JPEG's JPSearch Standard: Harmonizing Image Management and Search

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The goal of the JPSearch Project is to facilitate and unify access to distributed image repositories by defining interfaces and protocols for data exchange.

The highly visible spread of social media networks on the Web has resulted in a vast amount of visual data, which are omnipresent in the postings on Facebook, Twitter, and so on. Besides well-known social media services such as Flickr, many stock photo sites have been emerged that provide an immense amount of visual information. Together, all these services store petabytes of visual data as well as the corresponding metadata information (such as title and creator). Efficient and effective access to this data is crucial to enable a satisfactory use for consumers of those sites. (An excellent survey discussing all the relevant issues involved in this new age of image search is available elsewhere.[1])

To handle the tremendous amount of visual data, many application domains have defined various metadata formats for different needs. However, how to ensure interoperability in order to enable a unified retrieval as well as efficient access to visual metadata is still an unsolved research topic.[2] This lack of interoperability has already been treated in several research papers. (See related work for a good overview.[3]) The need for metadata interoperability is evident within all phases of the multimedia life cycle that constitutes the necessary phases, from media production to storage, retrieval, and consumption. Within these, a special focus lies on the relation between media resources, metadata, and users. The life cycle clearly shows the need for harmonization because the multimedia application domain is way too large to have one application to manage all the facets of the defined phases.[4]

Following this line of thought, Lynda Hardman and her colleagues focused on the lack of harmonization at the interface level.[5] They lifted the initial idea of the life cycle to canonical processes of semantically annotated media production. A canonical process is defined as the most general description of a fundamental process to foster interoperability among different systems. This can be seen as an abstraction layer for building the actual basement of, for instance, the Unified Modeling Language (UML) model. The need for canonical processes even arises in the domain of today's Web. As already mentioned, the amount of media sharing platforms is increasing daily. Nearly every sharing platform utilizes its own (proprietary) metadata formats and interfaces to store and retrieve the data, which prevents multimedia objects from being first class citizens of the Web.[6,7]

This lack of harmonization in image and metadata management led to the JPSearch initiative. JPSearch (ISO/IEC 24800) is a work item of the Joint Photographic Experts Group (JPEG) committee, formally known as ISO/IEC JTC1

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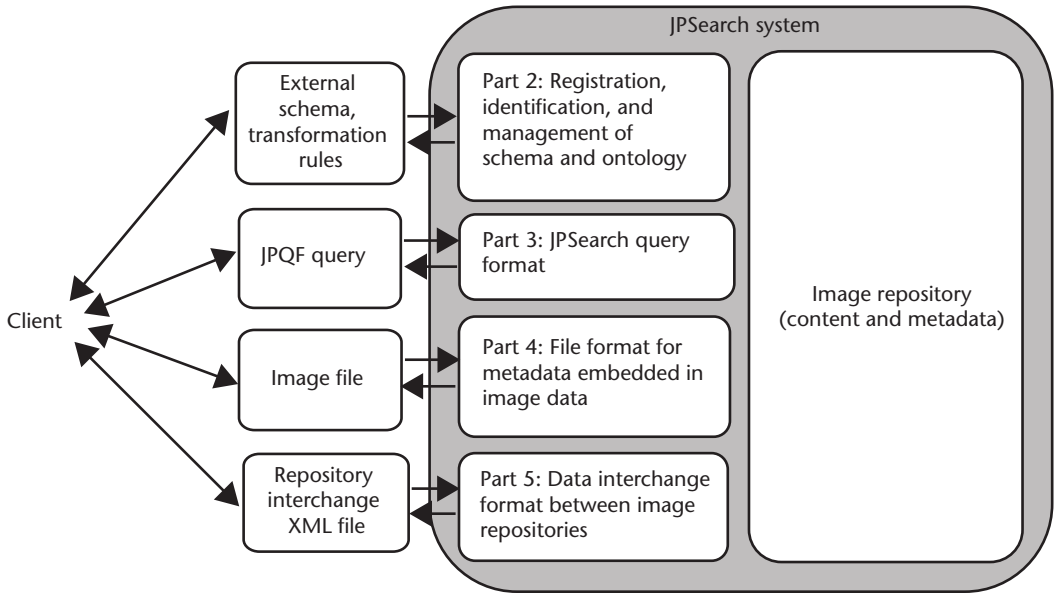

Figure 1. JPSearch is designed as a multipart specification.

SC29 WG 1. The JPSearch Project can be arranged as a continuation of the canonical processes with a special focus on the image retrieval domain. Its goal is to facilitate and unify access to distributed image repositories by defining interfaces and protocols for data exchange. The project defines clear interfaces for essential stages in the life cycle of images (such as file format and query language) as well as a core vocabulary with clear semantics to improve metadata interoperability. This article presents the JPSearch standard in detail and demonstrates its usage by introducing several dedicated case studies.

JPSearch Concepts and Benefits

Essentially, JPSearch specifies the necessary set of standardized interfaces to provide interoperability within the communication process among networked image repositories. In the context of JPSearch, a networked image repository is any network-accessible service that hosts and/or exposes digital image collections and their metadata. JPSearch enables a unified and interoperable interaction with such kinds of services for both humans and machines. ISO/IEC 24800 focuses on the processes of the digital image life cycle[8] with a lack of interoperability that are currently constraining the users' abilities to manipulate their image collections' metadata (for example, by migrating their images and metadata to a different service provider) and also on the processes for which a provision of standardized machine-friendly interfaces would facilitate programmatic access (such as a federated image retrieval). The basic processes that are supported by JPSearch are as follows (see Figures 1 and 2):

- *Image collection creation/maintenance*: The client can create or maintain data on a repository using a standardized data exchange format in which a digital image (resource) and its associated metadata are packed into a single data entity to guarantee their persistent association.
- *Image search/retrieve*: Clients can express a set of precise input parameters to describe their search criteria in addition to a set of preferred output parameters to depict the return result sets in a distributed retrieval environment.
- *Intrinsic metadata storage*: The instantiated metadata information (and also multiple metadata formats) can be stored intrinsically within the JPSearch image file format, which unburdens the transport of metadata and the image data.
- *Repository synchronization*: The client can synchronize entire or partial sets of images on a repository with local data. Through the synchronization of local data with different repositories, data migration from one repository to another (such as between a data cloud and a portable device) can be achieved.

The fact that these different processes depend on a certain way of referring to or expressing image metadata poses a challenge in terms of metadata interoperability because JPSearch is not restricted to a single metadata schema. On the one hand, the standard

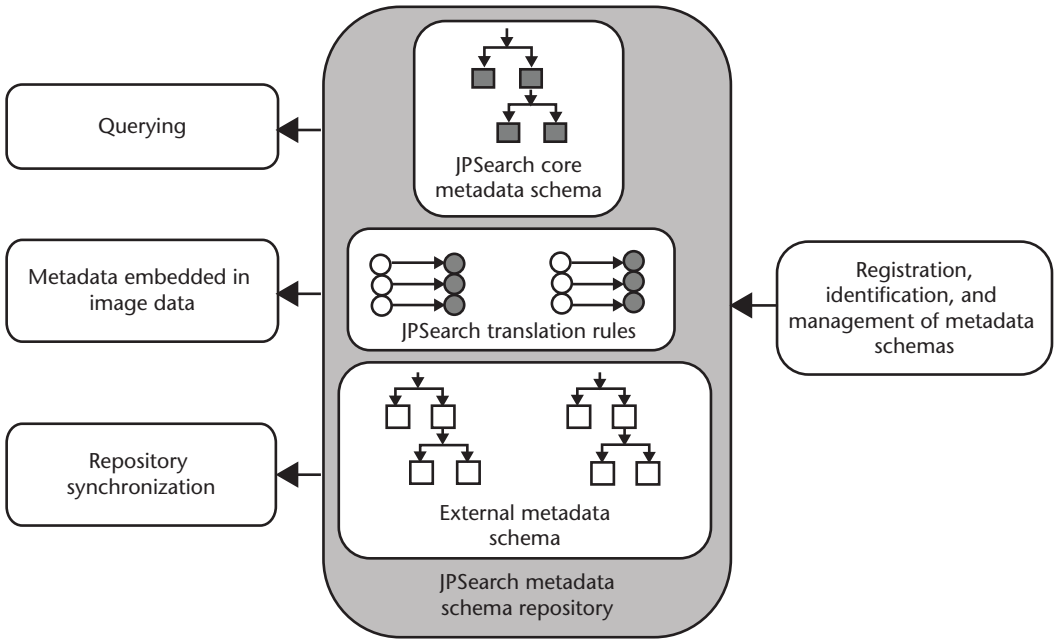

Figure 2. JPSearch metadata interoperability model overview. The JPSearch framework is not restricted to a single metadata format.

provides a reference metadata schema, called the JPSearch Core Metadata Schema, that serves as a metadata basis supporting interoperability among various image retrieval systems. On the other hand, the standard provides a translation rule language, which allows the publication of machine-readable translations between metadata terms in the JPSearch Core Metadata Schema and metadata terms belonging to proprietary metadata schemas. Note that it is not in the scope of JPSearch to standardize the individual components of an image retrieval repository (such as feature comparison or result generation). Instead, the standardization concentrates on specifying interface definitions among image retrieval components to ensure image search in a distributed, heterogeneous environment.

Image Metadata Interoperability

All JPSearch interfaces (querying, file format, synchronization) depend on a certain way of referring to or expressing image metadata, so metadata interoperability plays a crucial role in ISO/IEC 24800. The JPSearch framework is extremely flexible in terms of metadata management, and it is not restricted to a single metadata format. To achieve the maximum level of flexibility, the JPSearch framework is image metadata compliant with any metadata format that can be serialized in XML. Examples of supported metadata formats include Dublin Core and MPEG-7.[9]

Even though any XML-based metadata format can be used, JPSearch specifies the JPSearch Core Metadata Schema as the cornerstone of metadata interoperability. The Core Schema specifies the structure and rules to which any metadata of images must conform in order to be considered valid within a JPSearch-compliant system. A translation rule language allows the publication of machine-readable translations between metadata terms belonging to proprietary metadata schemas and metadata terms in the JPSearch Core Metadata Schema. Users can choose which metadata language to use in a JPSearch-based interaction (annotation, querying, and so on) if the proper translations are available.

JPSearch Registration Authority

According to the JPSearch specification, ISO/IEC 24800 compliant systems can manage multiple proprietary or community-specific metadata schemas besides the JPSearch Core Metadata Schema. To rationalize the usage of schemas and translation rules across different JPSearch systems, a global authority for schemas and their translation rules has been established where all JPSearch-compliant retrieval applications can obtain the information needed. The ISO Technical Management Board appointed the Distributed Multimedia Applications Group (DMAG-UPC, a research group of the Computer Architecture Department of the Universitat Politécnica de Catalunya) to serve as the registration authority (RA), which has been operative

since the summer of 2012. The JPSearch RA will maintain a list of metadata schemas together with their related translation rules, if any. More information about the JPSearch RA is available at http://dmag1.ac.upc.edu:8080/jpsearch-ra.

Parts of JPSearch

This section gives a detailed description of the composition of the JPSearch standard and its individual parts. JPSearch is a multipart standard and currently covers six parts. The first part provides a global view and introduction of the JPSearch specification and corresponds to the content of this article.

Part 2

JPSearch part 2 (ISO/IEC 24800-2) Registration, Identification, and Management of Schema and Ontology is intended to provide interoperability among various heterogeneous descriptions of JPEG/JPEG2000 images. It is natural that a description provided by one person for a certain JPEG image may not have the same structure and meaning as another description provided by another person for the same JPEG image. This part of JPSearch is developed to provide a solution to the problem of lacking interoperability in terms of different structural organization layouts of heterogeneous metadata.

This standard does not provide solutions for the semantic and subjective differences (culture, education, and so forth) between descriptions. JPSearch part 2 solves this problem by providing three key tools: core metadata, schema management tools, and schema translation rules. Also, these three tools support social tagging in combination with the JPSearch file format defined in part 4. The roles and benefits of each of these three tools are given in detail in the following sections.

JPSearch Core Metadata. The core metadata provides standardized representations of fundamental image description metadata, which is defined by using XML schema. The JPSearch Core Metadata Schema defines a single root element named ImageDescription. The ImageDescription element further contains 19 elements for image description, which are summarized in Table 1. These 19 elements are carefully selected as the minimum or common metadata terms from the various image-related metadata schemas such as Dublin Core, MPEG-7, and EXIF.[10] The JPSearch Core Metadata plays a key role in social tagging and metadata interoperability by providing base metadata through which other proprietary metadata instances can be interpreted.

Schema Management. The schema management tools provide functionality for registering, requesting, and replacing metadata schemas, translation rules, and contact information through the registration authority. Through these schema management tools, the JPSearch RA provides an authoritative way of publishing the translation rules or the link to them for the proprietary metadata schemas so that any JPSearch-compliant system can find the corresponding translation rules for metadata terms.

JPSearch Translation Rules Declaration Language. By using the JPSearch Translation Rules Declaration Language (JPTRDL), the schema translation rules define the translation of metadata terms between different metadata formats. The JPTRDL is a well-formed, schema-based language to specify machine-readable translation rules, and it has one root element named TranslationRules for keeping a set of rules. The TranslationRules element is equipped with the source and target metadata formats (by its namespaces) and an unlimited number of TranslationRule elements. Each TranslationRule element can specify a mapping from fields (element or attribute) of the source schema to fields of the target schema. The mapping strategy supports one-to-one, one-to-many, or many-to-one type mappings. The source field of mapping can be specified by XPath expressions, and optionally, the content of source field can be filtered using operations specified by using regular expressions or prefix/postfix operations. Therefore, any metadata instance of one schema can be translated into a metadata instance of another schema once the translation engine follows the translation rules provided by the RA. (For more details, see related work.[11])

Part 3

Part 3 specifies a precise input and output query syntax for retrieval in JPSearch-compliant repositories. The defined query language (JPQF) has been derived by the MPEG Query Format (MPQF) standard;[12] it restricts the available predicates and query types to its use for image data. For instance, the QueryByMedia query type only allows the integration of image data as example media. (Because JPQF is a subset of MPQF, the interested reader should see related

Table 1. Descriptions of the JPSearch core elements.

Element	Description
Identifier	Identifies an individual image
Modifiers	Names of the people who modified the image
Creators	Name of the person who created the image
Publisher	Name of the person or organization who made the image available
CreationDate	Date of creation
ModifiedDate	Date of modification
Description	Free text description of the image content
RightsDescription	Rights related information using either free text or another rights description standard
Source	Information about the source of the image
Keyword	List of keywords characterizing the image
Title	Title of the image
CollectionLabel	Name of the image's collection
PreferenceValue	Level of preference on the image given by the metadata provider
Rating	Rating information providing definition and value of the rating based on the controlled term
OriginalImageIdentifier	Identifier of the image from which the given image is originated
GPSPositioning	Location shown in the image
RegionOfInterest	Description of certain regions of the image with additional information including description using external metadata standards as well as content description of person, object, place, and event
Width	Width of the image in number of pixels
Height	Height of the image in number of pixels

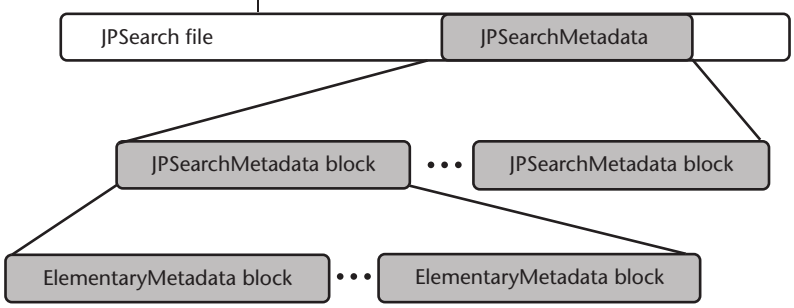

Figure 3. JPSearch file format.

work for example query requests and more details.[12])

Part 4

Part 4 specifies a novel JPSearch file format, which is an extension of the JPEG and JPEG 2000 image file formats. It is fully compatible with JPEG and JPEG 2000 and provides additional functionality carrying associated metadata within a file. The file format supports the storage of metadata in multiple metadata formats, but the information must also be present in the developed JPSearch Core format (see part 2).

Figure 3 shows the main concepts of the file format. It contains several JPSearchMetadata blocks, which are containers for JPSearch metadata and each of them has one or more ElementaryMetadata blocks inside. A ElementaryMetadata block is a basic structure and stores an instance of a certain metadata schema by a certain author. Multiple instances for the same schema can be instantiated simultaneously to implement social tagging functionality. Any type of metadata schemes can be used if they are registered as JPSearch metadata using the JPSearch RA.

Part 5

Part 5 defines a data interchange format that needs to be used for the exchange of image collections between JPSearch-compliant repositories. For this purpose, a metadata schema is designed to carry structural and semantic information regarding the exchange of an image or a collection of images and its associated metadata. To provide an easy and faithful transfer of data among diverse repositories, which are configured with different hardware and software components, the JPSearch data interchange format supports the following use cases:

- consolidating metadata generated on different systems,
- transferring data to a newer and enhanced system,
- synchronizing data between repositories and/or (mobile) devices,
- consolidating selected data to a centralized repository, and
- archiving data in a format that will survive current products.

To enable easy exchange of metadata between repositories, the JPSearch data interchange format encapsulates all the collection-level and item-level (image-level) metadata into a valid XML descriptor that is stored in a single text-based file. Optionally, the descriptive metadata can be compressed using BiM (a binary MPEG format for XML), which is an international standard defining a generic binary format for encoding XML documents. Only JPEG-conforming, JPEG-2000-conforming, and JPSearch-conforming code streams may be used as internal or external resources in the JPSearch data interchange binary file format for collection of images and metadata. In the case of internal resources, the referenced image data should be included in the media data box of the same interchange binary file. The external resource, however, is stored in the separate file from the data interchange binary file that includes references. External resources can be identified by the presence of a particular element, MediaInstance.

In part 5, two XML schemata are defined: JPSearch collection metadata schema and JPSearch XML metadata interchange format schema. The JPSearch collection metadata schema is used for descriptions about image collections supporting information exchange among image repositories. Using the elements supported in JPSearch collection metadata schema, information about image collections can be grouped and described within an XML element. For the exchange of metadata descriptions of images or collections, JPSearch XML metadata interchange format schema is being used to describe one-to-many relationship based metadata regarding internal or external resources. To describe metadata regarding an image at the item level, the elements from the JPSearch Core schema in part 2 of JPSearch is being utilized. It is worth noting that the description of metadata in alternative registered metadata schema is allowed in the JPSearch XML metadata interchange format schema providing flexibility in description composition.

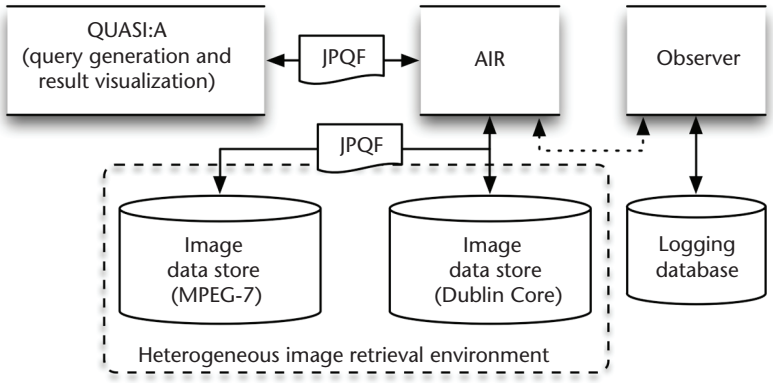

Figure 4. Overview of the AIR framework and its components.

Part 6

Part 6 describes reference software for the normative clauses and utility software demonstrating the usage scenarios of parts 2, 3, 4, and 5. The information in part 5 is helpful in determining the reference software modules and to understand the functionalities of the reference software that can be used either standalone or as a part of larger integrated software depending on the module.

JPSearch Already in Action: Example Implementations and Use Cases

Although the JPSearch standard has just recently been published, there are several projects and use cases where individual parts (or a combination of them) have been successfully applied.

Meta Search Engines

AIR is a middleware-based multimedia retrieval framework (see Figure 4) supporting MPQF as well as JPQF that is designed to operate in distributed and heterogeneous environments.[13] It offers two SOAP-based peripheral communication layers: backend and client communication layers. The first is intended to (de)register retrieval services and to perform service discovery by the use of filter criteria (such as supported JPQF query types). The second offers an API for JPQF query generation or direct transmission of JPQF queries. By analyzing an incoming query, AIR makes use of its internal service discovery functionality to determine the applicable (registered) retrieval services and (if required) their supported metadata formats

Figure 5. QUASI:A user interface for query generation and result presentation.

to execute metadata transformation on the basis of the JPSearch Transformation Rules.

Because JPQF is based on a machine-readable format and thus the creation of queries is not straightforward for human beings, the AIR environment also facilitates the generation of requests by the Query and Search for Images Application (QUASI:A) (see Figure 5). QUASI:A is a JavaFX-based stand-alone application that offers JPQF query generation as well as result presentation functionalities. The query generation process provides a means to arrange supported query types and predicates by the use of Boolean operators (such as AND) in a tree-based manner. This visualization technique ensures clarity and usability. The images stored in the aggregated result set are presented in a gallery fashioned way. Here, a single image in the gallery can be directly used as an input for a further similarity search or a subset (positive or negative examples) of the result set can operate a relevance feedback query.

In addition, the AIR framework has been successfully integrated in a distributed medical annotation and search environment, which has been developed in the context of the Theseus/Medico project.

Another example use case is the federated image search system developed by DMAG. The aim of this project is to provide the ability to search images, from a central point, on different servers such as Panoramio, Picasa, Twitter, or Flickr simultaneously.[14] The system is compliant with parts 2 and 3 of the JPSearch standard. It receives ISO/IEC 24800-3 (JPQF) queries addressing metadata in ISO/IEC 24800-2 format (extended with some EXIF fields, like the camera make and model) and rewrites them once for every metadata format that is supported (Panoramio, Picasa, and Flickr in the first public version). To ensure that the results are correct, they are reprocessed (or filtered) based on the search constraints whenever possible. This filtering also expands the search capabilities of each server because it allows searches that would not be possible without doing it. A demo of the system (see Figure 6) is available at http://dmag.ac.upc.edu/standardization/jpeg/demo-broker.

Optical Biopsy Retrieval System

Another example use of ISO/IEC 24800 is the BIOPSEARCH system, a content-based medical image retrieval application specialized in optical biopsies.[15] An optical biopsy is an optic diagnostic method capable of analyzing tissue on the surface as well as its depth without the need to extract it from the body. The system assists physicians and other medical personnel in the interpretation of optical biopsies obtained through confocal laser endomicroscopy (CLE), which is a novel technique for intravital microscopy during ongoing gastrointestinal endoscopy.

Most gastroenterologists are not trained to interpret mucosal pathology, and histopathologists are usually not available in the endoscopy suite. Thus, BIOPSEARCH may greatly facilitate CLE database management and diagnosis. The system, also developed by DMAG, lets users navigate and search an image database containing optical biopsies of the human colon. Users can retrieve information about precedent

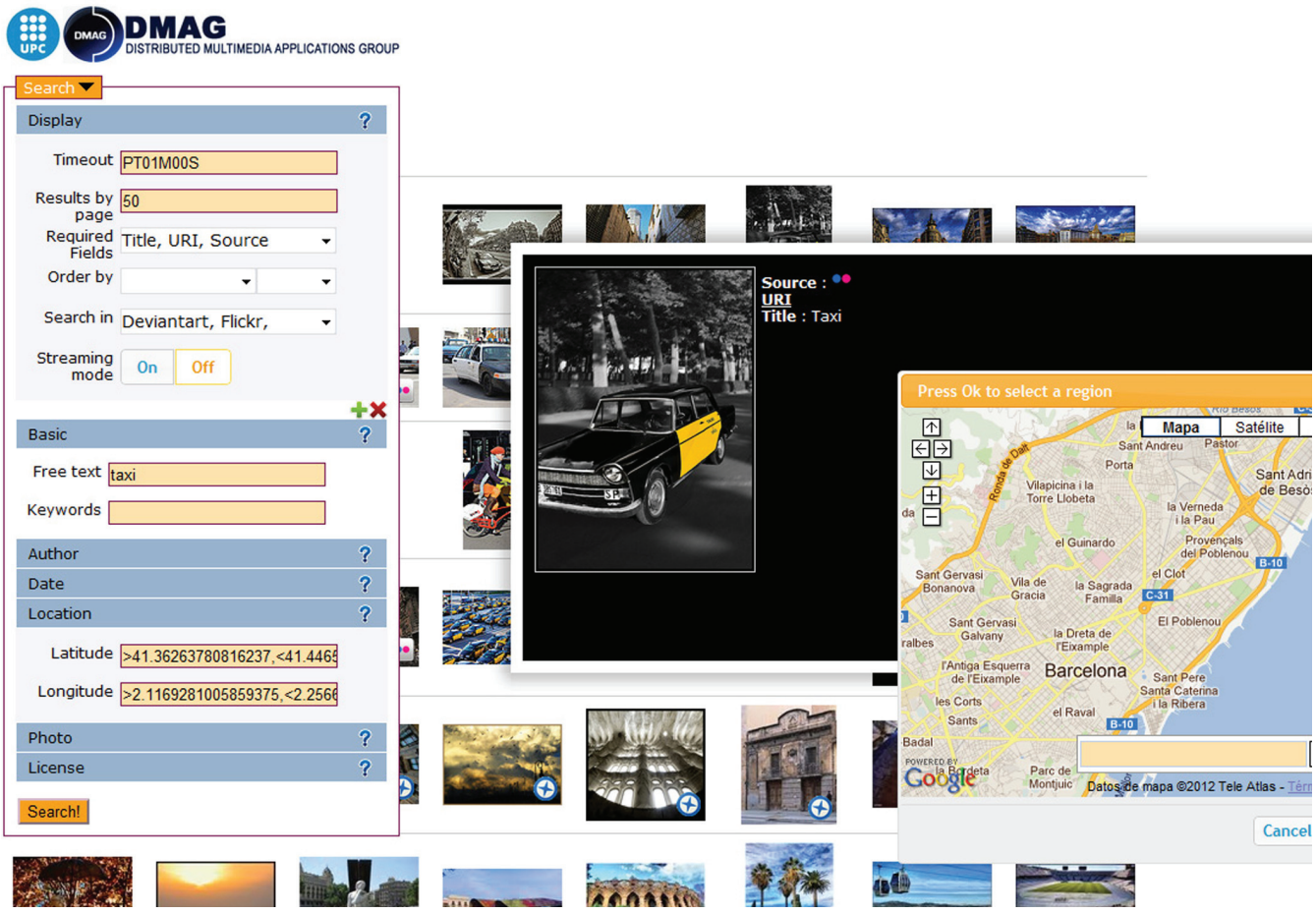

Figure 6. A JPSearch-compliant federated image search system that provides the ability to search images, from a central point, on different servers such as Panoramio, Picasa, or Flickr, simultaneously.

diagnostics by providing an example CLE image for content-based image retrieval (CBIR) by using keywords or by filtering different fields for structured retrieval. This system conforms with ISO/IEC 24800-2 and ISO/IEC 24800-3.

Content-Based Painting Retrieval

The Mobile Museum Guide is a mobile application developed at the Vrije Universiteit Brussel.[16] The application allows museum visitors to receive additional information about a painting by taking a picture of it. This application returns textual information rather than an image or a set of images. To enable content-based querying, the system performs preprocessing, feature extraction, and matching. The preprocessing step includes a foreground extraction that separates the painting from the background. Additionally, noise is reduced and contrast is enhanced.

Depending on the purpose, the preprocessing steps differ from application to application. The subsequent step characterizes the extracted painting by computing features that are expressed as a feature vector. For each image in the database, the feature vector is computed and stored beforehand in an analogous manner. The final step matches the feature vector of the query image with the feature vectors stored in the database. In this particular example, the Euclidian distance was used as a distance measure.

Although JPSearch only specifies the client-server interface, and not the processing steps, two main methodologies can be followed when adopting JPSearch for this particular use case.[17] For the first strategy, one can deploy preprocessing and feature extraction on the client side. In this case, only the feature vector is transmitted to the server. The second strategy sends the entire picture to the server, and all processing is

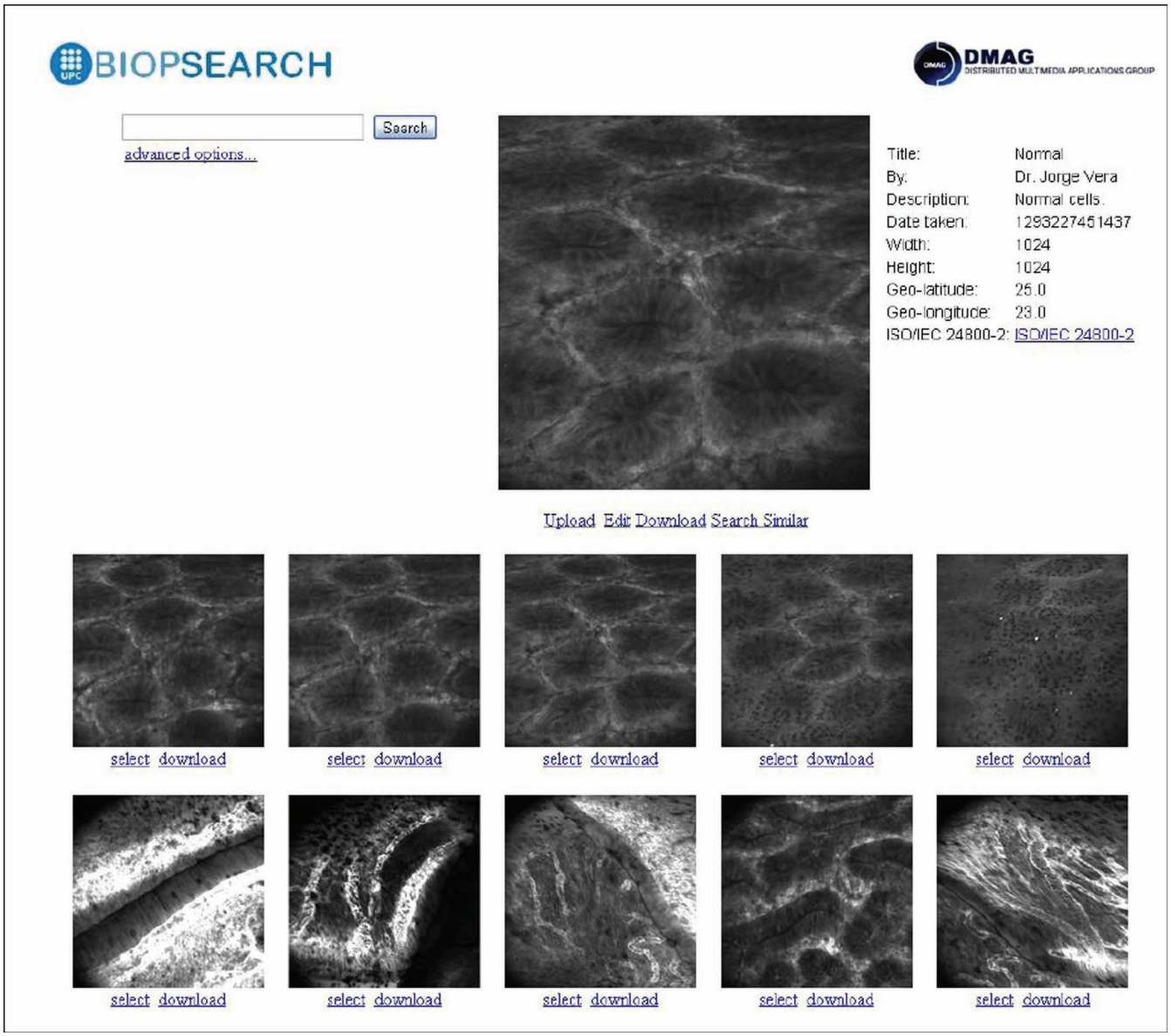

Figure 7. BIOPSEARCH content-based medical image retrieval application.

handled on the server side. The first strategy optimizes bandwidth usage and the second strategy minimizes processing and memory usage on the client side. Additionally, the second strategy may improve interoperability because the retrieval process does not depend on the chosen features. The best choice may depend on the usage scenario.

Conclusion and Outlook

With the JPSearch standard, there is now a metadata format specialized for visual data that is not as exhaustive as MPEG-7/MPEG-21 and therefore simpler and easier to use. However, JPSearch is detailed enough to fit requirements better than general formats such as Dublin Core. There is now a way to more tightly couple the visual data with its metadata, which brings in the new file format supporting an intrinsic storage mechanism. Lastly, JPSearch provides a way to search and synchronize visual data within and across silo-based image repositories.

The next steps of the JPSearch project deal with the development and adoption of a visual ontology that is aimed to be integrated as metadata descriptions and that will allow the cross

linking of information. With this feature, any visual information and its metadata can be interlinked with semantic concepts. Furthermore, the access capabilities of the standard will be enhanced by a data manipulation language offering a means to update, delete, and insert information. **MM**

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