JPSearch: Metadata Interoperability During Image Exchange

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Billions of new images are generated daily. However, the management and exchange of the associated metadata remains cumbersome. Therefore, the Joint Photographic Experts Group (JPEG) has recently promoted a new set of technologies enabling the interoperability between image repositories and/or their clients to an international standard. JPSearch is a suite of specifications that supports the enrichment with metadata data stored in JPEG or JPEG 2000 image formats. It addresses schema and ontology building blocks, a query format, a file format for metadata embedded in image data, and a data interchange format for image repositories.

1. Background

Creating, searching and managing digital images has become ubiquitous. With contemporary smartphones, it only takes a few seconds to take a photo and share it with friends via email, social media or image sharing websites. Afterwards, these pictures can be uploaded to a personal computer for post processing and/or archiving. In the first three months of 2012, on average more than 300 million photos were uploaded to Facebook per day[1]. Moreover, professionals, e.g. hospitals or press agencies, process millions of digital images daily.

Organizing this data poses multiple challenges. Several copies of the same images may be spread over several systems. When images are uploaded to a personal computer or a cloud computing infrastructure, metadata – such as social or personal annotations – are not always preserved. This is a consequence of the fact that these systems may use different metadata formats. Additionally, they may use non-compliant import and export schemes.

Searching digital images is a complex task. The first cause is inherent to the lack of consistency in usage of metadata schemas. This makes addressing specific metadata elements, e.g. the location, problematic. A second reason is the so-called semantic gap. Since not all images are textually annotated, researchers have been exploring methods for querying images by content. However, most common query languages do not support these novel techniques. Finally, accessing content of online repositories is not organized in a consistent way. Many of these repositories provide proprietary Application Programming Interfaces (APIs). These APIs differ from repository to repository and are often too restrictive to handle more advanced queries.

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[1] http://newsroom.fb.com/content/default.aspx?NewsAreaId=22

These issues related to image and metadata management prompted the JPEG committee to initiate the JPSearch standard. The objective of JPSearch is to address interoperability in image search and retrieval systems. For this purpose, JPSearch puts forward an abstract image search and retrieval framework. Interfaces and protocols for data exchange between the components of this architecture are standardized, with minimal restrictions on how these components perform their respective tasks. The use and reuse of metadata and associated metadata schemas is thus facilitated. A common query language is also defined to enable search over distributed repositories. Finally, an interchange format is specified to allow users to easily import and export their data and metadata among different applications and devices.

In the JPSearch framework, interoperability can be defined in different ways: between self-contained vertical image search systems providing federated search, between layers of an image search and retrieval system so that different modules can be supplied by distinct vendors, or at the metadata level such that different systems may add, update or query metadata.

2. Structure of the Standard

The Joint Photographic Experts Group defined the JPSearch specification. JPEG is a joint working group of the International Standardization Organization (ISO) and the International Electrotechnical Commission (IEC). It resides under JTC1, which is the ISO/IEC Joint Technical Committee for Information Technology. More specifically, the JPEG committee is Working Group 1 (WG1), Coding of Still Pictures, of JTC 1's subcommittee 29 (SC29), Coding of Audio, Picture, Multimedia and Hypermedia Information. The word "Joint" in JPEG however does not refer to the joint efforts of ISO and IEC, but to the fact that the JPEG activities are the result of an additional collaboration with the International Telecommunication Union ITU. The committee has defined the following image coding standards:

- The JPEG image coding standard (ISO/IEC IS 10918-1 | ITU-T Rec. T.81);
- JBIG-1 (ISO/IEC 11544 | ITU-T Rec. T.82) and JBIG-2 (ISO/IEC 14492 | ITU-T Rec. T.88);
- JPEG-LS (ISO/IEC 14495-1 | ITU-T Rec. T.87);
- JPEG 2000 (ISO/IEC 15444-1 | ITU-T Rec. T.800) [1] [3];
- JPEG XR (ISO/IEC 29199-2 | ITU-T Rec. T.832) [3].

Recently, the JPEG committee has increased its efforts in providing more system level support for its suite of standards, which resulted in the installment of the JPEG Systems group. One of the precursors of this evolution has been the definition of the JPSearch specification (ISO/IEC 24800-1 to 6) that aims at increasing the accessibility and interoperability of image repositories. The specification is composed of different components addressing the system framework (Part 1) [4], schema and ontology building blocks (Part 2) [5], the query format (Part 3) [6], the file format for metadata embedded in image data (Part 4) [7], the data interchange format for image repositories (Part 5) [8] and finally the reference software (Part 6) [9]. Each part is described hereafter. In-depth presentations of JPSearch can be found in [10][11].

2.1 Global Architecture (Part 1)

The JPSearch system architecture (ISO/IEC 28400-1) [4] is constructed such that it integrates smoothly in typical image processing and management architectures enabling bilateral exchange of information between content producers, consumers and/or aggregators (Fig. 1). The framework especially facilitates metadata survival in processing chains, which among others requires ontological interfacing. Moreover, it fills the gap of missing query formats and search semantics.

Essentially, this requires additional support during three critical phases of the life cycle of a digital (image) item, namely, the content creation/maintenance, the metadata synchronization and finally during search and retrieval processes.

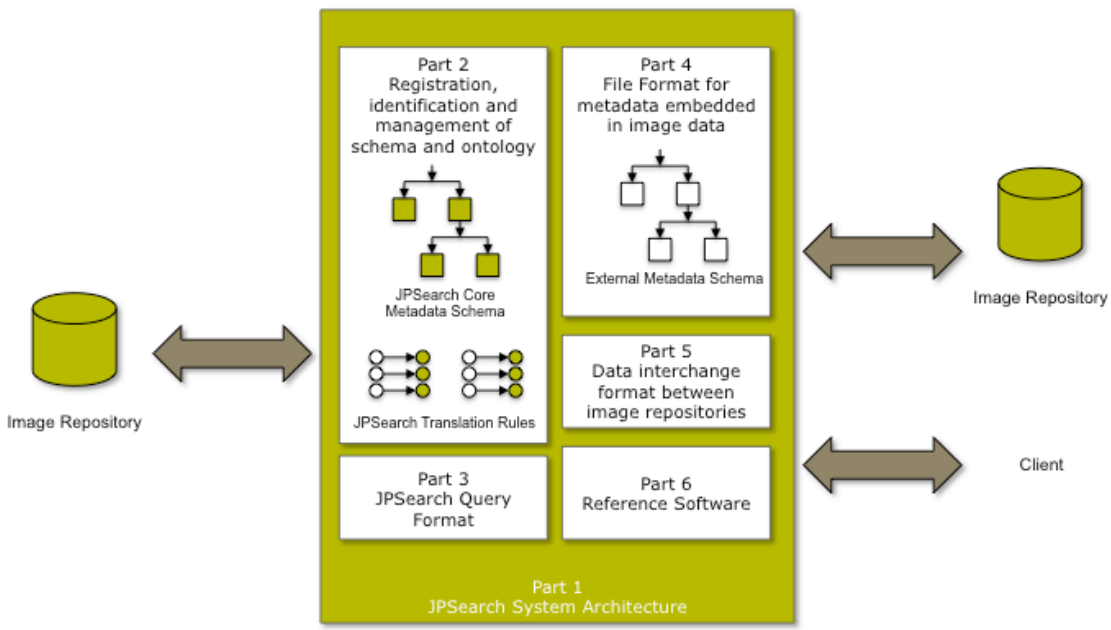

Figure 1 The global architecture of the JPSearch system.

Each of these life cycle phases is addressed by a specific part of the ISO/IEC 28400 suite of specifications. Part 4 supports the creation and maintenance processes by defining a file format for metadata embedded in image data (typically JPEG and JPEG 2000). Part 5 enables synchronization by defining a data interchange format between image repositories. A query format is specified in Part 3, facilitating image search and retrieval.

To couple these parts with a common metadata interoperability model, Part 2 describes the registration, identification and management of schema and ontology. Interoperability is maximized by supporting any image metadata format that can be serialized in Extensible Markup Language (XML).

The annexes of Part 1 contain use cases and examples to understand the use of the JPSearch framework, such as:

- Searching images in stock photo collections for usage in a magazine;

- Searching for and publishing authoritative themed sub-collections of images in order to support a collection curator or publisher that has a new theme;
- Mobile Tourist Information;
- Ad hoc search without time-consuming metadata housekeeping tasks by facilitating exchange of metadata embedded in the picture data;
- Rights clearance to publish a compliant business document by facilitating metadata exchange related to for example usage conditions and intellectual property;
- Tracking a physical object creation process using a temporal series of photos;
- Matching images between potentially distributed collections of a consumer or user with the purpose to synchronize associated metadata;
- Social metadata updating and sharing of images for searching;
- Image search in the medical domain;
- Open federated repositories (e.g. interfacing cultural heritage data repositories).

2.2 Schema and Ontology (Part 2)

JPSearch considers XML-based metadata. A system will use a given schema in order to specify its metadata. The schema characterizes a given type of XML document by defining constraints on its structure and content. More specifically, these constraints include grammatical rules and data types for the elements and attributes of the XML document. In order to be able to make use of a set of metadata, a user needs to understand the corresponding underlying schema. As different image repositories will typically use metadata expressed using different proprietary schemas, it makes searching over these repositories difficult.

The objective of Part 2 of the JPSearch specifications [5] is to be able to correctly understand and handle XML-based metadata expressed using different proprietary schemas. For this purpose, it defines a common metadata schema, referred to as JPSearch Core Metadata, along with rules to translate between proprietary metadata schemas and the JPSearch Core Metadata. It also defines a process to register a metadata schema and its translation rules with the JPSearch Registration Authority (JPSRA).

The JPSearch Core Metadata schema serves as the underlying foundation for interoperable search and retrieval operations across several image repositories. It is used in conjunction with the JPSearch Query Format, as defined in Part 3 of the specifications, to formulate requests to JPSearch compliant systems. A first data type, JPSearchCoreType, is defined to describe essential information about an image pertaining to search and retrieval information. More precisely, it contains important fields such as identifier, modifiers, creators, publisher, creation and modification dates, description, rights related information, source, keywords, title, GPS positioning, and regions of interest. Moreover, three other data types are specified to describe persons present within an image, the source of an image, and information related to the publisher of the work respectively.

Next, Part 2 defines translation rules, in a machine-readable format, to express the semantic and syntactic correspondence between proprietary metadata schema and JPSearch Core Metadata schema. A JPSearch Translation Rules Declaration Language (JPTRDL) is defined for this purpose. It specifies mappings expressed in terms of one-to-one, one-to-many and many-to-one relationships. Besides, content providers have to register their proprietary schema with the JPSRA. More specifically, the registration process requires information about the content provider, schema information, and the translation rules to reformulate a query from the JPSearch Core Metadata schema to the registered metadata schema. The JPSRA validates the submitted information as well as its correctness for JPSearch compliance in order to complete the registration procedure.

2.3 Query Format (Part 3)

The JPSearch Query Format (JPQF) is an essential element of the JPSearch framework that facilitates searching across repositories. It is an XML based query language that defines the syntax of queries, exchanged between client applications and repositories. To encourage interoperability and to avoid defining overlapping standards, JPQF is defined as a subset of the MPEG7 Query Format (MPQF), restricted to the image domain. While the initial JPQF specification referred to the adopted functionalities of MPQF, the current specification specifies the disabled functionalities [6]. As a consequence, additions or changes to MPQF are now automatically reflected in the JPSearch query format, without issuing an addendum or corrigendum within the JPEG committee. The query format consists of three parts: the input query format, the output result format and the query management tools.

The input query format specifies how to formulate search queries to send to a repository. An input query can consist of three parts: a declaration, an output description and a query condition. The declaration offers the possibility to define references to resources, e.g. images used for visual search. These resources can be referred to in the other parts of the query. The output description allows defining the structure and content of the expected result. The last part, the query condition, contains the actual search criteria. It offers different query types including query by media and query by free text. Several conditions can be combined using Boolean, arithmetic, and string expressions. The query can address elements and attributes in a metadata schema by using Xpath expressions.

The output result format specifies how to return aggregated results in order to present them to the user or provide them to intermediate systems for further processing. Finally, the query management part provides tools related to the organizational aspects of exchanging queries. This includes functionalities such as service discovery, service aggregation and service capability description.

2.4 File Format (Part 4)

The JPSearch File Format is specified in Part 4 [7] and enables interoperability between the different actors in an image management and processing value chain, ranging from the clients to the data repositories. When designing the JPSearch file format, the JPEG committee has opted for providing backward compatibility with its previously launched image coding standards. Hence, file format compatibility with the JPEG and JPEG 2000 standards has been assured. Moreover, JPSearch provides several extensions for file-format-independent metadata formats.

A JPSearch file contains a JPSearch container that can incorporate multiple JPSearch metadata blocks. These blocks each contain a metadata schema instance, while allowing multiple instances of the same schema by different authors to enable support for e.g. social tagging functionality. Fig. 2 illustrates the typical constructions of a JPSearch metadata block in a JPSearch file.

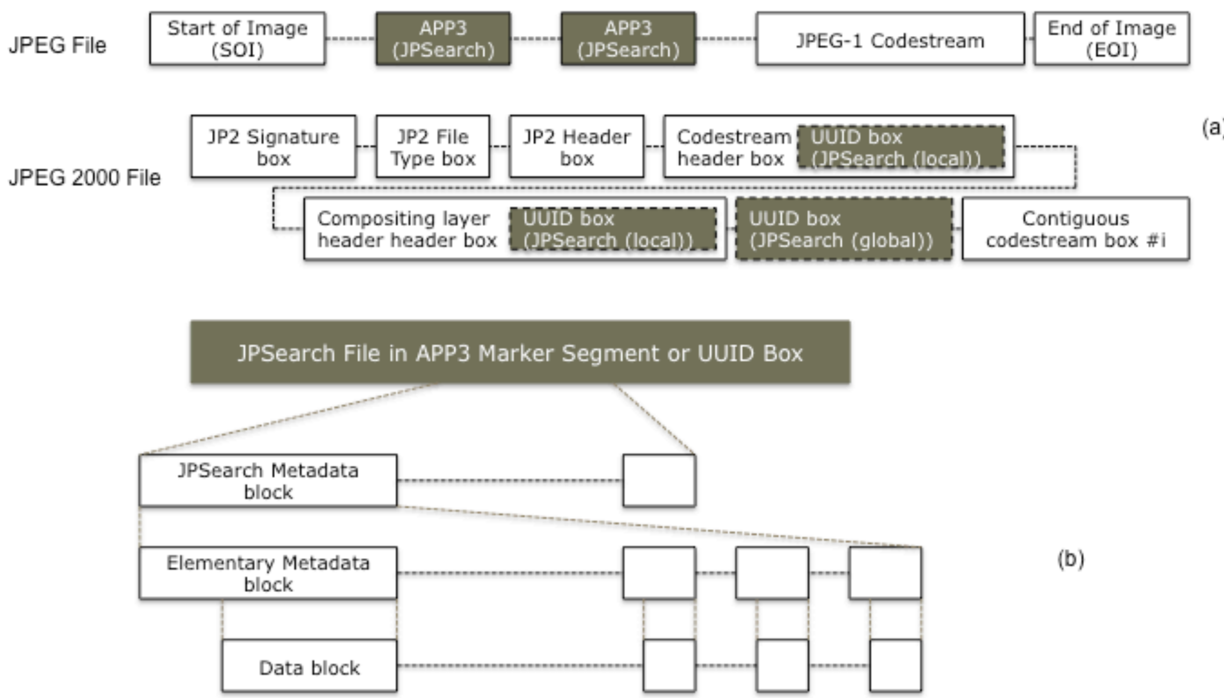

Figure 2 JPSearch files are embedded in JPEG or JPEG 2000 file formats (a), with the potential to have multiple JPSearch files carried by one image file. Each JPSearch file can contain on its turn multiple JPSearch Core Metadata Schema and Registered Schema (b). Each data block is an instance of a JPSearch Core Metadata schema (at least one) or JPSearch Registered Schema each association with a specific, potentially different author.

The JPSearch File Format extends the functionality of the JPEG and JPEG 2000 file formats, embedding the JPSearch metadata in respectively the application marker segments (APP3) and universally unique identifier (UUID) boxes, as illustrated in Fig.2.a. In both cases multiple JPSearch metadata blocks can be inserted in those files, and even exploit the typical layered structure of the JPEG 2000, i.e. JP2/JPX file formats. In the latter case it will be necessary to account for the functionality requested at consultation time of the JPEG 2000 files (e.g. random access or multiresolution support).

2.5 Data Interchange Format (Part 5)

The objective of the JPSearch data interchange format [8] is to enable a number of functionalities to improve the portability of metadata. This metadata can be associated to an image or a collection of images. More specifically, the JPSearch data interchange format addresses the synchronization and exchange of data between JPSearch compliant repositories on different systems. In addition, it enables the consolidation of metadata stored on a variety of devices and platforms, as well as the consolidation of metadata to a centralized repository. The durability and portability of data during system migration or switch is also ensured. Finally, data is archived in a format that can survive current software and hardware systems.

For this purpose, the JPSearch data interchange format incorporates both internal and external resources, including collection-level and item-level metadata along with encoded image bitstreams. Collection-level and item-level metadata can be combined into a valid XML description using a plain-text format. In order to obtain a more compact representation, the descriptive metadata can alternatively be coded using Binary MPEG format for XML (BiM) [12].

More specifically, two schemas are defined to describe metadata related to images and collections of images. The first, the JPSearch collection metadata schema defines the composition of XML metadata descriptions for image collections. Its intent is to make information exchange between image repositories easy. The second, the JPSearch XML metadata interchange format schema supports the interchange of XML metadata descriptions about images and collections. The JPSearch data interchange format includes descriptive elements from the JPSearch Core Metadata schema as defined in Part 2. In addition, it is possible to incorporate metadata expressed using external or user-defined schemas, for instance an MPEG-7 schema.

2.6 Reference Software (Part 6)

To support understanding and use of JPSearch, Part 6 of the specification provides reference software [9] that instantiates the functionality defined in the earlier parts.

The reference software comprises four Java based modules. The *Metadata Translation Module* ingests translated XML metadata into the JPSearch Core Description and vice versa. Currently supported XML formats include MPEG-7 and Dublin Core. The synthetic and semantic validity check of a JPQF input/out query is demonstrated by the *JPQF Query Processor Module*. This interpreter provides additionally the proper JPQF response. To integrate metadata descriptions in JPEG or JPEG 2000 files, the *Embedded Metadata Codec Module* embeds the XML description in JPSearch File Format in the image files. This approach still assures the correct interpretation of these image files in JPEG or JPEG 2000 compliant software. Finally, the *Repository Import/Export Module* enables the exchange of JPSearch metadata files between image repositories.

These software modules can be integrated in larger software environments supporting image repositories, or in solitary client software.

3. Comparison With Other Standards

Another working group within ISO/IEC SC29 is WG11 – Coding of Moving Pictures and Audio – also known as the Moving Picture Experts Group (MPEG). MPEG has developed the MPEG-7 standard, entitled Multimedia Content Description Interface and more formally referred to as ISO/IEC 15938 [13][14]. The objective of MPEG-7 is to standardize a content-based description of multimedia information, targeting applications such as efficient search and retrieval, browsing, filtering, and universal media access. More specifically, MPEG-7 defines Descriptors (D) and Description Schemes (DS). D specifies the syntax and semantics of each feature to describe multimedia content. In turn, DS characterizes the structure and semantic of the relationships between D and DS. Finally, MPEG-7 also standardizes a Description Definition Language (DLL). DLL is based on an XML schema. With the DLL, it is possible to express new or modified D and DS.

MPEG-7 and JPSearch obviously target common application domains. However, their specific objectives differ greatly. MPEG-7 focuses on rich multimedia content annotations, with D and DS, which can represent both low and high level features of the content. Moreover, MPEG-7 also includes tools for content management and intellectual property protection. JPSearch on the other hand does not concentrate on the annotation itself but rather on metadata interoperability, thus making metadata more valuable and extending its lifespan. For this purpose, JPSearch defines a search and retrieval framework and standardizes the interfaces and protocols for data exchange between the corresponding modules of the architecture. In other words, both MPEG-7 and JPSearch standards have different focuses and nicely complement each other.

As far as metadata is concerned, all JPSearch parts, Core schema, query format, metadata embedding, and interchange format, concentrate on the way to express metadata with the aim of metadata interoperability. In addition, JPSearch is very flexible and can handle different metadata representation, including MPEG-7, Dublin Core or Exif.

4. Target Applications

One target group of applications that could benefit from adopting JPSearch is online image sharing platforms, such as Flickr or Picasa. These repositories can support the query format to provide third party applications access to their content. The interchange format can be used to facilitate import and export of collections. Adopting the metadata facilities assures preservation of all metadata.

Client applications, e.g. mobile applications, can also benefit from adopting JPSearch. By supporting the query format for image search, they can support any compliant repository in a single application. Advanced features such as visual search can be integrated to interact with interoperable servers.

An example of an application that already adopts many facets of JPSearch is Cheese, developed at EPFL. Cheese is an image management platform for online use and mobile devices. Beside standard features such as image upload, tagging and keyword based search, it offers the user visual similarity based search, object based tagging and semi-automatic tag propagation. For improved interoperability between different image repositories and applications, the platform supports the export and import of image files with embedded metadata in JPSearch - Part 4 compliant format.

A use case of a JPSearch compliant mobile application is the Mobile Museum Guide, developed at the Vrije Universiteit Brussel. This application allows visitors of a museum to retrieve information about a painting by making a picture of it. Several options for adopting JPSearch in this scenario are illustrated in [10].

5. Current Activities & Future Plans

Most parts of JPSearch have now been accepted as international standards. However, the JPEG committee is still working on further improving image search interoperability. Two recent initiatives are the JPSearch API and a Resource Description Framework (RDF) extension. These topics are currently discussed and are work in progress.

Many contemporary online image services, including Flickr and Picasa, provide access to their data via an API. Third party developers can use these APIs to integrate the provider's data into their own applications. Often, these APIs are simple Representational State Transfer (REST) APIs. They make use of HTTP GET and POST actions for sending or retrieving requests. Response formats are simple, and typically based upon common standards such as XML or JavaScript Object Notation (JSON). In general, these REST APIs are efficient and easy to use.

JPSearch currently supports JPQF to query repositories. It can be seen as an API between clients and repositories. However, the query format was designed with another philosophy. Unlike REST APIs, JPQF only specifies the communication syntax, and not how these queries are sent or retrieved by clients and repositories. Additionally, JPQF was designed to express complex and diverse queries, but because of its diverse nature, simple queries are more complex than typical URL based queries used by many APIs. Therefore, the API will be defined as an addition to JPSearch and complement the current query format.

When designing the JPSearch API the committee will also focus on support for content based image retrieval applications. More specifically, the API will support efficient exchange of binary data such as descriptors or image data.

Two other recent proposals are to (1) formalize the integration of RDF triple tags within JPEG images and (2) standardize a JPEG ontology suite. The first proposal would formalize how triple tags should be integrated within JPEG images. Currently, this can be done in multiple ways. By formalizing this, individual JPEG images could be part of the cloud of linked data in a consistent way. The second proposal defends the need of a shared register of common metadata vocabularies. A metadata vocabulary is a specification of what terms to use in the metadata for a certain domain, and how these terms are defined.

6. Conclusions

Many consumer and professional systems exist today on the World Wide Web, on desktop computers and on imaging devices to store, manage, share and search images. These systems are often relying on proprietary technologies, tightly coupling components of the search process. This results in a closed ecosystem, preventing interoperation with other systems. Moreover, it severely limits the ability of users to freely export their data and metadata to different systems and devices. JPSearch defines the components of a still image search and retrieval framework in order to achieve interoperability. More specifically, it defines interfaces and protocols for data exchange between devices and systems.

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