1. INTRODUCTION

Visual Languages can be basically classified in two main categories: languages that provide a formalism for visual representation and languages for visual programming. To the first class belong languages that provide a logical interpretation of visual information such as images or pictorial objects. To the second class belong languages that support a visual representation of traditional data type to provide systems with a more user-oriented interface.

We consider the first approach and define a language for the definition of pictorial objects and visual queries on an image knowledge base. In the definition of our language we use a logical formalism instead of an approach based on grammars since this can enforce the importance of the semantics in reasoning about image content.

The proposed language is made up of a definition and a query language, both defined following description techniques based on a Knowledge Representation (KR) approach. The approach is declarative and defines a sketch-based language whose syntax and semantics stems from Description Logics (DL), a family of logic formalisms for KR. As any KR formalism, they are equipped with a syntax to express pieces of knowledge, a semantics (which for DL is usually model-theoretic), and a set of reasoning services that infer implicit knowledge from asserted expressions.

In such a definition, a set-theoretical view of images is needed both for the syntactic and for the semantic level. This has many advantages: the language we propose is compositional so it can provide a structured representation of objects; it is possible to
perform logical reasoning about the spatial representation component. Besides syntactic transformations can be proved to be sound with respect to the semantics. Finally, the method implements a sound and complete algorithm that performs reasoning services typical of a knowledge based environment such as subsumption, i.e., query containment, recognition, retrieval and classification. Besides, complex services such as reasoning about queries, e.g., containment and emptiness can be performed. These services can be used for both exact and approximate matching, using similarity measures.

As other approaches do, we start from low-level features extracted with image analysis to detect and characterize regions in an image. However, in contrast with feature-based approaches, the syntax we provide allows one to describe segmented regions as basic objects and complex objects as compositions of basic ones.

We believe that the main advantages that a knowledge representation approach brings to research in image retrieval can be summarized as follows:

1. It separates the problem of finding an intuitive semantics for query languages in image retrieval from the problem of implementing a correct algorithm for a given semantics.
2. Once the problem of image retrieval is semantically formalized, results and techniques from Computational Geometry can be exploited in assessing the computational complexity of the formalized retrieval problem, and in devising efficient algorithms, mostly for the approximate image retrieval problem. This is very much in the same spirit as finite model theory has been used in the study of complexity of query answering for relational databases [14].
3. Our language borrows from object modeling in Computer Graphics the hierarchical organization of classes of images [27]. This, in addition to an interpretation of composite shapes which one can immediately visualize, opens our logical approach to retrieval of images of 3D-objects constructed in a geometric language [44].
4. Our logical formalization, although simple, allows for extensions which are natural in logic, such as disjunction of components. Although alternative components of a complex shape are difficult to be shown in a sketch, they could be used to specify moving (i.e., non-rigid) parts of a composite shape. This exemplifies how our logical approach can shed light to extensions of our syntax suitable for, e.g., video sequence retrieval.
5. The language can be easily extended to represent and reason on vectorial images and adapted to new standard such as the W3C recommended Scalable Vector Graphics (SVG) [20].

2. KNOWLEDGE REPRESENTATION AND DESCRIPTION LOGICS

To make the work self-contained, we now give a brief introduction to Knowledge Representation and Description Logics; more details can be found in the literature, e.g. [59], [8], [23], [4].

**Knowledge Representation.** Knowledge Representation provides methods for representing high-level descriptions of the real world that can be used to build systems