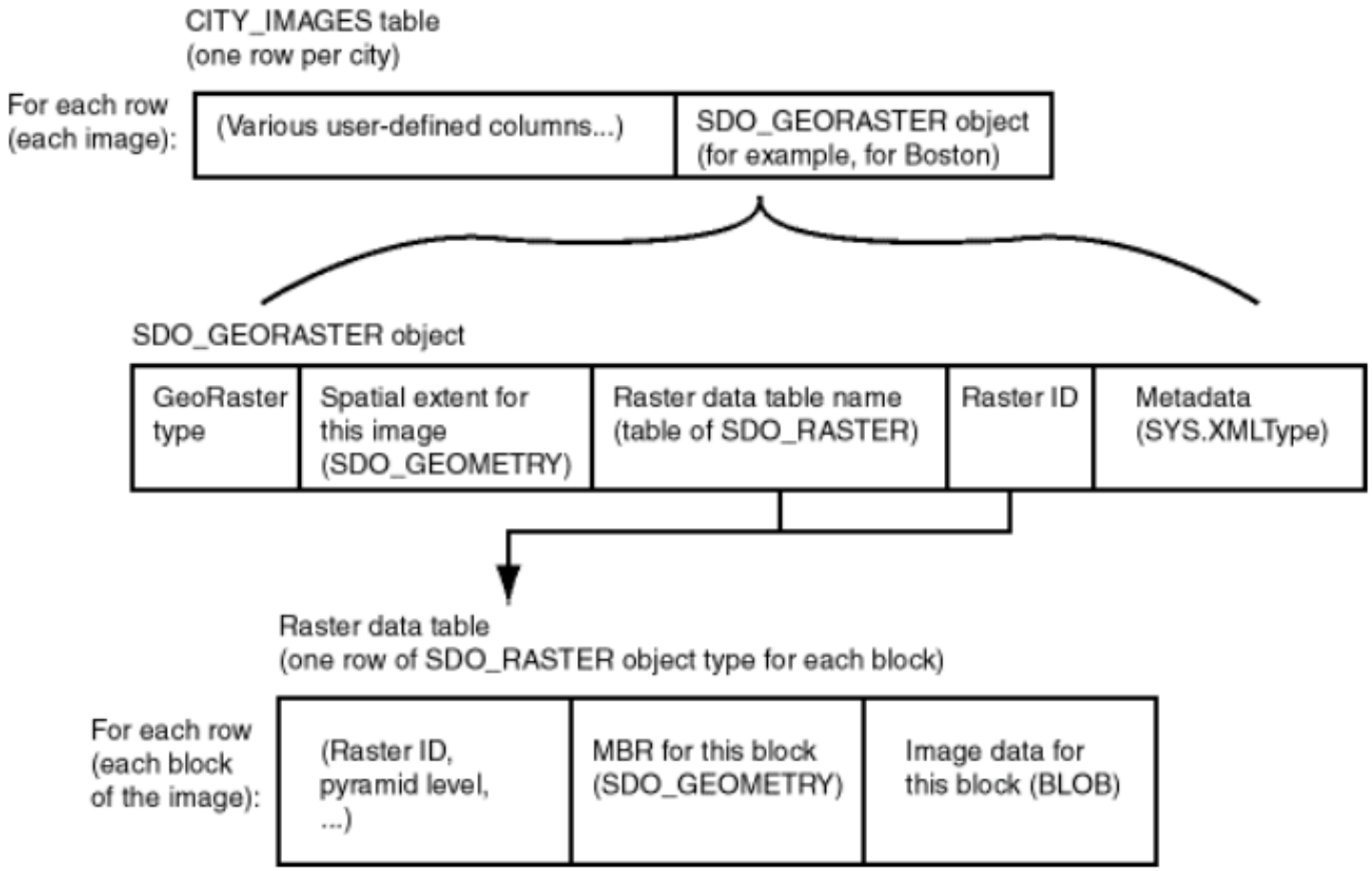
RowBlockNumber: the row block number

ColumnBlockNumber: the column block number

BlockMBR: the precise extent of the block

RasterBlock: the raster block as a binary large object (BLOB)

Example


CITY_IMAGES table
(one row per city)
For each row
(each image):
(Various user-defined columns...)
SDO_GEORASTER object
(for example, for Boston)
SDO_GEORASTER object
GeoRaster type
Spatial extent for this image (SDO_GEOMETRY)
Raster data table name (table of SDO_RASTER)
Raster ID
Metadata (SYS.XMLType)
Raster data table
(one row of SDO_RASTER object type for each block)
For each row
(each block
of the image):
(Raster ID, pyramid level, ...)
MBR for this block (SDO_GEOMETRY)
Image data for this block (BLOB)

GeoRaster – Layer, Bands and Interleaving

In GeoRaster, *band* and *layer* are different concepts.

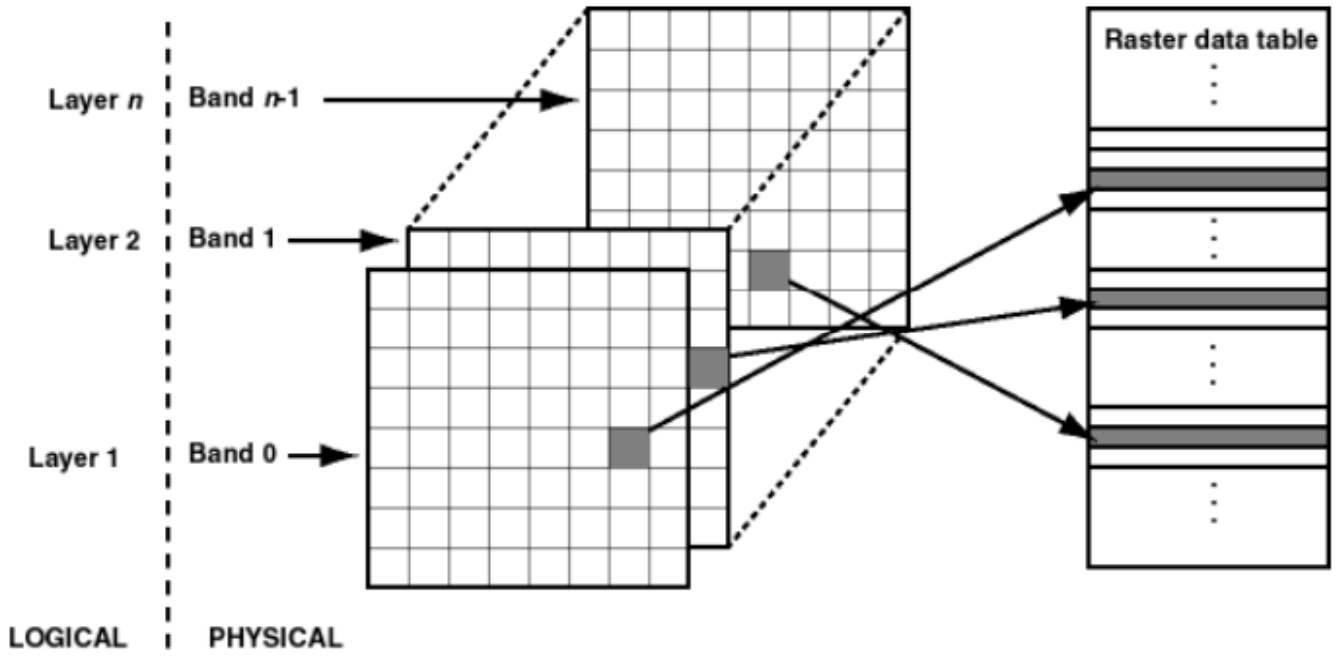
Band is a physical dimension of the multidimensional raster data set. Bands are numbered from *0* to *n-1*, where n is the highest layer number.

Layer is a logical concept in the GeoRaster data model. Layers are mapped to bands. Typically, one layer corresponds to one band. Layers are numbered from *1* to *n*; that is, *layerNumber* = *bandNumber* + 1.

A **GeoRaster object** can contain multiple bands, which can also be called multiple layers.

Interleaving: Must be one of the following values: BSQ (band sequential), BIL (band interleaved by line), or BIP (band interleaved by pixel). Example: interleaving=BSQ

GeoRaster – Layer and Band



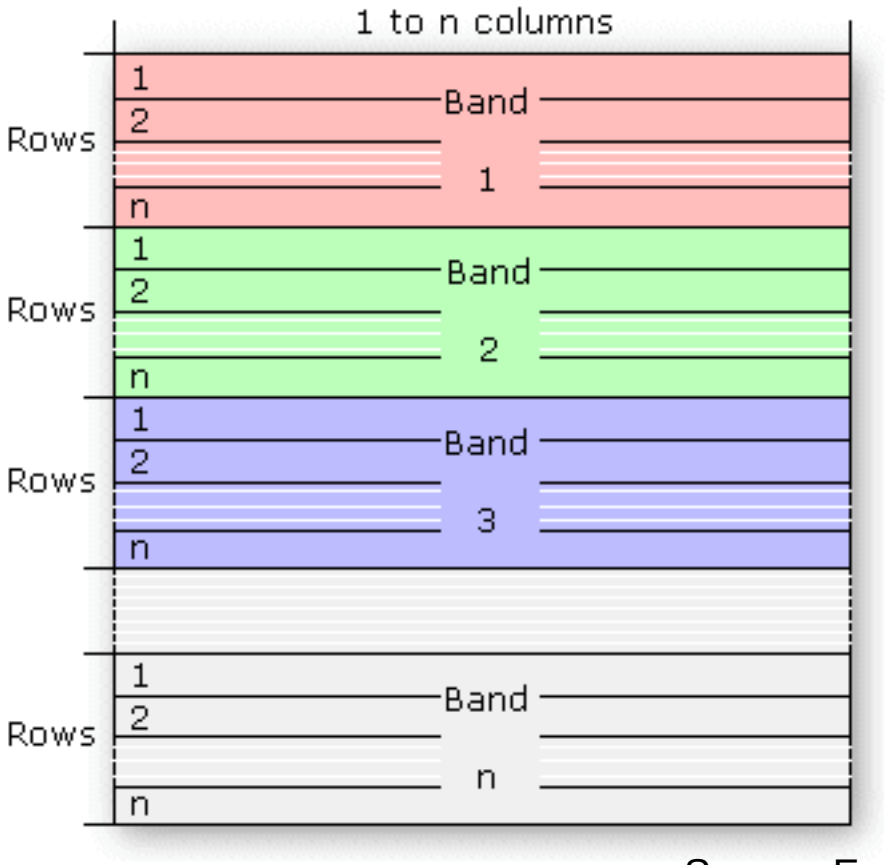
In GeoRaster, each layer is a two-dimensional matrix of cells that consists of the row dimension and the column dimension.

Example: for multichannel remote sensing imagery, the sublayers are used to model the channels or bands of the imagery.

This figure shows an image with multiple layers and a single raster data table. Each layer contains multiple blocks, each of which typically contains many cells. Each block has an entry in the raster data table. Note that GeoRaster starts layer numbering at 1 and band numbering at 0 (zero).

GeoRaster – Interleaving

Interleaving: Must be one of the following values: **BSQ (band sequential)**, BIL (band interleaved by line), or BIP (band interleaved by pixel). Example: interleaving=BSQ



Source: Esri ArcGIS's home page

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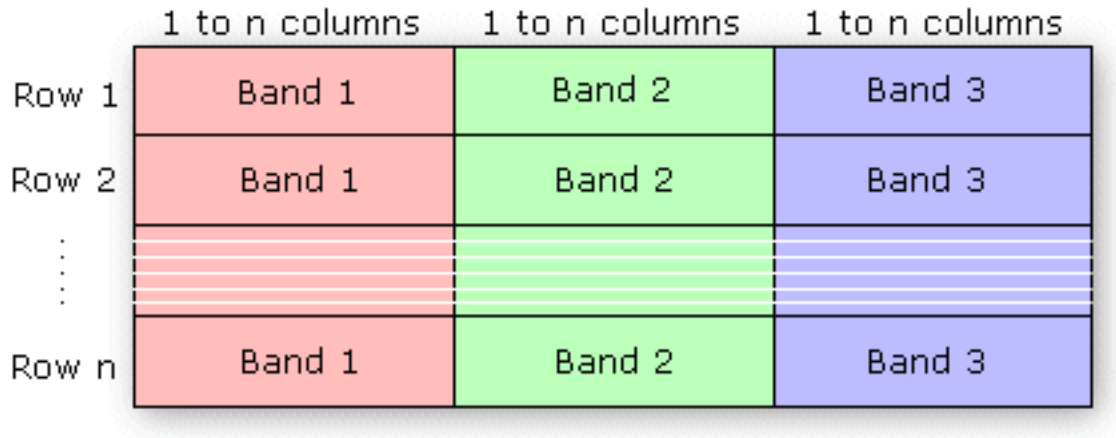
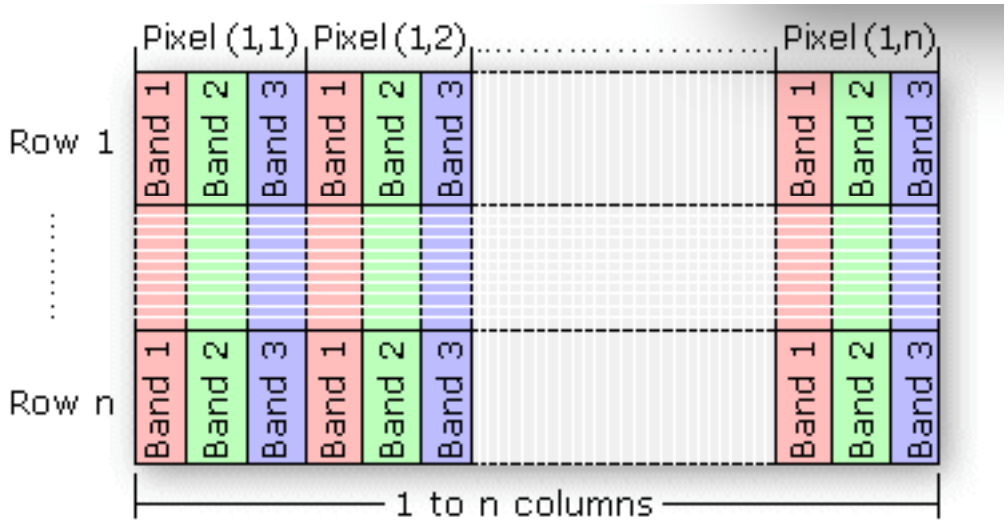


Source: Esri ArcGIS's home page

GeoRaster – Interleaving

Interleaving: Must be one of the following values: BSQ (band sequential), BIL (band interleaved by line), or **BIP (band interleaved by pixel)**. Example: interleaving=BSQ



Source: Esri ArcGIS's home page

GeoRaster – Interleaving

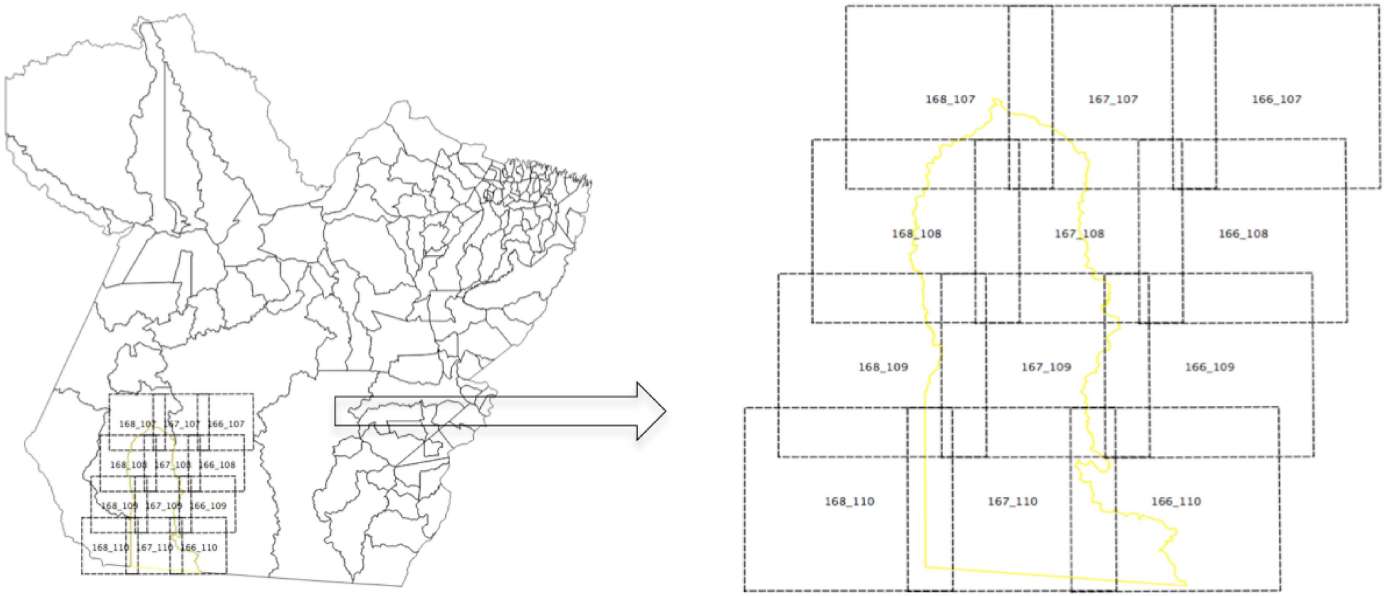
IMPORTANT NOTES:

(1) SDO_GEOR.importFrom: This procedure does not support source multiband raster data with BIL and BSQ interleaving types. Only BIP interleaving.

Case Study

Region of interest: Novo Progresso, Pará

Images: 12 CBERS-2B scenes (CCD sensor)



Case Study - Images

Spatial reference system: UTM / WGS-84 Datum.

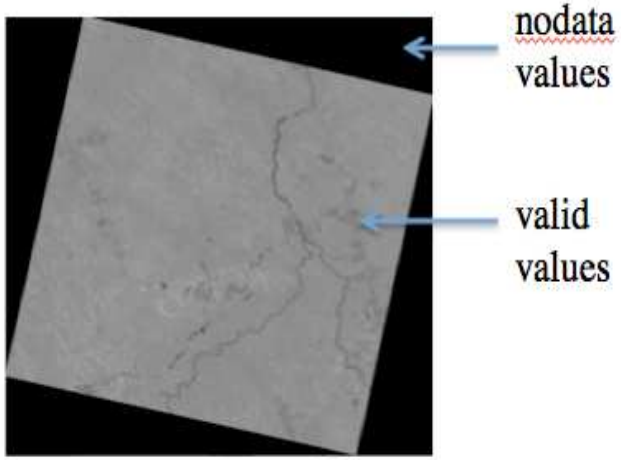
Spatial resolution: 20 meters

Radiometric resolution: 8 bits unsigned. It means that each image element, or pixel, has an integer value in the range of 0 to 255. The value 0 indicates pixels with "*no data*", or with no valid information.

Each scene has 3 bands (2, 3 and 4)

Each scene is a GeoTIFF file.

Total: 36 files.



Case Study – Create Tables

```
CREATE TABLE para_georaster
(       r_georid NUMBER,
        r_scene VARCHAR(10),
        r_band NUMBER,
        r_satellite VARCHAR(20),
        r_date VARCHAR(20),
        r_image MDSYS.SDO_GEORASTER);


CREATE TABLE para_raster OF MDSYS.SDO_RASTER
(PRIMARY KEY ( rasterID, pyramidLevel,
               bandBlockNumber, rowBlockNumber,
               columnBlockNumber));
```

Case Study – Import GeoTIFF files

One scene with its three bands is represented as a `georaster` object and stored in a row of the `para_georaster` table.

Tiles: 512 x 512 pixels.

Case Study – Import GeoTIFF files

We have 2 strategies to insert the GeoTIFF files (each file is one band) into the database using the package `sdo_geor`:

1. Import each file as it is, using the `sdo_geor.importFrom` function and, afterwards, use the `sdo_geor.mergeLayers` function to merge all bands of the same image into a single georaster object.

2. Create a new GeoTiff file combining all bands of a scene and, afterwards, use the `sdo_geor.importFrom` function to import the new file to a georaster object. The function `sdo_geor.importFrom` supports only multiple BIP (band interleaved by pixel) GeoTiff files.

Case Study – Import GeoTIFF files

```
DECLARE
        geor10 SDO_GEORASTER;
BEGIN
        INSERT INTO para_georaster VALUES(10, '167_108', 234,
        'CBERS2B_CCD1XS', '20090820',
        sdo_geor.init('para_raster') );

        SELECT r_image INTO geor10 FROM para_georaster
        WHERE r_georid = 10 FOR UPDATE;

        sdo_geor.importFrom(geor10,'blocking=TRUE
        blocksize=(512,512) spatialExtent=TRUE srid=32721',
        'GeoTIFF', 'file', '/home/../file1.tif');

        UPDATE para_georaster SET r_image = geor10
        WHERE r_georid = 10;
COMMIT;
END;
```

Using strategy 2

Case Study – Import GeoTIFF files

`sdo_geor.init` function: register automatically the new raster objects and their related raster data tables in the two metadata tables `user_sdo_geor_sysdata` and `all_sdo_geor_sysdata`.

`sdo_geor.importFrom` function: storage parameters (block size, compression type, pyramid generation using different resampling methods, …).

Important Note: to use the function `mdsys.sdo_geor.init`, your Oracle user must have permition to insert and update tables in the MDSYS schema!!!! Because of the metadata tables!

Case Study – Image Access

Return the raster value in a position given by a spatial coordinate (672512.103, 9214134.635):

```
SELECT sdo_geor.getCellValue(r_image, 0,
                sdo_geometry(2001, 32721,
                sdo_point_type(672512.103, 9214134.635, null),
                null, null), 1)
FROM para_georaster
WHERE r_georid = 10;
```

Case Study – Image Access

Extract statistics and histogram:

```
DECLARE
        geor10  SDO_GEORASTER;
        window  SDO_NUMBER_ARRAY := NULL;
BEGIN
        SELECT r_image INTO geor10 FROM para_georaster
        WHERE r_georid = 10 FOR UPDATE;

        sdo_geor.setBinFunction(geor10, 1,
                                sdo_number_array(0,10,1,0,255));

        sdo_geor.generateStatistics(  geor10, 'samplingFactor=1',
                                      window,'TRUE','1','TRUE');

        UPDATE para_georaster SET r_image=geor10 WHERE r_georid=10;
COMMIT;
END;
```

Case Study – Image Access

`sdo_geor.generateStatistics` function: extracts summarizing values, such as minimum, maximum and mean values. It can extract a histogram parameterized with a function to control the number of bins. It can also retrieve the statistics of a specific window within the image and to disregard *nodata* values.

This function stores the results in the georaster object metadata.

…

Case Study – Image Access

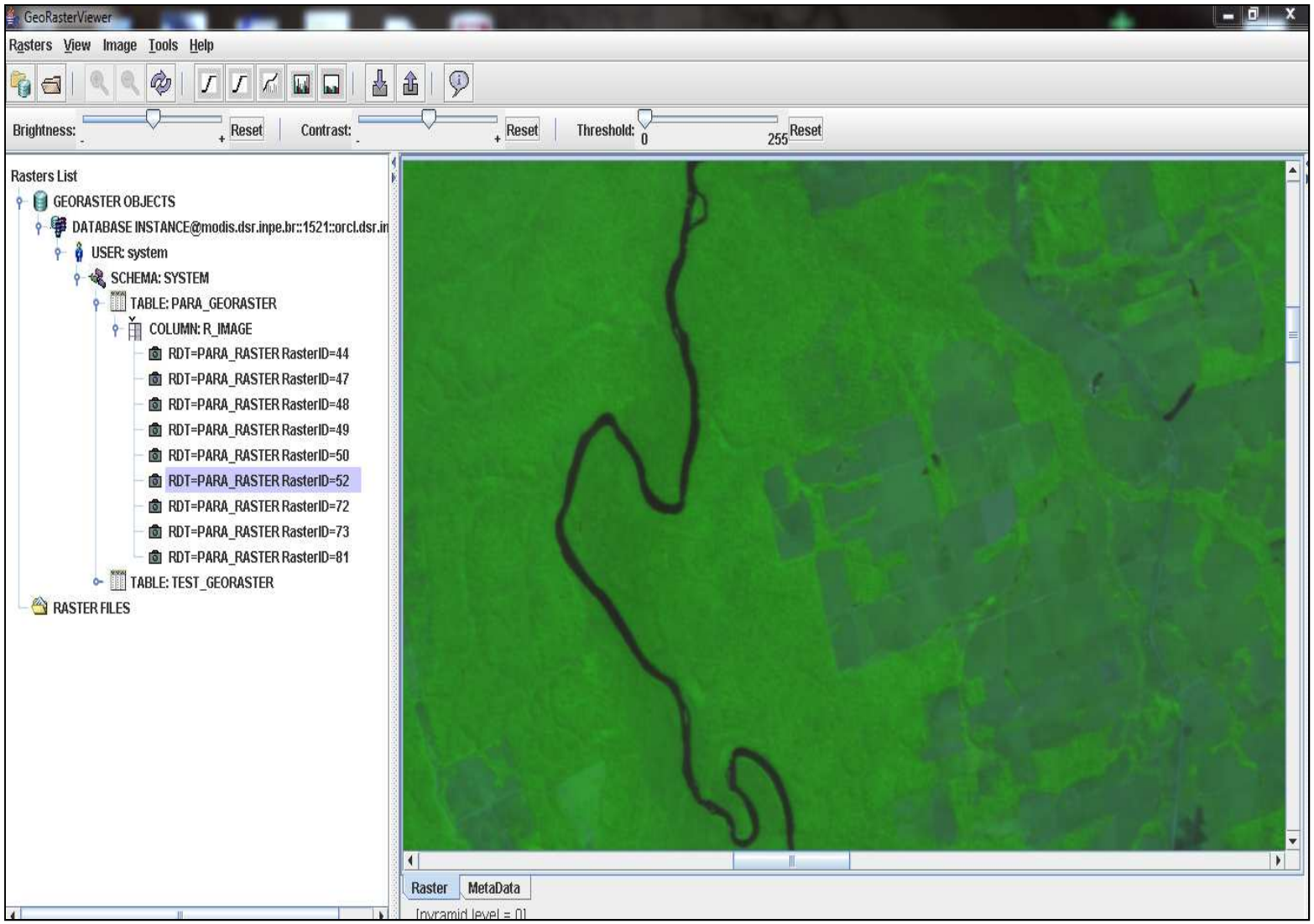
Get the store statistics and histogram from the georaster objects:

```
SELECT sdo_geor.getStatistics(r_image, 1)
FROM para_georaster WHERE r_georid = 10;

SELECT sdo_geor.getHistogram(r_image, 1)
FROM para_georaster WHERE r_georid = 10;
```

Case Study – Visualization

GeoRaster Viewer:



Case Study – Visualization

Georaster objects stores metadata about their visualization:

(1) Color map or *pallets*: mechanism to transform a range of input values into a range of colors (functions `sdo_geor.setColorMapTable` and `sdo_geor.setColorMap`)

Case Study – Visualization

Georaster objects stores metadata about their visualization:

(2) Association of image bands to Red-Green-Blue components of a display using the functions:

```
DECLARE
        geor SDO_GEORASTER;
BEGIN
        SELECT r_image INTO geor FROM para_georaster
        WHERE r_georid = 86 FOR UPDATE;

        sdo_geor.setDefaultRed(geor, 1);
        sdo_geor.setDefaultGreen(geor, 3);
        sdo_geor.setDefaultBlue(geor, 2);

        UPDATE para_georaster SET r_image = geor
        WHERE r_georid = 86;
COMMIT; END;
```

Case Study – Clip

We can clip a georaster object using a geometry (SDO_GEOMETRY) as a mask through the function `sdo_geor.subset`: