Mingei
Handbook

FORTH INSTITUTE OF COMPUTER SCIENCE

MINES ParisTech | PSL

ISTI
ISTITUTO DI SCIENZA E TECNOLOGIE DELL'INFORMAZIONE "A. FAEDO"

MIRALab SARL

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PIRAEUS BANK GROUP CULTURAL FOUNDATION

imaginary

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HAUS DER SEIDENKULTUR KREFELD

The Mingei Handbook

Craft representation and preservation

Version 1.3

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List of abbreviations

CH	Cultural Heritage
ICH	Intangible Cultural Heritage
MOP	Mingei Online Platform
AR	Augmented Reality
(G)UI	(Graphical) User Interface
EDM	Europeana Data Model
IPR	Intellectual Property Rights
TCs	Traditional Crafts
VR	Virtual Reality
XR	Extended Reality
HCD	Human-Centred Design ISO:9241-210:2010
Organisations **CIDOC**, ICOM's International Committee for Documentation; **ICOM,** International Council of Museums; **UNESCO**, United Nations Educational, Scientific and Cultural Organization; **UNWTO**, United Nations World Tourism Organisation.	

Foreword

Who is this handbook for?

This handbook is addressed to persons, social groups, or organisations, interested in the documentation, preservation, and safeguarding of crafts. These are mainly:

- Professionals and scholars working in the documentation of Cultural Heritage and History of Art.
- Practitioners for the documentation and promotion of their craft.
- Tutors interested in creating educational materials for their classes and workshops
- Regional authorities working on revenue stimulation for the safeguarding of crafts, through thematic tourism services, interested in providing interactive and educational experiences.

The contents of this handbook stem from the Mingei Innovation Action, "Representation and preservation of Heritage Crafts", which produced the Mingei Protocol for Craft Representation and Preservation, which is accompanied by a set of digital tools for its implementation.

In this handbook, we use this protocol to organise the guidelines for the craft representation and preservation tasks. We, however, do not bind the content of this handbook to the Mingei implementation of such tools. Rather, we show how such implementations can be achieved.

Central to the proposed implementation of a craft representation system is a platform that enables the authoring of such representation and the creation of a knowledge base that stores the authored representations. The Mingei Online Platform (MOP) is such a system, which we recommend for this purpose. Implementation examples are provided but, still, this handbook is not a manual for this system. The MOP manual can be found online, within the platform. You may wish to build you own system using these guidelines or use the MOP.

Note: This handbook is a living document and is periodically updated. You can find the latest version always on the following link: https://doi.org/10.5281/zenodo.6580124

Preface

Mingei strengthened the representation, digital conservation, and preservation of tangible and intangible heritage due to Traditional Crafts. A stepwise digitisation protocol for Heritage Crafts (HCs) and the technical tools to implement it, was created and applied in three pilot use cases.

Cultural preservation is vital in maintaining cultural identities, pluralism and socio-historical continuity. In the words of UNESCO (2017) on the role of culture for resilience, peace and security "Collectively preserving our Heritage, by protecting culture and promoting cultural pluralism, leads to more resilient and peaceful societies". Heritage preservation encourages tourism and crafts are a way that all visitors can be involved in a cultural experience, while cultural tourism is an important source of income in a community. Many tourists visit cultural sites to participate in culturally-enriching activities and tend to spend more time at these sites. Safeguarding, making accessible and enhancing cultural resources with digital and physical experiences in the context of cultural tourism incentivises craft practice, continuation, and preservation.

The overall objective of Mingei is the ability to represent HCs, through the curation of digital assets for their preservation. This representation captures the wide spectrum of knowledge that HC cover, from objects and their making, the hand gestures and tool uses that define craft motor skills, to the societal value, economic impact, and historical significance of HCs.

1. Introduction

We start with an understanding of what is craft, as used colloquially and in the literature. We then outline the knowledge we wish to capture, classified in craft "dimensions".

Then we present the foundations of this work, explaining the background and roots of the guidelines we have developed for this handbook. We then make an overview of the protocol, which is stepwise and has six steps. These steps are then presented in six corresponding parts of this handbook, each of which is discussed in sections. At the end of each section, a list of literature articles is recommended for further reading.

The handbook ends with an outlook for the future and open invitations for collaboration.

1.1 What is craft?

The definition of craft is a matter of debate, varying between cultures and historical periods. A selection of characteristic definitions is provided below.

- Craft is characterised by a **certain type of making**, in which objects are **created by hand** through the **skilled use of tools** to make objects of **functional use** and not solely of ornamental value [1].
- Craft is medium-specific and characterised by the type of product, involving the creation of essentially functional objects. Moreover, the craft is "identified with a **material** and the **technologies** to **manipulate** it" [2].
- Craft is an occupation or trade requiring manual dexterity or artistic skill (Meriam-Webster dictionary on the term craft).
- Craftsmanship has been characterised as the "workmanship of risk", to convey that "the quality of the result is not predetermined, but depends on the judgement, dexterity and care which the maker exercised as he works" [3].

Craft is performed by human persons. As such, they include historic, geographical, artistic, traditional, economic, and religious dimensions, relevant to the **context**. The anthropologic aspect is found in comprehensive definitions of craft, which denote a **social context** and link **craft evolution** with technological progress:

A craft is a **pastime** or a **profession** that requires **skills**. Mastery of a craft includes learning skills. Historically, specialized crafts with **high-value products** tended to concentrate in **urban centres** and formed guilds. The required skills often demanded a **higher level of education**, and craftsmen were usually in a more **privileged** position than the peasantry in the **societal hierarchy**. Crafts have undergone deep structural changes since the **Industrial Revolution**. The mass production of goods by large-scale industry has limited crafts to market segments in which mass-produced goods would not or cannot satisfy the preferences of potential buyers. (Adapted from Wikipedia on the term craft).

and underscore the relationship between craft and **artistic creation**:

"In the mid-1800s William Morris began to question the differences between art and craft by bringing an artistic aesthetic to a craft object, like wallpaper design. During the twentieth century, the boundaries between art and craft became blurred, particularly at the Bauhaus, as artists started to experiment with craft practices in their art. The artist Sonia Delaunay created geometric abstracts using textiles. Today contemporary artists use craft techniques." (from the "Art Terms" dictionary of the Tate Gallery on the term craft).

As such, and because of the relationship to tradition, crafts have been characterised as a form of **Intangible** Cultural Heritage, but which have **tangible** dimensions, such as materials, tools, and man-made objects.

1.3 Craft dimensions

In the literature, CH is often distinguished between tangible and intangible. Though crafts are considered intangible heritage, the way that this heritage is manifested is through material transformations and into articles of craft. As noted in the UNESCO page on Traditional Craftsmanship *"Traditional craftsmanship is perhaps the most tangible manifestation of intangible cultural heritage"*.

Artefacts, tools, and sites, belong to the tangible domain. As such they are physically transmitted in time through preservation, conservation, and restoration processes. They are digitally documented using words, photographs, and 3D digitisation. Digitisation of tangible heritage regards artefacts and sites and is of static nature.

The intangible domain includes history, collective memories, values, aesthetics and crafting instructions and processes. Intangible heritage is regarded as an intellectual process that is performed by living humans. It is often referred to as "Living Heritage" and is preserved through documentation, safeguarding, transmission, continuation, and development.

Tangible and intangible dimensions meet when crafting and item. During creation, materials are transformed into craft articles. This transformation is achieved by the actions of a person. To implement this transformation the human uses tools and performs actions. These actions are continuously gauged by the senses of the practitioner, who takes decisions during the crafting process. The way of creating the artefact or the motif of its decoration may refer to an intangible domain, as it may, for example, depict a story of oral tradition or a regional symbol.

1.2 What is the Mingei protocol and where does it come from?

The Mingei protocol is a **method,** that implements an approach to the Representation and Preservation of traditional crafts. The Mingei protocol is accompanied by digital tools and guidelines.

Craft Representation or **Craft Digitisation** is a digital representation of a craft instance and includes digital representations of knowledge elements and digital assets. Knowledge elements regard objects, materials, tools, locations, persons, actions, processes, and contextual knowledge in the form of events.

The Mingei protocol stands as a product of over 30 years of research in the digital preservation of CH.

The first generation of digitisation projects focused on the digitisation of tangible heritage, first in 2D and more recently in 3D. During the FP6 Programme of the EC, the MINERVA digitisation programme and several other projects continued its legacy. In these approaches, digitisation meant the faithful representation of the material properties. Digitisation regards the "factual" occurrence of an object, as a material event, with measurable dimensions and material properties. Today there are still open challenges, such as multispectral and multimodal digitisation, as well as the digitisation of non-Lambertian materials, including transparent and translucent ones. The boost of technological capabilities obtained from this has facilitated the work of curators and Heritage Professionals, in documenting assets and made possible the development of online repositories of shared and semantically interlinked content. In the particular case of information carriers, such as historic documents, digitisation is regarded material part of the item. The digitisation of the "intangible" component reached up to OCR transcription, without accessing the semantics of the digital text.

The second generation of digitisation projects touched on the topic of intangible heritage digitisation. These projects focused mainly on the digitisation of CH due to the performing arts. As in the first generation, the focus was on the faithful recording of human activity, in terms of motion and audio. As such, the digitisation of the performing arts refers to audio, video, or 3D motion digitisation.

The Mingei protocol follows all of these principles as its legacy. Cultural Heritage is found in both tangible and intangible domains. The protocol treats crafts adopting the digitisation principles by which CH has been digitised in the past and proposes new ones for intangible aspects not digitised in the past. Methodologically, crafts are treated as performing arts but with a tangible outcome. In particular:

- Digitisation of craft products is treated by tangible heritage digitisation principles.
- Digitisation of activity is treated by intangible heritage (or performing art) digitisation principles.
- Digitisation of processes is treated by knowledge representation principles.
- Socio-historical context is represented in the form of a narrative and treated by narratological principles.

1.4 Overview

The Mingei protocol is described as a series of steps, which are illustrated in Figure 2. In Step 1, documentation is acquired in the form of digital assets relevant to the representation of a craft. Based on these assets, knowledge about a craft is formed in Step 2. In Step 3, this knowledge is semantically represented craft representation and digitally preserved. This representation provides the foundation for the curation of craft processes and craft contextualisation narratives and which takes place in Step 4. This content is retrieved and presented using informational tools, multimodal presentations, and experiences in Step 5. These presentations are used to support craft preservation, tourism, and education in Step 6.

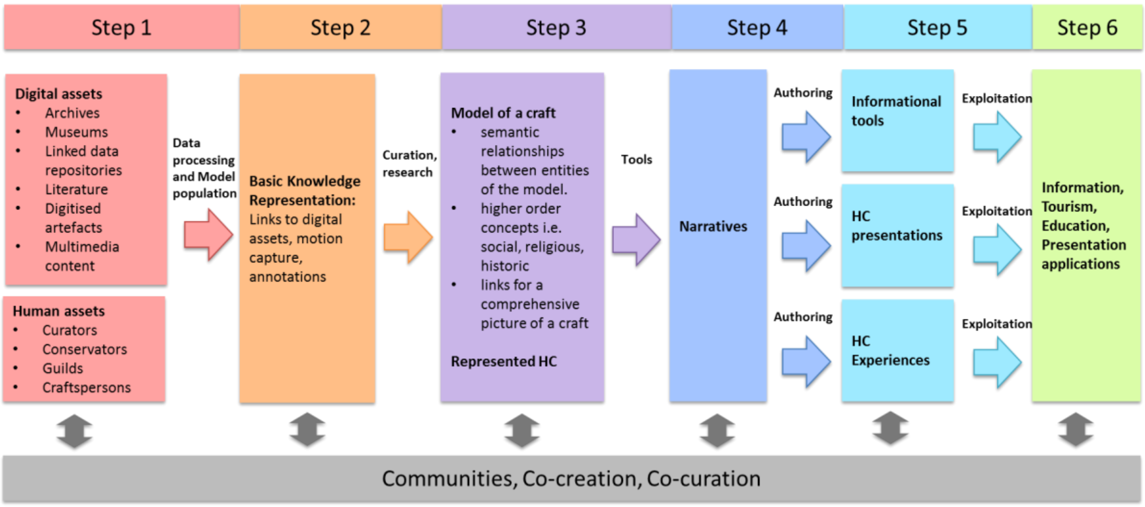

Figure 2. Illustration of the steps of the Mingei protocol.

The order of the protocol steps shows the flow of information and its transformation into knowledge and experiences. This does not mean that a step should be fully completed to proceed to the next one. For example, it is not necessary to acquire the entirety of the digital assets needed in Step 1 to proceed to Step 2. Ongoing curation of items and research may point to new assets to be acquired. Thus, steps can be revisited to add or improve the quality of the represented information.

1.5 References and further reading

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Step 1. Craft understanding and digitisation

In this step, we will identify the information and knowledge contents of the craft representation and acquire the digital assets on which this representation will be based.

The step has two tasks. First, in Craft Understanding, we will work with human and bibliographic sources of craft knowledge to target the knowledge that we wish to represent regarding a craft instance. Second, in Craft Recording, we will acquire digital assets that record and document the targeted knowledge.

2. Craft understanding

2.1 Working with practitioners and communities

The 2003 ICH Convention places communities at the centre of all its safeguarding activities and requires the prior and informed consent of the community or group concerned. Community involvement is required in the preparation and implementation of safeguarding programmes and must be willing to cooperate in the dissemination of best practices.

Collaborative creation, or co-creation, is the catalyst for finding out what is significant for craft representation among CH professionals, craft practitioners, and other stakeholders. A good-practice to achieve accurate representations is to iteratively review the modelling with practitioners, producing the final representation after several iterations.

To fruitfully collaborate with a CHI, association, community or individual relevant to the craft of study, the collaboration framework needs to be determined and a common understanding between involved partners should be achieved. In this, you should be able to present the purpose of your digitisation project, explain its value for posterity, and make clear how the way you are going to use knowledge and recordings.

A preliminary step in this task is to establish institutional communication and understand the collaboration goals of partners. This involves the acquisition and sharing of contact information, as well as, further logistic information, such as what are the optimal communication times and the communication tools. Notably, this step involves the identification of the legal signatories of the partners involved.

2.1.1 Legal

Your collaboration with a CHI, association, community or individual is to be specified and made clear to all parties. An agreement on the use of Intellectual Property Rights regarding the produced digitisations, information, presentations, and knowledge is to be specified and agreed upon by the institutions. For this purpose, a Memorandum of Understanding is to be prepared by a collaboration of legal signatories of institutions. The Agreement should define the purpose and mission of the study and answer matters that relate to IPR management.

2.1.2 Ethics, Health, and Safety

As the representation of the craft involves human participants it is mandatory to satisfy several requirements. Ethics, Data Protection, and Health & Safety requirements, are an integral part of research from beginning to end, and ethical compliance is pivotal for the success of the digitisation project and the accessibility of its result. Compliance with these requirements is not only to respect the legal framework, but aims the provision high-quality research, ownership, and sustainability of results.

Approval of designated Ethics Committees is a prerequisite, for conducting research with human participants. The designated Ethics Committee for the digitisation project should be identified and contacted at this stage. No interaction with human participants is to take place unless pertinent Ethics Requirements are satisfied. Compliance with data protection laws as well as health and safety regulations is determined by identifying the environments and modalities of digitisation, in collaboration with the designed ethics committees and relevant health and safety boards. In Table 1, pertinent requirements and relevant materials are summarised for the EU.

Table 1. Requirements for conducting research with human participants and relevant materials.

Requirement	Material

Ethics	European Commission's ethics self-assessment guidance, Ethics Appraisal Procedure.
Data Protection	GDPR law and additional national laws.
Health and Safety	Usage guidelines and safety warnings of devices used in the digitisation project, EU and national laws for the transportation of goods, use of machinery, and manned or unmanned vehicles.

2.1.3 Individual requirements

Individual partner requirements are to be investigated as community members may belong to a sensitive population. It is important to consider that some practitioners may be of senior age. As such, individual requirements of sensitive population groups need to be considered and applied. These requirements regard both the ethics of engagement to members of this group, which may be suffering from age-related diseases and consideration of pertinent requirements in the design of project outcomes.

2.1.4 Institutional assets

Communication with a CHI, community, or association can involve a description of the physical assets and collections of these institutions. CHIs and craft communities often have curated material, already prepared in the form of literature, guides, brochures or even interactive multimedia presentations. Typically CHIs have a catalogue of their items and may digital collections, along with pertinent metadata. In initial communications, it is important to specify these assets, as potential sources for knowledge collection.

2.2 Knowledge targeting

We formalise the knowledge to be collected as follows:

- Crafting knowledge refers to knowledge that enables the reenactment of handcrafting actions and crafting processes. This knowledge is independent of the person(s) that provided it and describes manufacturing tasks that transform materials into craft products, possibly using tools or machines.
- Craft context refers to the technological craft and its evolution, as well as the social and economic history of the social groups that have or still practice this craft. As such it may refer to specific historic figures, communities, locations, and artefacts.

As a guide to formalising each type of knowledge, we define the required outcomes from each.

2.2.1 Crafting knowledge

- A vocabulary of the nouns and verbs required to verbally describe the manufacturing process. This includes physical items, such as artefacts, materials, and also actions performed during craft practice. Each vocabulary entry will be associated with at least a digital asset that illustrates and exemplifies it, as well as with a reference to its semantic definition in a thesaurus.
- A mapping of the fundamental craft tasks and processes, in a verbal description, a storyboard and, then, in an activity diagram. In all outcomes, the sites, tools, materials, and actions performed by the practitioner(s) are referenced.
- Recordings of the nouns and verbs, or otherwise, the objects and actions of the crafting process(es).

2.2.2 Contextual knowledge

- A timeline of craft history, representing its origins, its technical evolution, as well as its aesthetical evolution in terms of art and design history.
- Historic figures, events, and objects that are of historical significance to the expression of a craft in a local community.

- A collection of stories and reference artefacts that illustrate and contextualise the expression of a craft over time.

2.3 Knowledge collection

In craft understanding, we target and collect both types of knowledge and produce this collection in a human-comprehensible format. To collect this knowledge we have two sources of information. First, the existing literature and digital resources. Second, craft practitioners and their communities or businesses.

Given the breadth of existing knowledge online today, we recommend consulting available knowledge before collecting knowledge from humans. Having done any available “homework” first will pay off in the efficiency of your interaction with practitioners because they would have to explain less to you.

We thus recommend the following steps in the collection of knowledge:

1. Orientation, or desk research.
2. Co-creation workshops, where practitioners are facilitated in the identification of the overall crafting methods and contextual elements.
3. Ethnography to comprehensively document these methods and contextual elements, through functional demonstrations or testimonies. Digitally enhanced ethnography is the association of craft items and actions with digital recordings that exemplify them.

2.3.1 Orientation

Before embarking on digitisation and knowledge representation tasks, it is recommended that a basic orientation is achieved on the available literature relevant to the craft instance of study. This orientation regards the acquisition of digital assets and the collection of knowledge. It is a preparation also called “desk research” or “secondary research”. Orientation increases the efficiency of craft understanding and facilitates discussions with practitioners.

Literature regarding crafts is available in a plethora of online resources. Encyclopaedias provide generic context but also references to sources and literature. An encyclopaedic background establishes a preliminary orientation, including vocabulary entries. Further research provides documentation, bibliographic assets, and online resources.

Valuable starting points are Encyclopaedia Britannica, Google Books, the UNESCO Digital Library, and the Representative List of the Intangible Cultural Heritage of Humanity. Although Wikipedia and Wikimedia are not peer-reviewed sources of information, they can be quite useful and reliable in retrieving elementary information, as well as images in a Creative Commons License. Pertinent digital assets exist in repositories such as those of Europeana, the UNESCO World Heritage Centre, the UNESCO Intangible Cultural Heritage portal, and the Google Arts and Culture portal.

More specific sources stem from curated material. These can be museum guides, catalogues, magazines, essays, and student theses. Photographs and illustrations in literature or photographic collections (museums, newspapers, information services, travel books), as well as videos (documentaries and ethnographic films), are useful for a prior understanding of the creation process.

2.2.2 Co-creation

Co-creation plays a central role in that a common language and mental model is achieved between practitioners and scholars. Thereafter, the specific targets of crafting and contextual knowledge are identified with the help of practitioners, communities, and CH professionals.

The first task of co-creation workshops is to understand the craft. As such nouns and verbs are used to describe crafting concepts and tasks. This is achieved by creating a draft vocabulary with these terms. The vocabulary should refer at least to the materials, the work sites and shops, the tools and machines, as well as craft actions and roles, the latter referring to. Notice that for the majority of tools encountered in traditional crafts there are entries in thesauri. Thus, in many cases what you will be eliciting from practitioners, is the local or emic naming of a tool. In this context, you can create a few visual aids to assist the description process and have a common visual and verbal reference for the group.

The second is that a thick description of the manufacturing process(es) is created. This description should document the main steps of the crafting process, naming their input materials or intermediate products and the outcome of each. Since we will be recording there are additional instructions, pertinent to the space of recording the viewing angles that should be available and so on. Textually and visually encoding the recording plan is invaluable to the economy of the demonstration and aids in forming an inventory of tools and materials needed for each step.

A guide and material to facilitate co-creation sessions are provided on the Mingei website on Co-creation for concept development. Below, we show examples of the co-creation results relating to the storyboard of patterned, silk-made, ecclesiastical textiles, using the Jacquard technology. Figure 1, shows the results from a co-creation session using the aforementioned materials and methods. The session resulted in the definition of the manufacturing process of the textiles, in six main steps and a storyboard for each one. The verbal representation of the steps can be found in Annex B. Storyboards are a quite useful tool to visualise events and processes, in a way comprehensible to non-technical participants. They can be in paper and hardcopy format. Icons for creating storyboards like those in the example, can be found in the aforementioned resource. There are several digital tools and printable such as Storyboard That, Canva, Boords, Vyond, and Wonder Unit.

Figure 1. Illustrative storyboard for the six steps of a textile manufacturing process.

The third is a collection of contextualization stories and reference physical items or sites. These stories should contextualise the history of a craft instance and its bearing community, as well as the technological and design history of the craft. These stories may also refer to traditional legends represented in the design of craft artefacts or examples of their aesthetics. Another way to organise stories is through “biographical objects”. Furthermore, many crafts have social and traditional events associated with them and sometimes festivals and exhibitions have played a role in craft technical and artistic evolution. For each topic, a draft narration should be prepared in free text.

2.3.3 Formalising co-creation results

This task regards the work required to pass human comprehensible descriptions, and the co-creation outcomes to formal ones so that they can be unambiguously encoded into meaningful knowledge representations. The task can be implemented using a “storyboard” similar to the one used in movies and documentaries.

A storyboard is a graphic organizer that consists of ordered illustrations for pre-visualizing a motion picture, animation, motion graphic or interactive media sequence. The goal is twofold. First, illustrate the decomposition of actions into simpler ones, so that you prepare for the recording sessions. Second, it is to validate and improve this plan with practitioners, by collecting feedback on underrepresented properties and concepts. Traditional aids for formalising the authoring of storyboards can be found online as printable forms that indicate the essential information. Digital aids also exist that enable the composition of storyboards from images, videos, and born-digital illustrations, enhanced with text and audiovisual annotations. In Figure 2 we show the storyboard created for the last step of the outlined process.

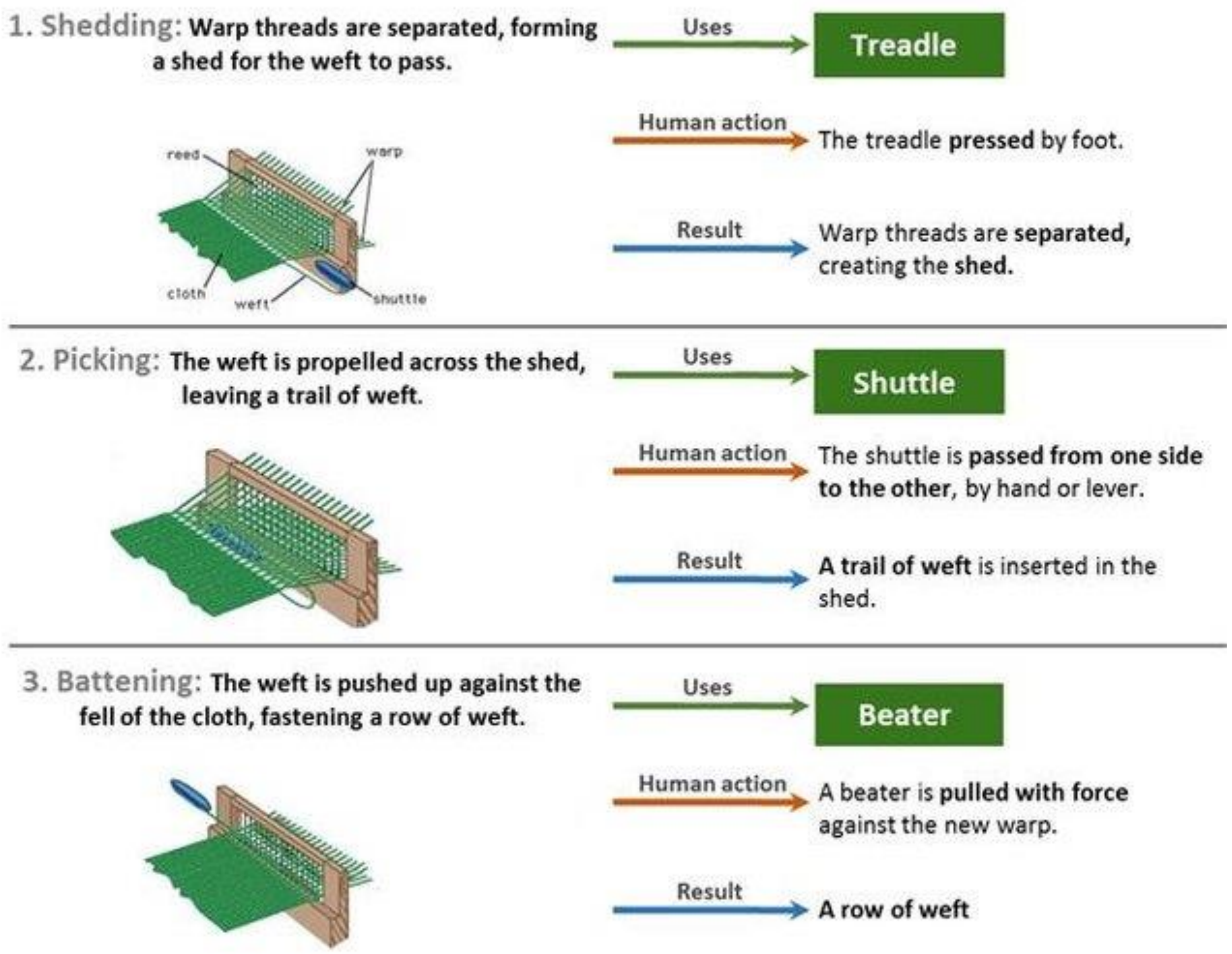

Figure 2. Storyboard for the weaving task.

2.2.4 Ethnography

The next task is in the field study of the crafting process. It comprises understanding and describing the manufacturing plan of the crafting process. In this task, the practitioner(s) demonstrate the tasks of the process as described in the storyboard. The targeted outcomes are an ethnographic study, that is a textual, schematic, and visual description of this plan.

The systematic study of human activity is a topic studied by anthropology. Traditionally, ethnography identifies and describes the activity of a person or a social unit. Ethnography studies cultural phenomena, from the viewpoint of the subject or subjects (emic), including the subject's interpretation of his/her behaviour. Ethnography relies heavily on participant observation seeking to document, in detail, patterns of interaction and the perspectives of participants. It has been employed in the workshop. If possible, the participation of the ethnographer even in marginal roles is recommended. Traditionally, ethnography has been practised as a "textual reconstruction of reality" often combined with hand-drawn sketches. With the advent of photography, audio recordings, and cinematography, these descriptions became richer, combining verbal with visual content. Today, a breadth of digital media enables us to acquire high-fidelity recordings of human activities, in a multitude of ways. During ethnography, we recommend collecting digital assets that exemplify the objects, actions, and designs. The technical way to achieve this is provided in the next section.

The ethnographic approach we take to understanding the crafting process is to consider it from a problem-solving viewpoint. From this perspective, the abstraction of a process is treated similarly to a recipe or an algorithm. What makes the crafting process differ from a recipe is that it may have decision points and, thus, alternate workflows. Decision points may be relevant to the properties of individual pieces of material, environmental conditions, as well as practitioner observations and judgements upon the course of the process. It may also contain parallel and combined activities, performed by one or more persons. Some steps take place only to handle exceptional events, such as a repair for a mistake or an accident.

The output of ethnography is the refinement of the storyboard description into an activity diagram, which enables the study and modelling of the crafting activity beyond the context of a visual demonstration.

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3. Craft recording

In this section, the ways to obtain the digital assets needed to represent a craft instance are presented and discussed.

3.1 What is a digital asset?

Physical assets are the objects (endurants) and events (perdurants) that are involved in a craft. **Endurant** assets are physical structures, such as materials, objects, and sites. **Perdurant** assets are expressed over time and refer to dynamic phenomena, such as hammering, carving, bending or painting a piece of material.

The digitisation of the physical world is the faithful recording of physical assets. **Digital assets** are computer files containing the digital recordings of physical assets. Digitisation refers to the recording of visual appearance and motion or other physical properties. The most relevant digital asset types are digital text, images, video, audio, 3D models, and 3D motion. In our knowledge base, we use all of these files under the abstraction of a media object for all digital assets. A media object contains a link to the digital asset, along with associated, technical meta-data to interpret the asset.

Digitisation targets are classified into two categories.

Endurants are objects and sites recorded through photographs and textured 3D meshes. The digital assets are images and textured 3D meshes. The choice of scanning modality for the 3D capture of endurants depends on subject size, material, and type of environment. In Figure 5, the media objects for a photograph and a 3D model obtained from photogrammetric reconstruction (right) are illustrated. The image shows a preview of the asset and the text shows the associated metadata. The red number indicates the "unique identifier" for this entity in our knowledge base.

Figure 5. Illustration of two digital assets digitizing an endurant entity.

Perdurants are practitioner postures and gestures. Motion data are acquired by motion sensors and video. They are time series of 3D locations, each one recording the 3D motion of a point on the surface of the practitioner's body. The measurements are topologically organised in a skeletal tree, a hierarchical data structure that represents avatar joints and limbs and is rooted at the avatar's torso. The branches of this tree are called body members. A posture is the configuration of the skeletal tree at a moment in time. A gesture is a chronologically ordered sequence of postures. The pose, i.e., location and orientation, of a held object is represented relative to a designated body member and is encoded as a rigid transformation, i.e., 3D rotation and translation. In Figure 6 the digital assets for two perdurants are illustrated. The left image shows a moment in a MoCap recording session and the middle image illustrates the obtained digital asset. The right image illustrates a digital asset obtained from markerless motion estimation in an archive documentary, its preview superimposing the estimated skeletal tree upon the original footage.

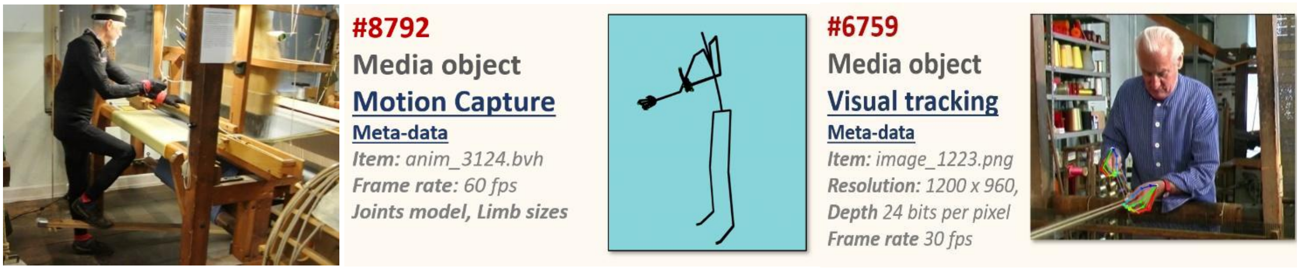

Figure 6. Illustration of digital assets that digitize perdurants entities.

3.2 Digitisation of endurant assets

Tangible heritage is the most digitised component of CH. Besides photographic documentation, the documentation of tangible heritage increasingly adopts 3D scanning and other digitisation technologies. Digital models or "twins" have a large range of uses, from the conservation and preservation of artefacts to the communication of their cultural value to the public.

3.2.1 Photographic documentation

In the fields of archaeology, art history and museology, many recordings and examination methods are based on imaging techniques. One of the oldest and most central non-destructive approaches is photography. In archaeology, photography is incorporated into archaeological documentation. Today, there are multiple types of photographic modalities used in a variety of domains from industrial inspection to forensics.

To simplify the recording task, it is important to classify the imaging target as to its shape and material. 2D assets are printed or written matter, manuscripts, photographs, films, and so on. A scanner or backlit photography is the recommended scanning modality, but imaging methods differ as per the material. 3D assets such as objects and sites are also documented by digital photography. In photographs, 3D surfaces are projectively flattened in 2D and thus additional issues arise when considering how best to create, display, and describe the digital surrogate. The Digitization Standards for the Canadian Museum of Civilization Corporation is an excellent reference for photographic documentation protocols, classified per the material artefact type.

3.2.2 3D Documentation

Surface scanning technologies have contributed to the digital documentation and 3D representation of CH monuments and artefacts. Besides digital preservation, the significance of accurate digitisation is of service to the physical **conservation** of artefacts and monuments. Several **3D scanning modalities** have been developed in the last 20 years, which can be distinguished as to whether they require contact or not, with the scanned surfaces and objects. Contact systems are not widespread in the CH domain, due to the possible fragility of artefacts. In contrast, non-contact scanning modalities are more widely employed, as they use light as the operating principle of the sensor. They can be further classified according to the sensor type, that is, into passive or active illumination systems. Currently, the most adopted and robust principles by end-user scanning modalities are time-of-flight, structured light vision, and photogrammetry.

Off-the-shelf products employ these principles in **variations**, such as terrestrial and aerial photogrammetry. In addition, **combinations** of such principles are found in devices, such as the combination of trinocular stereo with structured light and IMU information in various types of handheld scanners. Recently, such applications are available for mobile devices leading to sufficient for many purposes and cost-efficient 3D digitisation solutions. Conventional modalities fall in the aforementioned categorisation and are suitable for different types of environments, spatial scales, and indoor or outdoor conditions.

There are significant variations between the capabilities of different approaches. Triangulation techniques provide greater *accuracy* than time-of-flight but are reliable in short-range and difficult to apply in the field, due to the need for controlled illumination. When accuracy is a requirement, close *access* to the scanned object is required. If physical access is impractical, direct distance measurement techniques (time-of-flight) provide less accurate results, particularly when the sensor is airborne and not static. Thus, temporal relevance is the *sampling rate* of the sensor (i.e., a laser scan lasts much longer than the acquisition of a digital photograph). Also, of temporal relevance, is the *time duration* that is available for the digitisation, concerning the overall time required for a scan.

The 3D ICONS Guidelines is a comprehensive review of 3D scanning and processing guidelines. Important resources for 3D digitisation are available by Cultural Heritage Imaging, including tools, technology, and training, for several digitisation methods used in the conservation and preservation of tangible CH. The **guidelines** are not as apt as for photographic documentation, due to the increased complexity of 3D scanning targets and the variety of modalities. Modalities vary in operational capabilities and environmental conditions, as well as **cost**. In some cases, the commission of the digitisation or rental of equipment may be more efficient.

The applicability of digitisation modalities is presented in Figure 7, where a taxonomy of application domains of the discussed scanning modalities is illustrated. This taxonomy provides a recommendation of which modality to use depending on the size of the scanning target and its type, that is whether it is found indoors or outdoors.

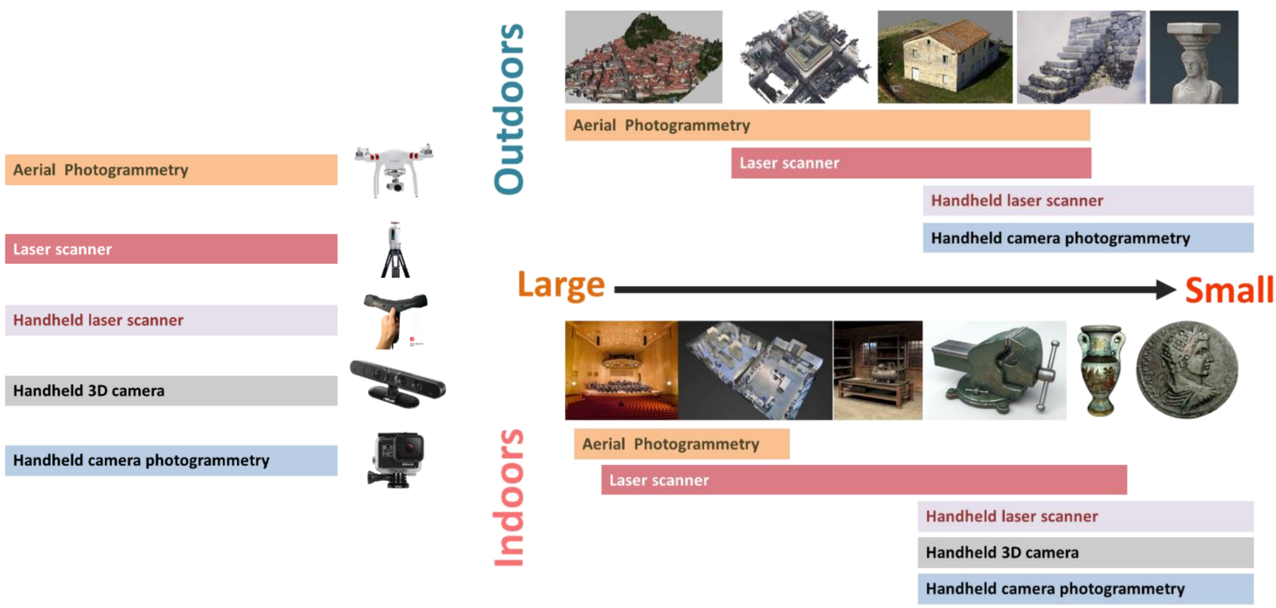

Figure 7. 3D scanning modalities and use cases in CH.

Large targets are sites and architectural structures. When scanned outdoors, aerial photogrammetry is the most convenient method and, usually, the only way to scan the top of these structures. The complementary terrestrial scan may come from either laser scanning or additional photogrammetric views. However, the indoor part of such structures almost invariably requires a laser scanner to cope with the limitation of photogrammetry in large indoor environments. For medium and small-size targets photogrammetry and handheld devices are more convenient, whether indoors or outdoors. The choice between scanning with conventional photogrammetry and a handheld device depends on the devices utilized and, in particular, the quality of their optics.

Below, the advantages and disadvantages of the aforementioned modalities are discussed.

Laser scanner

The **advantage** of laser scanning for scanning environments is that it is a very efficient, accurate, and robust modality. It provides a direct point measurement on the line of sight of every radius within its view sphere at a configurable resolution and an angular breadth of approximately 270 degrees of solid angle. Another significant advantage is that each scan takes place automatically and at a reasonable temporal duration. Laser scanning has been utilized for over 20 years and significant experience can be retrieved from the literature in the form of guidelines, while a range of software products exists that facilitate the registration of partial scans post-processing of scans. It is **limited** by light-absorbent (dark) surfaces, which do not reflect enough sensor radiance for the time-of-flight measurement to succeed. Another limitation is that there is no real-time feedback available; hence, a preparatory scan is typically required to find the locations where the scan should be placed.

The main **disadvantage** of laser scanning is the price of this modality: a reliable unit of medium accuracy (~2-3mm) with a scan range of about 70m is in the order of 30K Euros. In addition, a reliable unit weighs at least 7 to 8 kg. Moreover, a laser scanner at the ground has no line of sight to the top of a building and is out of its range. Airborne laser scanning (LIDAR) exists and awaits advances regarding the payload of the laser scanner and flight velocity. Another disadvantage is that occlusions give rise to the requirement of several scans to cover the surfaces of a scene; this is particularly pronounced in indoor environments that are usually cluttered with furniture. The acquired partial scans have to be combined, or registered, at a later stage. The registration procedure is not necessarily automatic, particularly for complex environments. To increase the automation of the procedure, the placement of markers in the scene is required. This is essential if high accuracy is required. In the outdoors, the operation of a laser scanner may be hindered by bright sunlight as it interferes with the radiation emitted from the scanner.

In **general,** laser scanning is a very useful tool, particularly in terms of accuracy and efficiency with little effort from the operator, on the field. It is particularly useful in cluttered indoor environments where photogrammetry becomes more tedious and illumination requirements are challenging.

<u>Photogrammetry</u>

Photogrammetric reconstructions employ multiple views to reconstruct the structure and appearance of 3D structures. Photogrammetry is scale-independent meaning that it can be applied on both small and large scales.

For the digitisation of outdoor environments, the proliferation of Unmanned Aerial Vehicles (drones) has broadened the horizons of aerial surveillance and facilitated **aerial** photogrammetric reconstruction, providing vantage viewpoints that greatly simplify reconstruction. Figure 8, demonstrates the photogrammetric reconstruction of a traditional village (large scale) and a statue of human size.

On the other hand, scene segments of interest may not be visible from aerial views, such as the scene locations below the eaves of buildings. Nevertheless, **terrestrial** views can be combined. This solution requires at least two scanning processes: one aerial and one or more terrestrial, depending on the complexity of the scene. Figure 9, shows two photogrammetric reconstructions of large and smaller scale, acquired by aerial and terrestrial imaging, respectively.

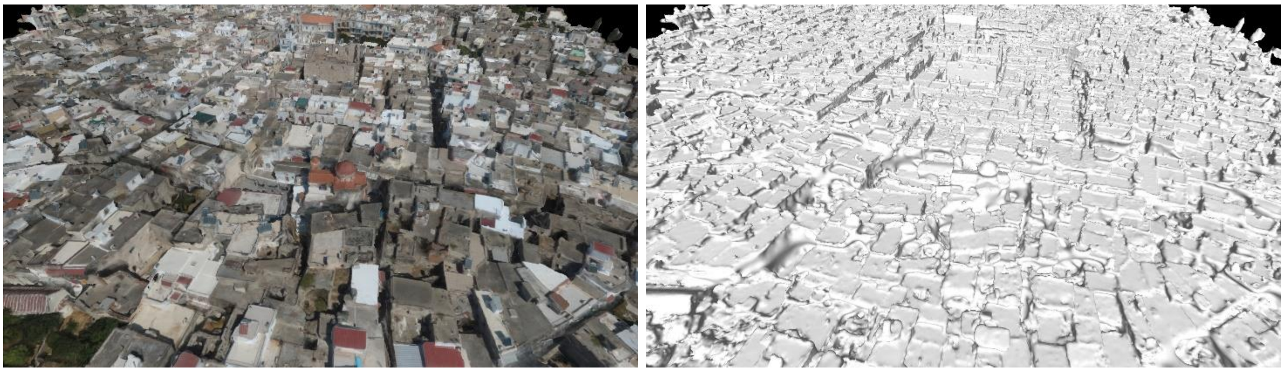

Figure 3. Large and smaller scale photogrammetric scans.

For indoor environments, photogrammetric reconstruction exhibits the **disadvantage** that it becomes less reliable for multiple reasons. The main ones are lack of sufficient illumination, lack of texture, particularly on blank walls and ceilings, and shiny surfaces (e.g., metallic) because they exhibit illumination specularities that hinder reconstruction. Photogrammetric reconstruction requires significant computational time to obtain results, because it is not based on direct measurements of spatial structure (i.e., such as the laser scanner), but is rather an algorithm that computationally infers structure from implicit measurements (images).

The main **advantages** of photogrammetry lie in its wide applicability and the relatively low cost of the equipment. Another advantage of photogrammetry is texture realism compared to laser scanning, which tends to provide low-resolution texture information. Photogrammetric reconstruction is less accurate than laser scanning, but it is particularly useful for photorealistic reconstructions and for practical usage in covering wide areas. Limitations of aerial photogrammetry due to occlusions can be compensated with the addition of terrestrial views.

Handheld scanners and mobile devices

During the last 10 years, the proliferation of imperceptible, active illumination sensors (RGB-D cameras) has played a significant role in the development of new approaches and attracted new interest to older works in the domain of 3D surface reconstruction. Today, several products provide a reliable solution for small ranges, where active illumination can reach and where inertial sensing is supportive of the quality of reconstruction. Most recently, mobile devices have made handheld scanners obsolete, due to their high-quality optics that provide high-quality textures and integration with LIDAR scanning and inertial sensing.

The **advantage** is that the scanning procedure is simpler and more accurate than photogrammetric image acquisition because active illumination allows for a higher degree of affinity in the trajectory of the handheld sensor. It thereby could comprise a handy and cost-efficient tool, for cases where a simple scan suffices the requirements of documentation.

In a **comparison with photogrammetry,** it falls short, particularly due to the limitations of sensor hardware. The most important limitation is the range within which it is reliable: 0.5m-1.5m. The digitisation modality is more resistant to lack of texture, due to the use of active illumination. The scanning modality is not sufficient for high-end 3D scanning and it may provide a photorealistic reconstruction of room or desk-sized artefacts.

The reconstruction of a mannequin and an industrial machine is shown in Figure 4.

Figure 4. 3D reconstruction of a traditionally attired mannequin (top) and industrial machine (bottom).

3.2.3 Acquiring photographs and scans

The number of photographs required to reconstruct a target depends on the size and complexity of the target, as well as the detail by which the target should be scanned. At least 50 images are required to capture most of the details of a medium-size target but the structural complexity of some targets could require hundreds of images to obtain an accurate 3D representation.

Acquiring as many angles as possible of the target is recommended. The first set of images should show the whole object, including ample portions of background, so that the camera pose estimation required for photogrammetry is robustly estimated. Additional images can focus on detail. Each photo should overlap the last by about 60% or more. The overlap should be included between images of the first and second sets.

In outdoors terrestrial imaging there are two main methods to acquire photographs. When working with planar or regular surfaces in application fields taking pictures by translating the camera is usually sufficient. For targets that require moving around the subject/scene is recommended. These two photogrammetric setups are illustrated in Figure 5.

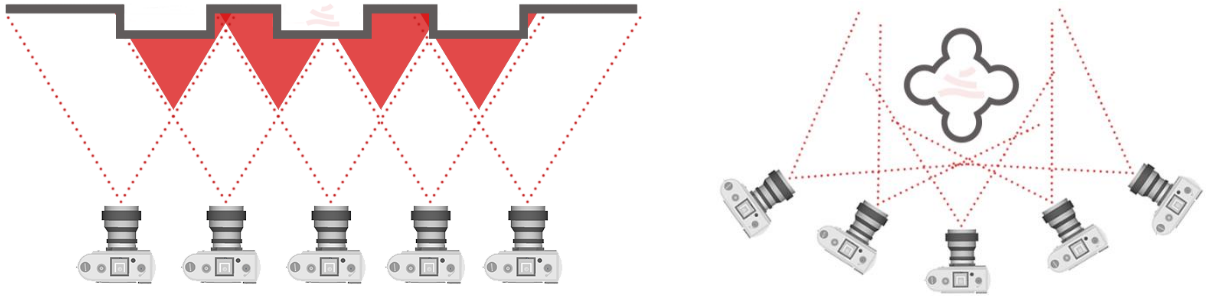

Figure 5. Terrestrial photogrammetric setups.

In indoor terrestrial imaging, it is important to take more images than outdoors to compensate for the lack of features and distance variability required for a robust camera pose estimation. The example recommends the best practice for capturing the interior of a room or a statue-like indoor structure. The example is illustrated in Figure 6

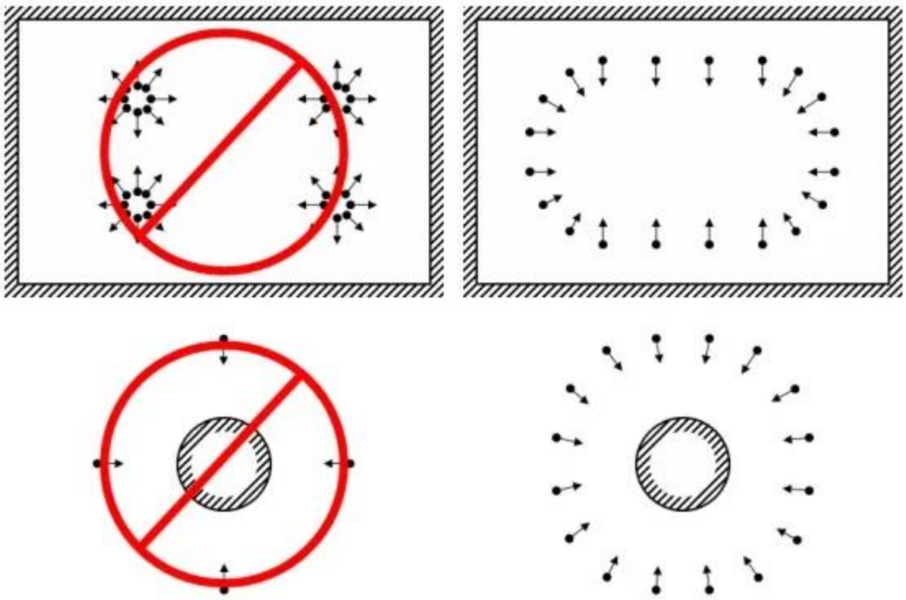

Figure 6. Indoor photogrammetric imaging setups.

When aerial imaging is used the rules that apply are similar.

If the target is the Earth's surface and the targeted model is a map-like representation, using the translative camera motion as in the previous examples is recommended. The flight path should be grid-wise, as shown below. A second grid, perpendicular to the first is recommended for increased reconstruction robustness. Overlap is recommended to be 80% or higher. The figure below shows the single and double-grid flight plans and the density of image samples acquired, in each case. Overlap between, non-consecutive, but spatially neighbouring images is shown on the bottom left. The two setups are illustrated in Figure 7.

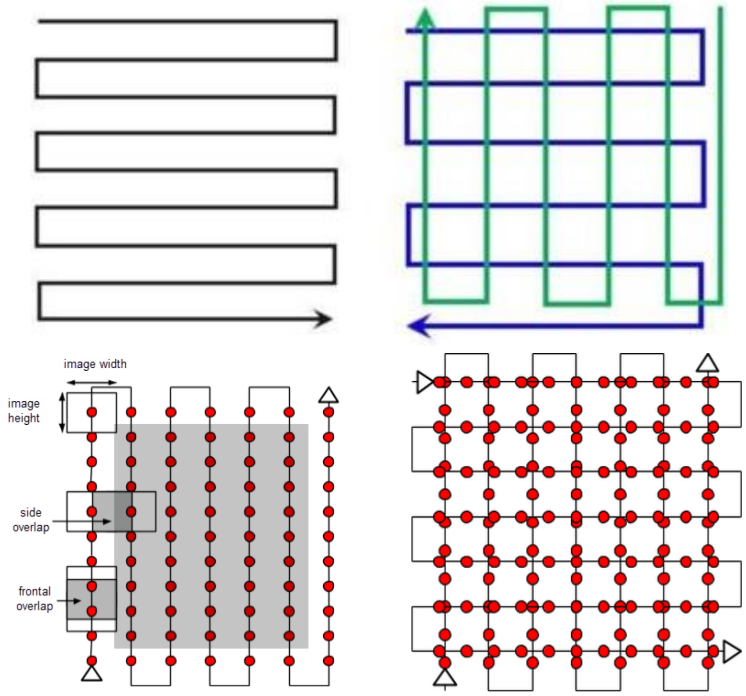

Figure 7. Aerial photogrammetric setups.

On the other hand, if a single structure is of interest, such as a building or stature, a circular path is recommended. Depending on the height, more than one concentric flight, at different heights is required, with the same amount of overlap between neighbouring images, laterally and at different heights. At least two scans are required particularly if the building has concavities, such as eaves. The single and double circular flight paths are illustrated in Figure 8

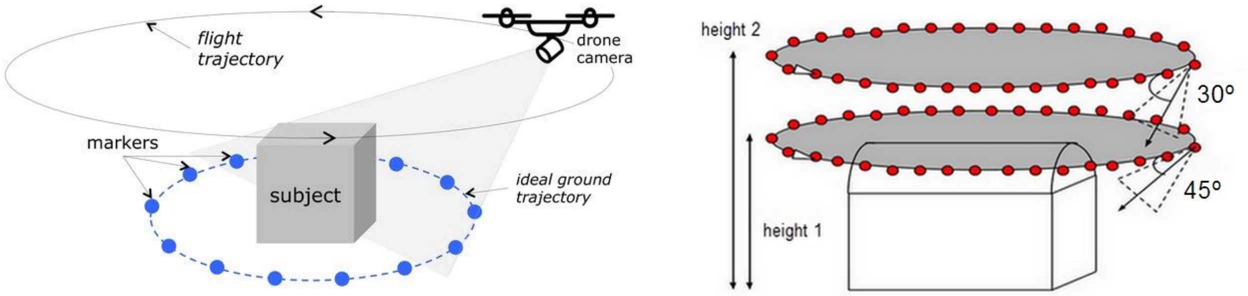

Figure 8. Circular photogrammetric image setup.

3.2.4 Comparative assessment of modalities

Handheld devices equipped with inertial sensing and active illumination provide greater robustness to reconstruction errors than photogrammetry. On the other hand, depending on the optics of the handheld device the texture quality varies. If a high-quality DSLR camera can supersede handheld devices in texture quality. In most cases though, a modern handheld device with active illumination or time-of-flight sensing provides quite sufficient results. Figure 9 compares the digital assets acquired from the scanning of the same physical asset (that of Figure 3) with a handheld device and photogrammetry, both with conventual equipment. The handheld scanner was a Faro Freestyle scanner and the camera used in photogrammetry was a GoPro 5.

Figure 9. Comparison of handheld scan (top) and photogrammetry (bottom).

As expected, comparing photogrammetry with laser scanning shows that the former exhibits better texture quality and the later better geometry. In Figure 10, two scans of the same object, a dressed mannequin, are shown, one acquired with a laser scanner and another from photogrammetry.

Figure 10. Comparison of laser scanning (top) and photogrammetry (bottom).

3.2.5 File formats

The reconstructed 3D models are stored in files that specify the geometry and appearance of the 3D model.

Geometry is usually encoded as an approximate mesh. The surface of a 3D model is first covered with a mesh of polygons, which determines the surface geometry of the target model. The approximation gets better as the triangles get smaller. However, the smaller the triangles, the larger the number of triangles is need to tile the surface, increasing the required computational resources.

The appearance of the model regards to colour and texture. More specifically, appearance describes surface reflection properties and determines the way that the model is rendered. Information about appearance can be encoded in two ways:

- Texture mapping. In texture mapping, every point in the 3D model's surface is mapped to a 2D image. Every surface point corresponds to a coordinate in this 2D image. The 2D image containing texture information needs to be stored within the same file or separately in a different file.
- Face attributes. Another way of storing texture information is to assign each face of the mesh a set of attributes. Common attributes include colour, texture and material type. A surface can have a specular component indicating the colour and intensity of true mirror reflections of light sources and other nearby surfaces. This approach is less relevant to scanning approaches and more relevant to the computer-aided design of objects.

The most widely used formats for 3D digitisations are STL, OBJ, and GLB. STL (STereoLithography) is important in the domains of 3D printing, rapid prototyping, and computer-aided manufacturing. STL encodes solely the surface geometry of a 3D model approximately using a triangular mesh. The OBJ file format is widely used in 3D graphics. The OBJ file format supports both approximate and precise encoding of surface geometry. For approximate encoding, the surface mesh is not restricted to triangular facets, but polygons can be used. For precise encoding, it uses smooth curves and surfaces such as NURBS. The OBJ format can encode colour and texture information. This information is stored in a separate file with the extension MTL (Material Template Library). GLB is the binary file format representation of 3D models saved in the GL Transmission Format (glTF). Information about 3D models such as node hierarchy, cameras, materials, animations and meshes in binary format. GLB file format results in compact file sizes, fast loading, complete 3D scene representation, and extensibility for further development. For conventional digital preservation and sharing purposes, the GLB format is preferred because it encodes the 3D model in a single file and, thus, is favourable for Web presentations.

3.4 Digitisation of perdurant assets

Human motion digitisation and analysis have gained particular interest in the last two decades, due to the wide range of applications relevant to ergonomy, rehabilitation, security, sports, human-computer interaction, medical education, robotics, cognitive research, entertainment, and many others. The central goal is to record the movement of subjects in three dimensions.

3.4.1 Motion recordings

Digitisation of human motion has been achieved by several methods, which can be classified based on the requirement that requires human subjects to wear markers or not.

Motion Capture (or MoCap) technologies measure the movement of subjects in three dimensions, based on wearable markers whose location in 3D is estimated by corresponding sensors. As such, the resulting data are not necessarily intuitive to visualize without some post-processing. Two main technologies are used, optical-based MoCap, and inertial measurement units (IMU) MoCap. Unlike normal video, MoCap directly extracts position information of human motion. The results encapsulate human motion in 3D with great detail and therefore show a complete representation of the recorded motion.

Visual methods use camera-type visual sensors to record the subject. These sensors are typically video cameras (RGB sensor), possibly with the addition of a depth camera (RGBD sensor). Motion is estimated in 3D by the processing of the visual stream, segmentation of the motion silhouette from the rest of the imaged scene, and fitting a 3D mathematic model into this silhouette. The cost of the unobtrusive nature of these methods is the confrontation with the problem of treating visual occlusions and the inference of subject motion missing from the acquired images, due to these occlusions. The methods have been the epicentre of many works in Computer Vision considerable progress has already been achieved in the last decade. Visual tracking is of particular importance to the documentation of CH because it means that a 3D representation of motion can be obtained from documentaries and archive footage.

3.4.2 Comparative assessment of motion recording modalities

Marker-based systems employ multiple cameras that encircle the recording volume. Retroreflective hemispherical markers are placed on the subject. IR light sources emit imperceptible light that is reflected with minimal scattering. A variant is the use of wearable LEDs that emit IR light instead of reflecting it. Each camera acquires 2D images where only the markers appear as white dots against a black background. The dots are triangulated and their motion is reconstructed in 3D. With enough cameras and an appropriate setup, it is possible to have an unobstructed view of a large area, but this is very hard to achieve in a cluttered environment where multiple occlusions are present. A benefit is that the system records only the markers, therefore background items are not included in the final recording. However, marker-based systems require more post-processing to extract joint angles from the cluster of markers, and they are not portable by their nature. Though they can be used for many different purposes, they need a structured environment. Moreover, optical-based systems are affected by sources of IR light (sun, heating bodies, and even a lot of people in a small room).

IMU MoCap systems are different in the sense that they do not measure displacement but acceleration. Each IMU is comprised of an accelerometer, a magnetometer, and a gyroscope that provide measurements in three dimensions concerning the earth's magnetic field. The output of one IMU is relative to a global coordinate frame. The main benefit of this method is that there is no need to generate a reference signal, such as the IR light in optical-based systems. This is of limited use when there is interest in the relative position between two body segments. Relative position is implicitly computed as the integration from multiple IMUs on multiple body parts. IMU systems are accurate with little noise. However, they are sensitive to magnetic distortions.

Sources of magnetic noise can be electrical appliances, metal furniture, and metallic structures within a building. Recently commercially available suits with embedded several IMUs to be worn by the subjects and their output is streamlined without the need for post-processing. However, the drawback is that IMU suits can be used to record only the motions of people, unlike marker-based systems which can track the motions of drones, robots, individuals with amputations etc.

Independently of the technology used to acquire motion recordings, the resulting data are always a chain of coordinate frames and the difference in position and orientation between them.

3.4.3 Motion recordings for crafts

IMU MoCap is recommended over marker-based, given its portability and the cluttered spaces of craft workshops. Visual MoCap is less accurate and recommended for cases where MoCap is not available or wearing a MoCap suit is hindering the ability of the practitioner to perform the recorded actions. Nevertheless, even is MoCap is used, a parallel video recording is recommended for reference.

The use of a storyboard prepared earlier is useful to increase the efficiency of the recording. Moreover, it is of practical use to isolate actions so that they can be used for exemplars later on. Repeating the action multiple times ensures capturing at least a representative performance of each action. Finally, noting which action is performed each time, eases the classification of recordings, later on.

In Figure 11, stills from the video recordings of three craft instances are shown. The recordings were acquired using an IMU MoCap suit and the images are from the parallel video recording. Though the recording is continuous, the legends show the notes produced during the recording, in compliance with the storyboard and recording plan.

(a) Press treadle and then push beater (b) Move the shuttle sideways (c) Leave treadle and then pull beater

Figure 11. MoCap of the weaving task.

3.5 Semiotic annotations

Similarly to the representation of verbal semantics, the topic of associating visual data with semantics, or semiotics, is an important tool in associating “meaning” with recording data. In verbal content, words and phrases correspond to semantics.

Endurant digital assets contain static visual data. The naming and classification of the physical asset are of use for the entire asset and enable the association of the 3D model or image with a semantic concept in a knowledge base. Moreover, regions of the assets may be associated with individual meanings, such as a weft, drawn, or carved symbol.

Similarly, perdurant assets are recorded by dynamic visual and 3D data and contain segments of interest, due to the occurrence of an action. The demarcation of actions within a recording, sometimes called parsing or articulation, contributes to the understanding and analysis of crafting activities.

To create semiotics that can be represented in a knowledge base, annotations can be created upon digital assets that link the asset with a knowledge entity. To implement this link, an annotation editor is required that stores the annotations along with a unique identifier (an "id") for each annotation. This way the annotation becomes a unique knowledge entity that relates the digital asset with a semantic concept. To author such semiotic annotations, annotation editors for endurant and perdurant assets can be used.

Below, a brief overview of annotation editors is provided. Depending on the type of asset their functionality differs. However, the most important feature of all editors is the format in which information is saved. It is recommended to use editors those store annotations in open formats so that these annotations can be then easily utilised in the knowledge base when linking assets with concepts.

3.5.1 Endurants

Annotation of endurant digital assets regards the annotation of images and 3D models.

A wide range of image annotation editors exist. All of them offer annotations upon the overall file at point locations in images. Standard features are the annotation of arbitrary (freehand) image regions and rectangular bounding boxes within the image.

The case is much similar for 3D model annotators. Point location annotations on the surface of the 3D model are offered by all editors. In objects, the user may wish to indicate which piece of a carafe is the handle or indicate a motif or symbol upon a piece of pottery. The annotation of free-hand regions on the 3D model is a feature that is not found in all editors. The reason is the somewhat tedious user task of marking the region of interest. We recommend using an annotation editor that enables the specification of geodesic regions of interest upon 3D models, a feature not available in most editors that offer only point-based annotation.

In Figure 12, a region-based annotation on a 3D model is shown. The 3D reconstruction of a marble-sculpted temple is shown, through the 3D GUI. In the example, the user wishes to annotate an approximately circular piece of the ornament, which symbolises a flower. By navigating in 3D, the user can find a view which facilitates convenient observation of the target. The user traces the region boundary around the ornament. Depending on the editor the 3D & RGB content may be utilised to more accurately and more automatically select the target, similarly to the "magic wand" tool in image processors.

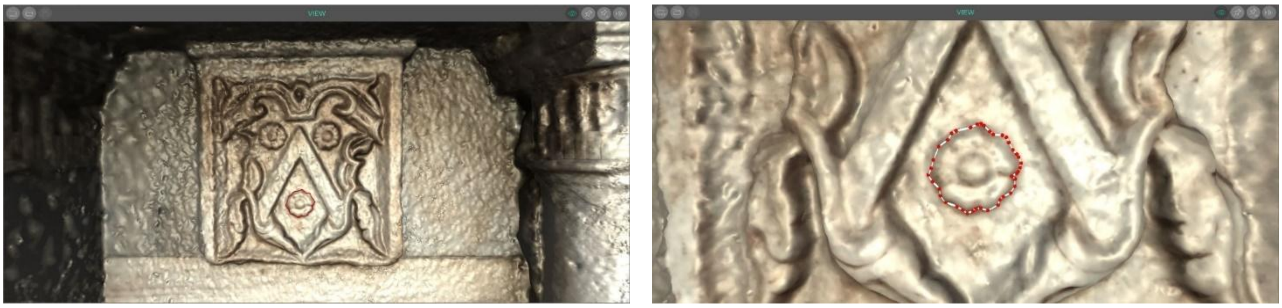

Figure 12. Region-based annotation of a 3D reconstruction.

3.5.2 Perdurants

Annotation editors for videos and motion animations are recommended to associate fragments of these digital assets to craft actions and gestures. The editor employ should allow to **visualise**, **editing**, and **annotate** 3D animation files, obtained by motion capture or visual tracking. In the case of visual tracking, temporally corresponding video can be also edited. The editor should allow the user to isolate animation segments and associated videos, for further annotation. The application should allow the synthesis of composite animation files and videos from such segments.

The annotation procedure is primarily time-oriented. A time line simplifies navigation through the animation and video and makes convenient the segmentation of video and animation segments. The BVH format is the most widely used open format for animations. In this case, a BVH visualisation is required. Additionally, controls should be provided for viewport transformations, such as 3D rotations, zoom-in-out, change of viewpoint etc. The annotation tasks should split animation files into parts (usually defining a specific motion) and then export those parts as new BVH files. Figure 13, is shown to be used in the isolation of a weaver pushing his foot on the treadle of a loom.

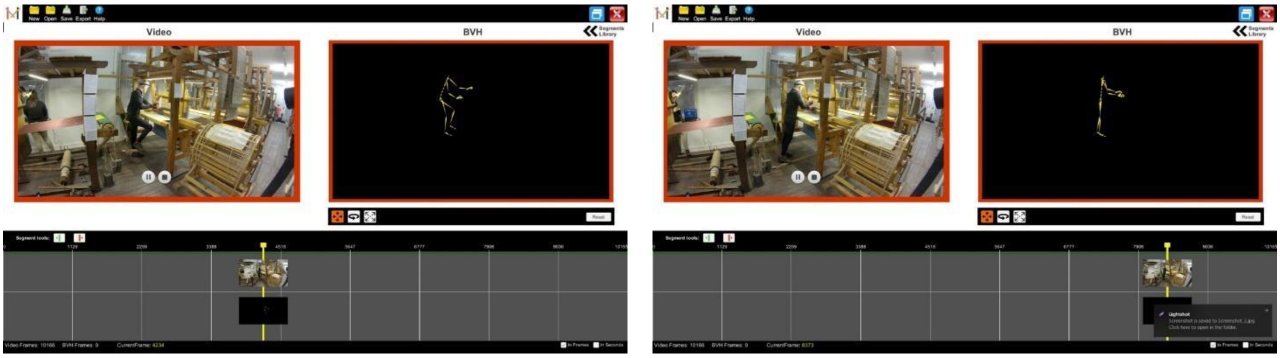

Figure 13. Animation Studio is used to isolate segments of 3D and video animations.

3.6 References and further reading

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Step 2 Knowledge representation

In this step, we create the building blocks of our craft representation. These blocks are knowledge entities that represent endurant and perdurant assets. The types of knowledge elements employed by our representation are Materials, Objects, Places, Persons, Social Groups, and Events. These are instantiated according to the co-creation and orientation results from Step 1.

4. Basic knowledge elements

Forming a knowledge element requires a comprehensive understanding of the assets and their digital representation (digital assets). This process is a basic digital curation process. Digital assets are represented in the knowledge base through knowledge elements, which associate digitisation data with the result of a curation process that yields metadata, annotations, and descriptions. The knowledge entity represents each digital.

We believe that the best way to plan the representation is a top-down, hierarchical decomposition of the story we wish to say. In our case, we have two types of stories to tell. The first is contextualisation stories, which can be thought of as historical narratives, or even myths and legends. The second is the presentation of crafting processes, in the form of an instructional presentation that supports its reenactment.

The semantic "glue" that links the knowledge elements required to represent these "stories" is the concept of the event. For conceptualisation, below we illustrate how events associate knowledge elements, for contextualisation and a crafting narrative. The generality and plasticity of the event as a concept provide the ability to represent a wide variety of topics and relate diverse notions and knowledge entities. Though formally all events are of the same type, we distinguish the way they are used, that is if used in a contextualisation narrative or a crafting process representation.

4.1 Conceptualisation

The first example is part of a contextualisation narrative, on the life of a practitioner of marble crafts. The illustration in Figure 14 represents the creation event of a funerary monument, at a cemetery in Bucharest. The event brings together the creator and the creation time and location as well as the knowledge entities of the material and the produced craftwork. Digital assets are associated with the person entity (a photograph) and the craftwork entity (photographs and a 3D model).

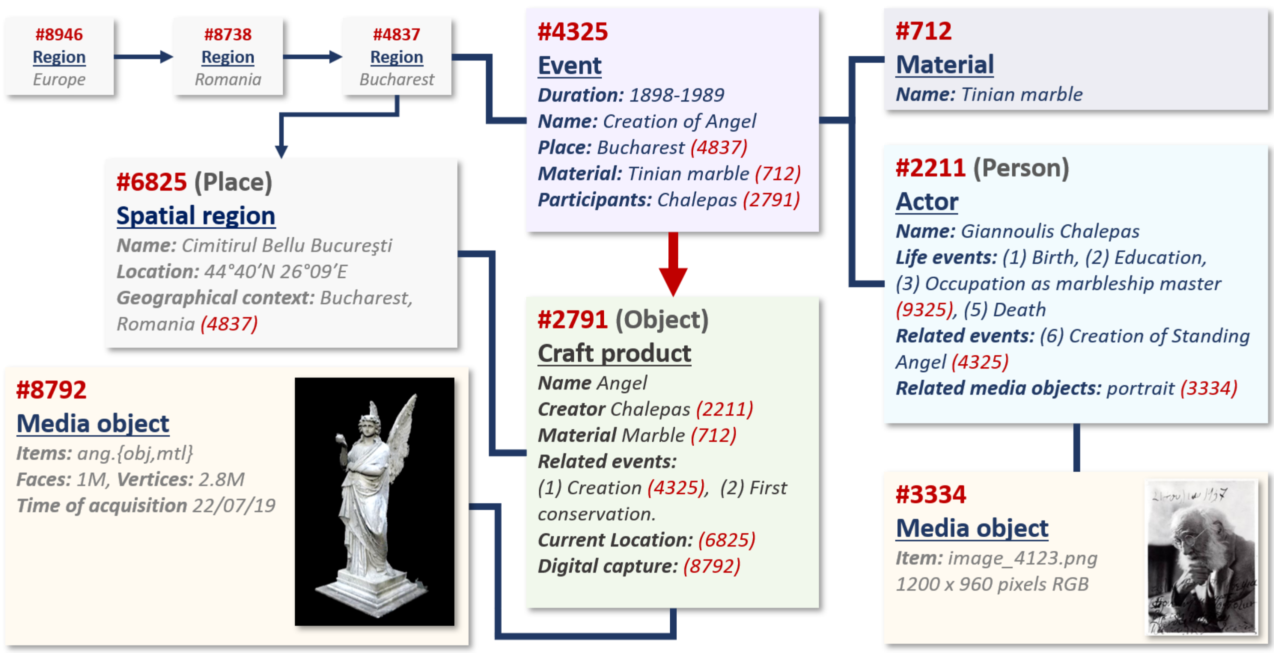


Figure 14. Relations of a contextualisation event to knowledge elements and media objects.

The second example, in Figure 15, is an event that took place during the production of a glass body. The event called bubbling brings together the practitioner, the production location, the tool that was used, the material and the produced glass body. Digital assets are associated with the tool and the event, such as motion and video recordings of the action.

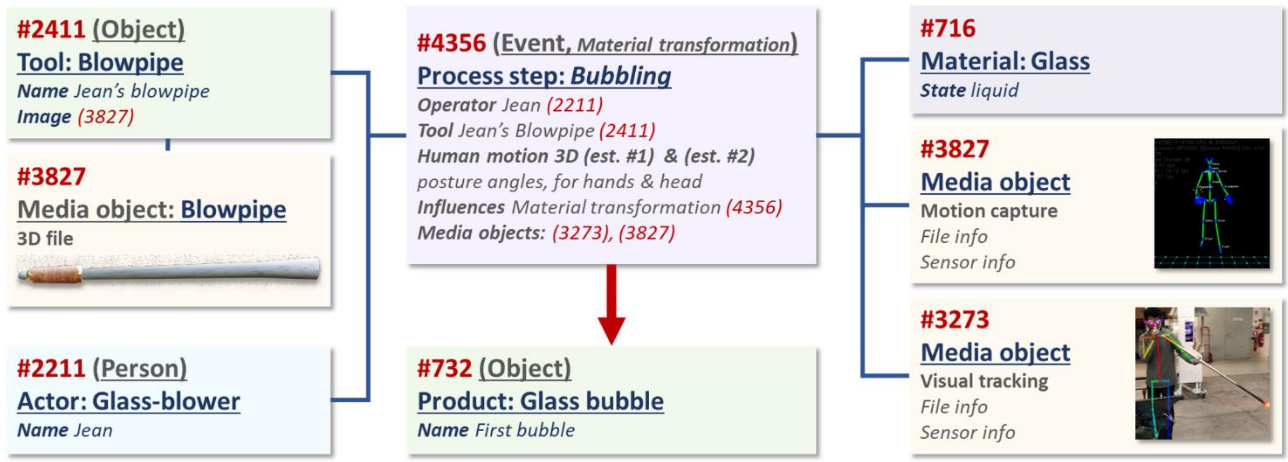


Figure 15. Relations of a crafting event to knowledge elements and media objects.

Once the conceptual diagrams are in place, it is straightforward to collect the objects, persons, locations, and other elements and instantiated them. When this is done, events can be instantiated, as all of their related entities are already existing in the system.

Digital assets may be linked to all types of knowledge elements. The purpose is to associate the instantiated knowledge entities with recordings that document them. Figure 16 illustrates the relation between a knowledge element and a digital asset. The knowledge element of a person is linked to a digital asset, which contains the digital image of that person along with technical meta-data for its appropriate presentation.

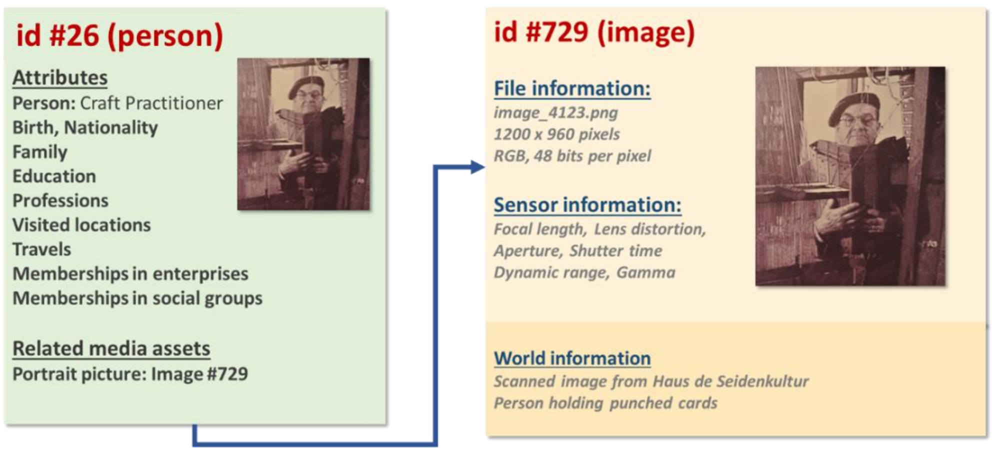


Figure 16. Relating a representation of a 'Person' to a 'Digital asset'.

Depending on the situation, a knowledge entity may or may not have an associated recording, while one entity may or may not have multiple recordings. In Figure 17, the relations between an object and three digital assets, two images of the object and one image of its sketch, are illustrated.

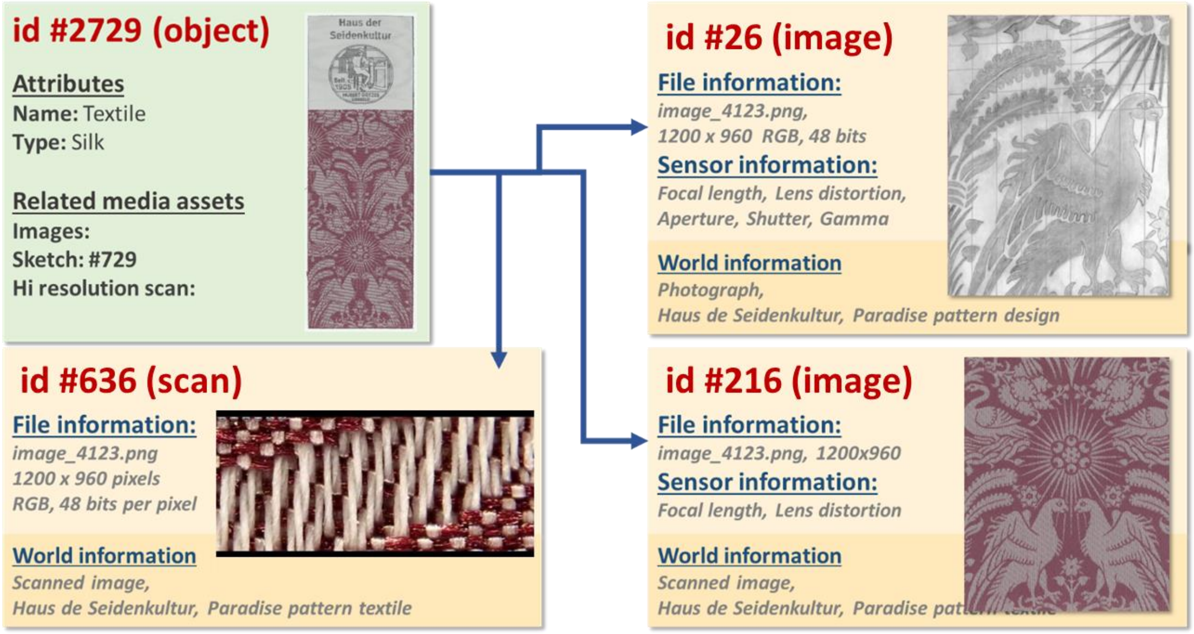


Figure 17. Object knowledge element (a silk page marker) and linked medial objects.

Knowledge elements may be also associated with parts of digital assets, as signified through annotations of the previous step. In Figure 18, an example is shown. An elephant is depicted in four historic and traditional textiles. The motif symbolises an elephant given to Charlemagne and is the first elephant in Europe. The story made its way into oral tradition and eventually became a folk motif found in garments and textiles even today.

Figure 18. Similar motifs refer to the same entity found in traditional textiles.

4.2 Knowledge representation

4.2.1 Places

Locations on the Earth are defined as points which have 2 coordinates, latitude and longitude. Regions are polygonal representations upon the surface of the Earth. Both are called "places". A semantic property of a place is whether there is, or was, a name associated with it. For named geographical locations, a database of location names (GeoNames) is used. The coordinates and further semantics, such as hierarchies of city, region, and state inclusion, are also available through this resource.

A more refined representation of locations may require addresses or even arbitrary user-defined locations on Earth that are not included in the database. The coordinates of these locations are provided through direct input of GPS coordinates.

A common modelling simplification in database names 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 other cases. For this reason, place knowledge elements may link to an arbitrary number of locations.

4.2.2 Materials

Materials are documented by name and can be classified into minerals, fauna, and flora. It ought to be noted that several materials are subject to naming legislation. For example, in Europe, there are regulations on the protection of designation of origin and geographical indication for materials and products (regulation 1151/2012 of the EU). More specific regulations exist for specific material classes, such as the regulation of fibre naming depending on their composition (e.g. regulation 1007/2011 of the EU).

4.2.3 Objects

Objects are composed of materials and cover a broad range of “things”. They are primarily used to represent craft artefacts, tools, and machinery. The ontology should provide links to events documenting the object such as its creation, the selling, or, if relevant, the destruction of an object.

4.2.4 Persons and social groups

Typical knowledge elements related to the life of a **person**, are long-term events such as occupation, education, and places of habitance, as well as key events such as collaborations with other persons, production of masterpieces and so on. The case is similar for **social groups**. Social groups can be used to represent the life of a company or an artistic movement. As in the case of persons, key events are associated with social groups, such as the passing of legislation relating to craft products, or an art festival or exhibition. In addition, social groups are associated with events that mark the initiation and termination of participation of individuals in that group.

4.2.5 Events

Events are the building blocks of contextualisation narratives and process representations. The principal property of the event is a time interval. Events are associated with places, participating persons or social groups, and objects. Digital assets can also be directly linked to events.

Events occur in time intervals delimited by an ordered pair of points in time. Depending on the required granularity of representation, some events may be considered to have a zero-time length although they have a very brief or infinitesimal duration.

Events can be linked to other events, to establish temporal relationships. These express the relations between the time intervals of events, such as simultaneous or sequential occurrences. Moreover, an event may include other events as parts of it, enabling hierarchical decompositions of complex events into simpler ones. Finally, events can be linked to express a causal dependency.

4.3 References and further reading

1. The CIDOC Conceptual Reference Model (CRM), ISO 21127:2014.
2. Partarakis N, Doulgeraki V, Karuzaki E, Galanakis G, Zabulis X, Meghini C, Bartalesi V, Metilli D., A Web-Based Platform for Traditional Craft Documentation. Multimodal Technologies and Interaction. 2022; 6(5):37, DOI: 10.3390/mti6050037.
3. Donald Davidson, Essays on Actions and Events, Clarendon Press, Oxford, 2001.
4. L. Donkin, Crafts and Conservation: Synthesis Report for ICCROM, 2001.

Step 3 Craft representation

In this step, we use knowledge elements to author two types of representations:

- Contextual representations, which are stories, or narratives, contextualise a craft instance and its expression by an individual or a social group.
- Crafting representations, which represent the manufacturing plan, or schema, and indicate how a handcrafting process should be performed.

5. Representation of craft context, craft methods, and craft practice

5.1 Context

5.1.1 The fabula

Context representation is based on historical or mythological stories that are built from real or imaginary events. The collection of stories formed in Step 1 is targeted at representing social, technological, economical, or cultural changes, which relate to a craft instance. These stories are treated as historical or imaginary events that influenced social groups, technological advances, and artistic movements.

The representation we use for contextualisation stories is borrowed from Narratology and is called *fabula.* A fabula is a series of happenings, in chronological order. The fabula is an abstraction that represents a set of facts that took place in the real or an imaginary world. Albeit any chronological series of events could suffice this definition, we assume that a meaningful fabula entertains a contextual topic. The facts it references are connected in a way that makes them a story. In other words, the fabula implicitly encodes causal relations, as per the judgement of its author.

Formally, a fabula is a set of coherent phenomena or cultural manifestations occurring in time and space. In more practical terms, fabulae is the grounding data structure for the representation of stories. We represent said phenomena with instances of Events, which refer to representations of the space and time that these events took place.

5.1.2 Authoring fabulae

To create a fabula, instantiated events are linked in chronological order, as illustrated in Figure 19. In this figure, a biographical fabula is illustrated about a weaver the moved to Krefeld and made a business which contributed to the establishment of Krefeld as a European silk centre, in the 18th century.

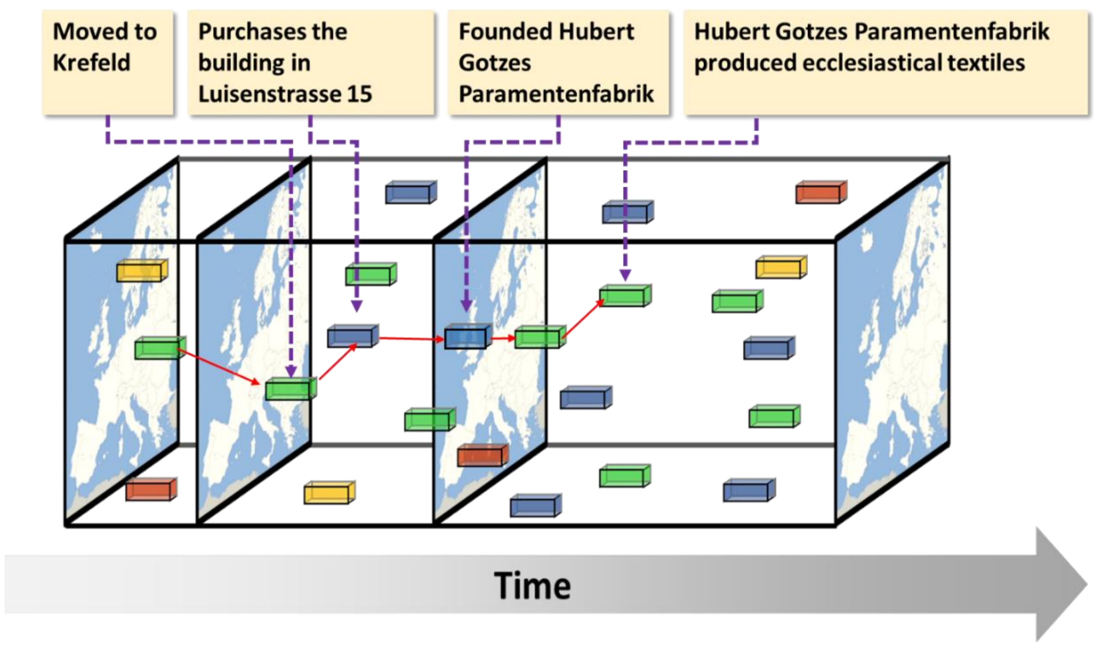


Figure 19. Illustration of a fabula.

Figure 20, is an indicative illustration of how data can be entered using conventional input forms, to instantiate Event knowledge entities, organise them in a list, and create a knowledge entity for the fabula. The fabular representation contains the list of events, but can also have additional attributes, such as an overall description and references to additional media objects (besides those linked to the events).

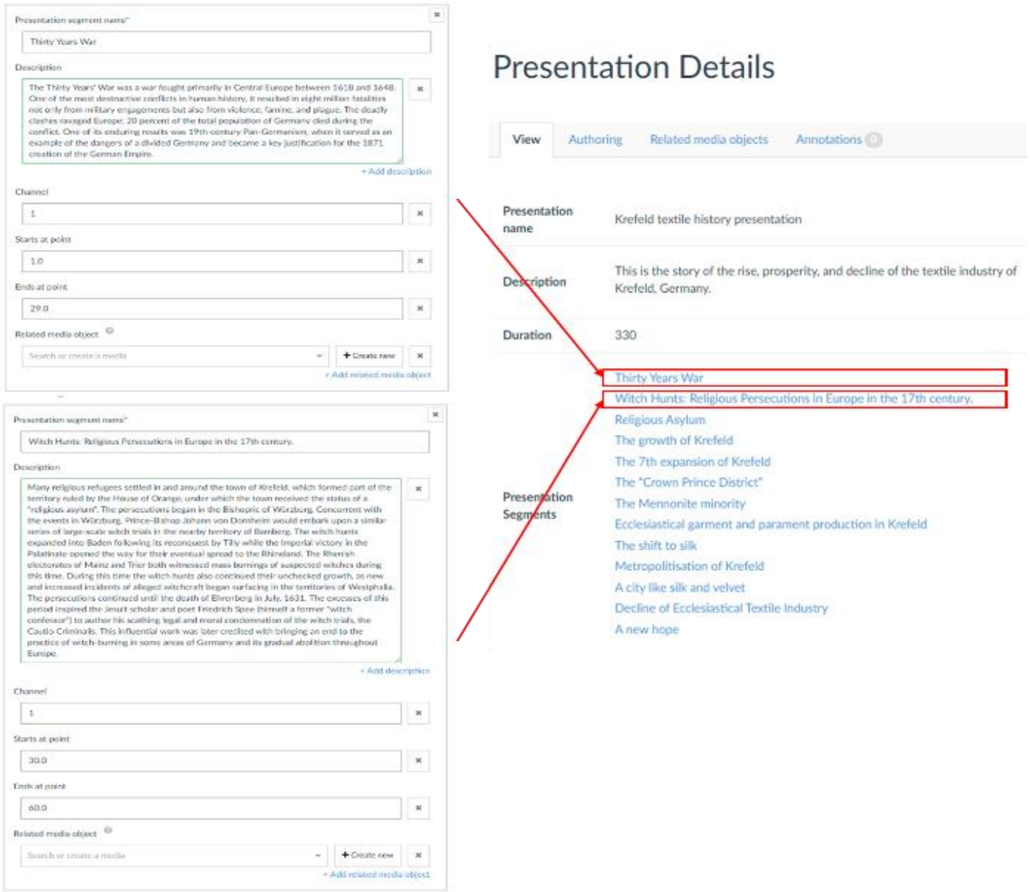


Figure 20. Data entry forms and organisation GUI for instantiating events and linking them in a fabula.

5.2 Methods

In Step 1, an understanding of the crafting process has been obtained and documented through ethnography and data collection. In that step, we identified the stages of crafting processes and created storyboards that describe them. In Step 2, we represented the endurant and perdurant entities involved in crafting processes using basic knowledge entities. In this step and this subsection, we will represent the "plan" of the crafting processes, or more formally, the process schema.

5.2.1 The process schema

A process schema encodes the actions (events) that should be performed to execute a particular crafting process. Examples of process schemas are wedding ceremonies, recipes, or diplomatic protocols. That is a process schema is a rule which describes how an activity, the crafting process in our case, should be performed.

A defining feature of crafting process schemas is that they contain branching points in their workflow. In many cases, the practitioner is called to make judgements and take appropriate decisions regarding which the next action should be. Moreover, the representation should be capable of encoding parallel or collaborative tasks, as well as decision points. To achieve this representation we will first make a diagram of this plan so that we can formalise it in a human-comprehensible way that can be evaluated with practitioners.

Activity diagrams are graphical representations of workflows of stepwise activities and actions. Activity diagrams were created to represent information flow and processing. They are of use in representing the flow and processing of materials through physical processes that transform them into craft products. Activity diagrams can represent parallel tasks and decision points. In Figure 21, an example of a sequential schema is shown, in particular, that of the weaving task presented in for the weaving task in the storyboard of Figure 2. The task is iterative and at each iteration, the practitioner judges whether the fabric is complete or the task should iterate. When the fabric is complete, then the process moves to another step, that of detaching the fabric from the loom.

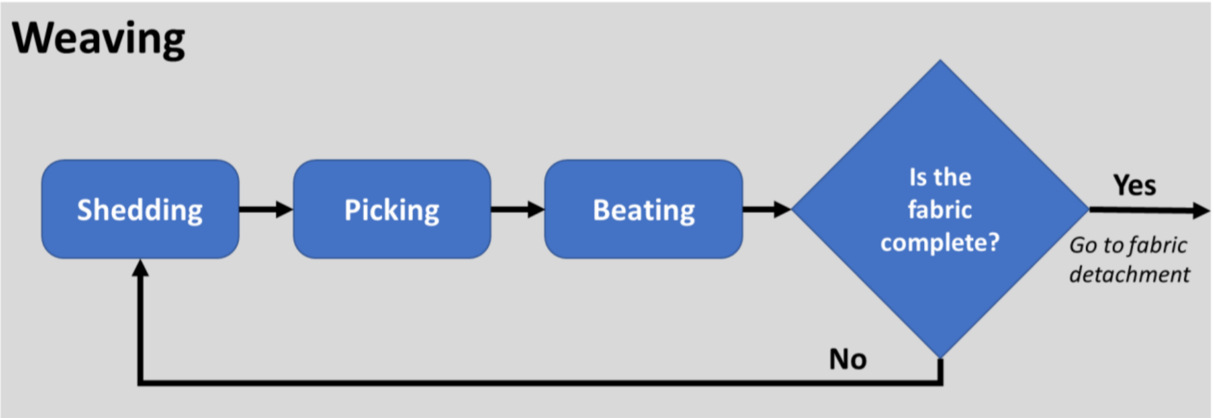


Figure 21. Process schema for weaving.

The next couple of examples come from the field of glassblowing and illustrate activity diagrams for parallel tasks and decision points. In the top row of Figure 22, the two simultaneous actions are carried out by two persons. The master glassblower hand-shapes the glass bubble with a piece of wet newspaper while rolling the blowpipe back and forth to keep the glass body rotating. The assistant is blowing from the other end of the blowpipe, moving in synchrony with the blowpipe's motion. This is represented in the activity diagram by a bifurcation into two concurrent flows, each for one person, which ends together.

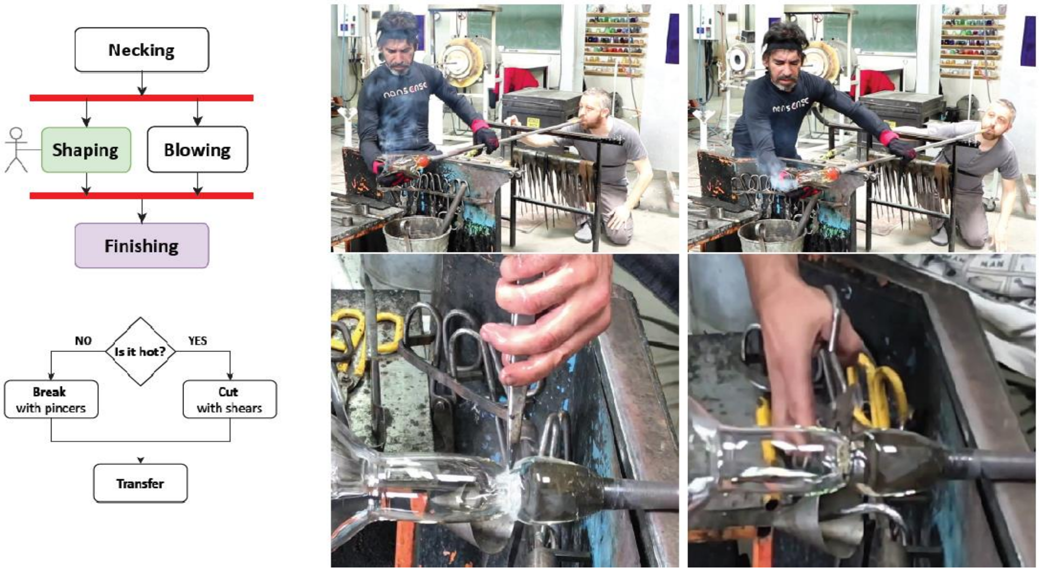


Figure 22. Representation of concurrent actions and decisions.

The bottom top row of Figure 22, shows a decision point, where the practitioner separates the glass body from the blowpipe. The way that the body should be detached from the tip of the blowpipe depends on the viscosity of the bubble, that is, its temperature. If judged to be hot enough, it is cut using a pair of shears (middle), without the danger of breaking. Otherwise, it is carved and broken away from the blowpipe, using a pair of pincers (right).

The aforementioned examples are steps of a larger schema that least to the creation of a glass carafe. The overall diagram is shown in Figure 23, with the basic steps of the process outlined. The process schema starts with creating a glass bubble which is then shaped into the main body of the carafe. Then leg and feet are added as attachments to this body, followed by the addition of an ornamental cord. Then the beak is shaped and, finally, the glass body is finished and annealed.

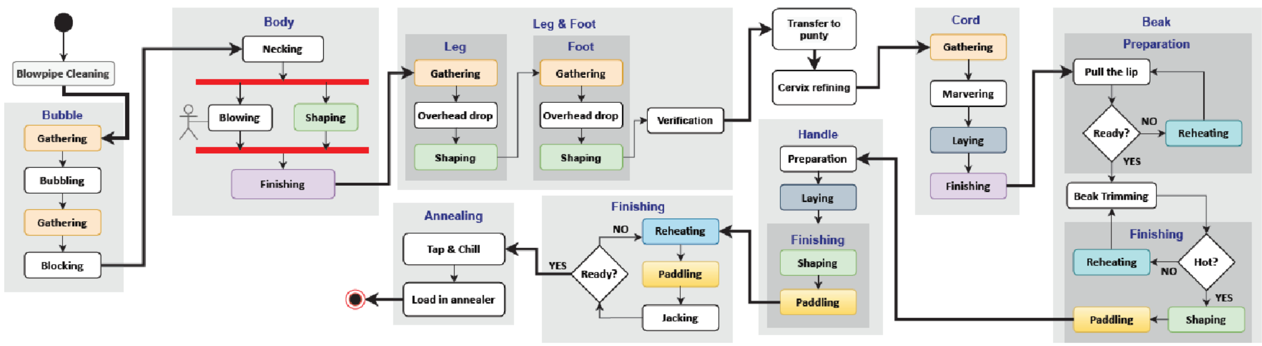


Figure 23. Activity diagram the creation of a glass carafe.

We recommend starting the design of the diagram from coarse to fine. The coarsest step represents the main steps of the process. Depending on the situation, these steps may be distinguished by the working site or the stepwise, part-by-part assembly of an artefact. We recommend that these steps are chosen so that they agree with the understanding of the practitioner.

The analysis ends when a targeted level of detail is reached. This level is set to that of simple actions that practitioners can identify. This recursive decomposition yields a hierarchy of schemas that start from a coarse description down to a fine analysis of elemental actions. The finest sub-steps are individual postures and elemental gestures, such as “grasping a hammer” or “a strike of the hammer upon a nail”.

5.2.2 Authoring process schemas

The activity diagram is a human-comprehensible format for author process plans and at the same time is a formal representation. The latter means that we can directly transcribe the activity diagram in a machine-interpretable format. Transition nodes relate process steps temporally and causally, while sub-step decomposition organizes them hierarchically.

In the activity diagram, crafting events are connected by four types of transition nodes Simple, Fork, Merge, Join, and Branch. Fork, Merge and Join nodes enable the representation of simultaneous or temporally overlapping actions, performed by multiple persons or body members. Branching nodes represent conditional actions of the practitioner, due to which executions of the same process schema may lead to the execution of different actions.

In Figure 24, we show how this schema can be represented using conventional input forms. Notice that the iterative nature of this task is represented in the last step which succeeded by a contains judgement, upon whether the fabric is complete.

6. Weaving

Step description

Substep	Substep description	Execution order	Substeps
Shedding	Using the treadle, warp threads are separated, forming a shed for the weft to pass.	Leads to Picking	0
Picking	Using the shuttle, the weft is propelled across the shed, leaving a trail of string.	Leads to Beating	0
Beating	Using the beater, the weft is pushed up against the fell of the cloth, fastening a row of the weft.	Leads to Judgement of completion	0
Judgement of completion	The practitioner decides if the fabric is complete or not.	Alternative path: The fabric has reached the prescribed dimensions. then Shedding Alternative path: The fabric is complete. then 7. Finishing Weaving	0

Figure 24. Encoding of a process schema using input forms.

To more closely illustrate the encoding of decision steps, the left part of Figure 25 encodes the glassblower decision shown in the bottom row of Figure 22. A possible implementation of the form for the encoding decision steps and linking the next step is shown on the right.

Detach glass body from blowpipe

Step description

The practitioner will detach the glass body from the blowpipe. Depending on the viscosity of the glass body the practitioner has to decide if the body should be cut with shears or broken with a pair of pincers.

Substep	Substep description	Execution order	Substeps
Viscocity judgement	The practitioner has to detach the glass body from the blowpipe. The practitioner must estimate the viscosity of the body and decide whether the body should be cut with a pair of shears or it should be broken with a pair of pincers.	Alternative path: Glass is in a semi liquid state then Cut with shears Alternative path: Glass is in a solid state then Break with pincers	0
Cut with shears	The practitioner uses a pair of shears to cut the semi-liquid glass body from the blowpipe.		0
Break with pincers	The practitioner uses a pair of pincers to carve a line at a line contour across the body, where the glass body should be broken. The practitioner strikes the body at the carved line to break it away from the blowpipe.		0

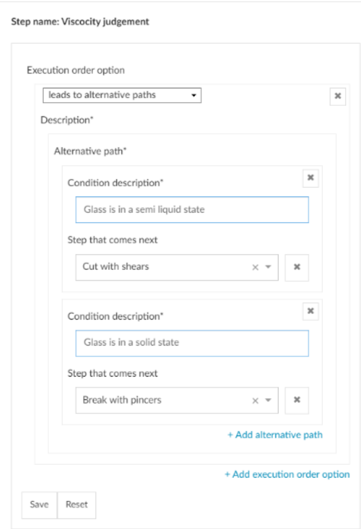


Figure 25. Encoding of a decision step.

5.3 Practice

In this task, we associate the recordings and knowledge we have for crafting activities with the steps of the schema, or otherwise, the model of the activity. The recordings we have from Step 1, are recordings of events. The knowledge elements from Step 2 identify the materials, items, and persons in the scene. The process schema enables us to associate recording segments with actions and associate 3D models of the participating objects with the process representation.

5.3.1 The process

Process steps are events and can be treated in the same way as when authoring events. Of importance to our goal is that these events are associated with the corresponding parts of the process schema. In this way, the knowledge we obtained on the understanding of the scene, i.e., the persons, objects, materials, and intended actions is directly associated with the recordings of these scene elements.

Notice that we can have multiple recordings of the same process schema, which provides the ability to better study and abstract the schema of a process, from its multiple expressions.

5.3.2 Authoring processes

We show that it is straightforward to create such a representation with conventional input forms.

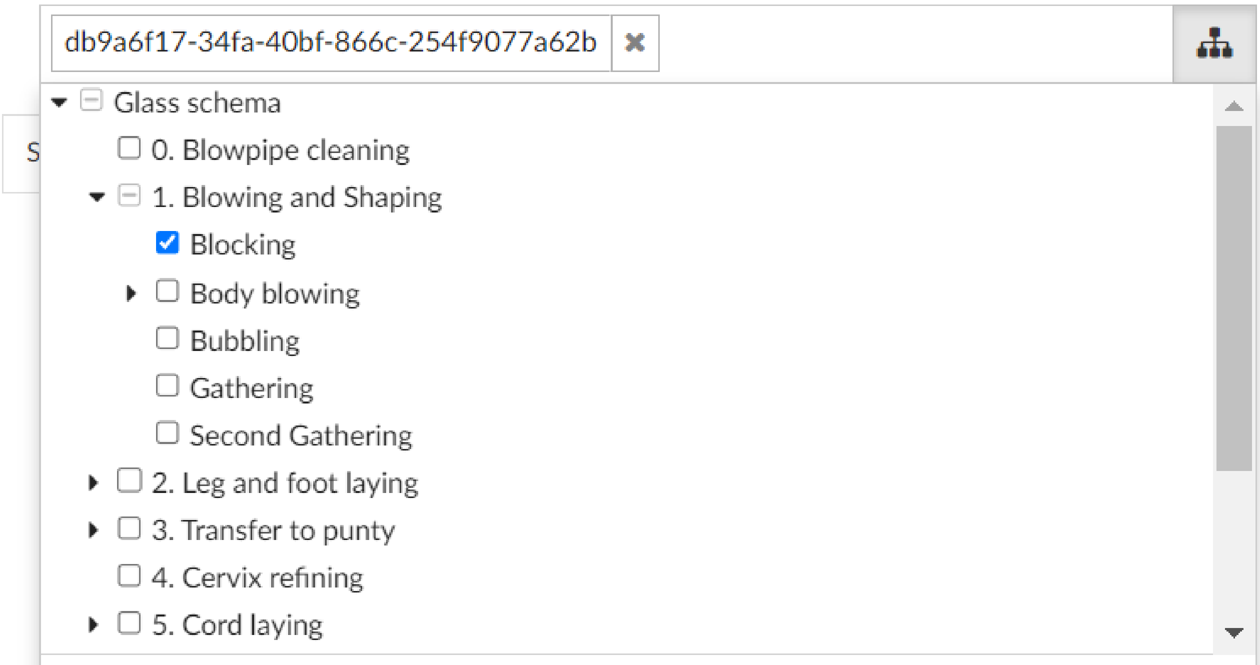


Figure 26. Association of process step to process schema step.

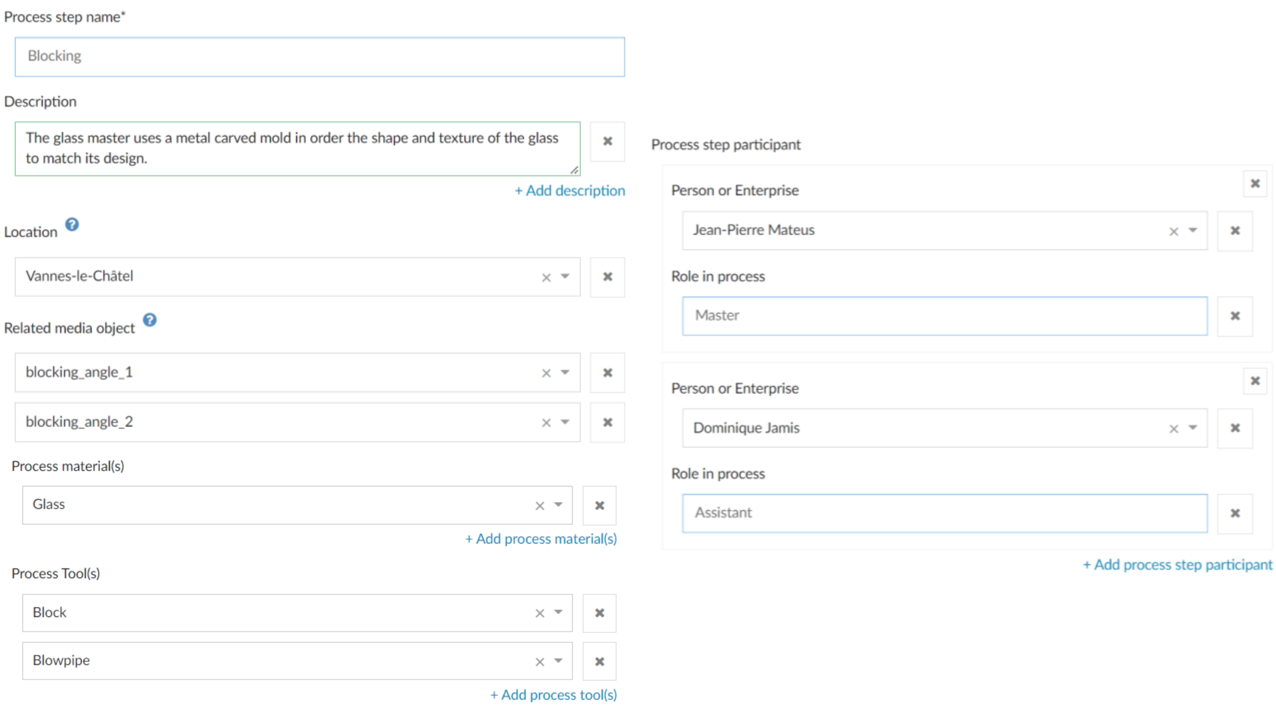


Figure 27. Form entry composition of a process step.

5.4 References and further reading

1. C. Meghini, V. Bartalesi, D. Metilli, Semantic Web, Representing narratives in digital libraries: The narrative ontology, (2021), DOI:10.3233/sw-200421.
2. N. Partarakis, P. Doulgeraki, E. Karuzaki, I. Adami, S. Ntoa, D. Metilli, V. Bartalesi, C. Meghini, Y. Marketakis, M. Theodoridou, D. Kaplanidi, X. Zabulis, ACM Journal on Computing and Cultural Heritage, Representation of socio-historical context to support the authoring and presentation of multimodal narratives: The Mingei Online Platform, (2021), DOI:10.1145/3465556.
3. X. Zabulis, C. Meghini, A. Dubois, P. Doulgeraki, N. Partarakis, I. Adami, E. Karuzaki, A. Carre, N. Patsiouras, D. Kaplanidi, D. Metilli, V. Bartalesi, C. Ringas, E. Tasiopoulou, Z. Stefanidi, (2022) Digitisation of traditional craft processes, ACM Journal on Computing and Cultural Heritage, DOI:10.1145/3494675.
4. Dolapo Adeniji-Neill, Tara Concannon-Gibney, Courtney Weida, Craft Objects and Storytelling, C.L. Weida (Ed.), Crafting Creativity & Creating Craft, 19–27. 2014 Sense Publishers.

Step 4 Conservation and presentation

In this step, we ensure the validity of the represented knowledge and information for posterity. The focus is to achieve adequate transmission through machine-interpretable and human-comprehensible means.

Machine interpretability regards digital conservation and digital preservation.

- Digital conservation regards the persistence of the stored knowledge and information against the wear of time, by describing the data (taking a backup) that encodes them, to cope with the finite lifetime of storage media, in the same way, that scribes copied from paper to paper to conserve the words against paper deterioration and wear.
- Digital preservation regards the persistence of the stored knowledge and information against the changes brought by new technologies, by the provision of meta-data that explain the contents of this knowledge and enable their transcription in new formats. That sometimes involves the transcription of knowledge and information, such as due to the change of language or storage media technologies.

Machine interpretability is central to both tasks because we want the computer to do them. Not only because they are tedious and menial, but also to protect the performance of both tasks from human errors.

Human comprehensibility regards the access of this content by humans in the meaningful and comprehensible format and organisation intended by the authors of information in the knowledge base. In other words, in this step, we ensure that the organisation of information is meaningful to humans and that knowledge and information are correctly and meaningfully associated, before proceeding to its export in advanced and experiential formats. In analogy, it is the same task when writing a piece of text that is accompanied by images, just like this one. The author(s) go(es) iterate between reviewing and editing. A simple and comprehensible format is essential to assist the author(s) in these tasks.

6. Digital conservation and digital preservation

The contents in our knowledge base are media objects and interrelated knowledge entities. Basic knowledge elements are directly linked to media objects. Process schemas, fabulae, and narratives are more complex, in that they are constructions of basic knowledge entities.

6.1 Technical Approach

We stand on the work in computer systems and advances in cloud computing to cope with the technicalities of system backups and related issues. To address conservation we recommend relying on cloud storage, thus assigning the maintenance of digital content to mass storage that is quite more cost-efficient than private maintenance.

To address findability knowledge entities should be registered to an online repository. We stand on the formality of the representation to achieve the goal of interoperable transcription, in internationally established formats, by Digital Humanities. Given the Semantic Web representation, our contents are accessible and findable online and in demand. These include formats to encode knowledge entities and meta-data as well as digital assets, which are encoded in conventional, widely used and open formats. Digital assets are accompanied by technical metadata, enabling content type identification and transformation to future formats.

In more technical terms, each entity whether a digital asset or a knowledge entity should have a unique IRI so that it can be individually addressed. The individual access to digital assets ensures that anyone can gain access to the sources, own recordings or third-party sources, of our study. Individual access to knowledge entities is access to the interpretation of these digital assets. Knowledge entities contain links to their associated digital assets. To make accessible the contents through an aggregator you would need a mapping between the knowledge base ontology and its knowledge representation model. For digital assets, the links should point to the source data files. For knowledge entities, the link points to the RDF encoding of that entity. In the EU the way to do so is through the National Aggregators that collaborate with the Europeana repository and request data to be accessible in the EDM and Dublin Core machine interpretability and interoperability standards.

Audio, video and 3D formats should be selected to be natively supported by WWW browsers to be accessible without the requirement of an external viewer or player. Note that this does not prohibit the use of, so-called, “embedded viewers”, such as a custom video player, which loads a digital asset and renders it instead of the browser. For images, you may consider associating a high-resolution, uncompressed image with a thumbnail so that online cataloguing becomes flexible.

6.2 Human comprehensibility

The human-comprehensible way we propose for accessing the knowledge base is hypertext. The reason is that the semantic relations between knowledge entities comprise an explorable knowledge graph. The implementation can employ a conventional Web interface that dynamically generates HTML pages from the knowledge elements and digital assets and a Web server that transmits them to the Web browser. We call these pages documentation pages.

This organisation reduces the effort of providing multiple ways of access to these presentations later on. The first part is the presentation of basic knowledge elements. We then proceed to the organisation of craft context and craft practice. The mechanism in presenting, or “narrating”, both crafting processes and contextualisation narratives as, in both cases, the presented content is a set of events.

6.3.1 Digital assets and knowledge elements

We propose an individual documentation page for each knowledge entity and media object. Documentation pages for digital assets should contain links to digital assets, textual presentation of metadata, and previews of the associated digital assets. Documentation pages for knowledge entities should contain a textual presentation of their attributes and implement semantic relations as hyperlinks that lead to the pages of cited entities. This way, browsing and exploration of knowledge through semantic associations are enabled.

The documentation pages should provide URLs to related digital assets and knowledge elements. Documentation pages for knowledge elements can be type-specific. Pages for instances person should provide biographical information and a portrait image. Location instances typically require the use of maps. Tools and artefacts are presented by images or 3D models. Events are knowledge entities and are presented on an individual documentation page. Documentation pages for process schemas show step schemas and their relations using hypertext. A serial presentation of the step hierarchy can be also provided. For locations, embedded, dynamic maps are provided. Timeline and calendar views are available for events.

Contents can be organised and presented spatiotemporally or thematically, using predefined queries. Dynamic queries can be prepared to create spatiotemporal or thematical overviews of the contents. A keyword-based search is a typical feature that can facilitate custom queries.

6.3.2 Context and storytelling

We propose to present context as a collection of stories, selected in Step 1. In Step 2, we instantiated the basic knowledge elements involved in these stories, such as locations, persons, events etc. In Step 3, we established relations between these knowledge elements to create fabulae that represent these stories chronologically.

In this step, we will create narration plans, for presenting the story encoded in a fabula. A story can be narrated in multiple ways, depending on the audience, technical facilities, or language. In other words, a fabula can have multiple narrations. Individual narrations of a fabula may differ as to their focus on different subsets of events in the fabula or may be adapted per user interest, language, age, or special needs. Moreover, the narration of the events of a fabula may be different than chronological, for example, in the case of a "flashback".

It is proposed that narrations are individually represented upon the fabula knowledge entity. The authoring of narrations uses the fabula and is implemented using narrative fragments corresponding to fabula events. The content of these fragments is text authored individually for narration. The narration can involve digital assets related to events and other knowledge elements. A benefit of using the knowledge base is that updates on knowledge elements are propagated also to the pertinent narratives.

The example in Figure 28, regards the example of the fabula illustrated in Figure 19. A textual narration is authored for the verbal presentation of each event to be presented. In this case, the narration mentions all fabula events in chronological order. Any media object can also be associated with the presentation segment.

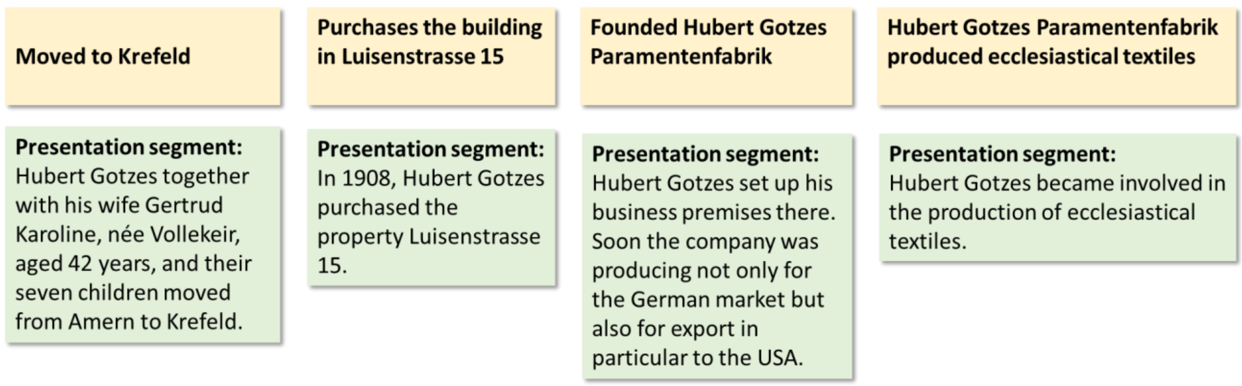


Figure 28. A fabula (top, yellow) and the narrations of its events (bottom, green).

The way that narrative segments can be authored and then dynamically compiled in a presentation is shown in Figure 29. In this case, the textual and image contents attached to presentation segments are concatenated to dynamically create a Web page for the narration. On the left, is the configuration of a Web for where narration segments are shown. On the right, the result is shown as a Web page, with two narrative segments magnified. Each narrative segment reads the entered text and shows the linked media objects to that narrative segment. The example is also demonstrated in the two margins left and right of the main narration, the output of queries to the knowledge base for relevant digital assets. On the left, all the tools referenced by the narrative are shown. On the right, products produced using these tools are shown. On the bottom right, a chronological listing of the narrated events is shown.

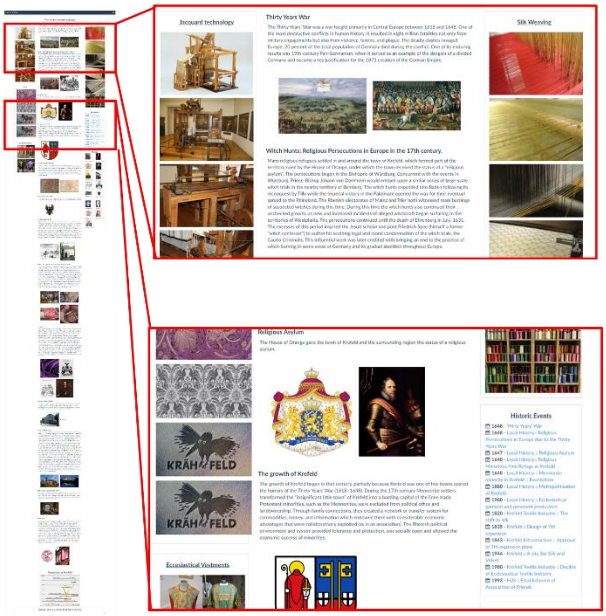
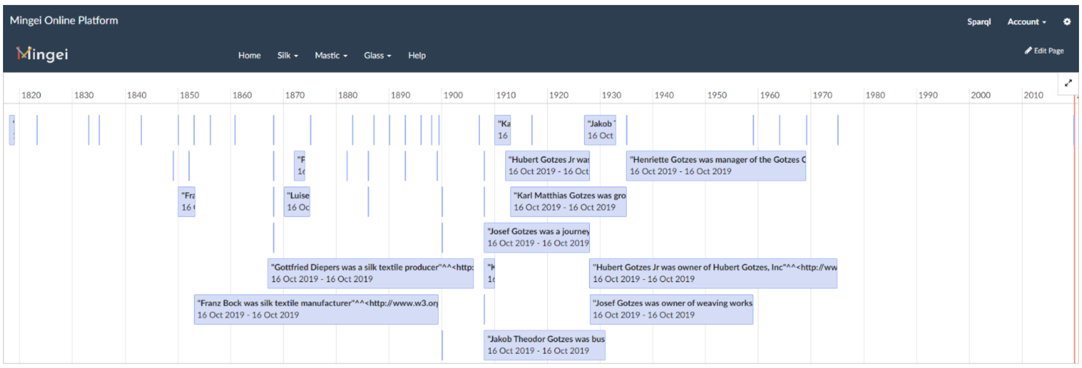


Figure 29. Presentation authoring and webpage preview.

Depending on the capabilities of your UI you may wish to include some conventional tools to illustrate temporal events and locations, that is timelines and maps, respectively. A temporal organisation registers events on a timeline. Using event locations events, objects, and persons can be placed on meaningful maps and presented in an exploratory nature. An example of such a map and timeline is shown in Figure 30, which presents the durations and locations of the events of the narrative.



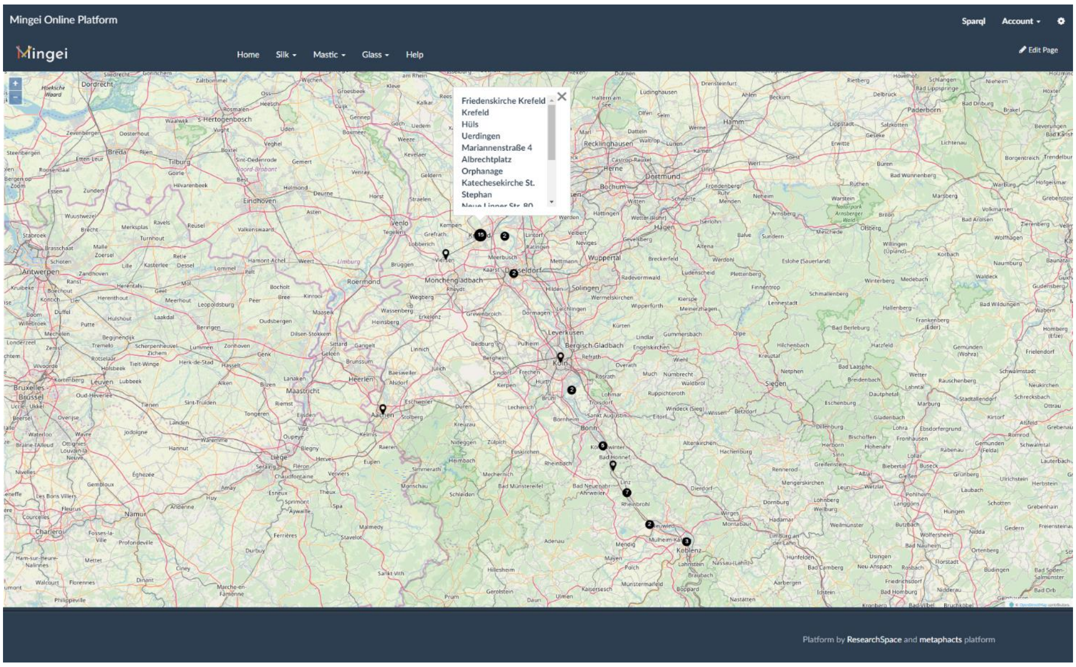


Figure 30. A timeline of events (top) of a narrative and their map locations (bottom).

The narration examples of this section, are indicative of the compositions that can be achieved using a simple hypertext output, such as a webpage. In the next step, we will explore multiple presentation modalities.

6.3.3 Practice and demonstration

In the same sense that a narrative narrates a fabula, a process narrates a corresponding, process schema. The process representation demonstrates the details of crafting processes, linking to recordings of this demonstration. In contrast to narrations, however, processes are always presented chronologically, interpreting the causal relations between conditional transitions and parallel tasks.

Similarly to a chronologic presentation of the fabula, a process is represented as a series of narration segments associated with events. In this case, these events are expressions of a process schema and thus can be associated with the knowledge elements that represent this schema. The presentation of a crafting process targets its reenactment and, thus, several dimensions are important to show in detail. Specifically:

- **Audiovisual and motion recordings** provide direct testimony of the events.
- **Explanations and commentary** complement audiovisual recordings, revealing the purpose and plan of action and indicating how to verify if the action was successful.
- **Keyframe and keyframe juxtaposition** (comics) in chronological order guides inference of human action and motion. Illustrated instructions presenting the stages of processing are key to the explanation of a schema.
- **Pictorial annotations** upon keyframes or videos, such as motion annotation, motion lines, or arrows facilitate comprehension of the movement and are widely used in visual instructions.
- **3D key poses and animations** of work gestures, grip and body posture, enable inspection from any viewpoint.

Using the media object abstraction any of these digital assets can be associated with presentation segments. As in the case of narratives, specific queries can enlighten the comprehension of a process. For example, a listing of the tools and materials that a process requires.

An example of organizing narration segments and associated media is shown below, obtained from the glasswork schema presented in Figure 31. The verbal description of steps is shown first in the text, followed by the video recordings of the represented actions. By linking the semantic representation of actions with their recordings an organised dataset is generated. The organisation is process-oriented, linking relevant descriptions and media objects together. In the next step, this organisation facilitates the input to diverse presentation modalities, specialising in the presentation of specific craft dimensions.

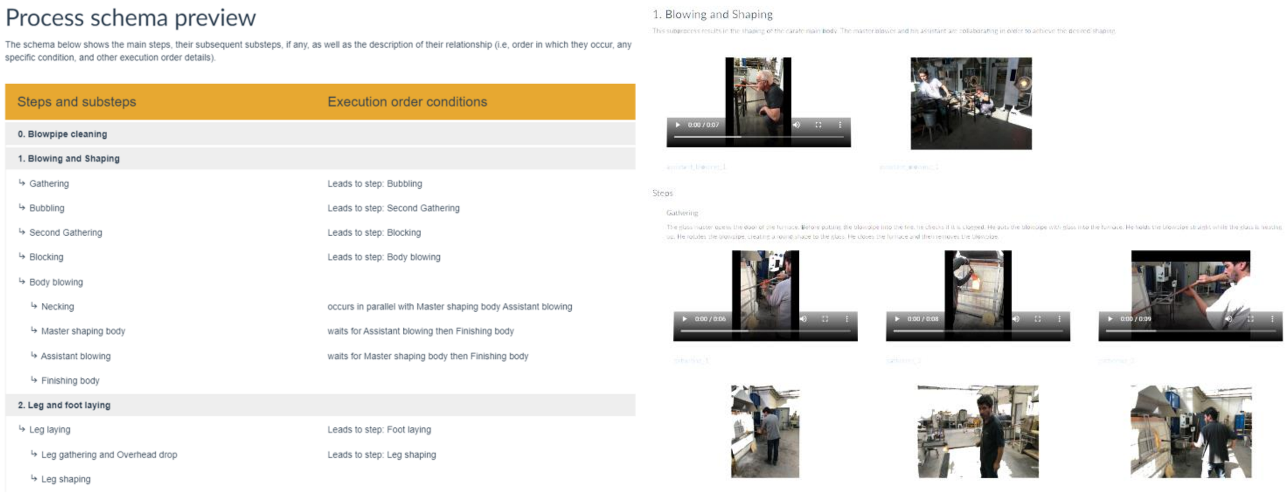


Figure 31. Verbal (left) and visual (right) presentation of a craft process representation.

6.3.4 Conclusion

Each narration fragment can be presented in more than one channel. A piece of text may be presented in written or audio form. In turn, audio narration may include dialogue, which can be recited by a single or by multiple speakers etc. At the same time, music can be played in the background on an independent audio channel. A mixer may modulate the levels of individual audio channels over time.

In a nutshell, what we propose is to organise the narration fragments of the stories or processes to be presented, so that they can be reused in multiple types of presentations. The organisation of fragments is event-based, depending on the events of a story or a process. For each event, we propose to collect pertinent verbal and visual narration content. The content can be presented in multiple media and formats, depending on the purpose of the presentation and the audience.

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Step 5 Presentation

A range of presentation modalities of relevance to craft presentation and presentation are proposed. These modalities are tailored to present different dimensions of craft expression. For these presentation modalities, the knowledge base is utilized as an infrastructure to provide content. This content can be digital assets, knowledge elements, narrations, and demonstrations.

The purpose of presentation modalities presentation of the contents of the knowledge base to humans, so that it catalyses the transmission of craft context and craft practice. Each presentation modality is a different narration medium and its format determines the use of the content. Depending on the content type, an appropriate narration channel is required. Multiple media can be employed to present narrations, starting from verbal and visual and reaching up to immersive and interactive narrations. A narration medium is utilized to communicate the story to the audience. Each narration has multiple presentations, which may differ in language or format (textual, audio, audiovisual, subtitled audiovisual, graphical novel, sign language etc).

7. Presentation modalities

7.1 Vocabularies

The direct output of the proposed organisation of knowledge is illustrated vocabularies of tools and crafting actions, which bring together verbal descriptions and visual recordings. In the same way, the steps where a specific tool is used can be retrieved, along with video recordings of such actions; and similarly, for the tools and materials required for a certain process. An example is provided for the case of Glass tools, in Figure 32.

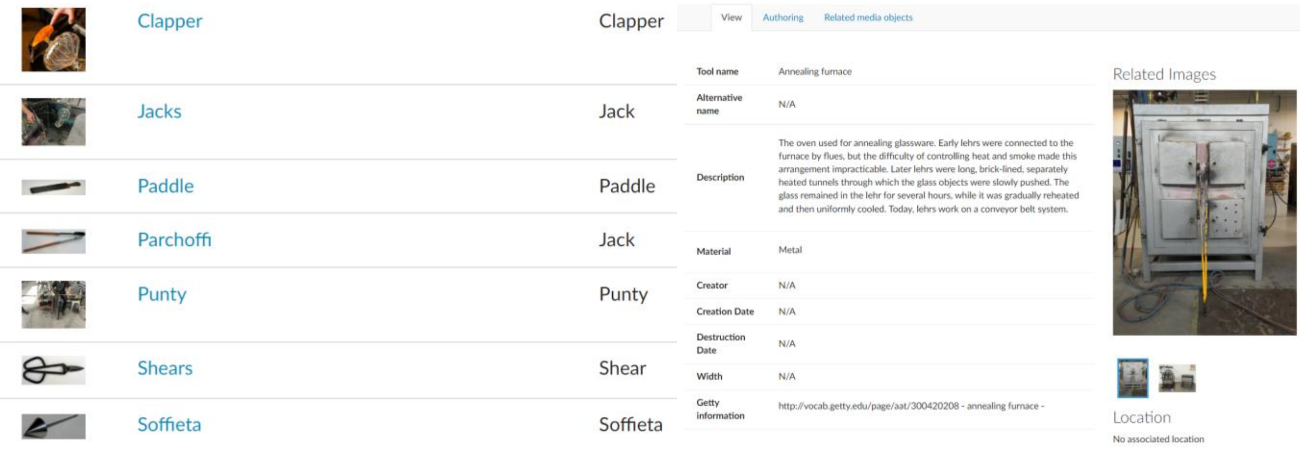

Figure 32. A vocabulary of glassblowing tools.

7.2 Keyframes and thick descriptions

The visualization of 3D human motion on a 2D canvas or display is employed by a wide spectrum of disciplines to abstract and provide insight into the motion of human subjects that is depicted by the 2D medium.

Illustrated and annotated visual instructions are used in a wide range of applications, where the transmission of practical knowledge on the physical manipulation of objects; examples can be found in safety, assembly, or usage instructions. Painters and illustrators have used specific annotations, such as motion lines and arrows, superimposition, and juxtaposition of visual keyframes for a better conveyance of human motion and action. Applications of human action visualization have wide use in 2D depictions, whether these are presented on screen or paper.

Several software commodities facilitate the creation of juxtaposed and annotated illustrations such as the one in Figure 33, which was created from key frames of digital assets acquired in Step 1. The example shows how to warp a spin of gold string used in the manufacturing of brocades.

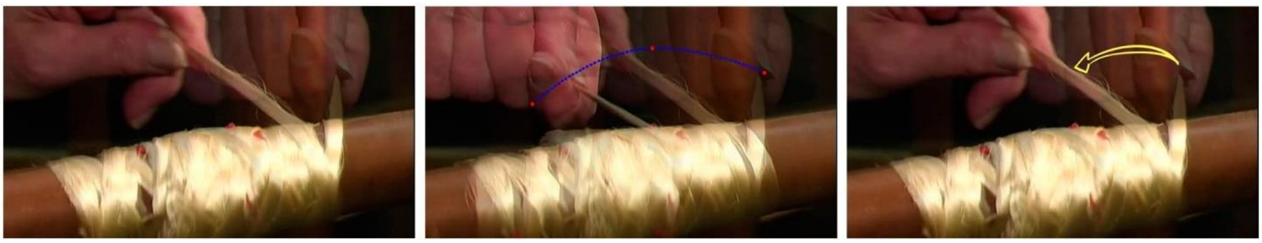

Figure 33. Illustrated instructions on producing a spin of gold string.

The textual annotation of juxtaposed keyframes is used in graphical novels and comics to create thick descriptions, where visual information is complemented with text. Figure 34, shown is an example from the field of glasswork where a carafe creation process is authored in the form of a graphical novel.

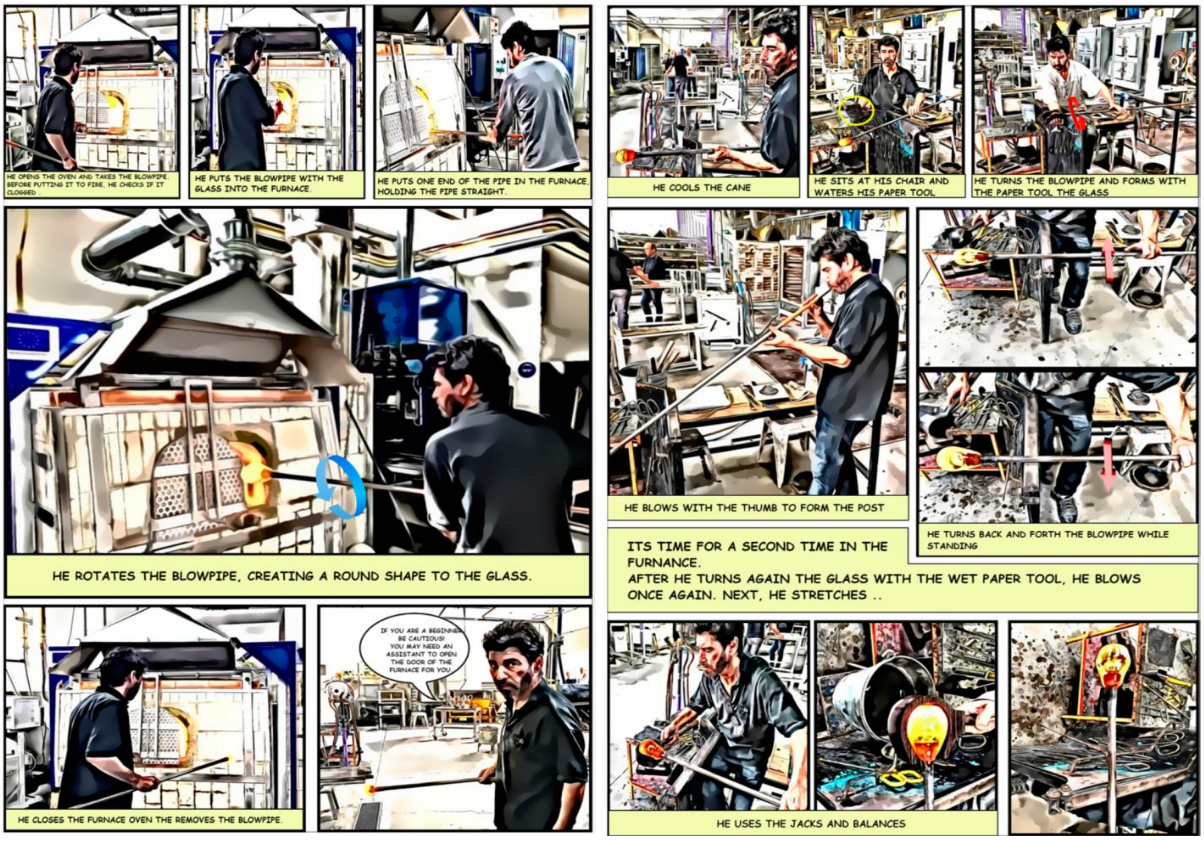

Figure 34. Illustrated instructions on glassblowing in the form of a graphic novel.

7.3 Audiovisual productions

Narrations can be in a form of ethnographic documentaries. The simplest narrative type is expository, which focuses on the provision of information on a topic and is based mainly on speech in the form of voice-over narration and interviews. The narration can be enhanced with images interviews, and archival material, assisting in the understanding of the subject.

Besides crafting process descriptions a list of prepared topics helps to motivate narration in front of the camera. The narration can contain the crafting process, the origin of materials, the tools used, and the final products. It is important to observe the area and the place and locate interesting shots.

After collecting the material, it is recommended to watch the collected material, select interesting video and audio clips, and through a simple editor (e.g. VideoPad).

You can use such an editor to assemble the shots you need and add the title of the documentary at the beginning of the video, including the name of the workshop and the place where it is situated. Add the logo of the project to be shown at the top right corner of the screen during the video.

Using such editors you can also use custom audio, including voice-over segments or music and adapt the visual material (images, videos) to the audio material and make use of interesting and attractive scenes, which are going to engage the interest of the viewers. Multilingual subtitles should transcribe voice and important sounds. Multiple languages can be supported this way.

At the end of the video, add credits to the people who participated in the video and those who worked behind the scenes. Provide information about your projects, such as the name and the source of funding. Export the final video in an mp4 file.

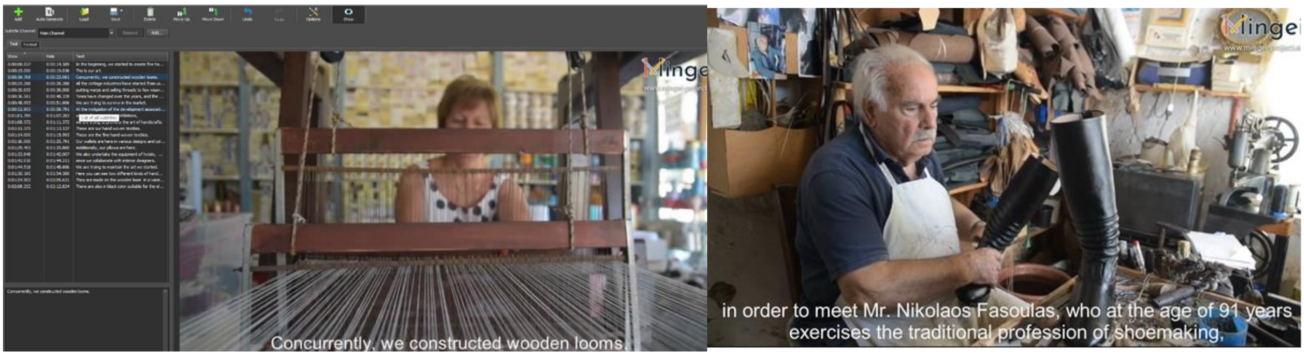

Figure 60. Creation of audiovisual narrations.

7.4 Virtual reenactment

Virtual Humans can be used for a virtual reenactment of crafting activities in 3D, available for inspection from the viewpoint of choice and learning by example (see Figure 35). The gestural know-how of the captured craft practitioner is used not only for replicating the movements of the practitioner but also for setting digitised craft tools in motion. The presented digital assets are treated as knowledge elements, retrieved from the MOP, with consistent naming, and linked to their semantic annotations. This is important because through these associations we can retrieve the actions and, in turn, corresponding motion assets demonstrating their use.

Figure 35.Demonstration of crafting activities by VHs.

7.5 Multimedia guides

The potential of audio and multimedia guides has increased with the proliferation of mobile devices. Starting from podcasts a variety of online and offline solutions exist today that enable museums and visitors to rapidly release accompanying content to permanent or temporary exhibitions. A central point in this effort is the organisation of content and digital assets.

Usually, for audio guides, the content has to be formalised for the duration needs of audio presentations. As such, it is recommended to prepare and organise content in a new presentation dedicated to the audio guide. A humble solution is to use the verbal narration content and multimedia and a voice synthesizer to create the audio narration. Better results are achieved with relatively little effort and still modest hardware equipment, namely a microphone.

It is important to record audio in a way that economizes post-processes and maximises compatibility with audio guide platforms. A sentence-by-sentence recording is recommended as it leads to initial audio files per sentence. Each sentence was recorded twice and the best recording was selected. The same recording equipment, speaker, and conditions should be preferably used for the recordings to economize on post-processing costs.

The example follows these instructions in the work of the curators of the Ethnographic Museum of Istria in Croatia. The exhibitions present traditional professions dedicating a room for each. Each exhibit inside a room is associated with a small narrative. The curators recorded their text sentence by sentence and compiled this content into an audio guide.

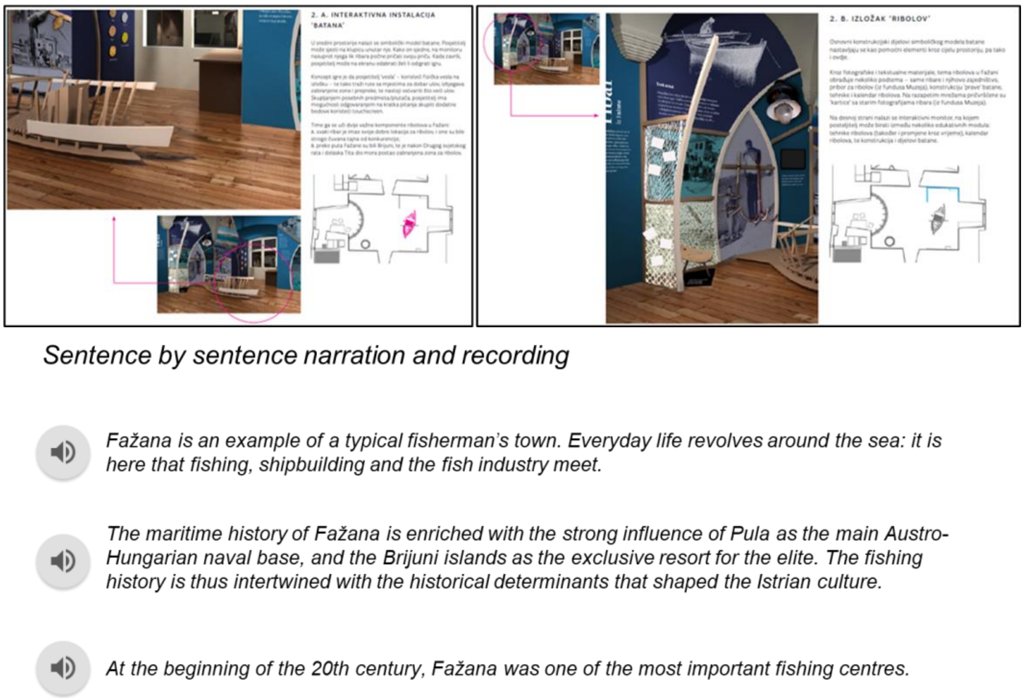

Figure 36. An audio guide.

The capacity of modern mobile devices enables the presentation of a wide range of multimedia types on mobile devices. These can be audiovisual productions, virtual reenactments, or virtual narration media.

7.6 Virtual narrators

Considering the penetration of new digital media in such physical and virtual spaces lack of accessibility may result to exclusion of a large user population. A cost-effective methodology for the implementation of VHs capable of narrating content in Sign Language is proposed. The methodology uses MoCap recording and VH animation.

Virtual Humans are today considered a commodity in the domain of computer animation, cinema, and games. Recent technical advances in VR and AR are accessible to the public through powerful mobile devices and inexpensive VR headsets.

A cost-effective methodology for achieving realistic storyteller VHs creation for CH applications is presented. The proposed methodology covers all steps of the creation and presentation of virtual storytellers in various settings including VR and AR, focusing on their looks, movement, and speech.

The primary hypothesis of realistic storytelling animation is that it is important that they look, move, and sound natural. Ultra-high-resolution VHs makes their appearance realistic, MoCap ensures that animations look natural, and software that can use voice recordings, lip-synching and facial expressions. The workflow proposed is shown in Figure 37. First, high-resolution VHs are created. Then, a MoCap is used to record the narrator's motion for the stories. The voice clips of each narration should be recorded in parallel with the motion capturing, as this will allow for synchronization between the recorded animation and the audio. To retarget the captured animation to the VH, a game engine is employed (in our case Unity). Voice recordings are used for narrations instead of synthetic speech. The face and lips of the VH are automatically controlled via software and that face-capturing solution should be avoided in the context discussed so that updates in voice recordings need not be accompanied by a re-capture of facial motion.

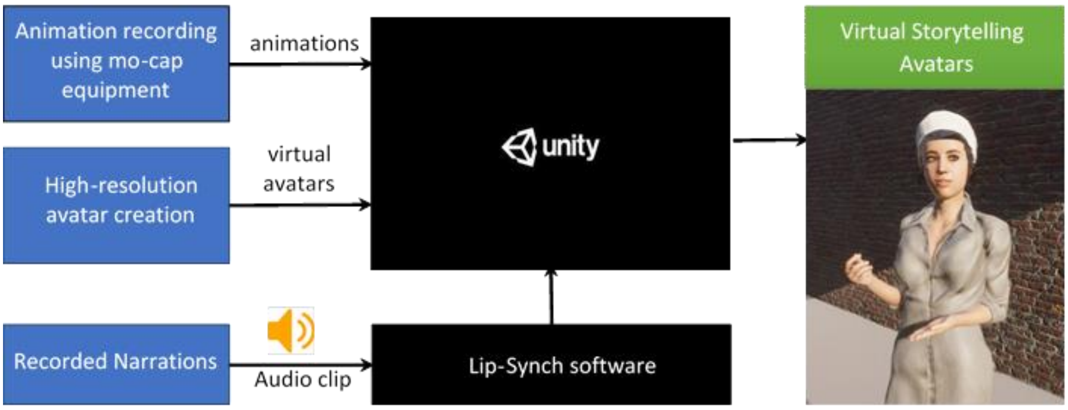

Figure 37. The workflow to bring narrator VHs to life.

Using MoCap is recommended in the recording of body motion during narration to be more realistic. It is also recommended to narrate the stories during the voice recordings to capture body language concerning the narrated content. This way, synchronization of voice and movement in the narration is easier and natural narration is guaranteed.

The main purpose of storyteller VHs is to complement a user’s visit to a CH site with audio stories. The narrator’s voice sounds clear and natural, while slight fluctuations in the narrator’s tone, speed, and volume can arise users’ interest and draw their attention to what’s important. This comes at the cost of having to process or re-record the audio clip every time the narration script changes. It is recommended to record natural human voice for every narration part that the humans have to reproduce, in separate audio clips so that the re-recording part (if needed) should be easier.

7.7 Sign Language

The proposed methodology is comprised of six steps, shown in Figure 38. In the first step, the narrative is authored, as in Step 1, and is optimized for Sign Language presentation. Then the VHs are implemented considering the characteristics of the person narrating the story (e.g. age, gender, occupation, historical clothing, etc.). Then, the narration is recorded using MoCap, both in sign language and orally. The resulting audio and animations are retargeted to animate the Virtual Narrator with the animation sequence defined by the recorded animation file. The resulting animations are exported in conventional 3D formats to augment the content of 3D applications delivered through standalone applications, the Web, mobile devices, AR, and VR.

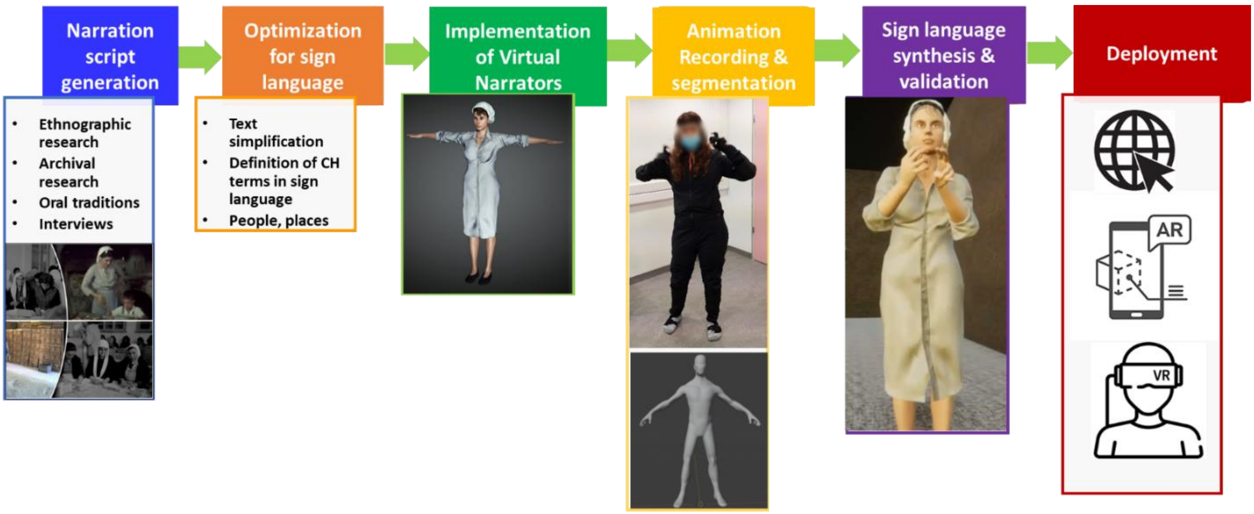

Figure 38. Illustration of the methodology for producing Sign Language animations performed by Virtual Narrators.

An example of such an application is shown in Figure 39. The methodology used to implement an application that provides narrations for visitors in AR. Upon activation of the application, the VH appears and provides different narration options. All narrations are available in plain language and sign language.

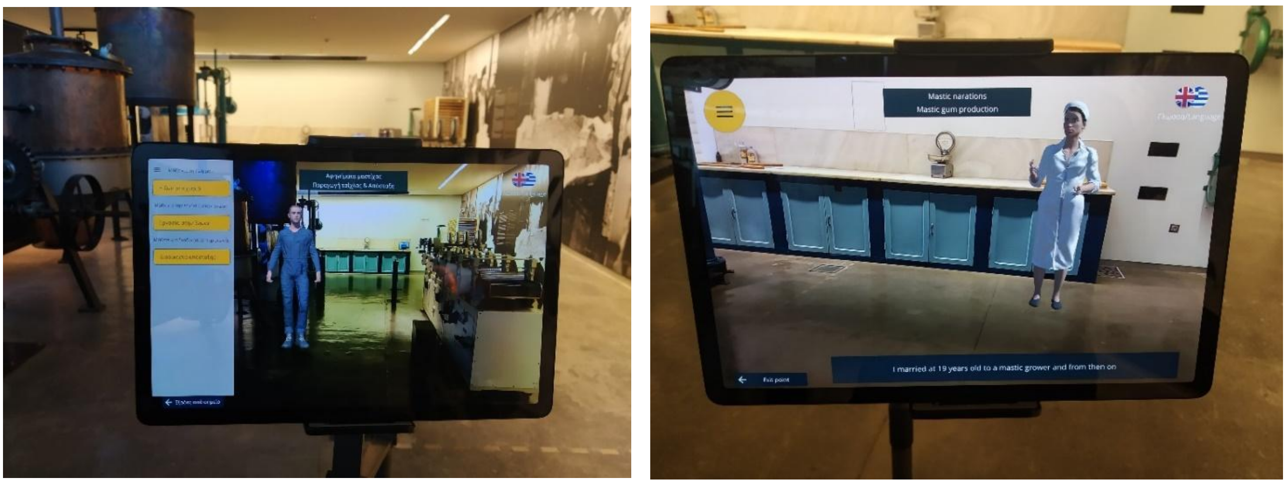

Figure 39 Virtual Narrators delivering oral and Sign Language narrations at the Mastic Museum of Chios.

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Step 6 Preservation

In this step, we provide indicative applications for the provision of experiential craft presentations. We then provide proposals of how the developed representations and technologies can be employed for the goal of craft preservation. We end this handbook with an identification of the limitations of this work and an outlook for future work.

8. Experiential presentations

8.1 Place-oriented presentation modalities

The presentation of environments is facilitated by spatial presentation modalities. The geographical organisation of narratives can be directly utilised in presentation modalities oriented to the presentation of geographical and spatial information. All spatial representations are enriched with locations of interest that are associated with knowledge elements in the ontology and occurred as predetermined locations on the map. These locations and associated digital assets can be retrieved directly from the knowledge base or other repositories. This way, spatial presentations can be enriched with any type of digital asset in the knowledge base, such as 3D reconstructions, historical information, video data, etc.

The basic elements of place-oriented presentation modalities are shown in Figure 40. The first is a system to create an immersive projection room that overviews a 3D environment, interactively navigating from bird-eye viewpoints. The second is a lightweight presentation of a 3D geophysical for mobile platforms.

Figure 40. Immersive and mobile presentation of geophysical context.

The additional information stemming from the 3D models of architectural structures and crafting environments can be explored multiply. The most typical is 3D navigation a 3D. More immersive experiences include a VR headset. A component that produces video output for a predetermined walkthrough of the virtual camera is recommended. The tool can contain a few common trajectories that can be parameterised, such as circling through an object of interest, rotating an object for inspection, looking around, etc. This is used extension to systematically create videos of 3D digital assets, for demonstration purposes. The primary video can then be enhanced with narration, subtitles, music etc. In addition, the tool can provide additional rendering modes (i.e., textureless, wireframe, etc.), to provide a detailed illustration of the geometrical structure where needed. The intended results tool is demonstrated in the two examples.

The first example regards the craft of Dry-Stone Walling (ICH, UNESCO inscription 14.COM 10.b.2). In the example (see Figure 41), traditional settlements for moving husbandry (ICH, UNESCO inscription 13.COM 10.b.10), which were built by Dry Stone Walling is presented, via a guided virtual walkthrough. The scene is composed of multiple scans, to support viewing both the inside and the outside of the structures.

Figure 41. Virtual walkthrough of husbandry settlements at the Psiloritis UNESCO Global GeoPark.

The second example regards the architecture of Mastic villages at Chios. The overview shows how the architecture served as a fortification of the village, for protection against invaders and pirates. Information on geographical location and context shows the environmental aspects affecting craft practice and development. During the flyover, users can stop at each village and retrieve multimedia and text information related to those villages as shown in Figure 42.

Figure 42. Annotated 3D reconstruction and virtual flyover.

A first-person VR application can be also used to explore places from a more realistic, first-person view, as in Figure 52. Conventional game engines enable virtual exploration of the natural environment from a terrestrial viewpoint. The terrain of the game is generated by importing the geophysical map. Then flora and fauna were imported together with 3D reconstructions of villages. In historical places, games can provide an exploration of different eras.

Figure 52. A VR application for the exploration of the natural environment of Chios.

8.2 Virtual exhibits in real places

The interactive modality shown in Figure 61 can present collections of digital assets in a physical space through interactive projections. The modality is designed having in mind that several museums have a large collection of artefacts in their storage, but no room to display them o represent past period exhibitions, to virtually re-visit them after they have ended. The modality enables interactive inspection of artefacts through gestures, and access to accompanying verbal and visual assets relevant to the exhibit, which are retrieved from the knowledge base.

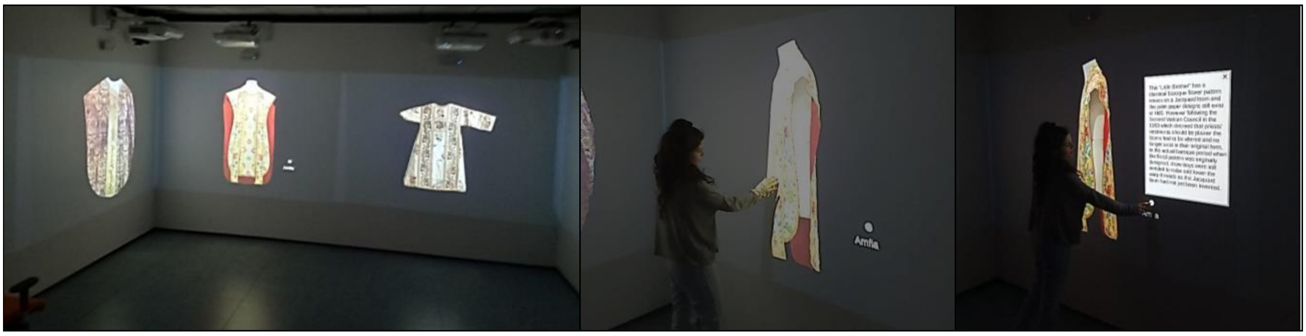

Figure 43. An interactive presentation modality for 3D models.

8.3 Mobile clients

Online educational games can be created in the form of mobile applications, available on Android and iOS. For textile design and manufacturing, two games were specifically designed to explain both the design of a pattern for a Jacquard loom and how the punching card is created from the paper design. For mastic cultivation, applications focus on seasonality and the cultivation tasks per time of year (see Figure 44).

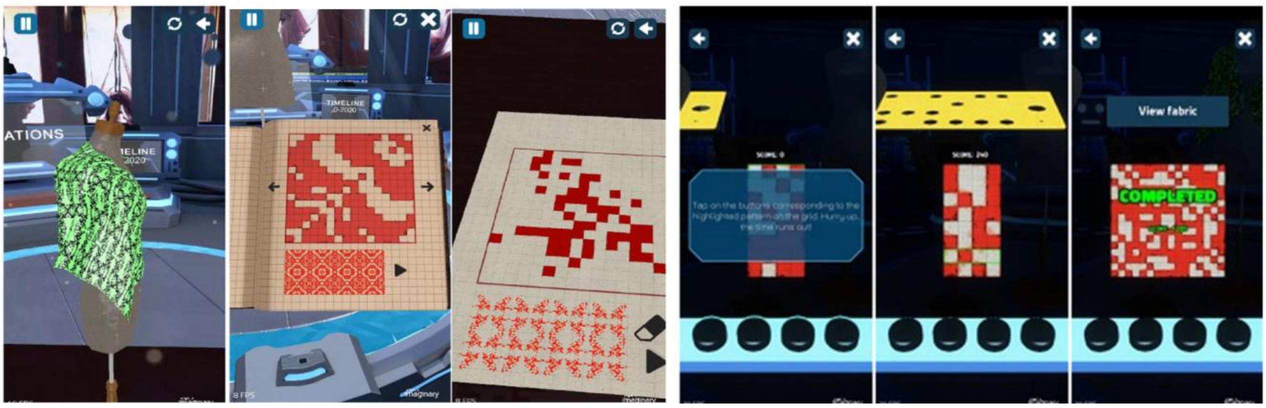

Figure 44. Edutainment applications for textiles design and manufacturing.

8.4 References and further reading

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9. Preservation applications

9.1 Awareness

Awareness and promotion of crafts are recommended to counter the *"falling demand or decreasing markets for craft product are partially due to a lack of awareness from potential customers that the craft exists"*. A Community Portal can provide a preliminary inventory for crafts, moderated content collections, digital exhibitions, technology, identity, and values, History of Art and Art movements, identification of communities that developed techniques and designs and traditions, memories, and values, and highlight common European culture due to crafts. Regional authorities will be welcome to add their local content to promote local identity, materials, products, and tourism services.

The provision of experiences, through introductory educational applications on HCs. Having a first-hand experience yields an experiential and better insight into HC and avails a cultural visit of significantly greater impact. In this way, a competitive advantage is to be provided for institutions and HC communities related to the tourism industry. HC learning experiences are strongly grounded in location and provide a "sense of place", directly promoting the regional tourism industry. The targeted raise of interest aims to attract prospective apprentices, whose lack of is a central problem in HC preservation. Educational services and conclusions obtained from their evaluation are expected to pave the way for more formal ways of supporting the teaching and preservation of HCs.

9.2 Education

Craft education regards theoretical craft knowledge taught in the classroom or the workshop. Technology is continuously providing tools aiding (remote) education and learning. Using digital assets for the curation of educational material can be streamlined with the following goals.

Introduce vocabulary, principles of material treatment, crafting processes, workspace configuration, recipes, work gestures, and measurement tools (e.g., tape measure, level). The semantic counterpart of these representations will produce verbal and visual instructions illustrating and guiding reenactment.

Guide across the inventory of techniques and learn to plan workflows. Focus on "skilled monitoring", the ability to evaluate changes brought by practitioner actions and decide if they "conform to images of how the work should look at any given stage of production". Theoretical problems as in Figure 45 ask to answer how the inventory of tools and techniques can be used to achieve the requested result.

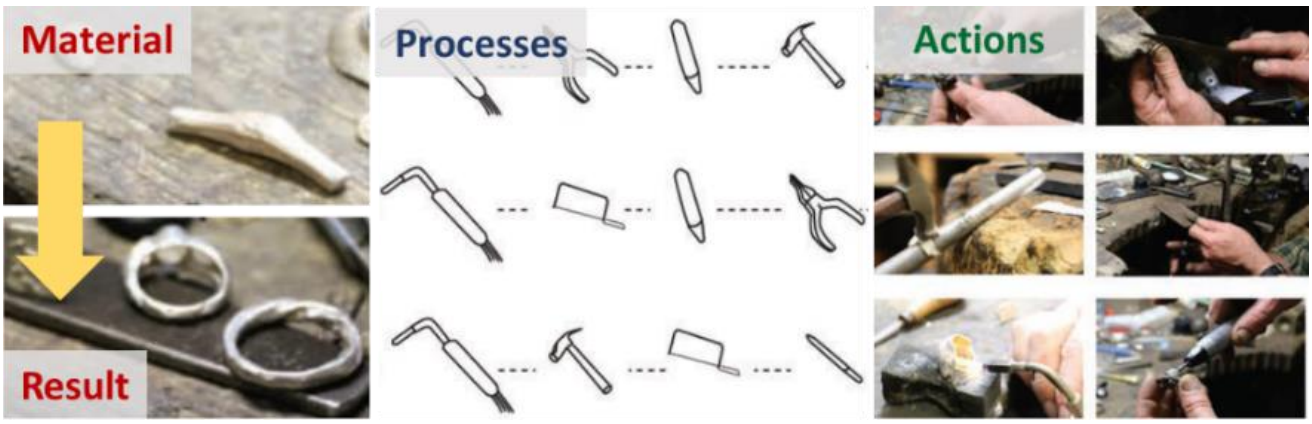

Figure 45. An educational exercise prompts the selection of tools and actions to achieve a specific result given a piece of material.

Develop critical thinking and judgement on treating craft as a problem-solving process and learn principles of continuous design and improvisation, as well as the handling of errors.

The provision of explanatory & interactive simulations enables learning by observation, enabling modulation of action parameters and study of their effects. The material should acknowledge that mistakes and uncertainty are part of skill development and positive reward systems. Immersion can be used for safety training before visiting the workshop. Commonly occurring errors and their handling will be included in education.

Educational programmes aided by the codesign and adoption of digital aids in knowledge transmission and training and certify digital design and fabrication capacities, across the range of materials and ways of formal and informal learning. To acknowledge this experience one can award personal badges that represent participation in events, with a role (e.g. student, instructor) and also provide the means to create personal portfolios of works and technique contributions.

9.3 Tutoring

Tutoring supports earning a living from a craft through teaching. Simple and immersive telepresence can be appropriated to enable essential interpersonal communication in online tutoring, feedback, and technical assistance on student work, widen access to craft instructors and engage remote students. Advanced tutoring services regard specific techniques for experienced crafters, to reach new markets.

Informal learning in workshops and masterclasses can be streamlined by authoring tools for educational material and skill development media, compatible with hybrid (online/onsite) participation. Live streaming tools for the transmission of practical knowledge, underscoring preference for multimodal and multichannel communication, to simultaneously show multiple views, narrate, visually annotate, and browse accompanying material.

9.4 Tourism and CHIs

Engaging cultural experiences have a positive impact on interest growth and tourism, which support HC communities and institutions and foster HC sustainability and preservation. Similarly, global trends in the valorisation of ICH indicate that the provision of tools to support the digital representation of ICH is expected to further assist this growth. Technologies for storytelling, and mobile and remote accessibility facilitate the reach of wider audiences. Training and educational tools contribute to the preservation of HCs and the long-term sustainability of associated economies. This is of significance, as the economic resource yielded through heritage and the re-use of digital assets is a primary motivator and funding source for CH preservation.

The example in Figure 46 comes from pottery and follows the basic steps that take place in different sites or workspace locations illustrating the collection of soil, its kneading into clay, its shaping into clay bodies on the potter's wheel, its decoration, and their firing.

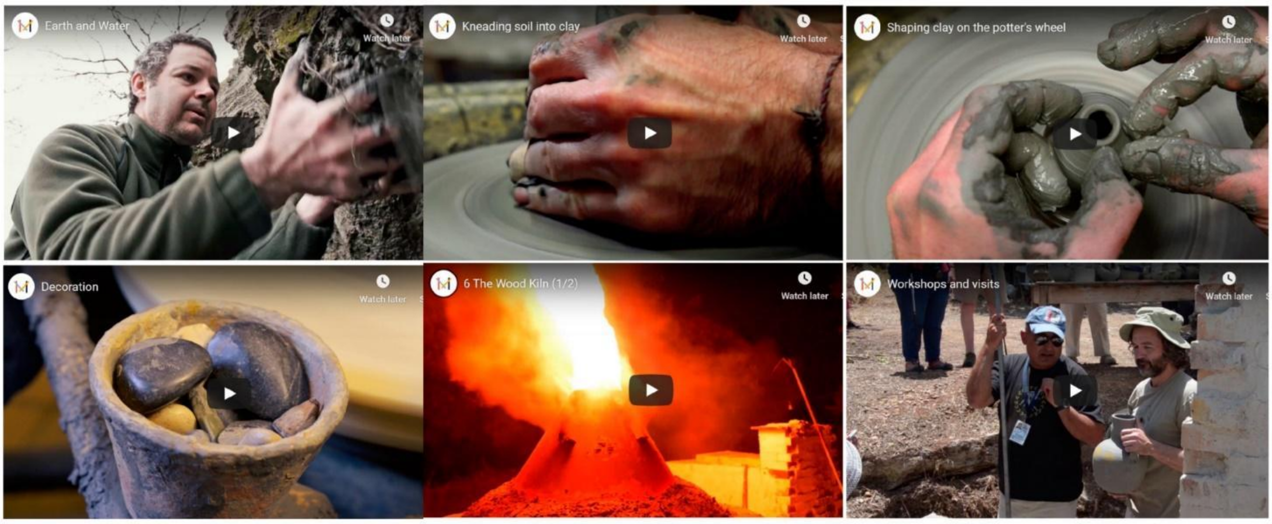

Figure 46. Pottery stages from the collection of raw material to the firing of clay bodies.

The improved preservation of objects, collections and sites enhances cultural history and cultural tourism. New content is useful for museums and CHIs in the form of comprehensive HC presentations. This new content when presented in captivating ways and a personalized fashion, adds to the services that CHIs provide. These services contribute to CH-related tourism, with enhanced content and thematic services that are expected to raise interest and awareness towards respective institutions' HCs.

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10. Outlook

Capacity-building aims to ensure the widest possible participation of all relevant stakeholders, especially relevant community groups, in the design and implementation of safeguarding activities. In this context, Mingei strives to provide good practice guides and technical tools for communities to manage and promote their content and outreach.

10.1 Limitations

A special type of knowledge included in crafts is “felt knowledge” or knowledge that is based on the sensory perception of practitioners. This is the practitioner’s interpretation of her qualia, to perceive the materials and her makings. Examples are the haptic sensation of a material (i.e. plaster dampness of the potter, or roughness of a textile), the sensations of heat and smell (i.e., in the glassmaking process), or the colour of an object, which is exploited by a skilled practitioner.

There exist ways to measure some of the physical properties that give rise to qualia, such as humidity, temperature, spectral, and chemical measurements. However, it ought to be pointed out that a CRAFT practitioner uses her senses. This is a limitation as technology does yet avail pertinent recordings.

A way that humans overcome this limitation and communicate the way they feel is verbal communication. Practitioner testimonies and narrations of their experiences are important and recorded, in the Mingei protocol. Another is through visual art or other types of abstractions. Yet, another way is to obtain own experiences. Skill development is facilitated by instruction, observation, and guided practice, (i.e. apprenticeship, tutoring) that leads to a skilled interpretation of qualia. The Mingei protocol will facilitate the design of experiential presentations that avail sensory stimuli and facilitate the development of craft skills. The co-design of these experiences with practitioners is mandatory for their relevance.

In the context of using the Mingei protocol, it is underscored that understanding a craft cannot be a theoretical only task. All of the narrations, documentaries and VR demonstrators cannot recreate “felt experiences”. Thus, besides conventional digital tools, Mingei representations include the knowledge for craft re-enactment, through the meticulous representation of craft processes and techniques.

10.2 Future objectives and work

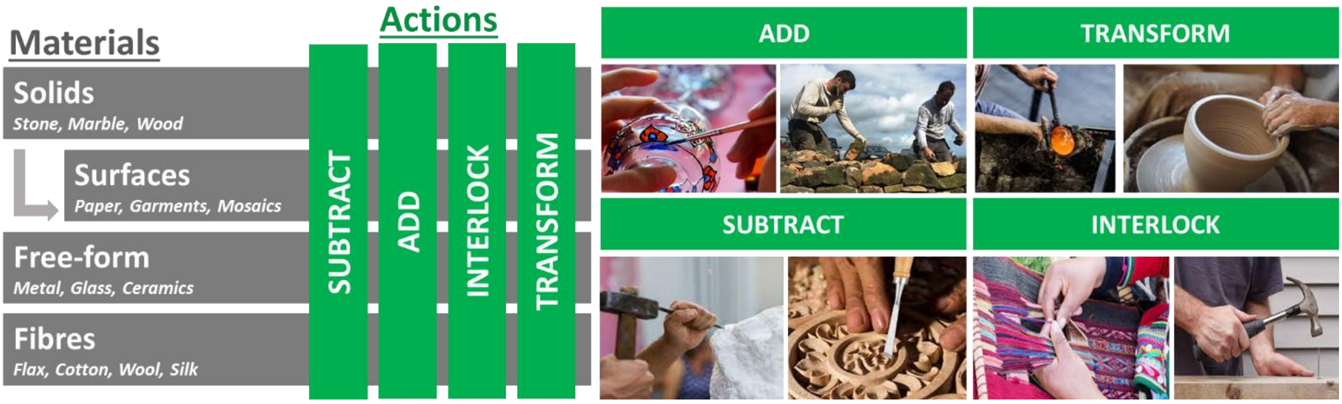
Our effort towards the exploration of CH digitisation does not end here. Parts of this work have been showcased as good practices in the “DigiTraining” Creative Europe co-funded project. Furthermore, this work has been published in several scientific publications in Open Access and public deliverables of Mingei. They are all available on the website of the project at https://www.mingei-project.eu/

Our intention is to keep updating it along with the opportunities we have for research and, in particular, in the forthcoming Research and Innovation Action, Craeft, “Craft Understanding, Education, Training, and Preservation for Posterity and Prosperity” to start in 2023.

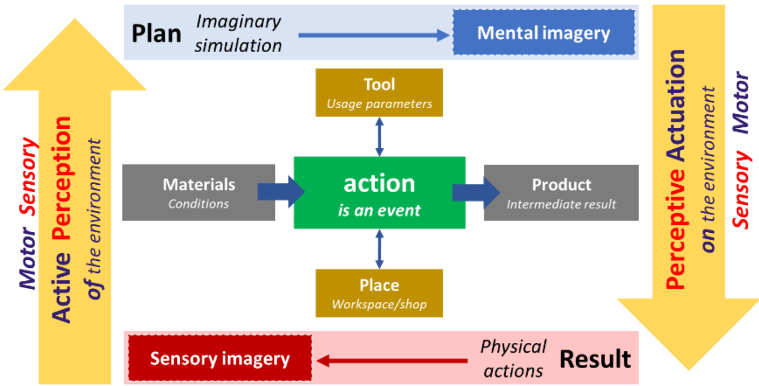
We state here some of the objectives we plan to study in the future and complement this handbook with their results.

10.2.1 Understanding crafting actions and processes, in a Maker-Material-Negotiation model

Craft taxonomies are material-oriented and classify materials by origin (mineral, flora, and fauna are the main classes) and special categories exist for compositions (e.g., musical instruments, brocades). To cope with the diversity of crafting techniques we adopt two classifications (see figure below), (1) Actions are classified into Add, Subtract, Interlock, or Transform operations. (2) Materials are classified by compatibility to practitioner actions, as Free-form (plastic) materials that take any shape, Fibres interlocked into fabrics and Solids that are reduced to a subset of their original volume. A notable subclass of 3D solids is 2D surfaces. Some crafts combine techniques, as in the crafting of musical instruments.



Through a unifying model, the mechanical, perceptual, and intellectual components of crafting activities can be brought together, as the negotiation between the maker and the material, with the following notions.



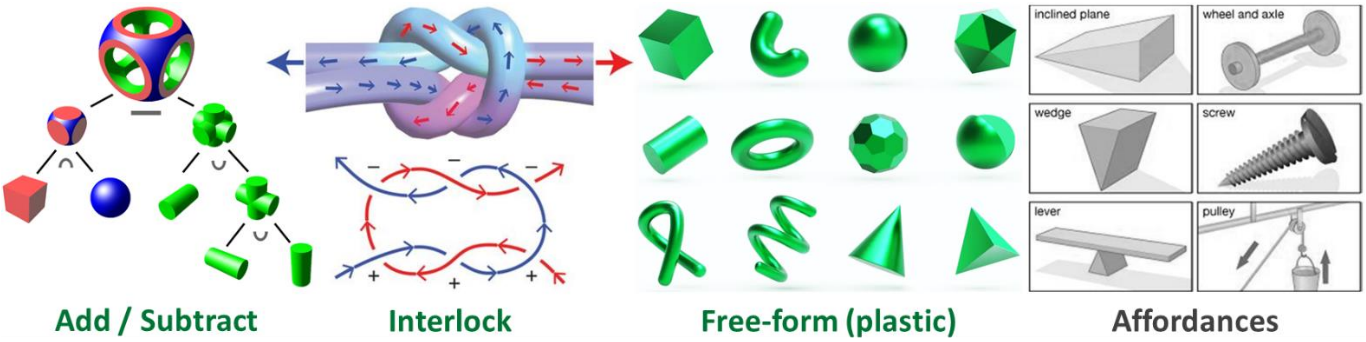
In crafts, actions transform materials. Action is the unit activity attended by a practitioner. Action plans are hypotheses for the achievement of goals, under prescribed conditions on the state and the spatial arrangement of materials. Plans require power and affordances, availed by working spaces, hands & body, and tools, and agents of, heat, moisture, chemical reaction or colour pigmentation. A goal is encoded in mental imagery, as the result of a mental simulation (planning). Mental imagery envisages the anticipated sensory imagery, should the goal be achieved. Actions upon materials are mediated by tools and/or hands. During the action, the practitioner attends to external (sensory) and internal (somatosensory) stimuli that inform on the course of the action. The practitioner modulates actuation parameters accordingly. The result is attended in perceptual imagery created by the senses. Due to actuation, more stimuli are generated. Some actions even have solely sensory goals, e.g. tactile inspection of surface smoothness. A technique or crafting process combines actions in umbrella plan called a process schema. Crafting processes interchange between work of risk and certainty. Special plans are made to handle errors. After acting, the practitioner compares mental and sensory imagery and updates or reconfirms the action parameters. Upon completion of a process, the practitioner reflects on its course and outcome and may update it.

Memories of internal signals (qualia) will be verbally testified, but also recognised out of simulated imagery generated by audio, visual, or haptic rendering. The particular rendering is, then, a digitisation of the sensory imagery the practitioner feels. The use of tacit knowledge is revealed by psychophysical analytics on perceptual performance (i.e., two-alternative forced-choice) tools. In these ways, advanced ethnographic observations will be designed and applied in eight RCIs spanning the range of techniques and materials.

The two foundations for the ethnographic documentation practices foreseen stem are the following. First, conventional ethnographic methods target craft work in the crafting workshop. Second, prior work of members of the consortium produced in the Mingei H2020 IA on the digitisation of and on craft traditional crafting processes representation will be employed. These works will be extended to cover aspects not captured by the above methods and, specifically, those aspects pertaining to tacit and ‘felt’ knowledge that cannot be captured by conventional digitisation methods. To achieve this, haptic interfaces will be used to synthesise this knowledge.

10.2.2 Digital reenactment of craft actions and processes

Understanding a cognitive process means being able to recreate or simulate it. To validate the sufficiency of the model, CRAEFT will create a generator for craft-specific simulators, based on generative a set of adaptive archetypal action simulators. Archetypal simulators will digitally reenact the basic classes of actions, abstracting mechanics via computational modelling of operation principles of (1) Add/Subtract by Constructive Solid Geometry, (2) Interlock by Knot/Textile Algebras, and (3) Free-form by mass-preserving, free-form 3D and 2D transforms. Simulators will model mechanical affordances as Archimedean Simple Machines (e.g. a knife is a wedge) or physical & chemical (conditioning) agents i.e., heat, moisture, chemical etc. Hands (and feet) enable a sea of diverse affordances and mechanics, are agents of energy, and dexterous force, and are (also) tactile sensors. Naturally, hand interaction follows the laws of physics, but the – yet unsurpassed – delicacy and granularity of control and sensation are to be studied more closely.



The proposed generator will refine archetypal simulators to specific craft-specific simulator instances. The implementation will use Artificial Intelligence to transfer knowledge and learn to simulate actions by refining archetypes from craft element annotations that associate semantic knowledge entities with digital recordings of hand, body, tool motion, gestures, material transformation events (semiotics), knowledge of the action taking place, and 3D/4D reconstruction of all material, dynamic events and deformations. The training of this generator will be scrutinous using comparative studies, to learn how the same action is parameterised and manifested across tools and materials.

Action simulators will visualise techniques, enable modulation of action parameters, space and time, offer inventories of tools, and predict the results of the action on the material. Such action simulations will be semi-automatically generated, with the human practitioner in the loop to ensure realism. Process simulators will organise actions and bring together partial results, considering fabrication constraints (e.g. order, concurrency, decision points) and spatial constraints of the workshop.

The simulation result, a realistic virtual artefact, is regarded as (simulated) mental imagery. Simulation analytics log the material quantity used or wasted, energy and time spent, work gestures and 'choreography' collaborating practitioners.

The Craft Studio will import and combine action and process simulators and enable 3D modelling and 4D simulation in a virtual workspace. The workspace will be experienced through conventional 3D multimedia or in immersive mode, stereoscopically and haptically. Visual immersive interfaces will include AR and VR. Haptics will simulate sensations created from the interaction of tools with materials. A special view of this environment will be the main interface for education and training applications and will be dedicated to problem-solving and dexterous exercises for the student: Educational simulations on action hypotheses and process schemas and Training simulations on sensorimotor, real-time tool control.

10.2.3 Education

Craft education regards theoretical craft knowledge taught in the classroom, i.e., inventory of tools, material conditions, material preparation recipes, and techniques. Technology is continuously providing tools aiding (remote) education and learning. We plan to blueprint the requirements and pave the way to adopt such tools in craft education, rather than adapt to the tools that will be, or are, available. Using digital assets We plan to streamline the curation of educational material per craft to:

[1. Introduce] vocabulary, principles of material treatment, crafting processes, workspace configuration, recipes, work gestures, and measurement tools (e.g., tape measure, level). The semantic counterpart of these representations will produce verbal and visual instructions illustrating and guiding reenactment.

[2. Guide] across the inventory of techniques and learn to plan workflows. Focus on skilled monitoring, the ability to evaluate changes brought by practitioner actions and decide if they conform to images of how the work should look at any given stage of production. Theoretical problems ask to answer how the inventory of tools and techniques can be used to achieve the requested result. These materials will be reused for experimental archaeology and simplified for general audiences (e.g., experiential presentations for ethnographic CHIs).

[3. Develop] critical thinking and judgement on treating craft as a problem-solving process and learn principles of continuous design and improvisation, as well as the handling of errors. For this reason, we plan to implement the import of partial results, to enter them and judge/predict the effect of the next action planned and assess risks.

10.2.4 Training

Mastery, tacit or embodied, knowledge and perception are recognised as the skill to move work as quickly as possible with a minimum of physical errors. Central to the development of dexterity, are learned interpretations of stimuli and experienced performance of appropriate actions. The way people master skills is through repeated practice. In crafts, the practice has a cost in material and workshop usage and, often, the instructor has to be present for the guidance of posture, attention, and action parameters. VR/AR systems are systematically used for vocational training. We plan to create craft-specific immersive vocational training systems with haptic interaction for tactile sensing and actuation. Passive and dynamic haptic rendering, will simulate inspective tactile sensing, tool usage, inertia due to the weight of objects, and handheld digital design tools with feedback using simple DIY hardware. These systems will economise the development of monitoring and actuation skills, by enabling (a) practice away from the workshop (b) repeated practice on virtual materials (c) immersive telepresence of instructors, to:

Educate [train] attention, and learn to detect and attend to perceptual stimuli and interpret their meaning in the monitoring and control of the action at hand. These stimuli are (a) external (e.g. audio/video), signifying material qualities, properties, and events and (b) internal (e.g., proprioceptive, tactile), on awareness of hand & body posture, modulation of applied force/tension, incidence angle etc. We plan to create training exercises in immersive simulation to train attention and interpretation of stimuli. Simulations will accustom the user to the audio environment (soundscape) of workshops, where noise is often present.

Train actuation regards the development of dexterous manipulation for tools of risk. In handwork, tactile interaction is essential to achieve realistic and beneficial training experiences for training both active perception and perceptive actuation. We plan to combine haptic rendering and immersive environments to (1) Introduce the affordances provided by hands and tools and their degrees of freedom and (2) Guide through action variability on different pieces of material. As bimanual coordination is crucial in the majority of tasks, we plan to draw ideas from background work on bimanual haptic controllers. (3) Develop actuation, coordination, and synchronisation skills, through opportunities for repeated practice, particularly for free-hand operations. Stress destabilises the learning process and, thus, training simulators will slow down the time to ease the practical challenge, similarly to music where practice initiates with a slow tempo.

10.2.5 Design

Develop new ideas, techniques, styles, and designs, first in realistic simulation (as a 'sketch') and then in the workshop, thus reducing experimentation costs. The workflow followed in a craft process is the practitioner's interpretation of the design, even if the designer and the maker are the same people. Risk, though, has a toll on material, energy, workspace usage, and practitioner time.

Haptic interfaces for design tools that capture the delicacy of human touch and increase design possibilities but also prepare for the actions to take place in the workshop.

Craft-specific 3D editing tools, similar to these raster and 3D graphics editors use. These tools will mimic actions on virtual materials. The workflow followed to create the virtual model is then exported as verbal and visual instructions to use in the real workshop. Efficient workflows lead to material savings.

Craft-specific computer-aided design tools that transfer designs and styles from digital assets and assist design with design templates and values that apply classic design principles including, Gestalt principles of perceptual organisation, symmetry, rhythm, and figure/ground separation, for images, anaglyphs, and 3D structures.

Manufacture specialised aids for the implementation of a workflow. This way, design-specific aids are easily fabricated and menial workflow parts automated.

Visual & haptic artefact preview in real environments in VR & AR. The utilisation of high-resolution surface scanning for accurate visual & haptic rendering. Visual simulation of the interaction of an artefact with illumination, to be implemented by the True-AR infrastructure. Haptic sensation from 2½D surface scanning.

Parts & pieces will be treated in the workflow implementation for the realistic functional preview of assets but also to study and optimise their implementation workflow.

Public comments and invitations for collaboration in further research are welcome.

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Annex A Web links

Web links in this document are provided in full text in this Annex. All references were accessed on the publication date of this version of the handbook.

3D ICONS Guidelines http://3dicons-project.eu/guidelines-and-case-studies/guidelines

Crazy Minnow Studio's Salsa lip-sync suite https://crazyminnowstudio.com/docs/salsa-lip-sync/modules/overview/

Cultural Heritage Imaging http://culturalheritageimaging.org/

Digitization Standards for the Canadian Museum of Civilization Corporation https://www.canada.ca/content/dam/chin-rcip/documents/services/digitization/standards-canadian-museum-civilization/smcc_numerisation-cmcc_digitization-eng.pdf?WT.contentAuthority=4.4.10

Encyclopaedia Britannica https://www.britannica.com/

European Commission's ethics self-assessment guidance http://ec.europa.eu/research/participants/docs/h2020-funding-guide/cross-cutting-issues/ethics_en.htm

Europeana https://www.europeana.eu/

Google Arts and Culture https://artsandculture.google.com/

Google Books https://books.google.com/

UNESCO Digital Library https://unesdoc.unesco.org/

UNESCO Intangible Cultural Heritage https://ich.unesco.org/

UNESCO page on Traditional Craftsmanship https://ich.unesco.org/en/traditional-craftsmanship-00057

UNESCO World Heritage Centre https://whc.unesco.org/

Wikipedia https://www.wikipedia.org/

Annex B Co-creation results on patterned silk textile manufacturing

The following is an example of the co-creation results in the form of notes, regarding the manufacturing of patterned silk textiles, using the Jacquard technology. It describes the overall process in steps that can be further analysed. At the same time, it provides a naming of the roles that each step requires.

1. Pattern Designer (Musterzeichner)

The pattern designer develops ideas for patterns which are to be incorporated into the woven textiles. To do this he requires considerable graphic and artistic talent. Depending on the technical options available in the weaving workshop, the specifications set out by the studio, the fashion trend and the designated use, he designs geometric or floral shapes and abstract or graphic representations. Sometimes he also provides various colour options.

2. Point Paper Designer (Patroneur)

The task of the point paper designer is to convert the artistic design of the pattern designer into a technical drawing according to the patterning options provided by the weaving machine.

To do this he transfers the design to a special paper, the so-called point paper. Each rectangle on the point paper symbolises a crossing of warp and weft threads. Depending on the pattern, colour is used to indicate in the appropriate rectangle which warp threads should be on top at the crossing point (weave). There are many different weaves and the point paper designer has to choose the most appropriate one so that the design in question appears as accurately as possible in the fabric.

3. Card Puncher (Kartenschläger)

The card puncher transforms the technical drawing made by the point paper designer into a punched card.

With his fingers on the keyboard he enters the data into the card-punching machine and with his foot he punches the card by activating the pedal. A hole in the card signalises to the Jacquard machine that a warp thread has to be raised. No hole in the card, and then the warp thread remains where it is. The space between the lower warp threads and the raised warp threads is referred to as the shed into which the weft thread can be inserted. One card is needed for each weft thread. Once they have been punched, the cards for each pattern are numbered and threaded together and then suspended in the Jacquard machine as an endless card set.

4. Preparing the warp (Warper)

A specific number of warp threads are reeled from spools parallel to one another onto the warp beam.

Depending on the number of spools available, the process is repeated until the required number of warp threads has been reached. Then all the warp threads are transferred from the warping beam to the warp beam at the same time. Sometimes the warp threads are coated with sizing to prevent abrasion.

5. Fitter (Vorrichter)

The fitter is responsible for setting up the loom. The looms are not set up just for one pattern but for as long a time as possible because the set-up process can be extremely complicated and time-consuming. It is only necessary to re-set the loom when one warp has been completely woven and a different quality warp is required. This is seldom the case because every standstill means an economic loss.

There are two different methods to install a new warp.

If the warp has the same number of threads, then the individual threads can be directly knotted to or pieced to the ends of the warp threads of the completely woven warp. If the new warp has a different number of threads (= different quality) then the harness has to be changed.

When a new harness is used, each warp thread is drawn through the appropriate heald which is attached to the harness string.

Then the warp threads are drawn through the slits in the reed and this enables the number of warp threads per centimetre and the weaving width to be determined.

6. Weaver (Weber)

The weaver is the person who produces the final product. The loom needed not to stand still therefore the weaver often had to work from daybreak to dusk. He needed good eyesight to find any flaws and dexterity to piece the torn threads together. From the weft brief, the weaver obtained information about the weft material and the weft density.

The weaver was a man who kept his entire family busy preparing the threads for weaving. For example, the children or the weaver's wife had to prepare the spools for the loom shuttles using a reeling wheel.

Manual weaving is extremely time-consuming. The amount of fabric produced depends on the fineness of the fabric and the warp and weft material used. In Krefeld, silk and gold threads were often used and these are both fine and delicate. The final product was therefore very expensive not only because of the materials used but also the necessary production time.

The amount of material produced is depending on the thickness and fragility of the weft and warp threads. Historically, materials used in Krefeld were often silk and gold thread, which are thin and fragile respectively. Additional to being expensive materials, the time to weave fabric with these materials makes the end product even more expensive.