Technology of Object-Oriented Languages and Systems TOOLS Eastern Europe'99, June 2-4, 1999 (98-109)

Object-Oriented Image Model

Peter L. Stanchev
Institute of Mathematics and Computer Science, Bulgarian Academy of Sciences
Acad. G. Bonchev St. 8, 1113 Sofia, Bulgaria
Phone: 359-2-979 3814, fax: 359-2-971 3649
E-mail: stanchev@bas.bg

ABSTRACT

In this paper we analyze the existing approaches to image data modeling and we propose an Object-Oriented Image Data (OOID) model. The model establishes taxonomy based on the systematization on the existing approaches. The image layouts (classes) in the model are described in semantic hierarchies with the help of grammar structures. The OOID model is applicable to a wide variety of image collections. An example for applying the OOID model to a plant picture database is given, as well as the realization of the model in the Sofia Image Database System.

Keywords

Data model, Image, Image model, Image database.

1. INTRODUCTION

Images are becoming an essential part of the information systems and multimedia applications. The image data model is one of the main issues in the design and development of any image database management system. The data model in should be extensible and have the expressive power to present the structure and contents of the image, their objects and the relationships among them. The design of an appropriate image data model will ensure smooth navigation among the images in an image database system. The complexity of the model arises because images are richer in information than text, and because images can be interpreted differently, according to the human perception of the application domain.

There is a lack of standard model for representing the semantic richness of an image. In this paper we analyze some existing tools and approaches to image data modeling and we propose an Object-Oriented Image Data (OOID) model. It can be applied on a wide variety of image collections. The model employs multiple logical representations of an image. The logical image representation can be viewed as a multiple level abstraction of the physical image view. The OOID model is based on the analysis of different image application domains such as: medical images, house furnishing design plans [1], electronic schema catalogues and geographical information systems [2]. The proposed OOID model together with the proposed General Image Retrieval model [3] and General Image Database System model [4] could be used as a frame for designing and building a wide range of image database systems.

2. IMAGE DATA

Before we analyze the various existing approaches to image data modeling and the proposed tools we introduce some of the basic methods using for description of the image and the image contents. The image data can be treated as physical image representation and their meaning as a logical image representation. The logical representation includes methods for describing the image and image-objects characteristics and the relationships among the image objects. In the following sections in the right part of the page methods and tools are described and in the left part an example of applying the correspondent method or tool over the following example plant image  is shown.

Physical image representation.

The most common forms of the physical image representation are the ***raster and vector forms***. The raster form includes the image header and image matrix.

NAME	**VALUE**
image name	herb 101
# of voxels in *x* direction	185
# of voxels in *y* direction	485
# of voxels in *z* direction	1
FOV in *x* direction in cm	6
FOV in *y* direction in cm	12.5
FOV in *z* direction in cm	NULL
# bytes per pixel	1
pixel organizations	RGB
compression schema	no
image type	TIFF

Image header. It describes the main image parameters. Some of the essential header fields are: image name, image format, number of pixels in x, y, z directions, Field of View (FOV) in x, y, z directions, number of bytes per pixel, organization of the color information in the image matrix, semantic of the image matrix (i.e. whether the pixel information in the matrix describes the pixels gray scale, its RGB components, or an index in a color bitmap part of the image header), image type and the compression schema for the image matrix.

(237,225,247)	. . .	(246,226,237)
. . .		
(244,245,245)	. . .	(245,227,238)

Image matrix. It contains the image data. The data can be one bit for black/white images, one bite for gray scale images, and three bytes for the true color images.

Some other form for physical image representations is the identification image

```
0011111100000000000
0111111111000000000
0011111000000000000
0000020000000000000
0000002000000000000
0000002000000000000
0000000200000000000
0000000200000000000
0000000020000000000
0000000020000000000
0000000002000000000
0000000002000000000
0000000000200000000
0000000000200000000
0000000000020000000
0000000000022000000
0333333300444000000
0003000004440000000
0000000044000000000
```

Identification image. This is an image, which serves to identify the membership of an image object in the image. If in the image there are K objects, 0 is used for the background points, 1 for the first object, 2 for the second, and so on.

The vector form is used for representing the graphical images.

Blossom = circle (center = (48, 36); radius = 1,6 cm),

stalk = rectangle (center = (72, 194); x = 1,1 cm; y = 8,4 cm),

leaf = rectangle (center = (44, 401); x = 2,6 cm; y = 1,1 cm),

root = rectangle (center = (101, 432); x = 1,5 cm; y = 1,6 cm).

Vector form. It is a set of mathematical equations, describing the image objects as a set of line, circle, arc, rectangular, etc.

Logical image description.

It includes the image and the image-objects descriptions. The image segmentation includes the process of identifying the image objects.

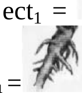
Plant = {$object_1$ = , $object_2$ = , $object_3$ = , $object_4$ = }

Image segmentation This is the process of defining the image-objects as a region of interest in the image using different segmentation techniques such as: threshold, texture, color, mouse drawings, multiple-spectral images, etc.

The image description includes the image meta and semantic attributes, color and texture attributes. The image objects can be described with their color, texture, shape, logical and semantic attributes.

META ATTRIBUTES	
Attribute name	**Attribute value**
name	Rions - tooth
source	book 102
remark	page 32
distribution	grass-lend
blossoming period	[March, November]

Image meta attributes. These attributes are attributes related to the process of the image creation. These attributes can be image acquisition date, image identification number and name, image modality device, image magnification, etc.

IMAGE SEMANTIC ATTRIBUTES	
Attribute name	**Attribute value**
use-in- medicine	big

Image semantic attributes. These attributes contain subjective information about the analyzed image. A specialist in the field of the specific image collection gives the values of such attributes.

OBJECT "ROOT" SEMANTIC ATTRIBUTES	
Attribute name	**Attribute value**
form	spindle
metamorphosis	none

Image-object semantic attributes. These are attributes, which subjectively describe the image-object characteristics.

OBJECT "ROOT" LOGICAL ATTRIBUTES	
Attribute name	**Attribute value**
length	1.5
with	1.6

Image object logical attributes. These are the attributes obtained, as a result of image measurement operations such as: calculating the high, with, diameter, area, perimeter and angles of image-objects.

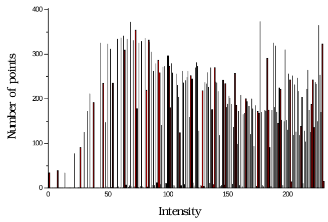


Image histogram

Image and image object color attributes. The ***color*** of the image or an image-object could be represented as a histogram of intensity of the pixels color, i.e. average red, green, and blue, overall average color, etc.

Image texture attributes:

Method: contrast;

Value = 1.38.

Image texture attributes. The values of these attributes can be obtained with the help of the following two classes of methods:

- structural, by identifying the structure primitives and their placement rules;
- statistical, taken into account the spatial distribution of the image pixel's intensity.

Survey of color and texture methods is given in [5].

Image object texture attributes:

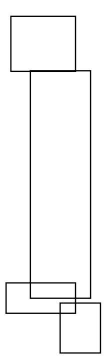
Object = “root”;

Method = contrast;

Value = 3,24.

Image object *texture attribute.* The most used characteristics, describing those attributes are: coarseness, contrast, directionality, regularity and roughness.

OBJECT “ROOT” SHAPE ATTRIBUTES	
Attribute name	**Attribute value**
centroid	(101, 432)
approximation	rectangle

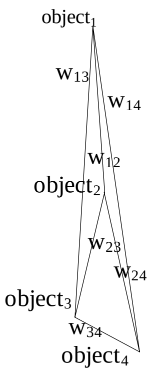


Minimum Boundary Rectangle

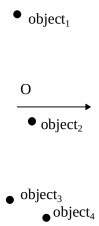
Image object’s shape attributes. These attributes can be described with the help of:

- boundary based geometrical methods such as: a list of corner points and a list of chain codes**,** Minimum Boundary Rectangle **(**the minimum size rectangle that completely bounds an image objects);
- geometrical region based methods on spatial domain such as: holes, Euler number, moment invariant and Zernike moments;
- structural region based methods on spatial domain such as: primitive and 2-D strings;
- region based transformation methods on domain such as: Hough transform, Walsh transform and Wavelet transform.

Survey of the shape description methods is presented in [6].

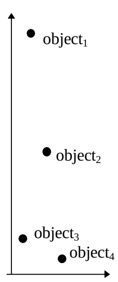


Spatial oriented graph. This is a fully connected weighted graph, where each vertex is connected to every other vertex in the graph. The weight of an edge connecting two vertices is the slope of the line joining the corresponding image object centroids



$\Theta\Re$-string = {$object_1$, $object_3$, $object_4$, $object_2$}

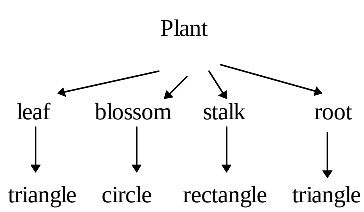
Θℜ- string. This sting represents the image objects name in the order by the radial sweep line, started at the image centroid paint, as the line sweeps one full revolution about the pivot paint.



Horizontal = {$object_3$, $object_1$, $object_2$, $object_4$};

Vertical = {$object_4$, $object_3$, $object_2$, $object_1$}.

2D string. This sting is a representation of the projection of the image object centroids along the axes.



Tree of elements. The image can be presented as hierarchical trees of elements that defined bigger object, and so on

V_T = {line, circle, arc, $\leftarrow$, $\uparrow$, $\rightarrow$, $\downarrow$}

V_N = {blossom, stalk, leaf, root}

P = Plant $\rightarrow$ blossom $\downarrow$ (stalk $\leftarrow$ leaf) $\downarrow$ root

Grammar structure. A string grammar is a four-tuple $G=(V_N,V_T,P,S)$, where V_N is a finite set of nonterminals (variables), V_T is a finite set of terminals (constants), $(V_T \cap V_N = \varnothing)$, P is a finite set of productions and S is the start (root) symbol ($S \in V_N$). Fuzzy grammar, based on fuzzy logic can be also used.

OBJ./ OBJ.	1	2	3	4
1	*	touch	disjoint	disjoint
2	*	*	touch	touch
3	*	*	*	touch
4	*	*	*	*

Topological set of relations. This relation is considered between two image-objects and contains: in, disjoint, touch, and cross.

OBJ./OBJ.	1	2	3	4
1	*	SW	S	SW
2	*	*	SE	SW
3	*	*	*	SW
4	*	*	*	*

V***ector set of relations.*** These set considers the relevant position of the image-objects: E, S, W, N, SE, SW, NW, NE in terms with the four world directions East, South, West, North.

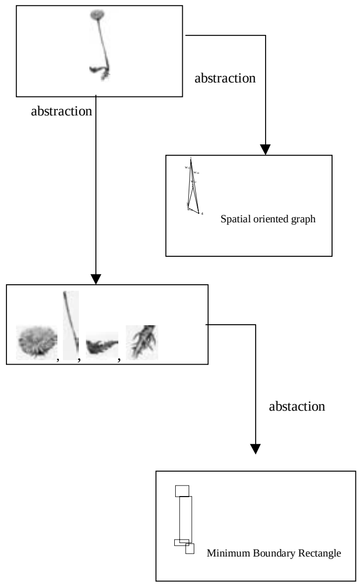
OBJ./ OBJ	1	2	3	4
1	*	very close	very far	very far
2	*	*	very close	very close
3	*	*	*	very close
4	*	*	*	*

Metric set of relations. This set is based on the distance between the image-objects and contains: close, far, very close, very far.

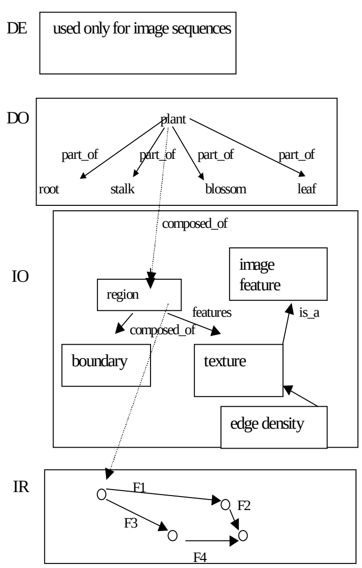
3. IMAGE DATA MODELS

An ***Image Data Model*** is a type of image data abstraction that is used to provide a conceptual image representation. It is a set of concepts that can be used to describe the structure of an image. The process of image description consists of extracting the global image characteristics, recognizing the image-objects and assigning a semantic to these objects. Approaches to image data modeling can be categorized based on the views of image data that the specific model supports.

Some valuable proposals for image data models are: VIMSYS image data model, model where images are presented as four plane layers [7]; $EMIR^2$- an extended model for image representation and retrieval [8]; and AIR - an adaptive image retrieval model [9].



Possible logical structure in AIR model

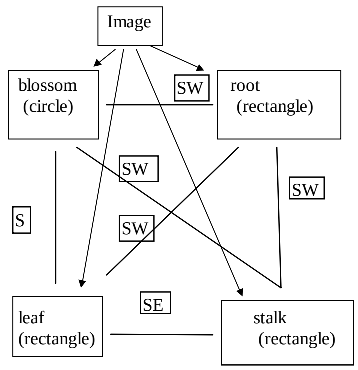


The planes in layered data model of VIMSYS

The ***AIR (Adaptive Image Retrieval) model*** claims that it is the first comprehensive and generic data model for a class of image application areas that coherently integrates logical image representations. It is a semantic data model that facilitates the modeling of an image and the image-objects in the image. It can be divided into three layers: physical level, logical level and semantic or external level representation. There are two kinds of transformations that occur in the model. The first is the transformation from the physical to the logical representation, such as a spatial oriented graph. The second transformation involves the derivation of the semantic attributes from the physical representation.

The ***VIMSYS (Visual Information Management System) model*** views the image information entities in four planes.

The model is based on the image characteristics and the inter-relations between those characteristics in an object oriented design. These planes are the domain objects and relations (DO), the domain events and relations (DE), the image objects and relations (IO) and the image representations and relations (IR). An object in this model has a set of attributes and methods associated with them. They are connected in a class attribute hierarchy. The attribute relationships are spatial, functional and semantic. The ***IO plane*** has three basic classes of objects: images, image features and feature organizations. These objets are related to one another through set-of, generalization (is-a) and feature of relations. Image feature is further classified into texture, color, intensity and geometric feature. The ***DO plane*** consists of a semantic levels specification of domain entities, build upon the two previous levels. The objects commit through an object-region graph. The ***DE plane*** has been included in the model to commode the event definition over image sequences. The ***IR plane*** is clearly functional.



Possible image description in the ***EMIR²*** model

The ***EMIR²* (Extended Model for Image Representation and Retrieval) model** combines different interpretations of an image in building its description. Each interpretation is presented by a particular view. An image is treated as a multiple-view object and is described by one physical view and four logical views: structural, spatial, perceptive and symbolic. For the description of the view context free grammar formalism is used. The ***structure*** view defines the set of image objects. The ***spatial*** view of an image object is concerned about the shape of the image objects (contour) and the spatial relations (far, near, overlap, etc.). That indicates their relative positions inside the image. The ***perceptive*** view includes all the visual attributes of the image and/or image objects. In the model this attributes are describing the color, brightness and texture. The ***symbolic*** view associates a semantic description to an image and/or image object. In the model two subsets of attributes are used: first associated with the image, e.g. size, date, author, etc., and those associated to the image objects, e.g. identifier, name, etc.

4. THE OOID MODEL DESCRIPTION

The proposed OOID model establishes taxonomy based on the systematization on the existing approaches. The main requirement to the proposed model could be summarized as:

- powerfulness. To be applicable to a wide variation of image collections;
- to consider the characteristics of the images and image objects as different types of data;
- to consider different types of relations among the image objects;
- to allow different kind of functions over the physical and logical image description.

The proposed approach for the image modeling includes:

- using language approach, where language structures are used for physical and logical image content description;
- using object oriented approach, where the image and the image objects are treated as objects containing appropriate functions calculating its functions.

The data model is object oriented. The image itself together with its semantic descriptions is treated as an object in terms of the object oriented approach. The image is presented in two layouts (classes) - logical and physical. The logical layout contains global description and content-based layouts (subclasses). The global description layout consists of the meta and the semantic attributes of the image. The content-based layout has two sub-layouts (subclasses): model-based and general purpose. The model based layout contains: (1) the attributes of the image-objects, described which their color, texture, shape, logical and semantic attributes and (2) relationships between the image-objects, described using topological, vector, metric or spatial criteria. The general-purpose layout describes the color and the texture of the image as an entity. The physical layout contains the image header and the image pixel's matrix. A semantic schema of the proposed model is shown in Figure 1.

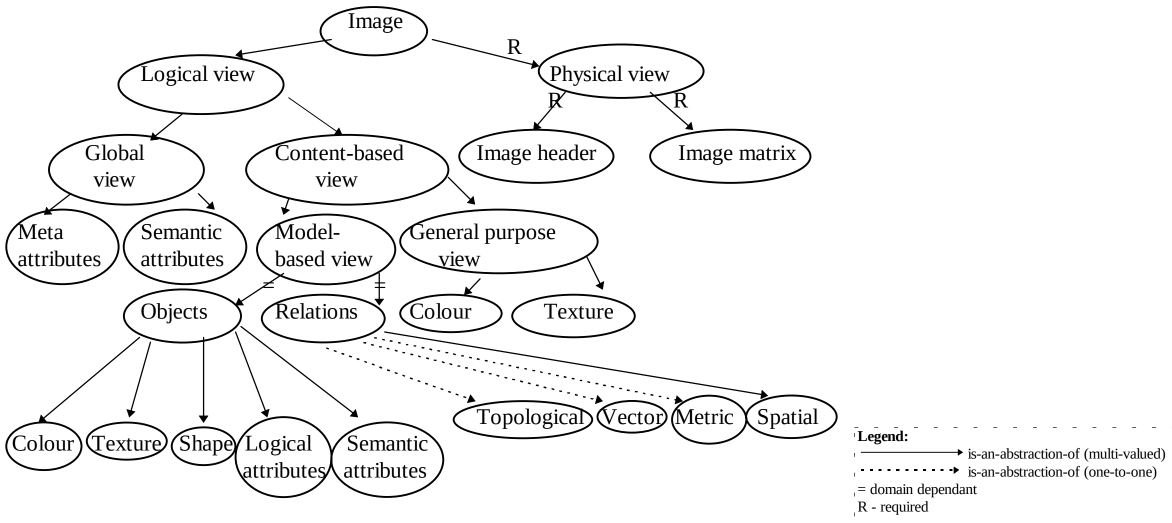


Figure 1. Semantic schema of the OOID model

The ***image data*** are defined as a composition of the physical view - the image itself, and the logical view - a description of the image content and additional information about the image. The ***logical view*** of a given image is defined as the description of the global image characteristics and the recognized image-objects and the semantics associated with them. The structured part of this information can be used in the image indexing and creating an image retrieval mechanism. There are two main approaches to the logical image description: based on the global image characteristics and based on the image content. In the ***global view*** approach the image content is described with the use of a list of attributes. Most of the available image database systems are using this approach for image description. Two kinds of attributes: meta and semantic attributes are used in this approach for global image description. An alternative to the global image description is based on the visual image content. The image ***content-based view*** describes the image-objects properties such as: color, texture patterns, shapes, image-object attributes and relevant location to each other of these image-objects. For the content-based description two approaches: model based and general-purpose based approaches are used. The ***model-based*** approach assumes that there exists some prior knowledge (model) about the types and the structure of the image-objects that can be part of the image. In this approach predefined image-objects are extracted from the image and the relationships between them are studded. The following properties of the image objects are analyzed: color, texture, shape, logical attributes, and semantic attributes. The following types of ***relations*** between the image-objects are considered in the OOID model: topological, vector, metric, and spatial. ***The physical view*** contains the pixel matrix of the image and its header. In our approach one physical image can be stored in several physical views (e.g. the image itself, the "thumbnail" image, the bitmap image, etc.).

5. AN EXAMPLE FOR APPLYING THE OOID MODEL

Let's consider the used in the previous section image of a plant picture. After the segmentation procedure the image is partitioned in the following image-objects: blossom, stalk, leaf, root. A possible view as a result of applying the OOID model to the example image is given in Figure 2. At present a software realization of the model for Windows 95 is considered in the Sofia Image Database Management System. An example for applying the OOID model through the Logical Image Definition Language in the system is shown in Figure 3.

PHYSICAL VIEW

Image header

NAME	VALUE
image name	herb 101
# of pixels in x direction	185
# of pixels in y direction	485
# of pixels in z direction	1
FOV in x direction in cm	6
FOV in y direction in cm	12.5
FOV in z direction in cm	NULL
# bytes per pixel	1
pixel organisations	RGB
compression schema	no compression
image type	TIFF

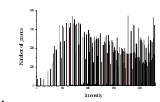
Image matrix

(237,225,247)	…	(246,226,237)

(24,245,245)	…	(245,227,238)

OBJECT	1	2	3	4
1	*	NE	NE	NE
2		*	NE	N
3			*	NW
4				*

CLASS: META ATTRIBUTES		**CLASS: SEMANTIC ATTRIBUTES**	
Attribute name	**Attribute Value**	**Attribute name**	**Attribute Value**
name	Rions - tooth	use-in-medicine	big
source	book 102		
remark	page 32		
distribution	grass-lend		
blossoming period	[March, November]		



Class: colour; **Method**: histogram; **Value**:
Class: texture; **Method**: contrast; **Value**: 1.38

Global view

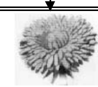
			
Class: name **Value** blossom	**Class**: name **Value:** stalk 1	**Class**: name **Value**: leaf 1	**Class**: name **Value** root
Class: colour **Method**: average **Value**: yellow	**Class**: colour **Method**: average **Value**: dark green	**Class**: colour **Method**: average **Value**: dark green	**Class**: colour **Method**: average: **Value**: brawn
Class: texture **Method**: contrast **Value**: 2,31	**Class**: texture **Method**: contrast **Value**: 0,91	**Class**: texture **Method**: contrast **Value**: 3,36	**Class**: texture **Method**: contrast **Value**: 3,24
Class: shape **Method**: centroid **Value**: (48,36)	**Class**: shape **Method**: centroid **Value**: (72,194)	**Class**: shape **Method**: centroid **Value**: (44,401)	**Class**: shape **Method**: centroid **Value**: (101,432)
Class: shape **Method**: approximation **Value**: circle	**Class**: shape **Method**: approximation **Value**: rectangle	**Class**: shape **Method**: approximation **Value**: triangle	**Class**: shape **Method**: approximation **Value**: rectangle
Class: logical attributes **Method**: length **Value**: 2,1	**Class**: logical attributes **Method**: length **Value**: 1,1	**Class**: logical attributes **Method**: length **Value**: 2,6	**Class**: logical attributes **Method**: length **Value**: 1,5
Class: logical attributes **Method**: with **Value**: 1,6	**Class**: logical attributes **Method**: with **Value**: 8,4	**Class**: logical attributes **Method**: with **Value**: 1,1	**Class**: logical attributes **Method**: with **Value**: 1,6
Class: semantic attributes **Method**: form **Value**: basket	**Class**: semantic attributes **Method**: form **Value**: smoothly	**Class**: semantic attributes **Method**: form **Value**: lanceolate	**Class**: semantic attributes **Method**: form **Value**: spindle
Class: semantic attributes **Method**: metamorphosis **Value**: tongue-shaped	**Class**: semantic attributes **Method**: metamorphosis **Value**: none	**Class**: semantic attributes **Method**: metamorphosis **Value**: none	**Class**: semantic attributes **Method**: metamorphosis **Value**: none

Figure2. Semantic representation for the OOID model of a plant image

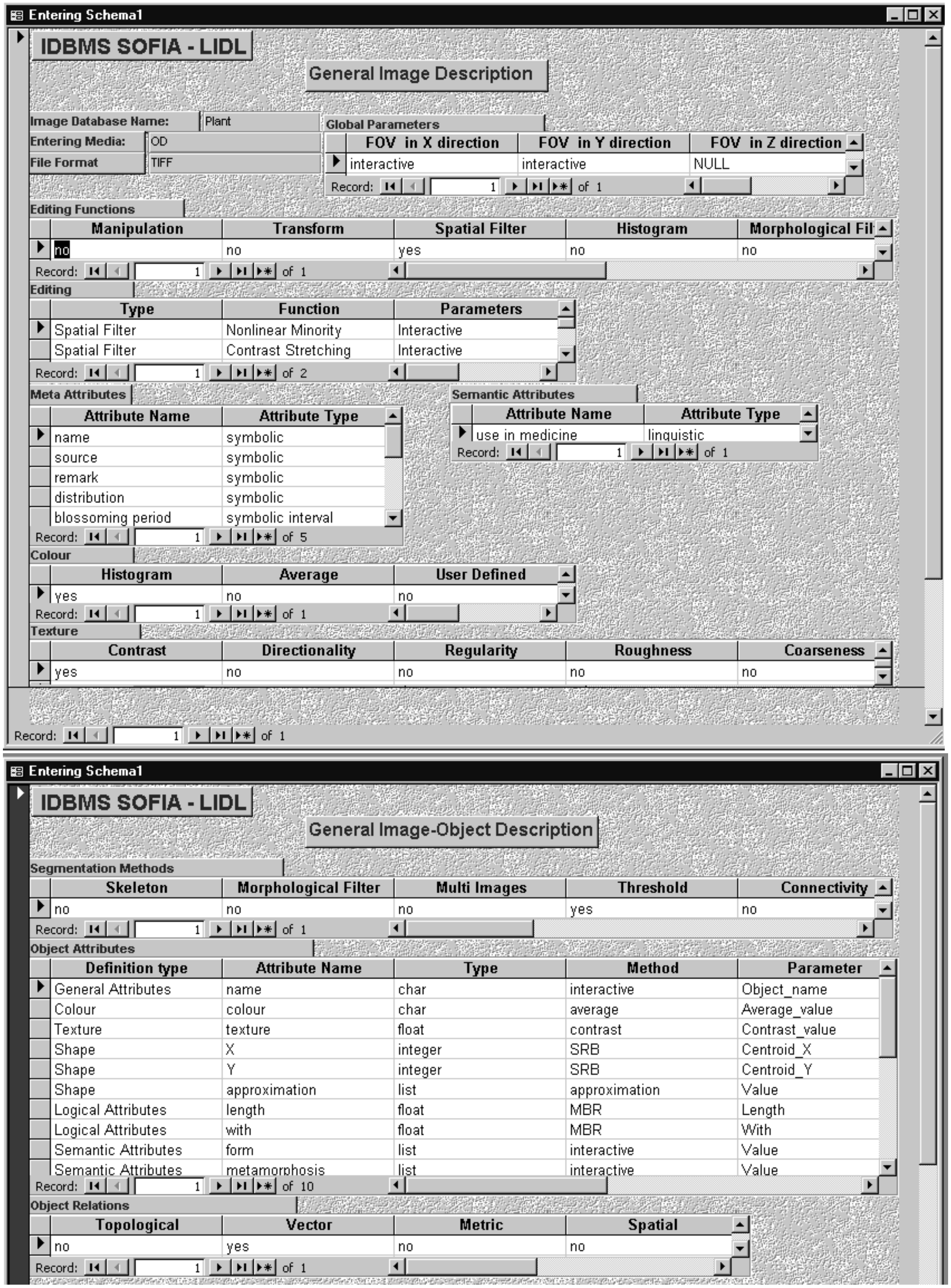


Figure 3. An example for applying the OOID model through the Logical Image Definition Language in the Sofia Image Database Management System

6. CONCLUSION

The main advantages of the proposed OOID model could be summarized as follows:

- its generality. The model uses the main techniques from the existing image data models and it is applicable to a wide variety of image collections;
- its practical applicability. The model can be used as a part of image retrieval and image database system;
- its flexibility. The model could be customized when used with a specific application.

The proposed model could be extended to include the description of multimedia objects such as voice and video.

7. ACKNOWLEDGMENTS

This work is partially supported by a project VRP – I 1/99 of the National Foundation for Science Research of Bulgaria and INCO Copernicus project INTELLECT (PL 961099).

8. REFERENCES

[1] Stanchev, P., and Rabitti, F. GRIM_DBMS: a GRaphical IMage DataBase Management System, in Kunii, T. (eds.), Visual Database Systems, (North-Holland, 1989), 415-430.

[2] Stanchev, P., Smeulders, A. and Groen, F. An Approach to Image Indexing of Document, in Knuth, E. and Wegner L. (eds.), Visual Database Systems II, (North Holland, 1992), 63-77.

[3] Stanchev, P. General Image Retrieval Model, in Proc. 27-th Spring Conference of the Union of the Bulgarian Mathematicians, (Pleven, 1998), 63-71.

[4] Stanchev, P. General Image Database Model, accepted for the Third Conference on Visual Information Systems, The Netherlands 1999.

[5] Van Otterloo, P. A Contour-Oriented Approach to Shape Analysis, Great Britain, Prentice Hall International, 1991.

[6] Furht, B., Smoliar, S. and Zhang, H. Video and Image Processing in Multimedia Systems, Norwell, Massachusetts, USA, (Kluwer Academic Publishers, 1995).

[7] Gupta, A., Weymouth, T. and Jain, R. Semantic Queries with Pictures: The VIMSYS Model, in Proc. 17th Conference on Very Large Databases, Palo Alto, California, (Morgan Kaufmann, 1991), 69-79.

[8] Mechkour, M. EMIR^2. An Extended Model for Image Representation and Retrieval, in Revell, N. and Tjoa, A. (eds.), Database and Expert Systems Applications, Berlin, (Springer -Verlag, 1995), 395-414.

[9] Gudivada, V., Raghavan, V. and Vanapipat, K. A Unified Approach to Data Modeling and Retrieval for a Class of Image Database Applications, IEEE Transactions on Data and Knowledge Engineering, 1994.