Representation of Socio-historical Context to Support the Authoring and Presentation of Multimodal Narratives: The Mingei Online Platform

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In this article, the Mingei Online Platform is presented as an authoring platform for the representation of social and historic context encompassing a focal topic of interest. The proposed representation is employed in the contextualised presentation of a given topic, through documented narratives that support its presentation to diverse audiences. Using the obtained representation, the documentation and digital preservation of social and historical dimensions of Cultural Heritage are demonstrated. The implementation follows the Human-Centred Design approach and has been conducted under an iterative design and evaluation approach involving both usability and domain experts.

CCS Concepts: • **Information systems** → **Web applications**; **Digital libraries and archives**;

Additional Key Words and Phrases: Semantic Web, knowledge representation, narratives authoring

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1 INTRODUCTION

Narratives are part of both tangible and intangible cultural heritage. The collection and care of heritage objects and sites is a universal practice of persons, families, and social groups to support their collective memories and values. Symbols embedded in public monuments often refer to narratives, and, thus, heritage sites may be linked to historic events that influenced the culture of a social group. Verbal communication, spoken or written, is one of our fundamental methods to transmit ideas, concepts, memories, and values. Practices, religious, and crafts are related to 'Narratives'. 'Narratives' are important also when presenting **Cultural Heritage (CH)**. In this work, an approach to the semantic representation of narratives that contextualise CH topics is proposed.

The **Mingei Online Platform (MOP)** [67] is an online system for the representation of the socio-historic context through narratives. The purpose is to (1) document, represent, and preserve intangible dimensions along with objects and sites; (2) contextualise presentation of tangible heritage; (3) systematise and facilitate the presentation of socio-historical context; and (4) explore and promote World Heritage, stimulate interest through educational and fascinating content.

In MOP the provided authoring tools enable data curators to author 'Narratives', their 'Narrations' and the 'Presentations' of each 'Narration' through simple form-based user interfaces. 'Narration' authoring is facilitated by providing the means to define how a 'Narration' will be presented to end-users.

Besides forms, the authoring tools provide means to visualize the 'Narrative' structure and its relation to other semantic entities. Tools to present generic information are provided, such as timelines, related media previews, and comprehensive narrative Web pages.

MOP provides facilities for exporting knowledge in various formats to support continuous reuse and sharing of information including direct open access to documented knowledge. Furthermore, it enhances the documented information by establishing a linkage between MOP and other relevant publicly available Knowledge Bases such as Europeana [27].

In this article, the approach followed by MOP is presented including the implementation details of the system and an exemplary use case applied in the context of the representation of the socio-historic context of the textile manufacturing craft in Krefeld Germany.

2 BACKGROUND AND RELATED WORK

2.1 Knowledge Representation for CH

Cultural Heritage is a domain where Semantic Web technologies are starting to be considered as standard tools [50]. There is a significant history of pertinent approaches, since the pioneering work of Europeana, which made possible the modelling of CH elements with semantic technologies in 2007 [16]. In this, according to the authors of this article, three phases of the adoption of semantic technologies in the CH sector can be distinguished.

During 2000–2010, projects relied mostly on existing approaches to knowledge classification, stemming from the library, and archival science. Existing work focused on catalogues and collections and the artefact descriptions in approaches that were exclusively object-centric or collection-centric (MINERVA [53], Europeana Rhine [4],

etc.). This required an immense data integration effort due to the heterogeneity of the source descriptions. The supported innovation was the semantic search, which allowed us to ask queries based on semantic categories but in return produced a list of metadata that were not exploited adequately to deliver innovative applications.

During 2010–2015, the focus shifted toward richer, event-centric representations, in response to the realization of the drawbacks and scarce utility of object-centric representations. The class 'Event' is one of the basic classes that the Europeana Data Model [16] inherited from the CIDOC-CRM [14]. This shift has not led to significant improvements, because, at the time, building representations of events and connecting them to object-centric representations was very difficult. Events could not be found in institutional repositories, and extracting them from external sources such as Wikipedia or Freebase did not lead to significant results. In this respect, Europeana is a case in point: The class 'Event' was not populated in the Danube release in 2011 [5].

Since 2015, significant changes are observed. ICT has contributed to this change (1) by providing breakthroughs in knowledge extraction from texts (e.g., References [52, 7]) and other media via deep learning methods and improved signal-processing techniques, (2) through scalable semantic systems based on solid implementations of Semantic Web standards and the evolution of Semantic Web technologies (e.g., Reference [5]), and (3) by consolidating existing ontologies, notably the CIDOC-CRM to provide higher expressivity and domain coverage. Furthermore, this was supported by the development of new representations of CH artefacts, based on new digitization techniques, able to exploit the above-mentioned technological advances [12].

The work presented in this article aspires to be part of the third phase of adoption of Semantic Web technologies and contribute to the expansion of the provided possibilities through 'Narrative' centric representations. The definition of the fundamental concepts in MOP was an outcome of a systematic study of HCs in the context of the Mingei project to identify the requirements [61] and define the technical components needed for craft representation and presentation [62]. MOP addresses these requirements and implements the technical framework to support the authoring of 'Narrative' centric representations.

2.2 Narratives Structure and Definitions Adopted by This Research Work

In literary theory, narratology is a discipline devoted to the study of the 'Narrative' structure and the logic, principles, and practices of its representation [68]. The earliest antecedent to modern narratology can be found in classical Aristotle's theory of aesthetics. Indeed, in *Poetics*, Aristotle defines a 'Narrative' as the imitation of real actions (praxis) that forms an argument (logos) whose fundamental units, or events, can be arranged in a plot (mythos) [69]. For Russian formalism, narratology is based on the idea of a common literary language, or a universal pattern of codes, that operates within the context of a work. A 'Narrative' can thus be conveyed through several different means of communication and a wide range of media, including speech, writing, gestures, music, and so on. In particular, Vladimir Propp's *Morphology of the Folktale* (1928) [70] proposed a model to represent folktales as combinations of basic building blocks, including 31 "narrative functions" and seven roles, or "spheres of action," of the characters. The theory of narratology was further developed by mid-20th-century structuralism. Claude Lévi-Strauss, in *Structural Anthropology* [71], outlined a grammar of mythology. In *Structural Semantics* [72], A. J. Greimas proposed a system of six basic structural elements of 'Narratives' called actants; Tzvetan Todorov was the first to coin the term *narratologie* [73]. Later, Gérard Genette [74] codified a system of analysis that studied both the 'Narration' and the act of narrating, considering them separately from the story and content of the text.

Since 1980, post-structuralist perspectives of narratology have been developed. In particular, Cognitive Narratology [75] considers narratology a psychological phenomenon and proposes a study of 'Narrative' aspects from a cognitive perspective. Empirical results from cognitive psychology highlight that most common-sense concepts cannot be characterised in terms of necessary/sufficient conditions. Monotonic description logics capture the aspects of compositional conceptual knowledge but are insufficient in representing prototypical knowledge. Russian formalism distinguishes between a *Fabula*, defined as a series of events taking place at a certain time at

a specific location, and a *syuzhet*, which is the particular way the story is narrated. Contrary to the order of the Fabula, which is strictly chronological, the order of the syuzhet corresponds to the way the events are presented in the 'Narrative' by the author [70, 76]. A similar distinction is drawn in structuralism by Chatman [77], who identifies the opposing concepts of story, i.e., the content that is transmitted, and discourse, i.e., the particular organization of that content. Currently, there is no universally accepted definition of the 'Narrative' structure. For instance, Crawford [78] posits that a 'Narrative' is a high-level structure based on causality, not on temporal or spatial relations. Genette [74] identifies five concepts that characterize the syntax of v: order, frequency, duration, voice, and mood. In addition to the Fabula and the syuzhet, Bal [79] defines a third level that constitutes the concrete representation of the content that is conveyed to the audience (e.g., the text in a novel).

Following the concept above, for clarity, we provide the definitions of the key concepts employed in this work as adopted by studying the theoretical work on 'Narratives' and the requirements posed by the technical implementation of this work. These definitions include (a) Socio-historic context, (b) 'Event', (c) 'Fabula', (d) 'Narrative', (e) 'Narration', (f) 'Presentations', (g) 'Presentation Segments', and (h) 'Channels'. Concepts included within apostrophes throughout the document refer to classes of the ontology that are used both for semantic representation in the ontology and as elements that can be authored in MOP.

Socio-historic context regards the representation of history based on the cultural and historical events taking place at the time where the source studied (text, archive, artefact, etc.) was created.

An 'Event' is something that occurs in space and time, including actions by individuals, as well as complex activities, by groups of persons or individuals. More formally, an 'Event' is the changes of state in cultural, social, or physical systems [14]. In MOP, events are considered to occur within a time interval delimited by time instants and the convention is also made that Events may have zero duration.

A 'Fabula' is a series of events taking place at a certain time at a specific location connected in chronologic order (Russian formalism). Sources of interest contain accounts of events that occurred, by whom, where, in which way, and so on, and which are relevant to the topic [48]. In the formation of events, researchers have a primary role. They use books, published research, testimonies, archives, and so on. In doing so, they report on events and the connection of these events is giving an account of what happened based on the studied resources.

A 'Narrative' is an abstraction that represents the story to be told, e.g., "The history of textile weaving at Krefeld."

'Narration' is the way that a story is told. There can be many 'Narrations' of the same story, focusing on different aspects of the Fabula, or presenting events in a different order. The encoding of the event sequence in the 'Narration' is called the plot.

'Presentations' are defined as the alternative ways that a 'Narration' can be presented. A 'Presentation' in the context of this work employs some medium, e.g., a mobile device, a VR headset, a Web browser, and so on.

'Presentation Segments' are components that when put together create the 'Presentation'. Each 'Presentation Segment' may be directed to a 'Channel'.

'Channels' are serial media of communication. When we watch a movie, we are simultaneously receiving information from several channels: The video channel transmits the images to us, an audio channel sends us the words of the actors, and another audio channel sends us the music that accompanies the scenes.

2.3 Digital Narratives

Computational narratology studies 'Narratives' from a computation perspective [65]. In the Artificial Intelligence field, computational narratology refers to story generation systems, i.e., computer applications that create a symbolic (written, spoken, or visual) 'Presentation' of a story typically based on a story's grammar. Some of the early storytelling systems are TALE-SPIN [32], UNIVERSE [25], GESTER [38], and JOSEPH [24], which change the story grammars to create new stories. Other storytelling systems are MINSTREL [46], MEXICA [40], and BRUTUS [8]. These are hybrid systems that implement a computer model of creativity in writing. Recently,

ontologies were used to generate 'Narratives'. For example, MAKEBELIEVE [27] uses common-sense knowledge, selected from the ontology of the OPEN MIND COMMONSENSE KNOWLEDGE BASE [45], to generate short stories from an initial one given by the user. PROTOPROPP [20] uses an ontology of explicitly relevant knowledge and the Case-Based Reasoning method over a defined set of tales. In FABULIST [42] the user supplies a description of an initial state of the world and a specific goal, and the system identifies the best sequence of actions to reach the goal. The concept of the event is a core element of narratology theory and the 'Narratives'. People conventionally refer to an event as an occurrence taking place at a certain time at a specific location. Various models have been developed for representing events on the Semantic Web, e.g., Event Ontology [18], Linking Open Descriptions of Events [43], and the F-Model [1]. More general models for semantic data organization are CIDOC-CRM [14], the ABC Ontology [23], and the Europeana Data Model [30].

From a semantic representation point of view, several projects and research work targeted the transmission of knowledge through 'Narratives'. The PATHS [18] and CULTURA project [2] created interactive personalised tour guides to present digital library and CH collections, respectively. In the same context, the Storyspace system [51] allowed the creation of curatorial 'Narratives' in a museum exhibition through Events. Each digital object has a linked creation event in its associated heritage object story.

Regarding authoring of stories with new and existing content the CIPHER project [22] developed a set of tools to facilitate the development of meaningful stories allowing authors to establish semantic relations between different contents.

Regarding visualisation of 'Narratives' the DECHO framework for the acquisition, ontological representation, and visualisation of knowledge [3] based on CIDOC-CRM [14] display 'Narratives' by linking together images or three-dimensional (3D) representations of archaeological objects via semantic hotspots [31]. Another visualisation tool is provided by the CADMOS suite of applications [29] that adopts a computer-supported semantic annotation of 'Narrative' media objects (video, text, audio, etc.) and integrates with a large common-sense ontology (YAGOSUMO). Additionally, The Labyrinth project is an ontology-based system for the visualisation of 'Narratives' [10]. In 2015, the Labyrinth system has been extended with a three-dimensional interface [11]. A similar project is Invisibilia, which is focused on the domain of contemporary public art [28]. Invisibilia takes as input an ontological representation, constructed using a CRM-based ontology for intangible art [26], and outputs a 3D layout featuring the artworks.

Several tools exist that allow the visualisation of data on a particular topic contained in existing knowledge bases (e.g., Wikidata, Freebase) in form of 'Narratives'. For example, Thinkbase and Thinkpedia [21] are two applications that produce visualisations of the semantic knowledge contained in Freebase and Wikipedia respectively, allowing the user to explore the semantic graphs of the two knowledge bases in an accessible and interactive way. Histropedia [66] allows users to create or view timelines on topics of their choice by importing statements from Wikidata. Links to relevant Wikipedia articles and Wikimedia Commons images are automatically added, resulting in rich spatiotemporal visualisations. The scope of the project includes research, education, tourism, and proprietary applications [33].

2.4 Contribution of This Work

The contributions of this research work can be summarised as follows.

MOP relies on a strong conceptualization, focused on a notion of 'Narratives', and exploits both sides of the representation, the semantic ('Fabula') and the signal-based ('Narration') side, and combines these two aspects by linking semantic notions, like events and actions, to the media objects that illustrate these notions. The objective of semantic 'Narratives' as applied by MOP is to help computers by providing them with the 'Fabula' and the way that it is associated with the 'Narration'. 'Narration' may have alternative 'Presentations'. 'Presentations' are ways of presenting a 'Narration' by providing a formal representation of it, as a semantic network consisting of 'Events', 'Persons', 'Locations', and so on. Moreover, these 'Events' are linked to data entries and in turn

data entries are linked to fragments of 'Media Objects'. In this way, the 'Narrative' as it is represented in our ontology (described below) can be obtained. Furthermore, to enhance the generated 'Narration' in MOP, publicly documented resources from Europeana are exploited. The linkage with Europeana is bilateral in the sense that the latter enables also the exposure of the information documented in MOP in a Europeana-compliant schema. Notice that the MOP representation is not only for the benefit of the human user, who can extract a lot of knowledge from 'Media Objects', but also of the machine that can analyse these signals and learn from them. In this article, we provide a representation of context and important tools that are necessary to transform socio-historic contextual information into 'Narratives'.

The 'Narrative' authoring and 'Presentation' tools provide "hooks" that enable the association of a 'Fabula' to its 'Narrative' and, in turn, to 'Narrations' and digital assets that help present the 'Narration' in multiple variations through multiple 'Presentations' and 'Presentation' modalities. MOP also expands the knowledge base upon which 'Narratives' can build supporting novel forms of 'Presentations' such as the 'Presentation' of motion-based 'Narratives' in 3D and VR [62, 64] and 2D visualisations of HC processes [63].

In MOP, knowledge is represented using the conceptualisation provided by an ontology, the **Mingei Crafts Ontology (CrO)** [34]. The ontology is providing a vocabulary and axioms to align the vocabulary terms with the conceptualization. The ontology harmonizes in a coherent vision many sub-domain ontologies, re-using solid results in knowledge representation that have now become standards, such as (a) 'Narrative' modelling, based on an extension of the CIDOC-CRM [14, 9] with narratological concepts; (b) time, based on the OWL time ontology [44]; (c) content representation, based on RDF; and (d) 4D-fluents for the representation of time-varying properties. Also, we have designed the required mappings between CrO and **Europeana Data Model (EDM)**. This will allow us to link particular instances of CrO with Europeana resources, enabling, therefore, the validation as well as the enrichment of resources and the ingestion of the latter in Europeana. Furthermore, the implementation of the ontology is based on standards: the Web architecture for identifying, storing and retrieving the basic resources using **Internationalized Resource Identifiers (IRIs)**, whether media objects, formal concepts or individuals; RDF as the basic data model for knowledge; OWL as ontology Web language; and SPARQL as a knowledge extraction language. Additionally, this work contributes an approach for managing representations based on open source software implementing the standards based on the ontology and a Web-based authoring environment, the MOP, including a rich presentation layer, addressing various kinds of devices and various kinds of users. Finally, this work contributes with a rich set of authoring tools for the creation of multimodal 'Narratives' and a pool of pilot 'Narratives' showing the full potential of all of the above.

3 THE PROPOSED APPROACH

Mingei proposes a systematic process for craft representation and 'Presentation'. This process can be summarised in a series of steps as follows. In STEP 1, the documentation is acquired in the form of digital assets that are relevant to the representation of a craft through the analysis by researchers of physical (e.g., books, archives, etc.), digitized, and human assets (craft practitioners). Based on these assets, knowledge about a craft is acquired and semantically represented using MOP. Subsequently, researchers formulate several text-based 'Narratives' that present the targeted socio-historical context. This text-based representation is used to identify events and their causal dependencies to formulate representations of 'Fabulae'. Then 'Narrations' are created to provide an abstraction of the 'Narrative' to be narrated. Different 'Narrations' are different ways of telling the 'Narrative' and each of which may have different 'Presentations'. Through alternative 'Presentations', Mingei is exploring multimodal 'Presentations' to make 'Narrations' appealing to different target audiences and through the usage of different technologies (e.g., the Web, VR, AR, mobile devices, books, etc.).

In this sense, the proposed approach follows the work of a researcher for the authoring of 'Narratives' that involve objects of CH significance and CH sites. The researcher uses books, published research, testimonies, archives, and so on. Then (s)he builds a representation of a series of events giving an account of what happened

Fig. 1. Digital assets representing an artefact and archive digitization.

in reality, based on the studied resources. The data curator's reporting of events is encoded in the MOP in the form of causal relations, established by him/her ('Fabula'). In this work, it is assumed that represented events are accurate and not contradicting. It is essential to understand that the representation critically depends on the outcome of the analysis and interpretation of the studied sources. Then the researcher uses the 'Narrative' tools provided by the MOP to associate a 'Fabula' to a 'Narrative' and, in turn, create 'Narrations' that represent alternative ways that the 'Narrative' can be told. Then each 'Narrations' may have different 'Presentations' to facilitate how it will be presented in alternative devices, language, and so on.

3.1 Formulation of Basic Data Entries

The formulation of basic data entries is systematised through an authoring environment that builds on top of an Ontology that adheres to knowledge representation standards in Cultural Heritage [58] and supports the representation of knowledge about 'Persons', 'Enterprises', 'Places', 'Objects', and related 'Media Objects'. This facilitates the data curators in transforming verbal and visual content into data entries. Furthermore, in MOP, a user-friendly user interface for the data curators is offered for integrating digitisation results produced by modern digital media and digital capturing technologies including **Motion Capture (MoCap)** and 2D and 3D digitisation, thus enhancing their representation capacity. 'Places' in particular avail information of pertinence to the 'Narratives' to be narrated. Refined representation of locations and sites may require addresses and arbitrary user-defined locations not included in the database. However, the coordinates of such locations can be acquired through a GIS or map interface. A common modelling simplification is that the entire region (e.g., a city) is associated with a single point location. This may be sufficient for some cases, but an overly coarse approximation in others.

Examples of the metadata as represented in MOP for media objects are shown in Figure 1 and Figure 2. Figure 1 shows the metadata of images taken to document a museum artefact and the corresponding metadata for archive digitization. Figure 2 presents digital assets linked to an artefact, a silk bookmarker, including high-resolution scans of the artefact.

Figure 3 presents an example of relating a representation of a 'Person' to a 'Media Object' of type image that presents a portrait of the person. The line represents a relation, that is the reference (link) to an entity (#729), which is a digital asset.

3.2 Representation of Socio-historic Context

3.2.1 'Events'. The principal attributes of an 'Event' are 'Time', 'Place', and 'Persons' (participants of the 'Event'). The representation of an 'Event' entails its association with data entries that represent the corresponding 'Persons' or social groups, the dates, times, or eras, as well as the locations, regions, or places that these

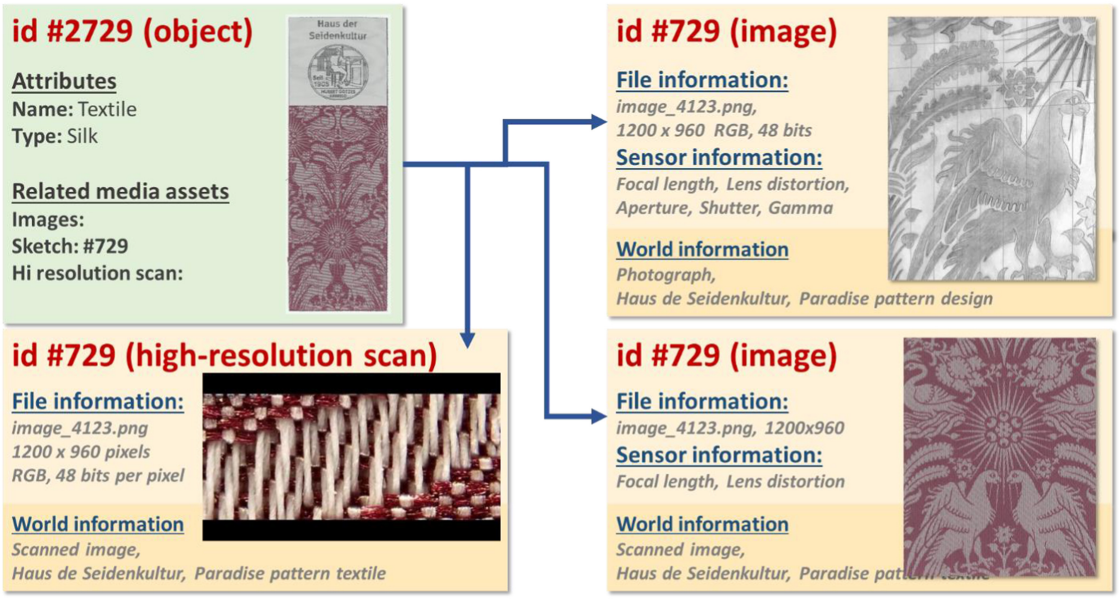

Fig. 2. Collection of data regarding an object (page marker sold at the museum) relevant to textile manufacturing at Krefeld and association to digital captures of the artefact.

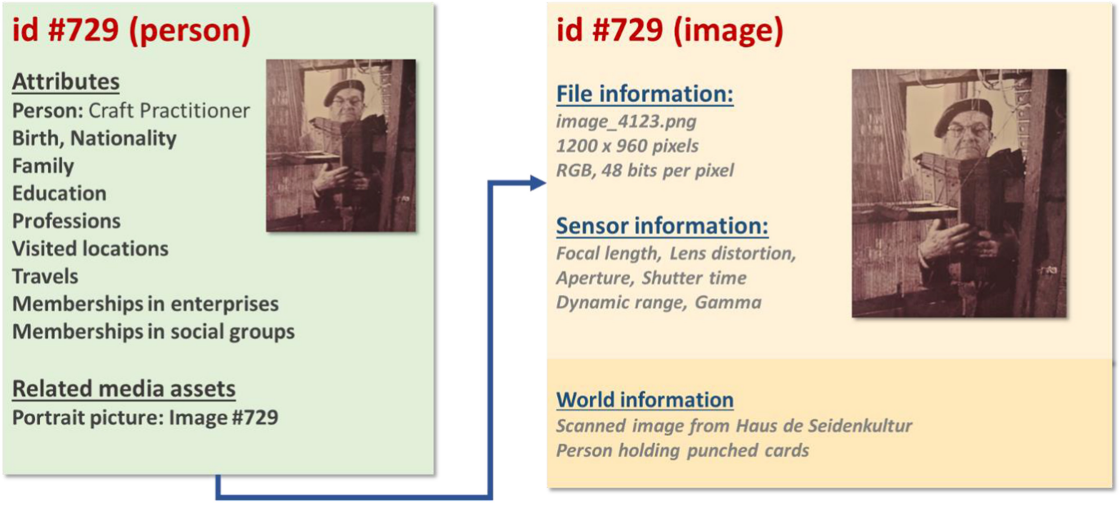

Fig. 3. Relating a representation of a 'Person' to a 'Media Object'.

'Events' occurred. To this end, in MOP, the creation of context representations through links among actors, locations, and 'Events' is facilitated.

Let us say we wish to represent the 'Event' of a building acquisition transaction. The building was built and equipped as a textile manufacturing workshop, and then its original owner sold it to another 'Person' along with its equipment. In Figure 4, we illustrate with yellowish hues the digital assets gathered. To document the 'Event', we need the basic data entries about the place of the 'Event', the date and time, and the participants. These are

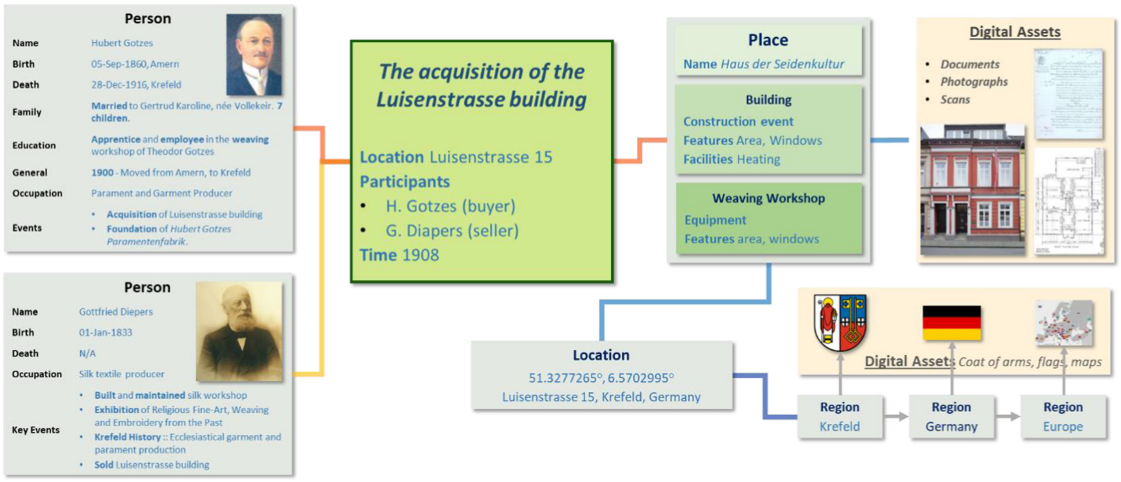

Fig. 4. Illustration of the representation of an event.

illustrated below, as the records for H. Gotzes, G. Diepers, and an address at Krefeld, Germany. We underscore the description of the building, which is specialised from generic (building) to craft-specific (workshop). The location is a data entry referred to by other 'Events', i.e., its construction and its renovation (shown simplified, for illustration). Semantic relations are illustrated by lines. In this case, the relations to the participants and the location of the 'Event' are shown. In turn, the location entity contains links to digital assets that document the location.

3.2.2 Formulation of 'Fabulae'. The next step is the structuring of 'Events' in MOP to 'Fabulae' presenting the sequence of 'Events' that are the backbone of a 'Narrative'. The basic element of the 'Narrative' we wish to represent, narrate, and present is 'Events'. Currently, the connection between 'Events' is established by two kinds of relations as follows:

1. Mereological, which, according to the Oxford English Dictionary, denotes the abstract study of the relations between parts and wholes. These are relating events to other events that include them as parts, e.g., the invention of the flying shuttle is part of the life of the Industrial Revolution.
2. Causal dependencies, relating 'Events' that in normal discourse are predicated to have a cause–effect relationship in the author's opinion, e.g., "the Industrial Revolution resulted in a reduction of the number of weavers."

Through this authoring environment, basic data entries are transformed into 'Fabulae', which are a series of 'Events' regarding a topic in a chronologic form as schematically shown in Figure 5.

3.2.3 'Narratives' and 'Presentations'. 'Narratives' consist of the following elements: (1) The 'Fabula', i.e., the 'Events' is chronologic order as reported to have happened in reality; (2) the 'Narration(s)', i.e., one or more expressions, each in its language and medium, which narrate the 'Narrative'; and (3) the 'Presentations', i.e., alternative ways that a 'Narration' can be presented. With regards to 'Presentations', textual, audio, and visual 'Media Objects' and 'Channels' are of fundamental importance. Thus, 'Presentations' define the way in which 'Narrations' are presented (see Figure 6). It is important to note that 'Narrations' are device independent. However, they can be presented differently through different 'Presentations' depending on the destination platform and the end-user profile. That makes 'Narratives' independent of the device used and the user accessing it. An example of a 'Presentation' that employs only the text 'Channel' is provided in Figure 7.

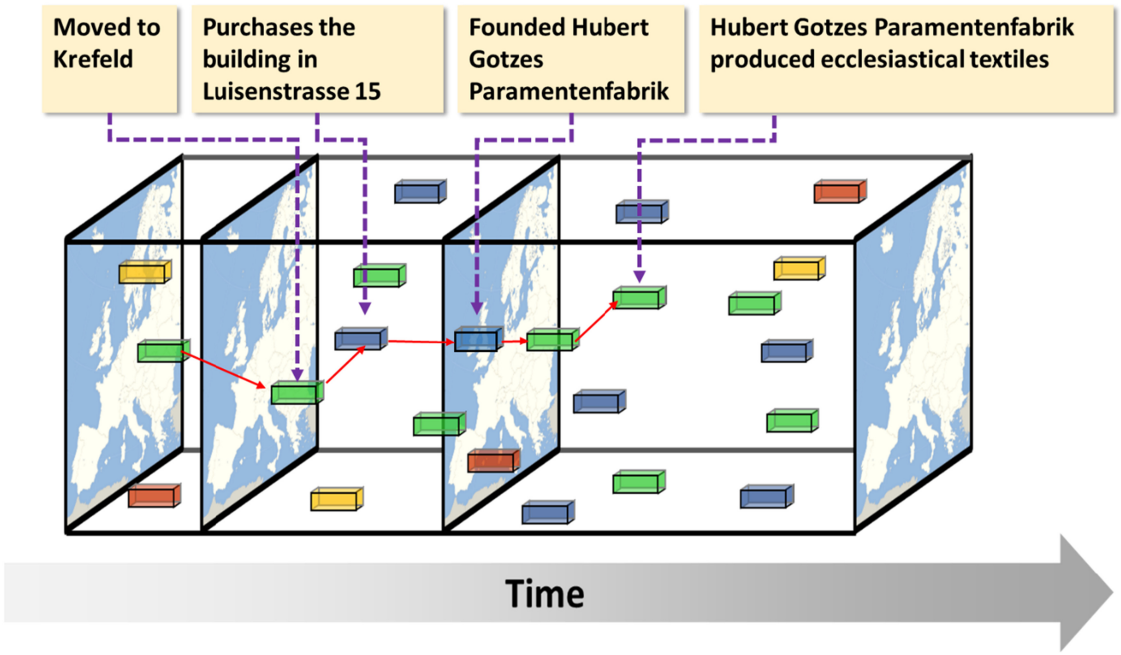

Fig. 5. Representation (simplified) of a 'Fabula'.

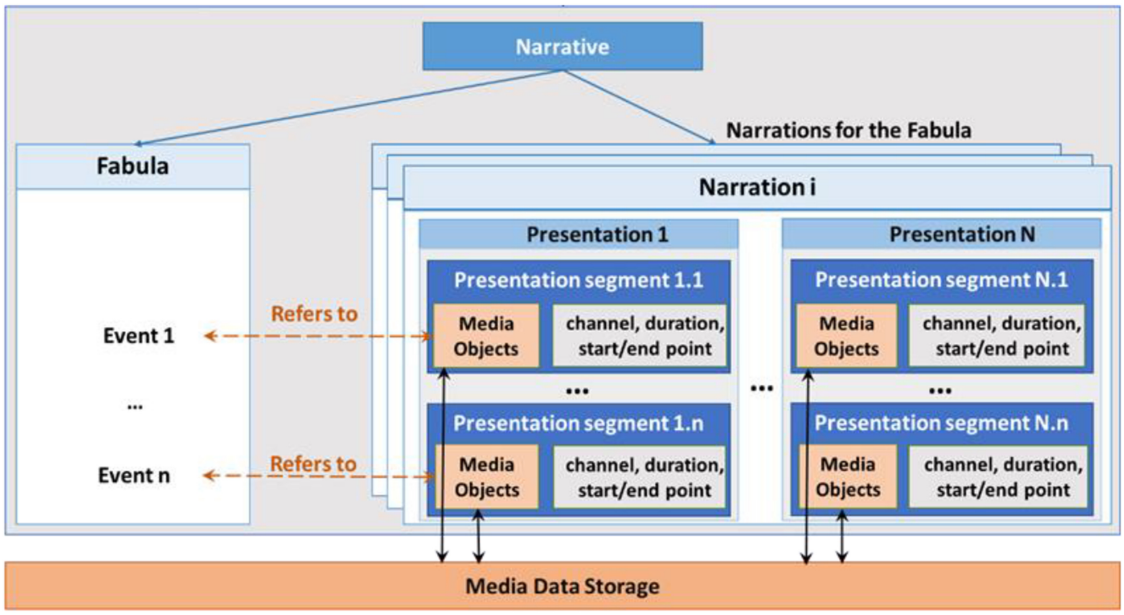

Fig. 6. The structure of the 'Narrative'.

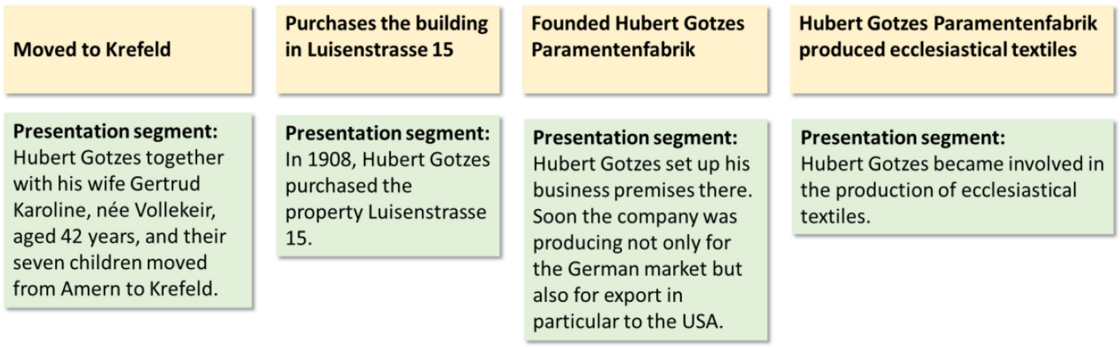

Fig. 7. Narration (simplified) of the 'Narrative' "The Hubert Gotzes' company."

4 IMPLEMENTATION

MOP is developed on top of **Research Space (RS)** [37, 41], a CH research platform, that is using Semantic Web languages and technologies. The integrated semantic components are designed to assist experts to create, annotate, assert, argue, search, cite, and justify research outcomes.

4.1 Conceptual Architecture

At a conceptual level, MOP can be considered in three knowledge representation steps, each one contributing to the representation of 'Narratives' on CH.

The first step regards the formulation of basic data entries, which include curated information about an element of knowledge and links to digital assets. Involved entities are 'Persons', 'Enterprises', 'Places', 'Objects', related 'Media Objects', and so on.

The second step regards the representation of knowledge in the time–space continuum. The reporting of an 'Event' requires at least two observations of this state in time. 'Events' are basic elements of 'Fabulae'. Data entries of the 'Event' type are employed to represent socio-historical context corresponding to changes in social and economic systems due to historic events. In terms of knowledge representation, the principal components of an event are (a) Time, (b) Place, (c) Participants, and (d) mereological and causal relations with other Events.

The third step concerns the creation of Narrations and Presentations, which will be used to present a comprehensive picture of the represented context.

4.2 MOP Implementation

The backend of the system consists of an ontology specification and a semantic repository together with a knowledge acquisition API compatible both with the CrO and with the EDM. The implementation of the UI is employing the RS toolkit on top of which semantic forms are developed to support knowledge and digital assets authoring. An overview of the supported authoring provisions of MOP is presented in Section 4.3.

The UI implementation follows the **Human-Centred Design (HCD)** process [57]. Using this methodology, all relevant stakeholder groups participate in all phases, including staff from CH organizations as well as representatives of the stakeholder groups. HCD is an iterative design process for interactive applications, systems, and products. Its main characteristic is that it places the end-users and other identified stakeholders' needs at the centre of each design and development phase of the system (tool, application, or product). The main goal of this process is to ensure that the resulted system meets the user's needs, supports his/her goals and objectives, and satisfies the main parameters of usability: ease of use, learnability, effectiveness, efficiency, and satisfaction. The HCD approach is empowered by co-creation. Overall, the design process of MOP components has gone through three design iterations. Design techniques used in these iterations included implementing minor improvements

Table 1. Mappings of CrO to EDM

Mingei Ontology	EDM
cro:MObject	edm:WebResource
cro:hasMOType à cro:MOType	ebucore:hasMimeType
crm:P94i_was_created_by → crm:E65_Creation → crm:P14_carried_out_by → crm:E39_Actor	dc:creator
cro:Narrative	edm:ProvidedCHO
crm:P3_has_note	dc:description
cro:has_action	edm:isNextInSequence
crm:P129_is_about	dc:subject

on the working version (based on agile development approach) and production of high-fidelity prototypes for targeted UI improvements when needed using the free online design and prototyping tool Figma [19]. Evaluation techniques used were 'beta' testing and expert-based evaluations in the form of cognitive walkthroughs and heuristics analysis [36].

4.2.1 Ontology. The CrO [34] is used to represent the knowledge collected and the relevant socio-historic context. It is an application ontology [35] obtained by integrating several existing ontologies, notably (a) the CIDOC-CRM, a top ontology and an ISO standard (ISO 21127:2014) forming the conceptual backbone of the CrO [14, 9]; (b) the Narrative Ontology, a domain ontology focused on the representation of 'Narratives' [48, 47]; (c) the FRBRoo, a domain ontology for bibliographic records, resulting from the harmonization of FRBR with CRM [15]; (d) OWL Time, a domain ontology recommended by W3C for the representation of time [44]; and (e) Dublin Core for simple resource description [13].

The ontology for 'Narratives' that is part of the CrO has been developed at ISTI CNR. A preliminary version of this ontology has already been published [48] and applied to introduce 'Narratives' in Europeana [47]. The final version of the ontology, used as the core ontology of the Mingei knowledge base, is reported in a scientific article that has been submitted for publication [49].

To make the Mingei ontology compliant with EDM, we have developed the required mappings for aligning particular class instances between the two schemata. Despite the rich structure of classes and properties of the Mingei Ontology, we have created the mappings for a particular subset of these resources. Some resources were not mapped to EDM, mainly because their scope was outside the scope covered by EDM. The following table shows some indicative mappings for classes and properties between the two schemata. As depicted in the table below, there are certain paths in Mingei Crafts Ontology that are mapped to a particular in EDM. This happens because of the event-centric philosophy of CrO compared to the simple and more fine-grained metadata of EDM.

The mappings described in Table 1 can be exploited in two ways: The first one aims at transforming Mingei descriptions from the MOP database to EDM ones through the formulation and execution of the appropriate SPARQL queries that will create the corresponding semantic triples. Although we described the transformation from Mingei to EDM, this can be carried the other way around as well (i.e., for enhancing particular resources in the MOP database with already publicly available information found in Europeana knowledge bases). The second approach aims at transforming resources using a schema mappings definition language (like X3ML [59]). In Mingei, the first approach is followed due to the advantages that (i) it can be triggered on the fly, (ii) it has access to the latest version of the data and any updates they might have, and (iii) it is efficient, since it relies only on SPARQL. Nevertheless, the second approach is also feasible to export Mingei data and transform them through the invocation of third-party applications for transforming the data offline.

Currently, the SPARQL endpoint provided by MOP supports the provision of metadata compatible with the following schemas: EDM, CIDOC-CRM, and CrO, thus making possible the reuse of data. Furthermore, as presented

in Section 4.2.3. knowledge elements in MOP can be used as linked open data through unique IRIs generated by the repository platform.

4.2.2 User Interface. The front-end was implemented using the RS toolkit, which provides HTML5 semantic components for structuring Web authoring forms, template pages, navigation menus, content panels, and other interaction and 'Presentation' elements (i.e., buttons, searches, drop-downs, table grids, etc.). It also provides 'Presentation' features such as interactive maps, a timeline component for visualising chronologically ordered events, and various image gallery components. The RS toolkit facilitated rapid prototyping in the first design iteration. Targeted design prototypes were produced thereafter, to visualize suggested design solutions and improvements stemming from the results of the design iterations.

UI templates: The ontology is providing the semantics of the knowledge representation employed by the RS toolkit. For example, a representation of a particular person can be associated with the ontology (model) as being of type 'Person' [54]. In this context using the RS toolkit UI templates have been created to define generic views that are being automatically applied to entire sets of instances, for example, to all instances of type 'Person'.

Application pages: For the 'Presentation' of a collection of knowledge such as, for example, the visualisation of a 'Presentation' of a 'Narration', application pages are used. These are pages that are not associated with any entity in the knowledge graph. Using application pages functionality that goes beyond associations with entities can be built. In application pages, the mark-up is bound with knowledge from the ontology. For application pages, HTML5 semantic components are used. The components are custom HTML5 components that operate on the result of SPARQL queries executed over the knowledge graph. HTML5 components allow formatting and structuring the content of application pages and templates providing functionality beyond that of native HTML mark-up.

Forms: Authoring forms for knowledge graphs are implemented using semantic forms from the RS toolkit. Semantic forms are structured with field definitions that are used to provide the functionality and querying mechanism to read and update values within the graph. Furthermore, a semantic form receives data through input elements. Forms and input elements are instantiated using HTML Components including references to the field definitions.

4.2.3 Data Storage and Repository Platform. In MOP, the asset storage, the triple storage, and the UI are implemented as distinct components of the system. The asset storage is based on a flexible, modular, open source repository platform with native linked data support by integrating a Fedora platform-based Web storage [17]. Triple storage is based on the GraphDB enterprise Semantic Graph Database. GraphDB implements the RDF4J framework interfaces and the W3C SPARQL Protocol specification and supports all RDF serialization formats. GraphDB is the preferred choice because of its community and commercial support, as well as excellent enterprise features such as cluster support and integration with external high-performance search applications. Furthermore, GraphDB supports semantic inferencing at scale, allowing MOP users to derive new semantic facts from existing facts. It handles massive loads, queries, and inferencing in real time.

Based on this structure, in MOP, knowledge authoring is provided through RS, access to linked data is provided through a GraphDB endpoint, and access to assets is provided through unique IRIs generated by the repository platform.

4.3 Authoring Provisions of MOP

4.3.1 Authoring Data Entries. In MOP, a Web-based, multimodal content 'Presentation' is provided. In essence, MOP can be considered as a gateway through which end-users can access the represented content in multiple formats. The primary objective of the components of MOP responsible for authoring data entries is to promote collaborative interdisciplinary authoring of knowledge that relates to and reveals different aspects of CH including material heritage. Using the authoring components of the platform, CH professionals (i.e., data

curators, museum professionals, researchers, academics, etc.) can author and store in the Mingei repository data entries related to the craft, such as 'Persons', 'Places', 'Enterprises', 'Objects', and so on.

4.3.2 Authoring Events and Fabulae. According to the Mingei ontology, an 'Event' describes a historical or social happening, which happened during a specified period in the past. An 'Event' can be semantically linked to various authored data entries related to the 'Event' from the repository, such as 'Persons', 'Places', and 'Media Objects'. It can also be linked to other 'Events' that occurred in that period or that had an impact on it, to further expand its historical or social context.

A MOP component facilitates the authoring of the 'Fabulae'. In the context of MOP, the 'Fabula' authoring components allow the semantic linking of a 'Fabula' to its related 'Events', which have been authored and stored in the Mingei repository. This can be done both by creating the 'Events' while authoring the 'Fabula' or assigning existing 'Events' to a 'Fabula'.

4.3.3 Authoring Narratives. In Mingei's Narrative Ontology, a 'Narrative' is to be presented by a narrator in a form provided by a 'Narration' and in the format identified by a 'Presentation'.

The authoring of 'Narratives' is supported by similar workflows like the ones for authoring 'Events' and 'Fabulae', and where the 'Narrative' authoring component allows a heritage professional (i.e., data curator, craft researcher, etc.) to synthesise a 'Narrative' using semantically linked data (i.e., basic data entries, events, and 'Fabulae') from the Mingei repository. Furthermore, recognising the diversity of target audiences and 'Presentation' technologies used in the project, this component supports the creation of different 'Narration' styles. This means that the user can "narrate" the same 'Narrative' in multiple ways according to the context of use.

A 'Narrative' is semantically linked to a 'Fabula' and one or more 'Narrations'. Furthermore, a 'Narration' is semantically linked to 'Presentations', which can be broken into one or more 'Presentation Segments'. The challenging thing for the author of a 'Narrative' is to understand the conceptual model involved and the interdependencies of the elements of a 'Narrative'. In a sense, the user has to work in an almost backward fashion starting from the segments and moving to the 'Presentations' and the 'Narrations', which are then linked to the 'Narrative'. An example of this workflow is presented in Sections 5.3–5.5.

5 USE CASE

To further support the 'Presentation' of this research work, in this section, a use case is provided, regarding the step-by-step authoring of a 'Narrative' in MOP. This is explained through the decomposition of the text-based 'Narrative' to information and the representation of information in the platform. A text-based 'Narrative' can be defined as the text generated by a researcher by studying and documenting the knowledge sources and reporting them in a form of a 'Narration'.

The authoring workflow is as follows. First, the basic data entries contributing to the 'Narrative' are formulated (see Section 3.1). Then the main 'Events' are authored and subsequently are organized chronologically in a 'Fabula'. Based on the formulated 'Fabula', a 'Narrative' is established to act as a container for alternative 'Narrations'. 'Narrations' are authored, using represented knowledge and digital assets. Finally, a 'Presentation' that determines how a 'Narration' will be presented on a specific device and audience is created, and the 'Presentation' becomes available through a Web page. Presentations are made of 'Presentation Segments'. 'Presentation Segments' relate to 'Media Objects' and provide information regarding how a 'Media Object' should be treated, i.e., when to play it (start/endpoint) and where to play it (channel).

In the case where authoring starts from a text-based 'Narratives', the transformation of text to basic data entries and 'Events' is needed to formulate 'Fabulae' and 'Narratives'. An example is presented below:

Narrative segment: In 1785, Edward Cartwright invented his first mechanical loom and continued to make improvements to it. The enhanced looms then went on sale in 1820. With the advent of mechanisation, the silk

entrepreneurs started to build factories where all the machines were powered by one source of energy and the workers were responsible for more than one loom.

Segment decomposition:

"In 1785 Edward Cartwright invented his first mechanical loom and continued to make improvements to it." → 'Event', Linked with a 'Person'

"Edward Cartwright" → 'Person', linked with 'Media Objects'

"Mechanical loom" → 'Object', linked with 'Media Objects', linked with 'Process' regarding its usage

"Improvements" → 'Events', linked with 'Media Objects'

"The enhanced looms then went on sale in 1820." → 'Event', linked with 'Media Objects', linked with 'Locations' where they were sold

"With the advent of mechanisation" → 'Events', the industrial revolution

"…the silk entrepreneurs started to build factories where all the machines were powered by one source of energy and the workers were responsible for more than one loom." → Event, linked with Locations of the factories, linked with events related to industrial revolution and electricity

5.1 Basic Data Entries

Basic data entries comprise basic statements that annotate or explain the role and significance of the acquired digital assets. These elements include any existing curated information or description of the asset. Knowledge statements forming the descriptions of the individual entities involved in the 'Narrative' are formed by the data curators. Examples of authored documentation in MOP are provided in Figure 8. On the top left side, the available 'Media Objects' (in particular, looms and loom parts) that are relevant with textile manufacturing is presented while on the top-right side the information page for a key 'Person' of the 'Narrative' of the craft "Gottfried Diepers" is presented. Furthermore, on the bottom left side, the location of historic 'Events' regarding textile manufacturing is presented while on the bottom right side a list of enterprises related to these historic 'Events' is displayed.

Multimedia management is supported through facilities that allow inserting, editing, and deleting 'Media Objects'. 'Media Objects' are classified into seven categories: 'Images', 'Videos', 'Audio', 'MoCap', '3D reconstructions', '3D objects', and 'Motion Vocabularies'. Media files are not directly managed in MOP but linked with MOP from any valid IRI. The actual storage of the files, in the case of owned digital content that is not referenced from external sources, is done asynchronously in the Fedora Platform to acquire a unique IRI that is then linked with the platform. Each media object has a name, a description, an image, a source file, and one or multiple 'Media Object Fragments'. 'Media Object Fragments' are continuous subsets of 'Media Objects', e.g., a snippet of text, audio or video, an image region, and so on. The source file of the 'Media Object' is referenced by an IRI that contains the location of the respective media object on the Web. The media preview tab contains the appropriate facilities for each media type to be reviewed for the user to be able to interact, inspect, and explore each digital asset according to its type, such as playing the video or rotating the 3D object. This is demonstrated in Figure 9. In the top left, the authoring tab is shown. In the top right, an image is previewed. In the bottom left, a 3D model is viewed. In the bottom right, a video is played.

Each 'Media Object' can be associated with 'Events', 'Fabulae', and other semantic elements of the 'Narrative'. This association links 'Media Objects' that annotate these elements. These annotations are quite useful for visualization and 'Presentation' purposes, providing a better overview of the data.

5.2 Reporting 'Events' and 'Fabulae'

Reporting 'Events' is the first step toward creating a 'Narrative'. Based on the selection of the 'Event' scope, the 'Event' main page offers the possibility to report new 'Events' using the authoring form presented in Figure 10 (left). In this form, the main information of the 'Event' is requested to be filled such as name,

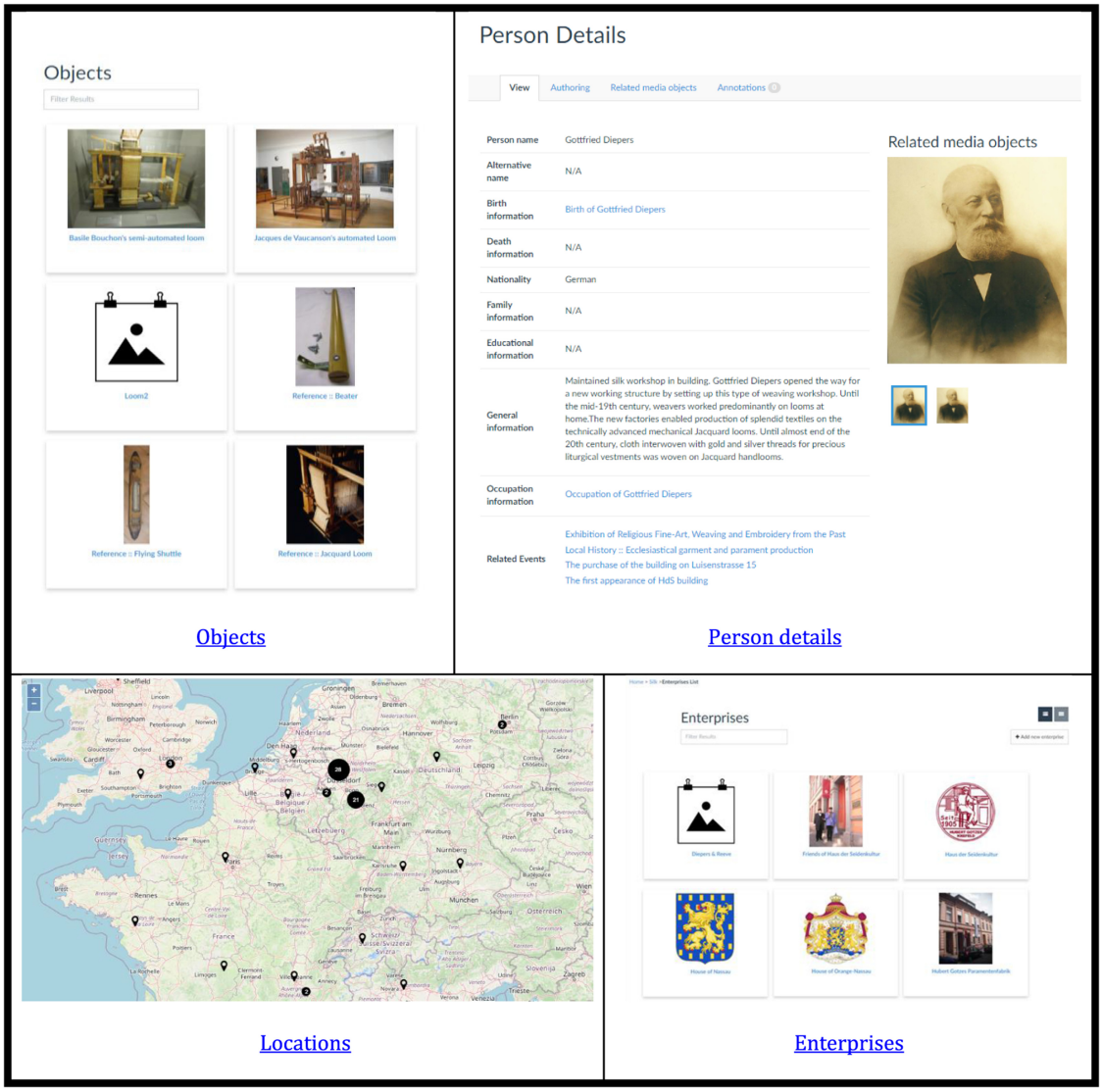

Fig. 8. Documentation examples.

alternative name, description, related 'Media Objects', and so on. Crucial to the representation of 'Events' is the definition of 'Persons' that participated in the 'Event' and the possible relations with other 'Events'. The details of a reported 'Event' are presented in Figure 10 (right).

It is expected that most of the 'Events' presented by a 'Narrative' and contained in a 'Fabula' will be reported in this step of the process and before the creation of the 'Fabula'. Nevertheless, this process can be iterative, and new 'Events' can be added at any stage of 'Narrative' development. This enables data curators to iteratively re-evaluate the knowledge required for the formulation of their 'Fabula'. With a set of 'Events' reported, the definition of a 'Fabula' follows. The 'Fabula' authoring page is structured as follows. Initially, a title and a description are requested, and then the association of 'Events' with the 'Fabula' is performed through the selection from drop-down fields (see Figure 11, left). After the association of 'Events' with a 'Fabula', the details

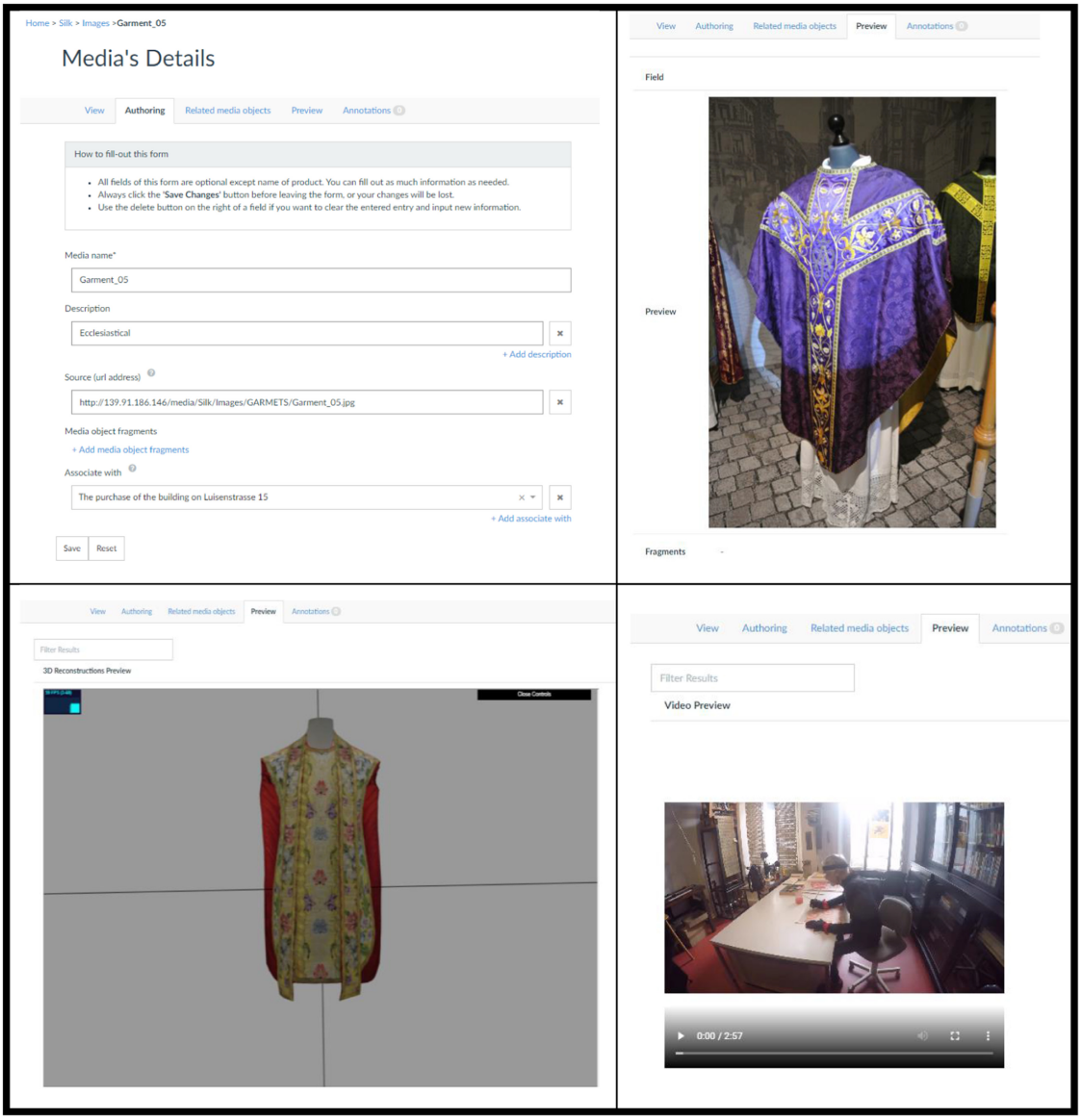

Fig. 9. Media objects authoring.

of the 'Fabula' can be previewed together with the locations associated with the 'Events' of the 'Fabula' (see Figure 11, right). The opposite may also be the case: with only partial knowledge of the 'Events', one sets out to create a 'Fabula' with a limited "starting" set of 'Events'. Then further research may be done offline by the expert/researcher to identify further 'Events' that complement the formulation of the 'Fabula'.

5.3 Authoring A 'Narrative' and 'Narrations'

After creating the 'Fabula', the data curator can author a 'Narrative' and link a set of 'Narrations' that present the 'Narrative' of the corresponding 'Fabula'. On the 'Narrative' authoring form (see Figure 12, left), the data

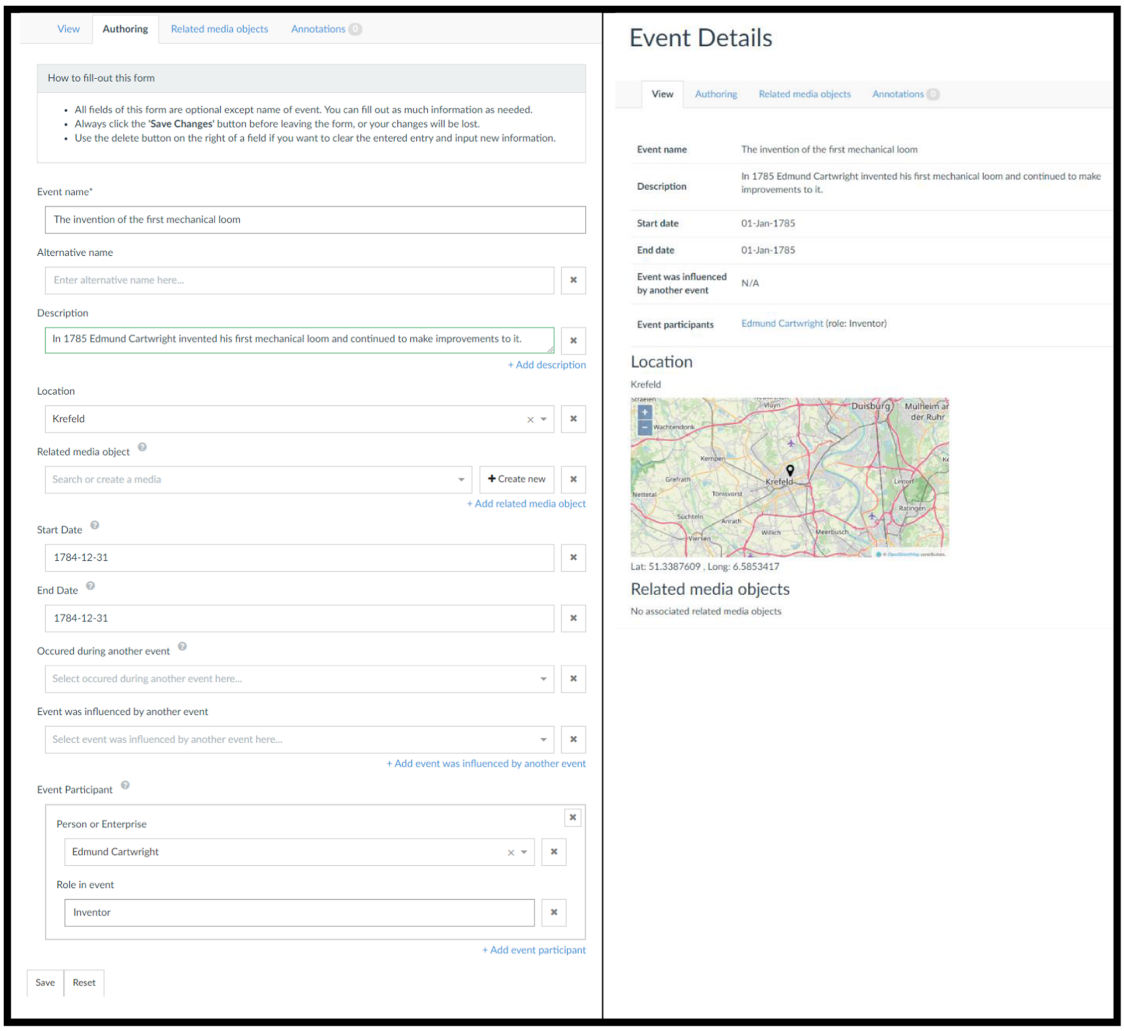

Fig. 10. Event authoring: "The invention of the first mechanical loom."

curator can provide additional information, including a description, linked 'Media Objects', and the 'Fabula' of the 'Narrative'. We have selected the "History of Krefeld Silk Industry" 'Fabula' from the drop-down menu in this example to create the "The Krefeld Textile Industry" 'Narrative'.

A 'Narrative' may have multiple 'Narrations' (e.g., for children, for adults, for families, etc.). New 'Narrations' can be created using the add 'Narration' functionality (to create a new 'Narration' from scratch) or by selecting an existing 'Narration' from the drop-down list (link to existing 'Narration'). In the same way, a 'Narration' may have multiple 'Presentations' (e.g., for the Web, for a mobile device, AR, etc.).

The authoring of a 'Narrative' is presented in Figure 12 while the authoring of a 'Narration' is presented in Figure 13. As seen in these two figures, both Narratives and Narrations are intended to give structure to the way information is presented. The authoring of the information presented to alternative devices and the linking with knowledge happens through the authoring of 'Presentation's.

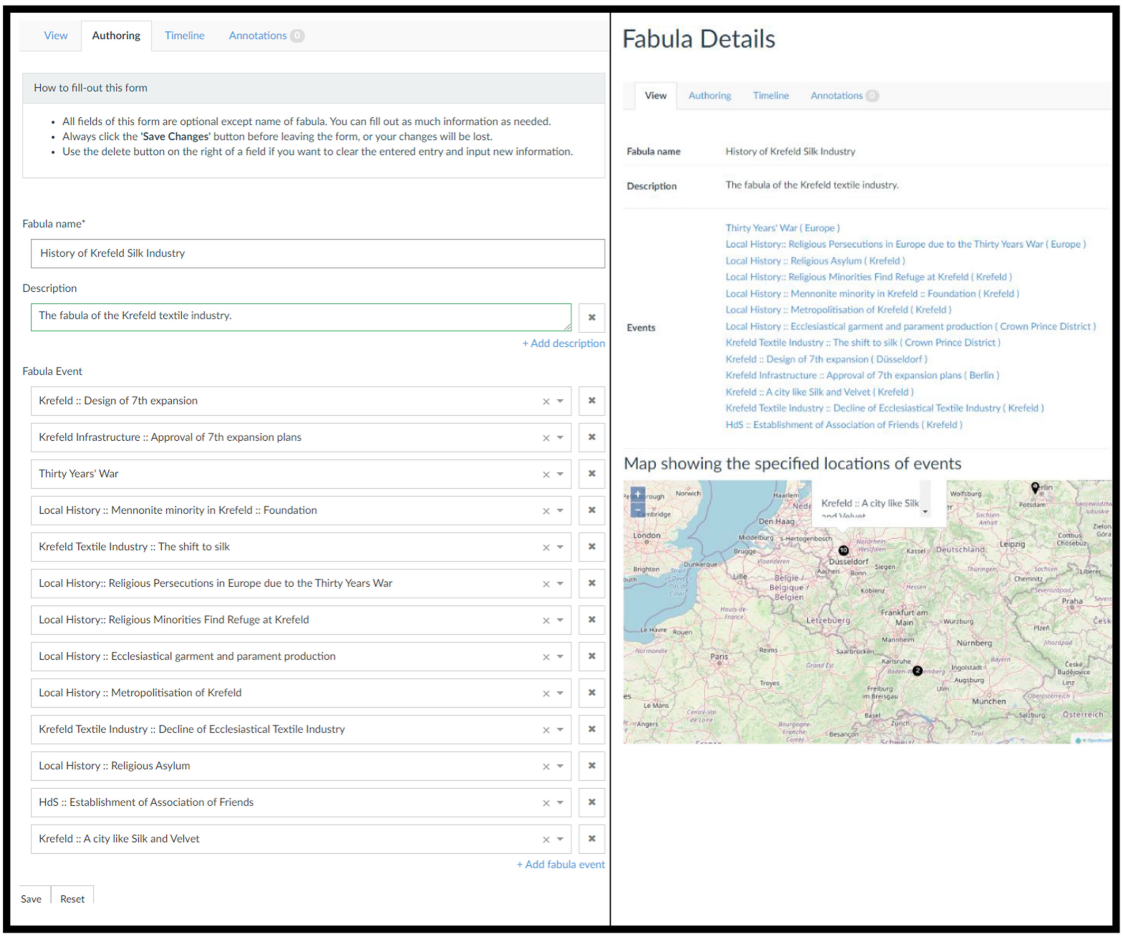

Fig. 11. Fabula authoring: "History of Krefeld Silk Industry."

5.4 Authoring a 'Presentation'

By now, the "Krefeld textile history Narration" has been authored, and the final step regards the creation of a 'Presentation'. This process starts by authoring the 'Presentation' details, within the Authoring tab (see Figure 14). Selecting to add a 'Presentation Segment' creates this new segment and links it directly to the 'Presentation' currently being authored. Figure 14 shows an example of 'Presentation Segments' created for the "Krefeld textile history" 'Presentation'.

5.5 Displaying a 'Presentation'

MOP automatically creates a Web preview for each 'Presentation'. In our example, one 'Narration', titled "The Krefeld textile industry," has been created to describe the contents of the "History of Krefeld Silk Industry" 'Fabula'. To create the Web preview, SPARQL queries are executed within the HTML page to fetch and display related data in an organized way. The result of the page is displayed in Figure 15. On the left, the whole Webpage is displayed. On the right, two fragments of the page are displayed.

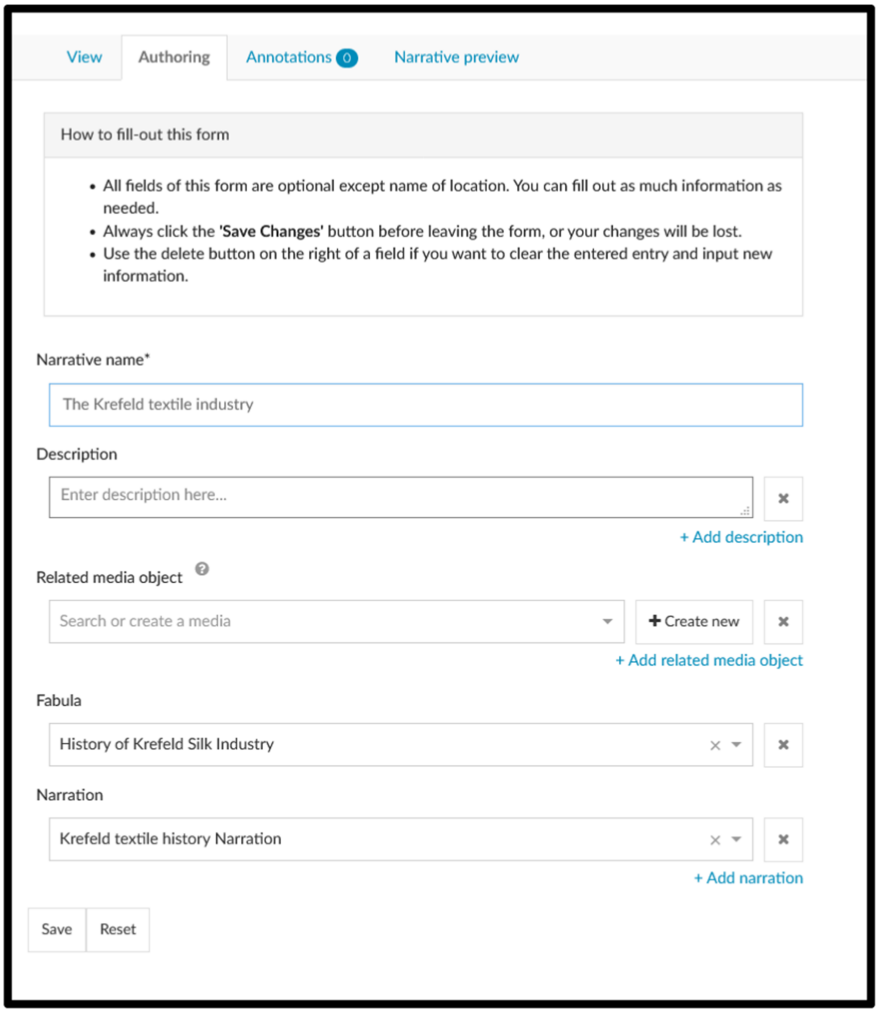

Fig. 12. Narrative authoring: "The Krefeld Textile Industry."

6 DISCUSSION

This work presented an authoring platform (MOP) for the semantic representation of cultural and socio-historic context encompassing a given, focal, topic of interest, such as a Heritage object, collection, site, or practice [67]. To this end, a description of the MOP implementation and authoring tools were provided, followed by a step-by-step demonstration regarding how the "Textile weaving at Krefeld" 'Narrative' was created. It is envisioned that these tools will be utilized by data curators and end-users to create 'Narratives', to present them to various audiences in various ways, and to inspire people from all over the world to become aware of their culture and CH.

6.1 Replicability of the Method, Reuse, and Exploitation of Results

As presented in Section 3, the MOP and the outcomes on the representation and presentation of HCs as presented in the use case section of this article are the results of the implementation of a systematic process for craft

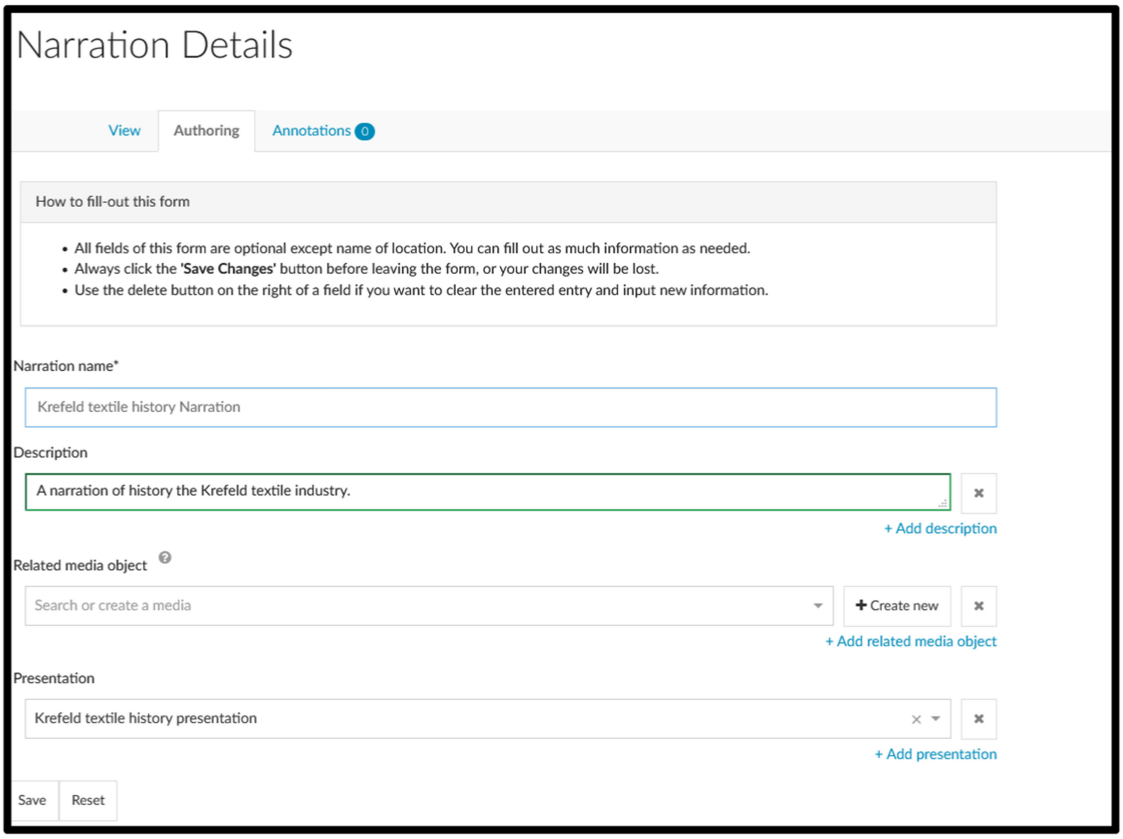

Fig. 13. Narration authoring: "The Krefeld Textile Industry" 'Narration'.

representation and presentation by Mingei. This process can be summarised in a series of steps. Of course, executing these steps linearly would mean that the entirety of digital assets would be acquired *a priori*. However, knowledge acquired in the second step may refer to non-digitised items, which are only then identified, and may be needed to be digitised as new digital assets in the context of the first step. Moreover, additional, more sophisticated digitisations of an asset may be acquired later if judged so by a CH professional. Thus, although the flow of information is presented linearly in these steps, it is executed iteratively by revisiting earlier steps, as new insights are obtained, through knowledge collection, data entry, and broadening of involved stakeholders.

In Mingei, the great challenge was that researchers and computer scientists had to work in parallel, since researchers were creating knowledge on Heritage Craft instances while computer scientists were implementing the semantic model, online platform, and tools for the representation and presentation of knowledge. This resulted in several iterations on knowledge representation, digitisation, and design development as both knowledge acquisition and technology implementation were constantly evolving and improving one another.

The outcome of this process is directly exploitable and replicable in the following ways. The technical results of the platform can be used to represent any craft instance and be extended with new features and functionality. This is already done through the exploitation of the platform by new research projects (e.g., DigiTraining project, www.digitraining-project.eu). The theoretical method and additional tools are encoded together with the platform in a scientific protocol for craft representation and presentation that will be formally released by the project for the scientific community and CHIs. Furthermore, the main concepts as defined by the Mingei

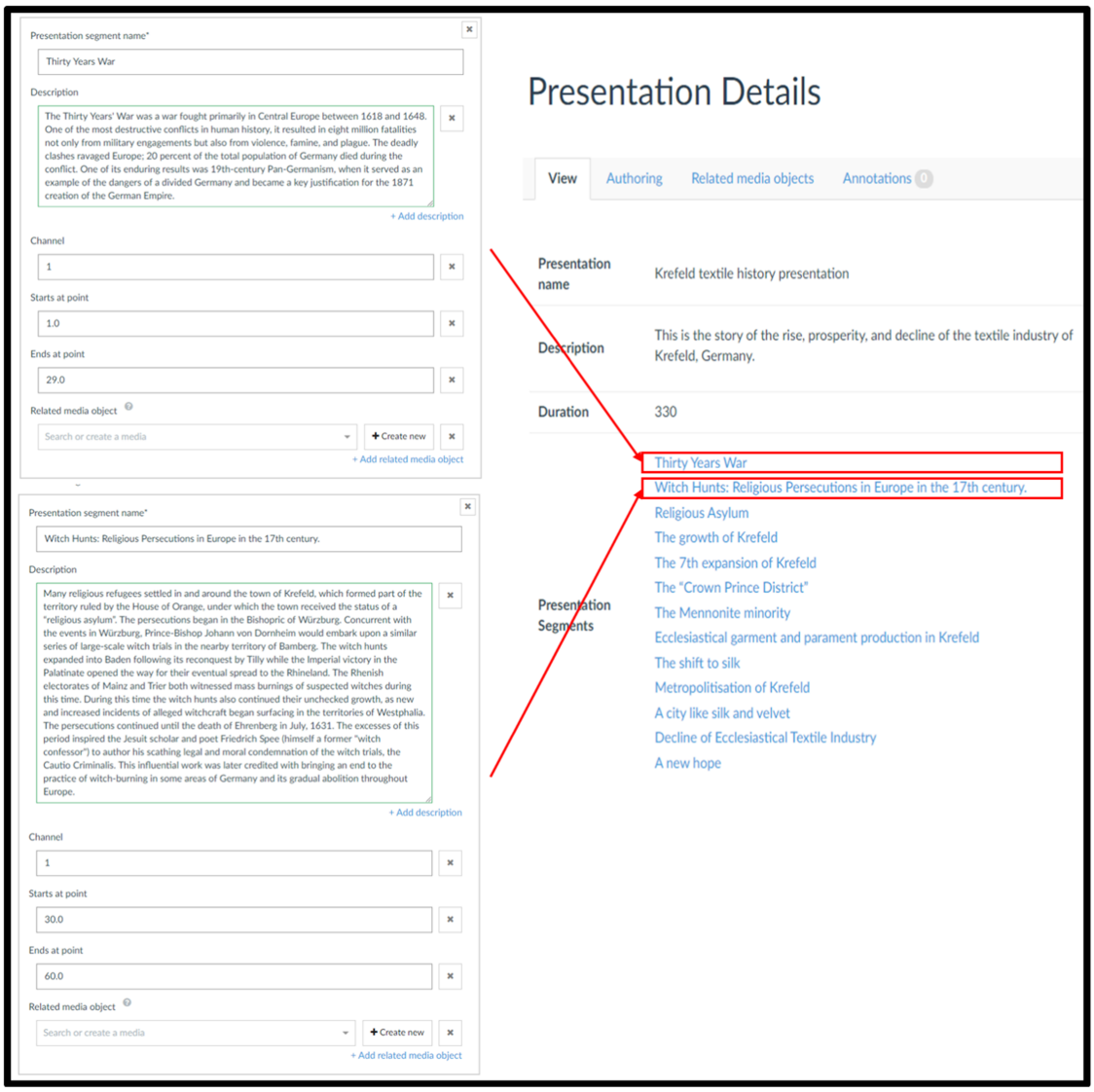

Fig. 14. Presentation authoring: "Krefeld Textile History" (left) authoring and (right) details tab.

Craft Ontology are published and accessible for reuse by the scientific community [34]. Finally, the knowledge can be accessed for further research directly through the MOP via the provided rest API.

6.2 Future Work

Future work on MOP will revolve around an expert-based evaluation of the user interface to address issues regarding the simplification of key procedures, such as the 'Narrative' authoring pipeline. This process is required, because the complexity of the ontology structure has been propagated in some cases to the user interface of the system. It is expected that this will result in redesign of some MOP-based workflows.

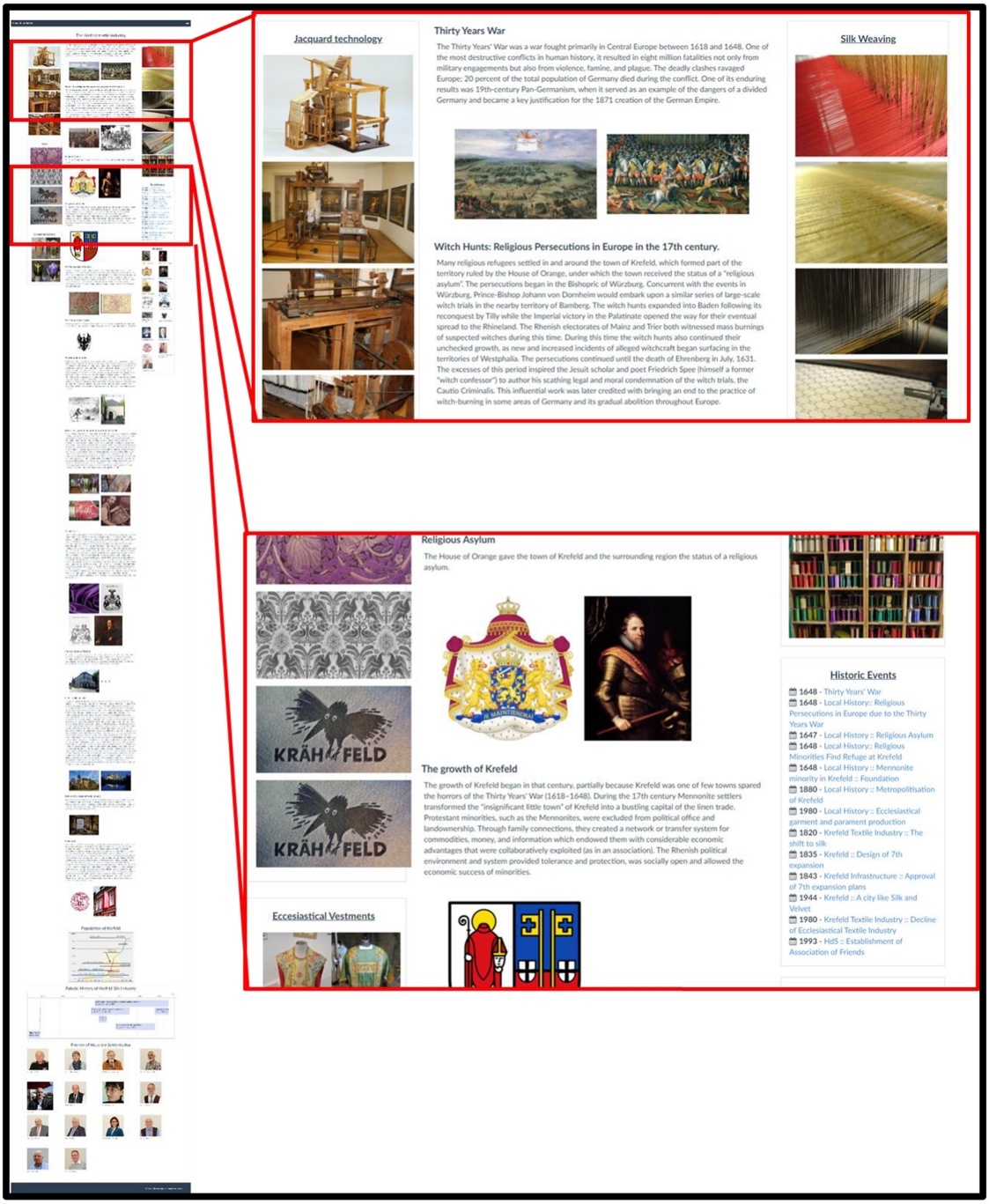

Fig. 15. A webpage previewing a 'Presentation' (Web-based 'Narrative' demonstration available at https://youtu.be/zENuV_1KCxk).

Then, a user-based evaluation of the provided functionality will be conducted to assess its usability and usefulness but also its potential to be used by different audiences for different purposes and CH context. It is foreseen that further design iterations will be required to address more targeted requirements such as the ones of museum educators and teachers. The implementation of extra targeted features is expected to enhance the applicability of MOP in even more application scenarios.

Regarding further uses of the presented platform, 'Narrative' tools will be extended and exhaustively tested in the context of the formulation of the Mingei pilots. This process will involve the implementation of context 'Presentations' for various devices, including desktop and mobiles exploring also outputs that are intended to employ alternative interaction modalities. Finally, the 'Narrative' functionalities will be further enhanced to support personalized 'Presentations' of 'Narration' based on user profile information, preferences, and presentation platform. This will be achieved by keeping semantic information for the different 'Presentations' of the 'Narratives' and enable/disable 'Presentation Segments' accordingly.

6.3 Further Validation

To achieve the widest-possible dissemination to the CH sector and the further validation of the proposed methods and tools, within 2021, MOP will be used by approximately 60 small and medium-size CHIs for the hands-on training of curators on the MOP concept and workflow. This will be done in the context of DigiTraining project [117] and will be an opportunity for the simultaneous evaluation of the MOP by diverse CH organisations. It is expected that this process will produce further finding and feedback regarding the further improvement of MOP.

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