Abstract. A ‘Russian doll’ is a decorative painted hollow wooden figure that can be contained in a larger figure of the same sort, which can, in turn, be contained in another figure, and this can be repeated as many times as needed. This paper describes the development of an OWL-based ontology designed for metadata versioning in the media post-production industry. This has been implemented using the same Russian doll principle: of a ‘record’ being able to “wrap” (or contain) another record, one which relates to the versioning of that metadata, repeated as often as needed. Our ontology for metadata used in the media industry distinguishes itself from others by addressing the full range of post-production processes, rather than the archiving of a finished product. The ontology has been developed using metadata fields provided by high profile UK-based post-production companies, informed by ethnographic and co-design work carried out with them. This is the basis for a prototype metadata management tool for use in both media post-production and on media productions. We present central design principles emerging from our collaborative research, and describe the process of co-developing this ontology with our partners.

Keywords: Creative metadata ontologies · Post-production workflows · Film & tv media

1 Introduction

The Creative Data team was formed as part of the StoryFutures research project to respond to the need, expressed by our post-production media industry partners, for a unified approach to how metadata is handled in the sector. The aim of Creative Data research is to stimulate and support innovation while providing a common approach where none currently exists, thus addressing the difficulties created by mishandling and loss of the metadata that is crucial to successful and
efficient post-production of media projects. The particular contribution of the ontology we describe in this paper is to handle dynamic changes to metadata - to feed into the Creative Data vision for an open access metadata management solution encompassing the numerous permutations enacted on metadata, during both the media production process and also the post-production of this media into a finished product.

The Creative Data team includes world-leading post-production industry partners based in the UK. Our collective aim is to create a new open source digital tool addressing technical and industry issues that currently inhibit metadata persistence, accuracy and reliability. Creative Data has documented the industry ‘pain points’ concerned with metadata, which add significant time, cost, and difficulty to post-production workflows. There is currently a great deal of disruptive technical and business remodelling taking place in the industry - also a window of opportunity for new approaches such as ours to be adopted. It therefore has become increasingly important that the provenance and reliability of metadata can be guaranteed to practitioners in all areas of the industry.

The handover of creative data, including metadata, from the production to post-production company, is carried out either physically or digitally, and occurs at different stages of a project’s production cycle. In an ideal scenario, data should be ingested into the systems of a post-production company in such a way that metadata is reliably stored, and is made accessible to those tasked to process it - with the aim of delivering the finished product back to the client in a timely fashion. However, in current practice, metadata often becomes separated from the source media itself, and what is therefore sought is a means of linking records of metadata on a centralised database, using what we have called the 'Russian doll' data design principle:

A record should be able to ‘wrap’ or contain another record relating to the versioning of that metadata.

While post-production practitioners rightly pride themselves on being trusted to untangle metadata issues, and to deliver to schedule, there are a range of obstacles that frequently have to be overcome by practitioners in order to do this, and a number of these are described in more detail in Sect. 4.1.

Practitioners generally extract and read metadata off from media files, and perform a variety of specialised searches and queries in order to compile and sort through the available information. There are often situations where documents and databases consulted do not conform to expected standards or have not been updated - resulting in metadata mismatches. Missing pieces of information sometimes have to be reverse engineered from snippets of other information available where guidance from production-side is unobtainable. There is currently no single point of reference across the industry for post-production pipelines to access metadata.

Practitioners are required to handle vast quantities of creative data appearing in a bewildering variety. This includes essential “hard” technical metadata: concerning camera lens type, make, serial number, focal length, roll number, exposures, duration of clip, frame-rates, and so on. The ‘ingest’ of data also includes
equally important “soft” metadata (a term used by a post-production partner). This relates to creative content: ‘Slate’ (the clapper board with chalked information concerning takes, shots, roll numbers and so on), reference photographs of sets and costumes, notes of camera positions, GPS, annotated scripts, shoot schedules, call sheets, character descriptions, editorial selections and decisions, handwritten notes from camera crews and script supervisors, and other tags and annotations associated with the media files - but not currently travelling with them. These types of metadata are key to supporting both the creative and the technical post-production processes - and have been made and added to audio-visual data captured on set or location (added by humans but also increasingly by machine learning).

Compounding the lack of a single point of reference for metadata is the absence of a common vocabulary across the industry - very often there are different terms being used for the same data elements. This applies equally to “hard” and “soft” metadata. The Creative Data team has therefore gathered from our partners an extensive set of metadata fields deemed to be common across the industry, upon which it is possible to build a common vocabulary (concept ontology) to help fashion suitable tooling to support centralised and universal access to metadata.

2 Related Work

When reviewing the literature in the area of ontologies for film and TV production, we elicited information from the perspective of researching previous work on ontology-based solutions for the media industry, focusing on those that manage metadata during all stages of the production process.

COMM is a core ontology for annotating multimedia in order to explain the composition of media objects and what its parts represent by using DOLCE as a foundation ontology [5]. Loculus is a metadata wrapper for managing, distributing, and reusing motion pictures. The Loculus schema enables information about an artifact from different stages of the production process to be encapsulated together [11]. The Creative Works Ontology is similar in that it is used to capture relationships between creative works and other relevant entities, initially focusing on film and television. Each work has metadata assigned to it such as awards nominated for or won and information about a specific release [7]. Although metadata from the various stages of the workflow are present in Loculus, this metadata is attached to a final product rather than being available for use during each stage of the production process. Similarly, COMM and the Creative Works Ontology does not focus on the production process but instead annotates the finished product to describe its features or attributes.

OntoFilm is a core ontology that conceptualises the domain of film production and its accompanying workflows using Semantic Web Rule Language (SWRL). It was developed in consultation with industry professionals after collaborative meetings confirming the need for a common ontological framework to bridge the semantic gap between pre-production concepts and post-production
metadata [6]. The Deep Film Access Project (DFAP) also researched the role of semantic technology in film production, focusing on how it could contribute to the integration of the data and metadata generated during the production life-cycle. Later versions of the DFAP ontology uses COMM and contains a remodelled version of Loculus for multimedia, foundational, and film production terminology [8]. Although OntoFilm and DFAP does connect metadata to each stage of the production workflow, it focuses solely on film production and, in the case of OntoFilm, aims to incorporate gaming animation production into future work. However, in addition to film production, the Creative Data team place an emphasis on addressing VFX, immersive and unscripted television workflows (see Sect. 4.2). This aims to support practitioners in the widest possible range of creative industry post-production scenarios.

3 Objectives

As described above, the aim of the Creative Data research is to revise how metadata is loaded, tracked, shared and used in the media industry - by developing a cloud-based database solution, to standardise the handling of metadata, and increase its reliability and assurance on its provenance. Our open-source approach to this problem will allow businesses to then create bespoke tooling on top of this open-source kernel. The preferred technology for the tool was identified as context-aware database design (for more information about the ‘Context Broker’ API, see [2]) and the metadata ontology described in the following sections. The creation of bespoke tools and sub-tools is already a common practice within this industry. The specific objectives for the tool can be summarised in three design principles which were carried forward into our subsequent tool development work:

1. **Log metadata against project data**: Unique identifiers can potentially link media-files to a complete history of any given data-item and its versions, including any associated metadata. This can be stored in and accessed via the cloud. This will be a fundamental reorientation of how metadata is referenced, ending the industry’s previous dependence on metadata that travels with but is not intrinsically linked into the production data itself.

2. **Track all of the technical amendments across a given project**: Unique identifiers can be used to follow the progress of data through its many versions, establishing whether metadata has been altered or omitted.

3. **Support a common vocabulary**: The industry employs many new specialist terminologies, as well as degree of legacy language. Without a common vocabulary, this terminology will continue to be a source of misunderstanding about metadata, causing further confusion and creating financial cost.

4 Methodology

The Creative Data Semantic Model (or Concept Ontology) was formed as part of a scoping exercise with our partners, over a period of time. It seeks to rationalise the various concepts and terms currently employed in the field, many of
which have overlapping meanings and can cause misunderstandings across disciplinary boundaries. The model supports a common vocabulary by providing a prioritised set of post-production concepts for our database tool, using a sample set of metadata fields. These were identified by our partners as essential for supporting the use cases given in Sect. 4.2. It is important to mention here that the sharing of these fields represents a significant first step towards the more integrated approach sought by the Creative Data team described in the Introduction. Notably, the original set of fields numbered several thousand, reflecting the complexity of the many workflows. However, for the purposes of creating an initial prototype the partners identified a smaller and key subset of fields (numbering approximately 350 fields), which were used as a building block during the development of the first iteration of the digital tool. This is referred to here as the sub-ontology - feedback from our partners upon this sub-ontology is constantly fed into the main and full ontology with its many more classes. Detailed information about the sub-ontology is available at: http://cs.rhul.ac.uk/home/zcva113/mstr2020.

Segments of the sub-ontology are also shown in Figs. 1, 2, 3 and 4. It is worth noting that the full ontology has a wide reach, encompassing metadata fields used not only in VFX, but also for immersive media projects in VR and AR.

After the initial scoping of the sub-ontology, work began by defining it with the Protégé ontology editing tool [4]. The sub-ontology could then be refined and visualised using the Cameo Concept Modeler plugin [1] for MagicDraw [3], taking advantage of it’s extensive features. This methodology allowed us to use diagrammatic outputs, such as those shown in this paper, to gather feedback from our partners at different stages of the ethnographic research, and also during collaborative meetings where the requirements of our metadata management tool was specified. In this way, the veracity of the modelling was authenticated by domain experts, and the capturing of domain-specific information regarding several specialised areas of post-production was assured.

4.1 ‘Russian Doll’ Metadata Versioning

Metadata versioning has been implemented in this project using principles that are analogous to Russian dolls. That is, a record should be able to ‘wrap’ or contain another record relating to the versioning of that metadata. The sub-ontology has two top-level classes aimed at linking metadata and connecting records that describe the transitions that metadata typically undergoes:

DataItems, Record

The former is an umbrella class for all entities in the ontology that can have metadata associated with it whilst the Record class encapsulates versioning metadata, including temporal details about a data item. Each instance of Record can be thought of as a record, tracking metadata adaptations of a DataItems instance which is, in turn, a record of a real-world entity.
To enable metadata versioning, every instance of *DataItems* and its sub-classes should have an instance of *Record* assigned to it upon creation, using the object properties *dataItemHasRecord* and *recordIsAboutDataItem*. Instances of *Record* have a creation date, which is implemented through the *recordCreatedOn* data property. This schema is shown in Fig. 1.

![Fig. 1. Segment diagram of the creative data semantic model (sub-ontology), showing the implementation of metadata versioning.](image)

| Entity name             | Description                                                                                   |
|-------------------------|-----------------------------------------------------------------------------------------------|
| *DataItems*             | Represents any entity that has metadata associated with it                                    |
| *Record*                | Encapsulates versioning metadata about an entity                                               |
| *recordIsAboutDataItem* | Links a record and the data item it is about                                                   |
| *dataItemHasRecord*     | The inverse of *recordIsAboutDataItem*                                                        |
| *hasRecordVersion*      | Links two versions of an entity record together to keep track of changes in metadata          |

When the metadata of a *DataItems* instance is changed, a copy of that instance of *DataItems* is made with the metadata adjustments applied and a new *Record* instance is also created for the new *DataItems* instance. These are again connected using the *dataItemHasRecord* and *recordIsAboutDataItem* properties. The two instances of *Record* - the original and the updated - are connected using the symmetric object property *hasRecordVersion* (See Table 1).

### 4.2 Use Cases, and Their Supporting Ontology Features

Below we provide details on how the semantic model described in the previous section has been applied to three Use Cases - these have been identified by our partners as being representative of key metadata generation and metadata sharing practices in the industry. ‘Pain-points’ associated with these use-cases are also described using quotes from our ethnographic research.

**Use Case 1: Television Post-production, Media Support**

Media support operatives prepare the data received from production clients, ready for use in the later stages of post-production - for edit support, where media files are aligned into ‘sync maps’, which can then edited
by a team of creatives (sound, colour, and picture editors). Workflows in media support begin with accepting media from the in-house librarian and sending “tech receipts” to clients - containing a hard drive snapshot of the contents of the drives delivered. The operative then makes a copy of this data, conforms it according to the desired format and finally ingests it into the workflow.

Pain points in the media support role centre on the absence of key meta-data required for data ingestion and for the workflows. For various reasons, the required input from production teams is omitted or made in error. In the current state of affairs, fixing this requires a great deal of “back and forth” communications between post-production and production, taking up the time of media support: “a lot of people [on the production side] don’t understand why we need roll numbers for example”, says one practitioner, and so “there’s a lot of feedback looping, a lot of people involved in getting media set up properly.”

**Ontology representation:** The *Asset* class has the following three subclasses - *Email*, *EmailReceipt* and *HardDriveSnapshot* - to allow communications and email receipts sent to the client to be represented in the ontology. Like instances of other subclasses of *Asset*, all instances of these subclasses are also assigned to an instance of *File*, which encapsulates the metadata that describes how an asset is stored on the file system. They can also be linked to an instance of the *Client* class to indicate who it has been sent to. This is shown in Figure 2. When ingesting data, a new instance of a subclass of *Asset* - typically *Clip* - is created and the values of its data type properties are entered either automatically (by importing the existing metadata) or manually. Importantly, this supports practitioners by enabling them to keep track of communications with clients in relation to a production and thereby creating a contact log.

**Use Case 2: Television Post-production, Descriptive Logging**

Unscripted and documentary content requires the addition of descriptive tags to the unedited footage, in order to be able to find and edit content in vast collections of data captured on camera ‘rigs’ set up on locations. This process is referred to as ‘live logging’ because it involves logs written by people trained by the post-house. These loggers write annotations into a bespoke timestamped tool. The aim is to record the relevant facts of a given capture, as to what the footage depicts. The post-production staff and editors are then able to search for, recover and create edits with specific content. The proposed tool allows users to carry through the descriptive metadata added by logging, so that this metadata can be accessed at any time during post-production, on the project timeline and database. Unlike the existing workflow, no exports of metadata selection are needed. The edit producer can search, read, create and send a list of clips and timecodes
within these clips, derived from the search from the descriptive metadata, to an editor.

Pain points for this use case are connected with the lack of persistence of metadata across post-production re-edsits, for example, when descriptive logs are lost after a near-final edit has been made. Hence, if and when a creative tweak to the final edit is needed, this requires the link to the descriptive logs to be painstakingly re-established.

**Ontology representation:** Each instance of Clip can have any number of instances of LoggingTag assigned to it to describe its contents. Each tag is given a name and type which would enable the user to search for and generate a list of clips that match these attributes. Each entry in this list would have details of the clip and the timecode associated with the tag that matched the search criteria. Multiple instances of the LoggingTag can have both the same name and be allocated to the same Clip so they are distinguished by their combination of Clip and timecode. This is shown in Figure 3. This supports practitioners by enabling them to quickly generate lists of clips and timecodes by tag, which allows them to efficiently find the content that they require later in the post-production stage and preventing such content from being lost.

**Use Case 3: Visual Effects for Film and TV, On-Set Shoot Data**

During the pre-production phase of a feature film, the production company may secure one or more vendors, to supply visual effects (VFX). This may involve the VFX company being on set to acquire the additional data
and associated metadata required for VFX. This process is referred to as ‘Shoot’. This metadata is then collated into an on-set VFX database, which must be organised in such a way that it can be passed on to the larger central data management database for users throughout the companies’ internal VFX pipeline. The proposed tool allows data-organising activities to take place while still on-set, using laptops and other devices, respecting the data schema in use within businesses. The user utilises the unique IDs of metadata items, knowing that IDs are always updated with current information. After clean-up this data is made accessible to other areas of the VFX pipeline.

Pain points connected to this use case are similar to those in Use Case 1 regarding the absence of key metadata. An ingest practitioner stated: “We troubleshoot a lot, with conversions, if something’s wrong, they come to us first.” In one example, it was said: “Well I had a producer once, and I asked them this, ‘Can you ask them if these shots are anamorphic or spherical? At the moment, my screen is frozen, I can’t see them’. And then, I had to say to them [as the question was not understood], ‘It means squishy or non-squishy!’”

**Ontology representation:** Data types such as clips, 3D models, and reference materials are represented as subclasses of the Asset class. All instances of Asset are also assigned to an instance of File, which encapsulates the metadata that describes how an asset is stored on the file system.
These instances of Asset, and in turn the instances of File, are then associated with a Shoot by assigning them to a Scene which in turn belongs to a Shoot. This supports practitioners by connecting any given Asset to its associated metadata and also to the Scene and to the Shoot that it has originally come from. In the design of a metadata management tool, this feature of the sub-ontology improves the process whereby metadata of interest is located - often at later stages of post-production where finding or re-acquiring this information requires a great deal of back-and-forth communications.

Fig. 4. Use Case 3: Segment diagram of the creative data semantic model (sub-ontology) showing the implementation of on-set VFX data management.

5 Discussion

Improving access to and correct understanding of metadata, and ensuring the persistence of metadata during the editing process, is the primary goal of implementing the Russian doll principle: that a Record should be able to ‘wrap’ or contain another Record relating to the versioning of that metadata. Our objective is to facilitate the communication channels needed to accomplish metadata coherence and consistency within workflows, by providing the underlying ontology and data model to support this.

Through metadata versioning, we can track the technical modifications across a project to identify when a data item has been modified and quickly trace where
and when errors were introduced. The project data itself is represented as a file on a computer and each have an instance of the *File* class which identifies the file through its data type properties *hasFilePath* and *hasFileName*. Each instance of *File* can then be allocated to an instance of *Asset* or one of its subclasses, which have their own set of metadata fields and values where appropriate. This means we can link files stored on disk to its ontological representation and its associated metadata, including the metadata history.

While we have extended the metadata wrapping approach, as has been seen in Sect. 4.1, we acknowledge that the deliberately limited scope of the sub-ontology, which covers three specifically chosen use-cases, does leave a number of questions open as to how to scale our approach. However, our technology testing and prototyping work has highlighted the potential for ontology-based solutions for metadata management in post-production. We have identified three main goals for our tool and have successfully developed a limited-scope prototype for a semantic model that could be used to achieve these overarching goals. As our prototyping work continues, we can observe that media metadata is itself wrapped in a larger ‘universe’ of metadata, a wider ecology of metadata sharing [9,10]. We may anticipate that our technical and design principles, including those of metadata versioning shown in Fig. 1, can be made to transfer to other fields and domains beyond that of production and post-production.

6 Conclusion

Unlike other media ontologies, the Creative Data Semantic Model has the capacity to manage the ebb and flow of metadata changes across film, unscripted television production, and VFX. As the media industry continues to reshape itself it is essential that the provenance and reliability of metadata can be guaranteed across workflows, and that this can also be addressed in new workflows.

In future work, Creative Data will extend the data management tool, using the sub-ontology to manage metadata about digital assets in production, ensuring consistency and correctness is applied to creative content in the selected scenarios. This can then be merged with the full ontology of the entire range of metadata fields, integrating this with the data management tool. Other avenues of research include: 1. New efficiencies in workflow designs; 2. New services relating to metadata usage to be conceived and delivered; 3. Show clients the knock-on effects of creative and technical decisions made early-on; 4. Training resources built on ontologies; 5. Venn diagram generators visualising the ontology and metadata - the latter two being especially under-researched areas.

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