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**Warburg Iconographic Database: from relational tables to interoperable metadata**

**Introduction**

The art historian and cultural theorist Aby Warburg (1866-1929) gives his name to one of world’s leading centres for interdisciplinary studies in the humanities and sciences, the Warburg Institute in London. Warburg used his primary academic interest, the transmission and reception of the classical tradition in Western (particularly Renaissance) culture, to illuminate his wider interests in anthropology, history and the visual arts. His most important physical legacy was the Kulturwissenschaftliche Bibliothek Warburg, the private library for cultural studies which he established in Hamburg in 1926 to house his extensive collection. His most important intellectual legacy in the eyes of many scholars, and possibly his most perplexing, is his *Bilderatlas,* literally an atlas of images, to which he gave the name *Mnemosyne* (memory).

In this project Warburg covered 40 wooden panels in black cloth and attached over 1000 images, not just photographs of acknowledged artworks but also images from newspapers, magazines and more ephemeral sources. Very little annotation adorns Warburg’s creation apart from titles to each panel – anything from *Migrations of the ancient gods* to *From the Muses to Manet* to *The classical tradition today*. Warburg attempts to communicate his ideas through the juxtaposition of these images and leaves much of the interpretation to those who view the Atlas. Many have been the scholarly pages devoted to unravelling the often cryptic messages encoded in this network of images.

Warburg’s interest in the image and its ramifications inspired much of the scholarly work undertaken at the Institute founded in London in 1933 which bears his name. One of the acknowledged founders of the discipline of iconology, Erwin Panofsky (1892-1968), carried out much of his pioneering research at the Institute. Fritz Saxl (1890-1948) and Ernst Gombrich (1909-2001), two illustrious names from art history in the United Kingdom, both served as its directors. But it is to the art historian Rudolf Wittkower (1901-1971) that is owed one of the unique resources of the Institute, its Photographic Collection.

This collection contains, in the words of its website, “physical photographs of sculptures, paintings, drawings, prints, tapestries and other forms of imagery... [including] tens of thousands of late nineteenth and early twentieth-century photographs and slides, together with hundreds of thousands of images added since the Institute came to London in 1933” (Warburg Institute, 2018). More important than its size, historical provenance and scope is the unique way in which it is organized, by iconographic subject, not artist or period.

Wittkower, the first curator of the collection, devised a taxonomy based on iconographic types in the 1930s. This subject index, currently numbering some 18,000 categories, forms the basis on which the folders of the collection are organized. Reflecting its provenance and the academic interests of its progenitors, this index is highly detailed in its categorization of European iconography but rather less so in the case of others: it does, however, provide at least summary, and often more detailed, overviews of Islamic, Egyptian, Indian and Mesopotamian iconography (Warburg Institute, n.d.).

No other iconographic collection is arranged so comprehensively by subject as that of the Warburg which makes it a unique resource for art historians. It is particularly valuable for researchers who wish to trace the development of given subjects or stories, their diachronic journey through the history of art and the patterns of their appearances in this history. No other resource allows analyses of these types to be carried out with such ease; this has ensured the centrality of the collection in the study of iconology.

**The Warburg Iconographic Database**

Since 2010, the Photographic Collection has been undertaking an extensive digitization programme: to date approximately 80,000 of the Collection’s 400,000 images have been scanned and added to its database. The bulk of these relate to the theme of classical antiquity and its influence on later periods, one of Aby Warburg’s principal scholarly interests (Duits, 2018, p.162). The continued digitization programme is mainly funded by external grant income, particularly from the Kress Foundation who in recent years have funded the conversion of several tranches of the collection.

The Iconographic Database employs an extended version of Wittkower’s classification scheme, translated into a facetted taxonomy (Duits, 2018, p.162). This extends considerably the granularity of the subject index to the paper collection, usually by adding extensive sub-facets to the categories of the original classification. Up to eight taxonomic levels are available to record an iconographic subject; this allows very detailed descriptions, for instance:-

RELIGIOUS ICONOGRAPHY

-Typology and Prophecy

-Cycles

-Manuscripts and Prints

-Speculum humanae salvationis

-Chapter 34: Pentecost

-Chapter 34c: The Israelites receive the Ten Commandments

-Variant: An angel giving the tablets of the Law to Moses

The Warburg taxonomy forms a complement to *IconClass*, the widely-established standard for the classification of iconographic subjects (IconClass, 2018). This scheme, which has been in development since its inception in the 1970s, comprises approximately 28,000 concepts arranged hierarchically, like the Dewey Decimal Classification on which it is partly modelled, into ten broad categories. The depth of its constituent subject areas varies, but it is particularly strong in the representation of biblical subjects and classical mythology.

Although there is considerable overlap between the two taxonomies, the Warburg’s scheme is more detailed in many areas. One example of this is the mythological story of Apollo and Daphne, a single facet in *IconClass.* In the Warburg taxonomy, the story is sub-divided into eight facets, some of which are divided further. The facet detailing Daphne’s transformation into a laurel tree, for example, is sub-divided a further eight times to reflect different stages of her transformation (Duits, 2018, p.162): these go into such details as transformation involving only her arms and hair, arms and toes, arms and feet, and her complete transformation. Such details are not available in the broader taxonomy that is *IconClass*.

One further notable feature of the Warburg taxonomy is its malleability as a reflection of current iconographical research. The scheme is as a much a research output as a classification mechanism, reflecting new insights into iconography which emerge as a result of the scholarly investigations of the Photographic Collection’s staff. As their research uncovers areas which require changes to the taxonomy these are readily and easily made, much more speedily than the mechanisms for amendments to the *IconClass* scheme allow. The Warburg taxonomy is thus a dynamic entity, changing frequently to represent the latest developments in iconographic research.

At present the Iconographic Database and its constituent metadata is stored in a series of mySql tables and interfaced by a set of PHP scripts. The taxonomy itself is encoded in a series of eight tables, each containing one level of the hierarchy. At the top of the taxonomic tree is a table containing the 15 top-level categories which form the starting point for exploring the semantic space described:-

ANTIQUITIES

ARCHITECTURE

ASIAN ICONOGRAPHY

ERANOS ARCHIVE

GESTURES & EXPRESSION

GODS & MYTHS

HISTORY

LITERATURE

MAGIC & SCIENCE

ORNAMENT

PORTRAITS

PRE-CLASSICAL ICONOGRAPHY

RELIGIOUS ICONOGRAPHY

RITUAL

SECULAR ICONOGRAPHY

SOCIAL LIFE

Lower-level tables are slightly more complicated as they require columns to indicate the parent of each term. A further complication arises from the occasional need to arrange the facets at a lower level in something other than alphabetical order; the books of the Old Testament, for instance, which begin:-

Genesis / Exodus / Leviticus / Numbers / Deuteronomy / Josue (A.V. Joshua) / Judges

are more logically rendered in the order in which they appear than alphabetically. One column in all of the tables below the top level, therefore, provides a numerical indicator of a term’s sequencing.

Encoding a complex taxonomy of this type within the relational tables of a database such as mySql presents multiple problems. The hierarchical structure of such a taxonomy fits clumsily into the relational structure, requiring a complex set of links or joins between tables to record its multiple levels. Links within these chains are easily broken, particularly if, as is the case here, the taxonomy is revised on a regular basis.

Even more problematic is the limited interoperability of a taxonomy encoded as a set of relational tables. It is difficult to share such a scheme with, or transfer it to, other systems except by a direct export and import of the tables. Translating it to systems not based on mySql requires significant data editing to retain the hierarchies of its internal structure. There is, therefore, the significant risk that the research encapsulated in the taxonomy, which is potentially of value to a wide scholarly community, remains hidden within the depths of the mySql labyrinth on the Warburg’s servers.

<FIGURE1.1 HERE>

Some other features of the metadata within the Database as a whole are also impediments to its interoperabilty. This screenshot of thumbnails depicting Daphne’s transformation reveal an inconsistent set of captions: the first image, on the far left, indicates that this is a plate from the works of Ovid (but not which one) from the second half of the 15th century, the second that it is from a manuscript of [Konrad] Celtis, the fourth from works by Cambiaso. The others only indicate places of provenance and dates.

This inconsistent set of captions is generated from each item’s metadata: in the case of Ovid and Celtis from a field giving brief bibliographic information on the source of the photo, in the case of Cambiaso from an author/creator field. The others, those giving place names, are also, rather confusingly, from an author-creator field; in these cases the caption records the geographic provenance of a work when the artist is not named.

These generated captions are understandable when read in the context of the taxonomic hierachy within which the image finds its place but make little sense outside it. Carrying out a search for ‘Daphne’, for instance, returns a set of thumbnails without the taxonomic description but with the cryptic captions alone:-

<FIGURE 1.2 HERE>

This problem arises as a result of the image-level metadata within the Database containing no cataloguer-supplied title or caption field: because the metadata is devised specifically for use in the context of the extensive taxonomy this appeared redundant. If, however, it is desired to share the Database outside the specific context of the interface within which it is currently presented, this would present significant problems of comprehensibility.

Some means of producing meaningful titles or captions for each image therefore appears necessary. In some instances the images themselves may have titles: this will be so for many paintings, for instance. Where this is not the case consistent rules for generating these titles are necessary. The large number of images, and the relatively small amount of staff time available for any possible re-cataloguing of this material, means that these titles will generally have to be auto-generated by applying a set of consistent rules, resorting to manual generation only where this is not possible (hopefully in a small number of cases only).

 **The move to interoperability**

The case for moving the Database and its metadata from the confines of mySql tables to more interoperable formats seemed compelling. Such a move would allow the Photographic Collection to widen its reach well beyond the Institute itself by sharing its taxonomy and the Database with others who could make use of it. In particular, it was felt that the taxonomy offers a viable complement, or even alternative, to *IconClass* for those who require much more detailed and granular descriptions of iconographic subjects than the more established standard could offer.

Two stages were identified to allow the move to interoperability. The first was the definition of a clearer data model for the Database than the one that was currently locked away in its tables. This would involve, for instance, the rectification of omissions such as the image titles noted above as well as a consolidation of existing fields and structures to ensure a greater overall coherence for the metadata landscape.

The second stage would be the serialization of the data model into an interoperable metadata syntax. This would include the choice of encoding to be used (almost certainly XML) and the choice of schemas in the encoding language that would enable the data model to be encapsulated. If at all possible, it was decided to use pre-existing schemas which had found their place in the digital library and digital humanities communities instead of creating bespoke schemas specifically for the Database. This would avoid having to duplicate earlier work and ensure that the metadata so painstakingly compiled for the Database could more readily be transferred to, and used by, others.

**Stage one: the data model**

Designing a data model for the Iconographic Database was an opportunity to take an entirely fresh look at its overall design unencumbered by its current manifestation as a series of mySql tables. Such a model has two sets of components, the metadata facets that would be included and their semantically-expressed relationships. Rather than starting with a completely blank sheet, it proved better to build such a model on the foundations of a pre-existing conceptual model, CIDOC-CRM (<http://www.cidoc-crm.org/>).

There are many advantages to using such a model when undertaking an exercise such as this. It can act as a checklist of fundamentals, ensuring that, in carrying out the exercise of defining a data model from scratch, nothing vital is omitted. Because a conceptual model is usually built on the collective expertise of established practitioners, it can usually be relied upon to present a coherent, thought-out synthesis of best practice and so can help ensure that one’s designs do not head off tangentially from what is required. It can, therefore, potentially save a significant amount of time and effort when approaching the task of designing a data model from scratch.

Too rigid an application of a conceptual model has the potential, however, to act as something of a straitjacket if it is allowed to constrain one’s ideas or force them into a form in which one's requirements are not met. This is a particular danger if an inappropriate model is chosen. It is important to be selective and critical when choosing one and to be flexible in its application. It may act as a foundation or framework but should not form the entire edifice on which a data model is built.

The conceptual model chosen for this project, CIDOC-CRM, is well established in the GLAM (galleries, libraries, archives and museums) sector. It is an ISO-standard ontology designed to enable the exchange of cultural heritage information through the definition of high-level concepts for objects and their environment: specifically it provides:

“definitions and a formal structure for describing the implicit and explicit concepts and relationships used in cultural heritage documentation...to promote a shared understanding of cultural heritage information by providing a common and extensible semantic framework that any cultural heritage information can be mapped to” (<http://www.cidoc-crm.org/>)

At its highest level, CIDOC-CRM divides its classes into four categories:-

* + Space-Time , which covers a broad sets of concepts such as era or period, place and time span
	+ Events, which includes when things come into existence or leave it and events that involve people
	+ Material Things, tangible objects
	+ Immaterial Things, intangible concepts or components of information

Below this level are narrower classes which form the components of a data model. These may include such concepts as **Man-made Thing**, **Conceptual Object**, **Temporal Entity**, **Time Span**, **Symbolic Object** and **Actor.**

Classes in CIDOC-CRM are accompanied by an extensive set of properties which may be used to join them semantically. Those referencing a time span, for instance, including **Temporal Entity**, **Period**, and **Event,** may be joined to other classes by such properties as **has time-span, took place at**, **at some time within,** and **had at most duration**. In all, 148 properties are available to link the 90 entities within the CIDOC-CRM class hierarchy, allowing a rich and complex web of data to be modelled.

The data model for the Iconographic Database was compiled by the Deputy Curator of the Photographic Collection, Dr Rembrandt Duits, who created and designed the Database from its initial inception. His model, expressed in terms of the CIDOC-CRM ontology, takes the form shown in Figure 1.3.

<FIGURE 1.3 HERE>

At the centre of the diagram are the four core components of the Database: the image itself, the work of art in which it is instantiated, the photo that represents the work of art and the digital file in which the photo is encoded and stored. The image is conceived as a **Symbolic Object**, defined by CIDOC-CRM as a “sign of any nature, which may serve to designate something, or to communicate some propositional content.” (<http://www.cidoc-crm.org/Entity/e90-symbolic-object/version-6.2>). The photo itself and the work of art are both **Man-made Things**, “discrete, identifiable man-made items that are documented as single units… [which are] either intellectual products or man-made physical things, and are characterized by relative stability” (http://www.cidoc-crm.org/Entity/e71-man-made-thing/version-6.2.1). The digital file is an **Information Object**, “identifiable immaterial items…[which] have an objectively recognizable structure and are documented as single units…[and do] not depend on a specific physical carrier” (<http://www.cidoc-crm.org/Entity/e73-information-object/version-6.2>).

The most abstract component, the image, has three linkages, one to the work of art that it represents, another to its classification in the taxonomy and a third to the photo in cases where this represents only part of the art work but is nonetheless a self-contained image (for instance, a photo of a single panel with a saint from a larger altarpiece). The other three components require a much more extensive set of linkages to describe them adequately.

The work of art represented in the image has ten linkages to other classes. The first of these provides information on its physical location (**Place appellation** in the CIDOC-CRM scheme): this may describe its current location or those which it occupied in the past, the latter employing a **Time span** class linked to the buildings cited in order to provide temporal information of its historical locales. The work itself may be assigned a time span to indicate particularly the diachronic dimensions of works that are no longer in existence. A further class allows inventory numbers or identifiers to be assigned to the work and the **Actor** class allows the essential component of the artist who created the work to be linked to it.

Contextual information is very important for a work of art and so several linked classes provide this type of background metadata. These include details of monographs or other textual items in which the work of art is to be found and also a bibliography of secondary literature which discusses it. A final class allows the work to be related to others by any relevant criteria.

The photograph of the work of art has an equally rich set of linkages available. Here the CIDOC-CRM **Actor** class identifies the photographer who captured the image in the photograph. As is the case for the work of art itself, an identifier class is essential for the efficient management of the photograph: this is the identifier used for the physical copy held in the Photographic Collection where available. To place the photograph in context, it can be associated with the **Conceptual objects** ‘Named set’ (which refers to specific sub-collections within the Collection of which it is a part) or ‘Project name’ (if it was produced in the context of a particular project originating in the Institute). Its physical location is also recorded in a location name element.

As many parts of the Collection owe their origins to specific funded projects, there is space in the data model for a project name and also to record the often complicated copyright information associated with a photograph. A final class, the CIDOC-CRM **Attribute assignment** (an assertion about the properties of an object), indicates whether the photograph was captured in analogue or digital form.

It is important to distinguish the photograph from the digital object in which it is stored in the Database: the latter requires a distinct set of administrative and technical metadata. In addition to employing the **Actor** class for the person responsible for the digital file (for instance, the scanner operator), it is also used to identify the sponsor who made possible the digitization: this is important as large parts of the conversion of collections to digital form were only made possible through grants from external bodies (such as the Samuel H. Kress Foundation who have funded this for significant parts of the Database).

Two **Temporal Entity** classes identify the production date of the digital object and its insertion into the Database: the latter can often be considerably later than the former owing to the need to find time and personnel to carry out the rigorous cataloguing necessary to ensure its scholarly value. A final class, in this case an **Attribute Assignment**, details access restrictions on the digital file: in some cases, viewing is limited to thumbnails only for copyright reasons.

Despite its apparent complexity, this data model fits readily into the CIDOC-CRM scheme: every component readily finds a place within the extensive set of classes and properties that it provides. Undertaking this exercise in the context of CIDOC-CRM, rather than beginning with an entirely blank sheet, proved a highly effective way of concentrating attention on the essentials of what such a data model is trying to do. The constraints and discipline of working within the context of the broader model ensured a coherent overall scheme was readily produced.

This was particularly important in the definition of the four core components at the centre of the diagram. It is important to separate out the abstract concept of an ‘image’ from its physical or digital manifestations and the work of art in which it is instantiated. It is to this abstraction that classification metadata about an iconographic subject is most effectively attached and so its definition as a symbolic object is an essential part of the model. Without CIDOC-CRM as a prompt, it would have been possible to conflate this abstract but essential concept with its manifestations and so lose important descriptive functionality from the model.

**Stage two: serializing the model**

Once the data model is fully mapped out in this fashion, the next stage of the conversion of the Database is its serialization into interoperable data standards. Two sets of choices must be made at this stage: the first is the syntax, or encoding mechanism, within which the data will be held, the second the choice of standards employing that syntax which will form the containers for it.

The choice of syntax for the Database was relatively easy to make. XML, the eXtensible Markup Language, is one of the most widespread languages for encoding interoperable metadata for many important reasons. Because it is encoded as text, it is software independent and so ideal as a mechanism for data transfer. It is one of the most robust formats for archival purposes, in part for the same reason: despite the frequent obsolescence of data formats, text seems the least likely of all to be unreadable many years in the future.

Despite the simplicity of its encoding mechanism, XML is capable of encoding complex data structures, often with much greater clarity than the relational tables which have held sway over database design for so long. It is particularly effective at recording hierarchical relationships, such as those which predominate in the taxonomy of the Database. XML allows its metadata elements to be nested within each other so modelling these hierarchies elegantly and efficiently. It is for this reason that it is used particularly in environments where hierarchical models prevail, such as text encoding (the Text Encoding Initiative (TEI) (Text Encoding Initiative, 2013)) and archival description (the Encoded Archival Description (EAD) (Library of Congress, 2017)).

The choice of XML for an encoding medium is relatively simple to make: the choice of the XML schema in which the metadata is to be held is rather more difficult. This is because of the sheer number of standards around, many of which overlap in their functions. Not for nothing did the computer scientist Andrew Tannenbaum quip “the nice thing about standards is that you have so many to choose from” (Tannenbaum, 2003, p.254). Luckily for the Warburg Iconographic Database a number of established standards stood out.

For the taxonomy an obvious contender was the Metadata Authority Description Schema (MADS) (Library of Congress, 2011), one of a family of bibliographic schemas produced by the Library of Congress. The Library of Congress website describes it as “an XML schema for an authority element set that may be used to provide metadata about agents (people, organizations), events, and terms (topics, geographics, genres, etc.) “. As such, it is ideal for encoding a taxonomy of subject terms. MADS allows each subject term to be encoded in a separate file or an entire collection of such terms to be listed together in a single ‘MADS collection’: the latter approach was chosen for the Database as it allows the taxonomy to be treated, and if necessary interchanged, as a single entity.

At the top of the hierarchy in the taxonomy are the 15 top-level categories described above. A sample entry for one of these takes this form:-

<mads>

 <authority ID="vpc-cat1-9">

 <topic valueURI="http://warburg.sas.ac.uk/vpc/id/cat1/9"

 authorityURI="http://warburg.sas.ac.uk/vpc">Magic and Science</topic>

 </authority>

</mads>

The topic itself is recorded, unsurprisingly, in the <topic>element. It is assigned a unique URI (the valueURI attribute) by which it is referenced from outside the MADS file: the authorityURI attribute indicates that this URI is assigned by the Warburg Institute Photographic Collection. Each record in MADS is given a unique ID (the ID attribute of <authority>) by which it is referenced from within the MADS file itself.

Below this top level, the MADS record for a given topic is similar except for the inclusion of a reference to its immediate parent. One level down from **Magic and Science**, for instance, is the topic **Astronomy and Astrology**:

<mads>

 <authority ID="vpc-cat2-71">

 <topic valueURI="http://warburg.sas.ac.uk/vpc/id/cat2/71"

 authorityURI="http://warburg.sas.ac.uk/vpc">Astronomy and astrology</topic>

 </authority>

 <related type="broader"

 xlink:href="#vpc-cat1-9">

 <topic>Magic and Science</topic>

 </related>

</mads>

This only differs from its parent element by the inclusion of a <related> element with a type attribute set to ‘broader’. The crucial link to its parent is made by the xlink:href attribute in which the internal ID of its parent (in this case vpc-cat1-9)is given.

Each level down the hierarchy is treated in the same way: a <related> element uses an xlink:href attribute to reference its parent. The topic **Planets**, for instance, a sub-category of Astronomy and Astrology, is recorded in this way:-

<mads>

 <authority ID="vpc-cat3-647">

 <topic valueURI=http://warburg.sas.ac.uk/vpc/id/cat3/647

 authorityURI="http://warburg.sas.ac.uk/vpc">Planets</topic>

 </authority>

 <related type="broader" xlink:href="#vpc-cat2-71">

 <topic>Astronomy and astrology</topic>

 </related>

 </mads>

In this way, a thread is built up which allows each subject term to trace its line from the top of the hierarchy. The entire taxonomy can readily be contained in a single file: this represents its canonical or definitive version and in this form it can be transferred across systems and archived for long-term preservation.

The relative complexity of the hierarchical chains of the MADS format, and in particular the necessity of an integrated system of internal IDs without any broken linkages, may make it difficult to maintain the taxonomy manually if encoded in this form. For this reason, the MADS file is the output from the system in which the taxonomy is maintained and edited, not the primary mechanism by which these operations are performed. At present it is generated by a simple Python script which interrogates the mySql tables in which the Database is currently stored. The script iteratively runs through the levels of the taxonomy, generates the <mads> elements for each and, for any below the top, inserts references to its parent element.

The structure of a MADS file, based as it is on a chain of internal references, is logical and simple to process but relatively difficult for humans to decode: for this reason, alternative ‘views’ of the same data may be generated to make this chain of linkages easier to read. One of these is an XML file in which the thread for each topic is fully expanded: the subject noted earlier, for instance, an angel giving the tablets of the law to Moses, would have an entry as follows:-

<category category-uri="http://warburg.sas.ac.uk/vpc/id/cat8/1474">RELIGIOUS ICONOGRAPHY / Typology and Prophecy / Cycles / Manuscripts and Prints / Speculum humanae salvationis / Chapter 34: Pentecost / Chapter 34c: The Israelites receive the Ten Commandments / Variant: An angel giving the tablets of the Law to Moses</category>

An ‘expanded’ version of the taxonomy of this kind may readily be used to generate the thread of topics in the user interface as shown in Figure 1.

For the item-level records for each image, another XML-based standard from the same ‘family’ of schemas produced by the Library of Congress was an obvious choice. METS, the Metadata Encoding and Description Standard (Library of Congress, 2014a) is, in the words of its website, ‘a standard for encoding descriptive, administrative, and structural metadata regarding objects within a digital library’. It is designed to accommodate the complex array of these three types of metadata which are essential for describing and administering a digital object and is widely used amongst practitioners of digital asset management.

METS is a packaging standard for metadata, not a schema for descriptive or administrative metadata in its own right. It does not, for instance, contain any elements for bibliographic description or technical information about an object, nor any rights metadata necessary to enforce its intellectual property rights. Instead it acts as a container for other standards containing metadata of this kind, each of which has a logical place within the METS architecture. The one type of metadata encoded directly in METS is structural, the internal structure of a complex digital object, which is recorded in a hierarchical map within its architecture.

Three XML standards are embedded within the METS record for an image in order to record the extensive metadata mapped out in the data model described above. The first, and most extensive, of these is MODS (Metadata Object Description Schema) (Library of Congress, 2010), another standard from the same Library of Congress family as MADS and METS. This schema is a set of bibliographic elements intended primarily, but not exclusively, to provide descriptive metadata for objects in library collections. It is derived from MARC21, the primary bibliographic standard for library catalogues, but adds a number of elements which are specifically relevant to digital objects.

Two MODS files are embedded within the METS file for any given image: the first relates to its digital manifestation, the second to the work of art that it depicts. These two conceptually distinct items have separate locations within the METS architecture, the former within its container element for descriptive metadata, the latter within a subset of its administrative metadata section containing ‘source metadata’, that which relates to the analogue original from which a digital object is derived. This division neatly carves us the four core concepts of the data model, the first covering the **Photo** and **Digital File**, the second the **Image** and **Work of Art**.

The majority of the descriptive metadata for any given image relates to the work of art that it depicts and so goes into the MODS file within the source metadata section. This includes such standard information as artists’ names, dates of creation, physical location, bibliographic citations referencing the work and details of the book or manuscript in which it is found (if any). It can also include more atypical bibliographic metadata, such as auction dates, where these are necessary to identify the previous location of a work of art.

The most intellectually important metadata in the MODS file detailing the digital manifestation is its iconographic subjects: these are recorded by simple references to their URIs in the MADS file discussed earlier:-

<mods:subject valueURI="http:/warburg.sas.ac.uk/vpc/id/cat6/2727"/>

<mods:subject valueURI="http:/warburg.sas.ac.uk/vpc/id/cat3/680"/>

<mods:subject valueURI="http:/warburg.sas.ac.uk/vpc/id/cat5/1274"/>

<mods:subject valueURI="http:/warburg.sas.ac.uk/vpc/id/cat3/2862"/>

For each subject, the valueURI attribute contains the URI of the <topic> element’s valueURI attribute in the taxonomy MADS file.

In addition to this subject information, this section is limited to an identifier for the image, a note of the sub-collection of the Database to which it belongs, and information on the metadata record itself, including details of any funding which supported its creation.

In addition to an image’s descriptive metadata and that of the work of art that it depicts, technical information on its provenance is important to record. In the case of the Iconographic Database this is limited to recording the date and time of its creation and the photographer who created it. To do this, metadata is embedded in the section of the METS file containing digital provenance metadata using a further standard, PREMIS (**PREservation Metadata: Implementation Strategies)** **(Library of Congress, 2008)**.

PREMIS, also maintained by the Library of Congress, is in the words of its website “an international standard for metadata to support the preservation of digital objects and ensure their long-term usability“. It can be used to record, with some verbosity it must be said, an extensive set of metadata relating to the creation of an object and its digital life thereafter. To record the date of creation of an image and the photographer who created it, the following metadata is necessary:-

<premis:agent>
 <premis:agentIdentifier>
 <premis:agentIdentifierType>local</premis:agentIdentifierType>
 <premis:agentIdentifierValue>vpc-agent-smith-j</premis:agentIdentifierValue>
 </premis:agentIdentifier>
 <premis:agentName>Smith, J</premis:agentName>
</premis:agent>
<premis:event>
 <premis:eventIdentifier>
 <premis:eventIdentifierType>local</premis:eventIdentifierType>
 <premis:eventIdentifierValue>vpc-88950-photo-creation</premis:eventIdentifierValue>
 </premis:eventIdentifier>

<premis:eventType><http://id.loc.gov/vocabulary/preservation/eventType/cre> </prems:eventType>
<premis:eventDateTime>2018-07-12T2016:4:10+00:00</premis:eventDateTime>
<premis:linkingAgentIdentifier>
 <premis:linkingAgentIdentifierType>local</premis:linkingAgentIdentifierType>
 <premis:linkingAgentIdentifierValue>vpc-agent-smith-j
 </premis:linkingAgentIdentifierValue>
 <premis:linkingAgentRole
 authorityURI=”<http://id.loc.gov/vocabulary/relators>”
 valueURI="http://id.loc.gov/vocabulary/relators/pht">Photographer
 </premis:linkingAgentRole>
</premis:linkingAgentIdentifier>
<premis:linkingObjectIdentifier>
 <premis:linkingObjectIdentifierType>local</premis:linkingObjectIdentifierType>
 <premis:linkingObjectIdentifierValue>vpc-88950-photo
 </premis:linkingObjectIdentifierValue>
</premis:linkingObjectIdentifier>

</premis:event>

PREMIS, like many XML schemas, operates by establishing a series of linkages using internal IDs. In this example, the ‘agent’, in the PREMIS scheme the person or organization responsible for performing an action, is identified by the element <premis:agentIdentifier>, and their role by<premis:linkingAgentRole>: the latter uses a controlled vocabulary, the MARC Relator Codes (Library of Congress, 2014b), to identifier the agent as a photographer. The identifier for this agent is then used in the <premis:linkingAgentIdentifier> element to link them to the photo itself (referenced in the <premis:linkingObjectIdentifier> element).

Although the PREMIS schema is relatively verbose, it is logical and easy to accommodate when processing in a live system. The single event captured in the Iconographic Database can, of course, be supplemented by a much more extensive listings, but, at present, this ‘audit trail’ of actions performed on the object is limited to its creation, the only event recorded in the database. It is hoped that new versions of the database will allow the recording of more extensive details of image’s lifecycle in order to enhance its preservation in the long term.

The final component of the complex digital object that is an image in the Database is a listing of the files of which it is comprised. METS has a section for this as well, the file section or <fileSec>. A sample listing in this inventory looks like this:-

 <fileSec>

 <fileGrp ID="wpc-88950-photo1">

 <file ID="wpc88950-photo1-0" GROUPID="0">

 <FLocat LOCTYPE="URL"
 xlink:href="http://warburg.sas.ac.uk/vpc/pdfs\_wi\_id/00080770.tif"/>

 </file>

 <file ID="wpc-88950-photo1-1" GROUPID="1">

 <FLocat LOCTYPE="URL"
 xlink:href="http://warburg.sas.ac.uk/vpc/pdfs\_wi\_id/00080770.jpg"/>

 </file>

 <file ID="wpc-88950-photo1-2" GROUPID="3">

 <FLocat LOCTYPE="URL"
 xlink:href="http://warburg.sas.ac.uk/vpc/pdfs\_wi\_id/00080770.jpg"/>

 </file>

 </fileGrp>

 </fileSec>

Three files for a single image are recorded here, an archival, uncompressed TIFF image as originally captured, a full-size JPEG for delivery and a smaller JPEG which acts as a thumbnail for browsing. These respective functions are delineated by the GROUPID attribute to the <file> element, a free-text attribute which can be used to group files by any relevant criterion: in this case, it uses an arbitrary, locally-defined numeric scheme to differentiate these functions.

Despite the apparent complexity and verbosity of this METS serialization of the data model, every component has a logical and unambiguous location within its architecture. At an initial glance, it may appear that the hierarchies of a METS file, and of the schemas used within it, make a potentially disjoint match with the distinctly non-hierarchical linkages of the data model in Figure 3. In practice, METS and these schemas allow a fluid set of linkages to operate within their architectures, cutting across these hierarchies as required, and so no significant mismatch occurs. Every component and linkage in the Data Model can be accommodated within the serialization as it is detailed here.

An alternative approach that has been articulated by some practitioners of digital asset management (for instance (Lagoze et al., 2006)) argues that RDF-based networks of semantic linkages are the most appropriate method for serializing a data model of this kind. This is the approach taken by the widely-used Fedora Commons repository system (Fedora Commons, 2013) which employs an architecture of this kind, the Fedora Content Model Architecture (Fedora Commons, 2002). In this methodology, a complex set of RDF statements expressing semantic linkages (such as isPartOf, isConstituentOf or isDependentOf) is used to express the relationships within and external to a complex digital object. It is often advocated for use in rapidly-changing metadata environments, either on its own (Waddington et al., 2016) or in conjunction with XML schemas (Gartner and Hedges, 2013).

This allows an easy translation of a diagrammatically-expressed data model (such as Figure 3) into a form that can be readily machine-processed, but there are many reasons for preferring the approach advocated here which utilizes the more rigid hierarchies of an XML architecture. The complexity of data modelling involved in developing coherent ontologies, data cleansing problems and skills shortages have been cited as particular issues for RDF-based approaches to metadata, particularly in the library sector (Hawtin et al., 2011). They also present problems for digital preservation owing to their incompatibility with the package-based models on which current practices are based: in particular, the blurred boundaries of RDF-based metadata make it difficult to establish domains of responsibility for preservation (Gartner, 2016, p.92).

**The next steps**

This two stage process of metadata redesign has produced a robust data model that meets fully the intellectual and scholarly requirements of this unique database, the only one currently in existence that takes iconography as the primary focus for its survey of art history. A data model that did not meet these needs would have reduced severely the value of this resource, particularly in simplifying its iconographic backbone to a point where its raison-d’etre would be lost. The serialization into the well-established XML schemas of MADS, MODS, PREMIS and METS has captured this data model in all of its richness and reified its abstraction into a tangible set of metadata records in fully interoperable formats which can form the basis of delivery systems on any platform.

The next steps to be taken are the re-design of the Iconographic Database system to one that incorporates this newly-designed metadata as the basis of its operations. This will involve the creation of two user-interfaces, one for the delivery of the Database to its end users, the other (perhaps more complex) to allow the creation and editing of its constituent records. Despite its well-proven functionality within its user base, the current interface is relatively clunky and unattractive and so will need revising to enhance the profile of the Database amongst a wider cohort of potential users. This important work will be passed to professional designers, from whom tenders are being sought at the time of writing.

An important principle that must be established for the new interface is that the system which delivers it must be based on the canonical, XML-serialized form of the metadata. While the new system may not itself be one which is itself fully XML-compliant, it must be able to import directly from the MADS and METS files and export to them seamlessly and fluently. These files form the definitive ‘statement’ of the Database’s metadata and so the core on which the system will operate, whether this is directly or indirectly though real-time import and export functionalities.

Several possible platforms currently exist which could readily host the next version of the Database. Although investigations are still on-going, it appears that Islandora (Islandora, 2013), a modular digital asset platform built on the Fedora Commons repository, will be able to accommodate the requirements mapped out for this revision. Islandora is likely to be a suitable platform because it is open-source and so readily customizable, and also because it is based on a sound metadata core which can accommodate METS, MADS and MODS relatively easily.

Whatever platform is chosen in the relatively near future, the strategy outlined above is designed specifically to ensure the viability of the Database in the much longer term. The use of XML and these well-supported schemas will ensure that its metadata will be readily transferrable to any future system when the platforms that are currently available are long obsolete. The metadata discussed here is very much the infrastructure on which any superstructure resides and so the work that has gone into ensuring its robust format and content is essential, arguably more so than that which goes in to the (relatively) ephemeral interfaces by which it is made available to users.

**Conclusions**

The approach discussed throughout this chapter demonstrates how a highly valuable and scholarly resource can move from a skillful but relatively ad hoc construct to a more solid and interoperable basis. This is not to underestimate the work that went into its initial creation, which produced a system finely attuned to the needs of its user constituencies and one which developed an important resource in its own right, the taxonomy which forms the backbone of the Database. The move from relational tables to interoperable metadata discussed here aims to open this resource to a much wider user base and to allow its unique approach to art history to find a foothold in the scholarly landscape outside the Warburg Institute.

The move to interoperability must be made in a methodical and logical way if the richness of a resource such as this is not to be lost in the process. The challenge in such a case is always to avoid simplifying not only the content of its constituent metadata but also the chain of linkages within which this content is embedded. Interoperability may be more easily achieved by simplification of this kind, reducing the complex structures of a metadata environment to something ‘flatter’ and so uncomplicated, but this should be resisted: the scholarly worth of this resource in particular lies as much in the intellectual structures embedded within it and the unitary metadata components that they contain.

Three components to the process of moving to interoperability have been highlighted in this chapter, all of which are important to ensuring that it is achieved in a robust and usable fashion. The first is to ensure that there is, if at all possible, a solid standards-based backbone to the process as a whole. There are many good reasons for ensuring community-based standards underpin such an exercise, including the avoidance of redoing work already done by experts in the field and ensuring that the end product does not exist in a silo of its own construction.

Standards underpinned this project at both its inception and final manifestation. The construction of the data model was based on the conceptual model of CIDOC-CRM which focused thoughts at this abstract stage, providing a framework on which it could be built and separating out concepts, such as symbolic, man-made and information objects, which require separate treatments when drawing up their more concrete manifestations as metadata. It is, of course, not essential, to employ a conceptual model of this type when drawing up a data model, and it should certainly be avoided if it involves distorting one’s requirements to ensure conformance with it in an over-rigid way. It is, however, an important and useful tool when applied appropriately and where it has clear relevance to the metadata environment being constructed.

The second component to the process is the compilation of an overall data model at an appropriate level of abstraction. This is where one should attempt to codify the landscape of the metadata requirements for the redesign and, just as importantly, to establish their interrelationships in a coherent overall structure. Overall coherence is important to ensure a robust structure which will be easy to maintain and develop further. It is, therefore, important to concentrate on the ‘big picture’ at this stage, not to become overwhelmed with details which can obscure this. This is the stage where serious questions about the purpose of the metadata redesign need to be asked and answered and when it is important to take a critical view of what is produced. This is much easier to do when one has an abstract view, unencumbered with excessive detail, of the scheme as a whole.

Putting together such a data model diagrammatically, as in Figure 3, is an excellent way of clarifying one’s thoughts at this important stage. It can make more concrete the abstractions with which one is juggling at this point, enabling them to become something more tangible and malleable. Establishing the structural links between the components of a data model becomes easier and clearer when everything is laid out in this diagrammatic form as does the sense of an overview of the environment being created as a whole.

The third component is the serialization of the data model into concrete schemas which will form the containers in which the metadata will be held, preserved and disseminated. This process has three sub-components to it. The first is the choice of the syntax for encoding the metadata: here we have chosen XML for the various reasons described above. The second is the choice of schemas that employ this syntax. Many factors may go in to this choice, including an assessment of their functionality, their provenance and the sectors in which they originated. Some reasons for the choices made in this case have been cited earlier: the overriding factor was, and has to be, their ability to absorb the data model without distorting it or excising its significant features. A detailed examination and assessment of potential schemas is a vital part of the process and plenty of time and attention should be expended on this.

The final sub-component is the translation of the data model into the schemas themselves. This is a skilled and often complex procedure, requiring a thorough understanding of the data model and the semantics of the chosen schemas. There is not always a one-to-one match from a component in the data model to an element in an XML schema: often a combination of elements and attributes is necessary to express the semantics of components accurately and without distortion. At each stage of the translation it is necessary to ask if this has been achieved and whether anything is missing in the serialized form of any given component: if so, one must go back to the beginning and start the process again. As is the case in the compilation of the data model, it is necessary to be critical of one’s work and to be ready to take another approach if anything is lost of the richness of the model from which it is drawn.

This discussion should make it clear that the process as a whole is more than a simple translation of a set of metadata elements. In the case of a relational database of this type such an approach would be more of a hindrance than a help as the architectures of semantic data models and XML are much more elegant and flexible than the rigid structures of relational tables.

Even without these architectural considerations, the process has to be seen as a way of rethinking the Database and its rationale. Examining its metadata requirements in this way, mapping out its structures and clarifying the functions of its components and their interrelationships allows a critical assessment of its functions and their priorities. From here it is possible to improve it in more ways than ensuring the interoperability of its metadata alone. Inconsistencies and redundancies can be removed, priorities established and serious consideration given to its user constituencies and how their needs can be met. Not for the first time, metadata can prove itself a way to question and clarify far more than the ways in which something is described and administered: it can seed considerations of the rationale behind a system at a far more basic level and so transform it as a whole.

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