What is needed to digitise knowledge on Heritage Crafts?

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Using a punch card machine
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Heritage Crafts (HCs) involve tangible craft artefacts, materials, and tools and encompass traditional craftsmanship as a form of Intangible Cultural Heritage. Intangible HC dimensions include dexterity, know-how, and skilled use of tools, as well as identity and traditions of the communities in which craftsmanship is, or was, practiced. Despite their cultural significance, efforts towards HC digital representation and presentation are scattered. In the Mingei EU Innovation Action, an approach is developed towards systematising the representation of Heritage Crafts as Cultural Heritage for their preservation. The representation is expected to capture the wide spectrum of knowledge topics that HCs cover, from objects and their making, to hand gestures and tool uses that define craft motor skills, to the societal value, economic impact, and historical significance. In this article, we focus on the approach towards the creation of a knowledge and its representation. Examples and experiments are presented for two craft instances that are studied in this action.

Keywords: crafts, heritage crafts, representation, digitisation.

1. Introduction

Heritage Crafts, or crafts that are of Cultural Heritage (CH) significance, involve tangible artefacts, traditional materials and tools and comprise a form of Intangible Cultural Heritage (ICH). Their dimensions include knowledge on materials, dexterity, know-how, and skilled use of tools, as well as, tradition and a common sense of identity of the communities in which they are, or were, practiced. HCs are part of the history and economic life of the areas and communities in which they flourished. Their nature, diversity, excellence and significance vary over time and they are part of the CH and history of local societies, nations, and continents. HCs are object of cultural exchange or may be secret and have been decisive to the economic or military dominance of a nation. As such, HCs are components of the origins of modern societies, their history and culture.

The Convention for the Safeguarding of the ICH (UNESCO, 2003) proposes five domains where Intangible ICH is manifested: (a) oral traditions and expressions, (b) performing arts, (c) social practices, rituals and festive events, (d) knowledge and practices concerning nature and the universe, and (e) **traditional craftsmanship**.

Craft is characterised by a certain type of making, in which objects are created by hand through the skilled use of tools (Donkin, 2001) to make objects of functional use and not solely of ornamental value. Metcalf portrays materials and tools, as the identifying property of crafts (Metcalf, 1993). We adopt as baseline definitions that (Jennings, 2012) **Heritage** is ***"****what we inherit from the past that we value and pass forward from generation to generation****"*** and that **Heritage Crafts** (HCs) are *''practices which employ manual dexterity and skill, and an understanding of traditional materials, designs and techniques to make or repair useful things*". We call a **craft instance** the practice of a craft by a community or individuals, possibly specified by geographical or temporal context. A characteristic of crafts is their manifestation through multiple **tangible** and **intangible** dimensions.

Mingei is an EU Innovation Action (Horizon 2020) on the "digitisation" of HCs. Its main goal is to provide ways to represent HCs based on digital assets and semantic annotations, in a way that captures and preserves their tangible and intangible dimensions. In the context of this paper, we focus on the identification and the representation of the required knowledge to do so. We call **digital assets** the digital representation of text, audio, images, 3D physical structures, human motion, and curated literature, where such knowledge is documented. Such material usually stems from observation and interaction with craft practitioners. HCs cover a broad spectrum of tangible and intangible dimensions, whose representation requires the interdisciplinary effort.

2. Related work

Despite progress in the digitisation of tangible assets and other forms of ICH, there is lack of systematic action on representing, documenting, and preserving HCs. To date, efforts for HC representation and preservation have been scattered geographically and thematically. There is a need for knowledge representation that captures, organizes, and presents information on *materials, tools & artefacts, skills & know-how, rites & traditions*, as well as analyses of the *economic, societal* and *cultural impact* of HCs.

2.1 Craft representations

In the **humanities**, literature exists on the documentation of specific craft instances (e.g. Geijer 1979, and Hecht 1989), as well as, documentaries and inscriptions in the online repositories of cultural inventories. The Living Human Treasures programme of UNESCO contains verbal and functional testimonies that provide insight into traditional craftsmanship through the Living Human Treasures programme. International projects underpin the need for documentation and preservation of CH due to HCs, i.e., the Erasmus+ EU programme Discovering Traditional Crafts across Europe, the Chinese Craft Project (Barra, 2012).

A few studies on the representation of HCs treat the topic in an integrated manner. The collaboration of a wide range of experts under UNESCO provided a theoretical basis, towards the representation of ICH (UNESCO, 2003). A seminal work towards defining craft representations is the ICCROM report on crafts and their conservation (Donkin, 2001). This report is enlightening towards understanding that Heritage Crafts encompasses both tangible and intangible dimensions. In (Costin, 1998), social context, group membership, social relations are reviewed.

2.2 Digital representation of CH

For tangible CH, the maturity of the digitisation methods resulted in direct benefits to stakeholders. The **success of assisting CH valorisation through digital technologies** (availability, accessibility, engaging and interactive presentations) is **due to the captivating content of stories, memories,** and **meaning** that CH offers. Global trends in valorisation of ICH indicate that **supporting and streamlining digital representation of ICH assists its growth** and is **recommended by the UN World Tourism Organisation** (UNWTO, 2012).

Items of **tangible cultural heritage** (TCH) are physical testimonies of human history and activity. Photographic documentation and 3D digitisation are becoming a prerequisite in the documentation of TCH. Digital models of artefacts have a wide range of uses, from conservation and preservation to communication of cultural value. The outcomes of early digitisation projects on good practice guides for digitisation of books, documents, and 2D artworks have nowadays become the norm (ETH, 2006) (CARLI, 2017) (Brosseau, 2006). The proliferation of surface scanning technologies enabled the dense recording of structural information of 3D artefacts and monuments. Pertinent guidelines and good practice guides are achieving maturity; nevertheless the wide variety of digitisation modalities calls for the selection of the appropriate tool per type of environment. An overview of surface scanning modalities and corresponding digitisation approaches can be found in (3D-ICONS, 2014). Guidelines on file management, digital preservation, online publication, and IPR management can be in the MINERVA handbook (MINERVA, 2003).

Crafts bring together **intangible dimensions** such as dexterity, skill and know-how, with tangible elements such as materials and the tools for their transformation into artefacts. **Human motion** is a key component of many forms of ICH, such as dances, crafts, and rituals. Recording the motion of humans in 3D has been the target of ICH projects, such as i-Treasures, MODUL DANCE, DANCE, European Theatre lab, and TERPSIHORE. Digitisation of human motion has been achieved by a number of methods, which can be classified based on whether it is required for the subject to wear markers or not. ICH furthermore includes **audio**, such as speech, testimonies, songs, and music. Pertinent digitisation projects have provided guidelines and standard for audio recordings and their digital preservation (IFLA/UNESCO, 1999), (Bradley, 2006), (UNESCO, 2003), (Bradley, 2007), (UNESCO, 2016).

Digitisation projects have triggered the emergence of **online repositories** and libraries of information that include relevant literature, photographs, economic records, and other, such as the UNESCO World Heritage List, the UNESCO Intangible Cultural Heritage, the UNESCO's World Heritage Centre and Collection, Europeana, and UNESCO's Digital Archiving Project has been recording and archiving intangible forms of cultural expressions, to preserve the images and sounds relevant to CH. Online repositories have made possible the formulation of stories and narratives that could potentially provide more appealing ways of presenting and accessing CH while preserving the validity of scientifically curated knowledge sources. Examples of such approaches include stories provided in Europeana and the Google Arts and Culture repositories.

This work maps the content and knowledge types towards HC representation and identifies approaches to the digitisation of these knowledge types. Case studies, lessons learned and planning for future work are furthermore provided.

3. What is the knowledge we need to represent?

Knowledge representation is a digital encoding that captures in the form of structured data semantics, concepts, properties, relationships, and entities of knowledge. This representation is required to provide machine-interpretable statements, taxonomical structures (concept hierarchies), and relationships between concepts and digital assets. Such a representation is required to guarantee robust storage and content-based retrieval of knowledge.

Our point of departure is the knowledge on craft documentation, according to the dimensions identified in (Donkin, 2001). The baseline goal is to safeguard, retrieve, and present HCs in a way that provides a comprehensive picture of the craft instance. In this section, we initially examine ways of understanding HCs. We, thereafter, propose approaches to knowledge inventory and representation for their tangible and intangible dimensions.

3.1 How is craft understanding obtained?

In the library. Archives and the literature provide background and orientation information on HCs. Besides textual descriptions, photographs depicting craftspeople at work or social environment offer significant information on craft contextualisation. Video documentation of craft work documents craft practice, craftsperson movement, tools and/or machines usage, the workshop, etc. Online repositories offer a wealth of multimedia archives, where HCs are shown to be practiced, documentaries, oral testimonies, as well as, scanned documents and journals. Contextual information may exist in a demonstration videos or audio testimonies, as craftspeople might offer information on their craft and pertinent life aspects.

In the field. Narrative interview is a kind of semi-structured interview. The researcher prepares open-ended questions to guide conversation. The aim of this interview is to extract spontaneous information and general information that leads to storytelling. Photo and video elicitation is a qualitative method (Banks, 2001) (Ketelle, 2010) used to trigger the elicitation of information. Visual material has an effect on the participant's sequence of thoughts and stimulates memory associations. Geography of workshops is used to understand the relation between the body, the tools, the matter and the space where a craft is performed. The framework of "operational sequences" of action (Leroi-Gourhan, 1993), facilitates understanding of the interaction gestural and sensitive actions, the interaction between tool

usage and material transformation, and the 'choreography' of motion in the workshop. As craft knowledge is mostly non-verbal, this tool defines and documents the technical craft gestures.

In the lab. Analysis tools aid understanding of content from digital data. In document digitisation, OCR is now a commonplace technology used to transcribe the textual content from images into digital text. Historic document analysis has been the epicentre of research of IMPACT and tranScriptorium. Speech transcription into digital has increased the automation of the process. Such technologies economise the researcher's time by automating tedious processes. Similarly, advances in image analysis, computer vision, and new sensors, automate the tedious measurement processes entailed in the modelling of artefacts or motion capture of craftspeople.

3.2 Craft materials, objects, and environments

3.2.1 Knowledge inventory

Materials, tools and machines of craft practice, protective or traditional clothing relevant to the craft, and the physical environment or workshop are tangible components of crafts. Digital documentation of TCH elements is the object of photographic and 3D digitisation (see Section 2.2.1). The collected knowledge in the form of **basic knowledge elements** comprises basic statements that explain the role and significance of digital assets. These elements include any existing curated information or description about the asset. Knowledge statements forming the descriptions of the individual entities involved in the craft process are formed, mostly manually, by the knowledge curators. The involved entities are: objects, actors, actions, concepts, tools, places, and digital assets that document steps of the craft.

3.2.2 Knowledge representation

These above entities are formally described by statements using classes and properties of the Mingei Crafts Ontology (CrO) used for describing CH content linked by a craft. CrO is an application ontology obtained by integrating several existing ontologies, notably: (a) the CIDOC CRM,[1] a top ontology and ISO standard (21127:2006) forming the conceptual backbone of the CrO; (b) the Narrative Ontology, a domain ontology focussed on the representation of narratives (Bartalesi, 2017); (c) the FRBRoo,[2] resulting from the harmonization of FRBR, a domain ontology for bibliographic records, with CRM; and (d) OWL Time,[3] a domain ontology recommended by W3C for the representation of time. In addition, CrO includes extensions to the above ontologies needed to model specific aspects of reality relevant to Mingei, such as for instance **event schemas**. CrO is endowed with the classes and properties for modelling **events** and their **relationships**, and for distinguishing between time-dependent (perdurant) and time-independent (endurant) entities (Masolo, 2003). This allowed the further extension of the model to support the formulation of **fabulas** (Bruner, 1986) and the definition of narratives (cf. Section 3.4.2). Properties of CrO account for the content, form, and significance of an entity and, where appropriate, its spatio-temporal placement.

[1] http://www.cidoc-crm.org/
[2] http://www.cidoc-crm.org/frbroo/home-0
[3] https://www.w3.org/TR/owl-time/

To reduce the gap between visual and textual descriptions of objects we create dictionaries that associate names and colloquialisms, textual descriptions, and digital models of the objects. Dictionary items are linked to entities in the knowledge base, thereby associated with their digital documentation and their semantic interpretation in the craft context.

3.3 Craft practice

3.3.1 Knowledge inventory

Craft practice regards **actions**, **activities**, and **processes**, where one or multiple **practitioners** use handicrafts, tools, and materials to create artefacts or prepare materials. These activities range from laborious or dexterous and include intangible aspects, such as skill, know-how, and artistic creation (Figure 1). The digital documentation of physical events is the object of motion digitisation (see Section 2.2.2). The targeted knowledge regards the actions, intermediate and final products, a semantic organisation of actions and activities, and a representation of purpose and causality of these actions in the context of a given craft activity. For the representation of events, since the narratives that are relevant for Mingei are centred on craft, which is a human activity, the ontology equates events with activities of CIDOC-CRM. This notion includes complex, composite and long-lasting actions such as the building of a settlement or a war, as well as simple, short-lived actions such as the opening of a door.

Figure 1. Craft activities.

3.3.2 Knowledge representation - Schemas

Knowledge inventory is organised on the sequence of processes of craftspeople, during the transformation of materials into products. These processes involve tools, human actions, and skills, and are relevant to space (i.e., workshop, environment), geography, season, or historical time.

The basic elements of pertinent representations are actions that comprise craft processes, as well as, the links that relate these actions between each other and with the objects that document or

contextualize them. We regard **actions** as a special kind of **events**, following a well-known approach in the philosophy of language (Davidson, 2001).

In this context, there is a need to represent descriptions that give the structure of a whole class of events, by stating a number of axioms that characterize the events in this class. We will call such descriptions **event schemas** and say that an event conforms to the schema if it is structured according to the schema's description. In practice, an event schema represents something that may happen and that has always the same structure at every occurrence. Schemas are abstractly modelled as sub-classes of the class Event. An execution of the schema is an event that conforms to the schema. Inside a schema, the actions are related to each other in three ways:

- **Temporal** links are induced by the relationships that hold between the temporal intervals in which events are placed.
- **Causal** dependency links. These links are stronger than the temporal links because they impose an order of execution, whereas the temporal links do not always have the same force.
- **Inclusion** links, stating which event is included, or part of, which other event. The inclusion relation is a powerful knowledge organization mechanism as it allows establishing a hierarchical structure amongst the steps of a craft process.

Beyond the semantic representation of actions and processes through event schemas, **Motion Vocabularies** (MVs) are created to associate actions to recorded events, or otherwise executions of these schemas. The creation of a motion vocabulary is a technical process that involves the MoCap of practitioners and the segmentation of the recorded animations into distinct actions. The MoCap (Motion Capture) animation files are segmented to isolate human motion in actions of interest (animation clipping). This is achieved through an animation editor which further supports isolation of skeleton parts, to exclude indifferent movements and treat concurrent actions. This way, the extracted animation segments correspond to individual actions. **Motion Vocabulary Items** (MVIs) are recorded segments that are selected to represent actions or action parts. MVIs can be combined and interleaved as building blocks of procedure representations. An MV can be used to create sequences of actions and procedures, and be used to encode a wider variety of actions than the initial recordings.

3.4 Craft context

Space and **time** are defining factors of a craft instance.

- Information on geographical location and range is relevant, as environmental aspects affect craft practice and development. The availability of materials depending on location is of relevance, such as when based on endemic flora or fauna.
- Intangible heritage is continuously updated as times change and new people are involved in them. As technology advances, new tools become available to craftspeople which, in turn, may adapt their techniques to make use of them.

For general geographical context we have referred to the GeoNames resource, to associate names of places with GPS coordinates. For locations that are relevant to the craft instance, we provide this association using GPS coordinates with the context-specific names (i.e., the workshop of Hubert Gotzes). This is achieved using a digital map as a user interface, such as OpenMaps and Google Maps. The locations are represented in XML format containing both names and GPS coordinates.

Time is modelled both as time intervals and time points. Time intervals are connected to events and associate events with their interval of occurrence in time. In addition, we use the thirteen properties capturing the basic temporal relations in Allen's algebra on time intervals namely "is equal in time to", "finishes", "is finished by", "starts", "is started by", "occurs during", "includes", "overlaps in time with", "is overlapped in time by", "meets in time with", "is met in time by", "occurs before", and "occurs after". All these properties relate time intervals with events (Nebel, 1995).

3.4.1 Knowledge inventory

The knowledge on **skills of specific craftspeople**, whether master or apprentices is important to understand their role in a craft workshop or community. **Representative communities or institutions** provide valid knowledge on craft instances. The **transmission of craftsmanship** through apprenticeship is part of crafts and an essential element of their preservation.

Differentiation of **gender** and **age roles** is present in craft practice and relate to the positions of genders and ages in craft communities. **Stratification** and **hierarchy** of community and **everyday-life habits** are in close connection with the craft and its community. **Rituals and festive events** determine local culture and provide a sense of identity among a community; such events often occur annually, concern a change of status of a community member, or are related to historical events, religion, or commemorated local practice. Some craft instances contain **religious** references, or craft products may be used for religious ceremonies. Stories, songs, myths and legends are part of the **oral tradition** of communities, usually told by elders to the young, during a feast, a celebration, or work. Craftspeople testimonies provide an **emic presentation** and a more ethical view on making assumptions about the cultural significance of the craft.

Crafts have an **economic dimension**, since craft artefacts are almost always items for sale. The producers might sell products themselves or through associations or companies for the distribution of their products. Access to imports of materials and export of products define the economic life of a region and craft economy may shape the life of its inhabitants.

Art and **design** are present in almost all crafts. Patterns, motifs and shapes of a craft object can be traditional or new. It is important to note if there are creations defined by the craft locality. These instances are unique and might depend on social, religious, or environmental characteristics of the location. Moreover, contemporary artists are increasingly interested in learning a craft to apply it in their artworks, or collaborate with craftspeople for the production of artworks (Gottesman, 2016).

Historical and social events and **technological advances** are relevant to craft development, such as for example the Industrial Revolution in textile manufacturing.

3.4.2 Knowledge representation - Fabulas

CrO defines the modelling schema of basic knowledge elements. Semantic links regard an event-centred association of basic knowledge elements that comprise the context representation of a craft context. Relationships established between basic knowledge elements are: (a) Representation of historical, social, and economic events and linking with craft development, (b) Links between the digital assets and model entities, (c) Representation of stories traditions and (d) Biographical information.

Based on the aforementioned basic representation the CrO defines narratives as a network of events, each set in time and connected to the components (people, places, etc.) taking part in the event. The sequence of events in chronological order is called **fabula**. The fabula is generally represented partially in narrative graphs of CrO, mainly because the information we have about it is usually incomplete. The sequence of events in the order presented by the narrator is called plot. The narration is a work (e.g. a text or video) expressing the plot of the narrative.

3.5 Implementation

For the implementation of the knowledge authoring tools (Mingei Online Authoring Platform) the ResearchSpace framework was used. ResearchSpace[4] uses Semantic Web technology to support CH research. For the implementation of the knowledge authoring tools, the CrO and the extensions to support narratives were imported in ResearchSpace, to enable knowledge authoring and inferences. Then, the knowledge was modelled using this ontology and the appropriate authoring facilities were implemented to support knowledge curation (see Figure 2).

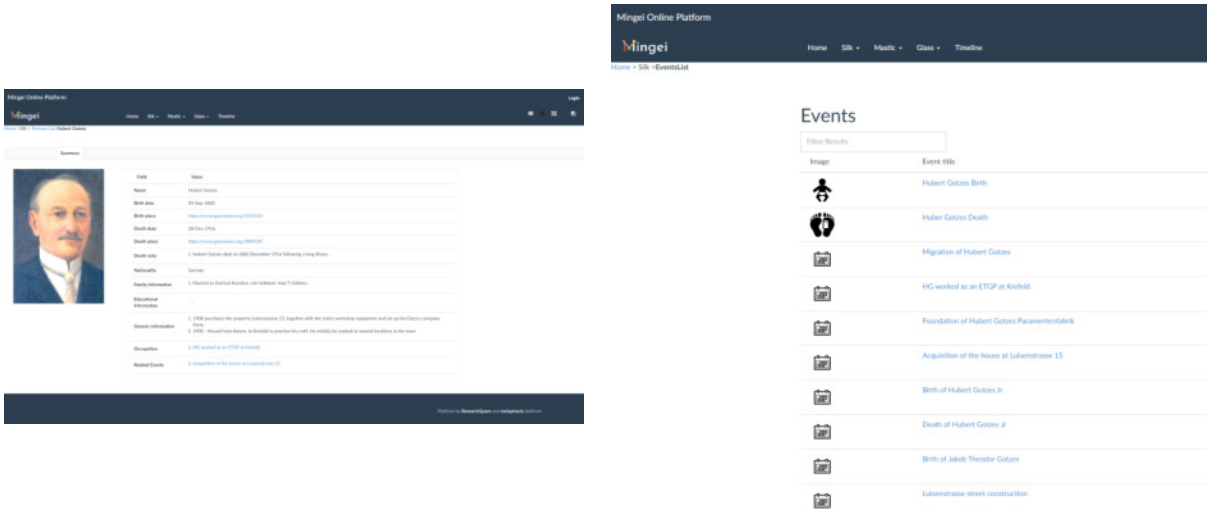

Figure 2. Knowledge representation in ResearchSpace.

5. Experiments and case studies

To assess knowledge inventory on HCs and its representation, we utilise two craft instances as examples. Patterned silk fabric manufacturing using Jacquard weaving belongs to the broad class of fabric manufacturing, known to be globally practiced since the Palaeolithic Era. We study the instance of this craft as practice in the silk workshops of Krefeld, Germany, since the early 1700s. In contrast, mastic

[4] https://public.researchspace.org/

cultivation, inscribed in UNESCO's list of Representative ICH of the Humanity, is a highly localised instance, because it concerns an agricultural practice, exclusively practiced on Chios, Greece, due to the endemic nature of where the tree that produces the mastic resin grows.

The results presented in this section are the first outcomes of the application of the proposed approach for the aforementioned HC instances. Under this perspective, they cannot be considered complete but are adequate to validate our hypothesis and proposed methodology. As both the process and the application of technologies are work in progress, several aspects will be changed or improved in the future. The rest of this section presents examples and experiments conducted during the first nine months of the Mingei project and are categorised in correspondence to the knowledge domains presented in the previous section.

5.1 Basic knowledge elements

The digitisation of **documentation** can provide craft insights and illustrate complex crafting procedures. In Figure 3, technical drawings (Rosselt, 1887) for the construction of a Jacquard loom and its operation are shown

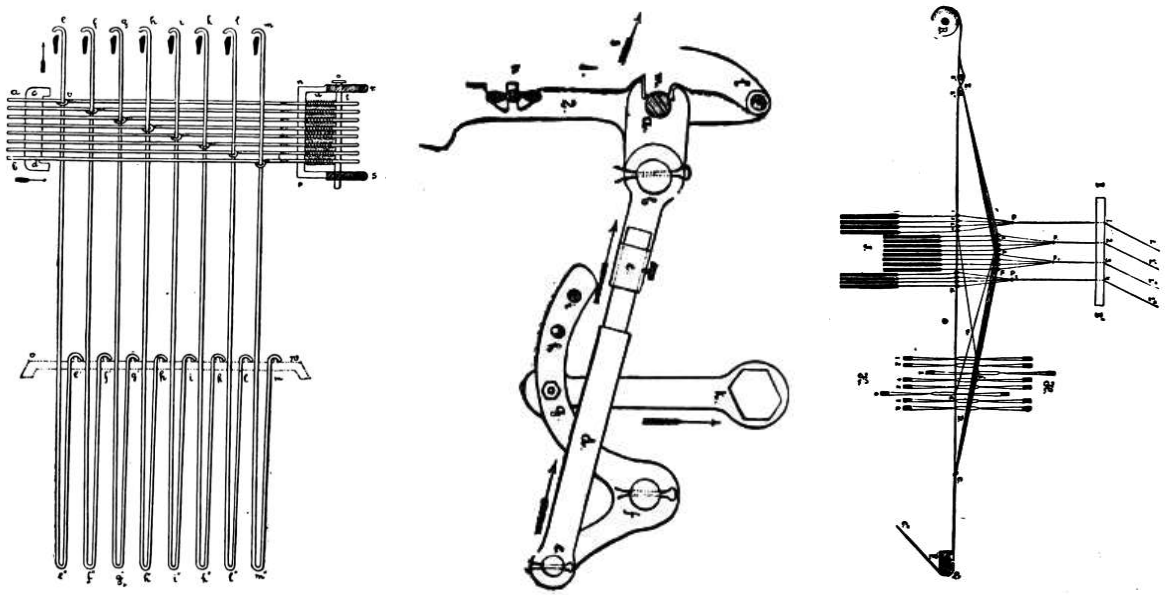

Figure 3. Technical drawings for the Jacquard attachment.

In Figure 4, the process of **3D digitisation of a deformable objects,** an ecclesiastical garment from the collection of the reputed silk textile producer Gotzes at Krefeld, Germany, is shown. In Figure 5, **indoors 3D reconstructions** of mastic processing machines are shown. In Figure 6, the architectural environment of mastic production villages is shown through **aerial 3D reconstruction**; their characteristic structure reveals fortification against pirates and storage buildings for mastic at the centre of the village that were guarded.

Figure 4. Original images (top) of an ecclesiastical vestment made from silk and gold brocade and photogrammetric 3D reconstruction (bottom). 3D view at https://youtu.be/4pVji8M_vW4 ©Mingei project.

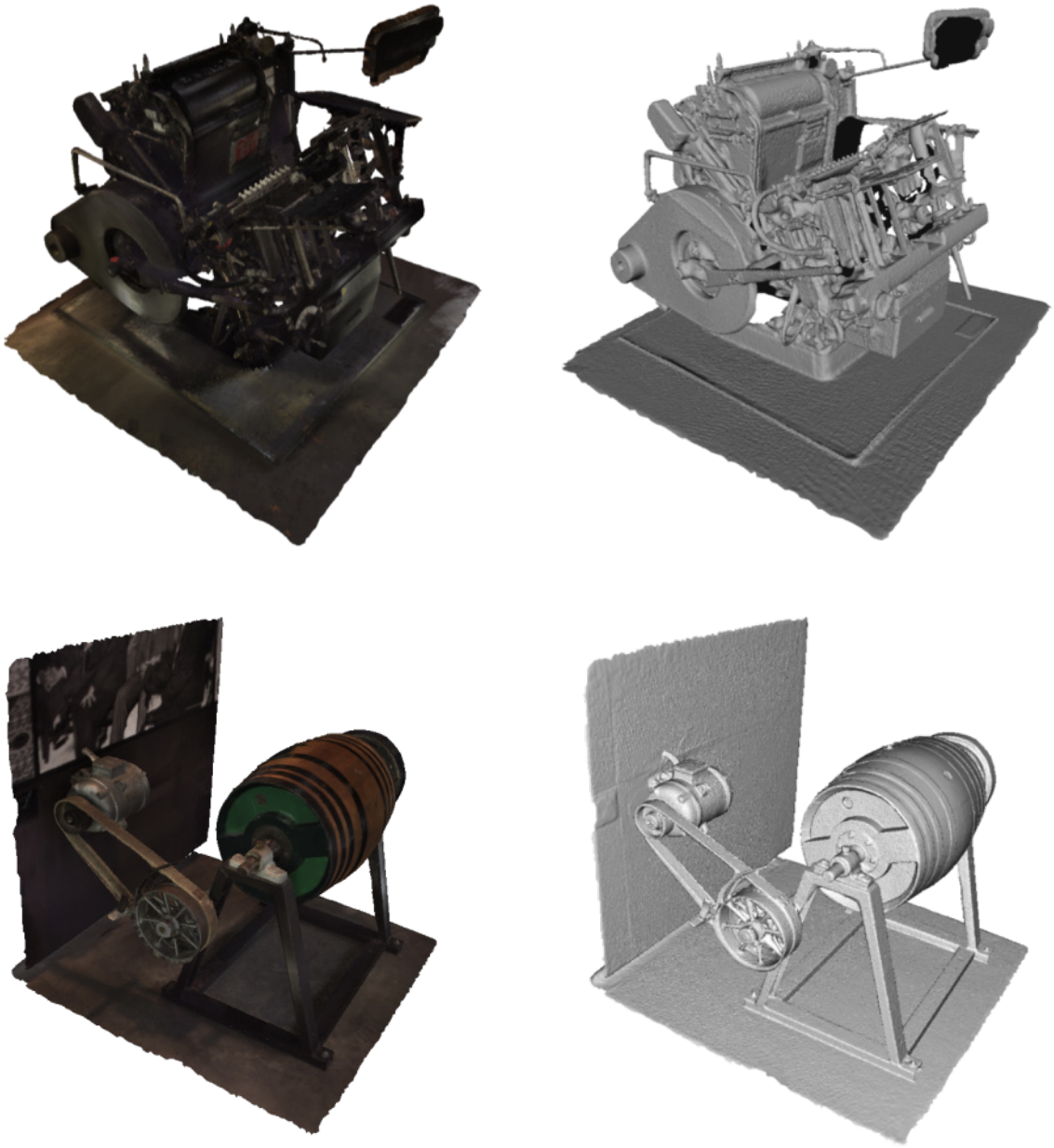

Figure 5. 3D reconstruction of mastic processing machines.

Figure 6. 3D reconstruction of mastic village architecture at Chios.

Digitisation of human motion provides documentation of body posture, tool grip and manipulation, and use of mechanised apparatuses. The analysis and interpretation of this digitisation can provide insight into the skill of the craft worker. Our example comes from the preparation of cards for Jacquard weaving, where the fabric design is transferred to squared paper. A skilled worker translates the design into punched cards using a card punching, or keyboard, machine. The configuration of posture and apparatus is reminiscent of a piano player. The operator sits on a stool reading the design in front of

him, similar to a sheet of music. Educational material on card punching (Posselt, E., 1893) recommends uninterrupted gaze from the pattern, similar to touch-typing, for mastering the technique. In (National Museums Scotland, 2016, the worker exemplary follows this practice, achieving quick and efficient typing (Figure 7).

Figure 7. Using a punch card machine.
©Video still courtesy of National Museums Scotland - https://youtu.be/OlJns3fPItE

In our re-enactment, by a knowledgeable but non-recently-practiced worker, we observe a slower and less efficient punching pace, as the worker needs to look at his fingers between punches (Figure 8. To record and represent this observation, we have estimated the person's pose on each frame of the video and reconstructed it in 3D using (Qammaz 2019).

Figure 8. A card puncher reads the design (left), looks at his hands (middle), and presses the treadle of a punching machine (right) ©Mingei project

Figures 9 shows how photographic and 3D documentation are combined in a digital dictionary of tools for mastic cultivation. The particular entry that has a formal and a colloquial designation, both for which the original Greek name is provided.

<table>
<tr><td>Timitiri (Τιμητήρι) or Xistiri (Ξυστρί)</td><td colspan="2">Handheld agricultural tool with metal head and wooden handle used to collect the mastic gum. Two versions of the tool are shown.</td></tr>
<tr><td colspan="3">Photographic documentation</td></tr>
<tr><td colspan="2">  </td><td>  </td></tr>
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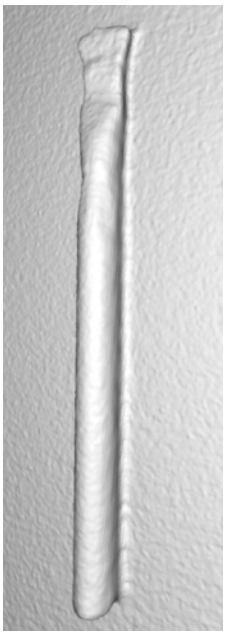
<tr><td>  </td><td>  </td><td>  </td></tr>
</table>

Figure 9. An entry in the dictionary of the mastic cultivation representation ©Mingei project.

5.2 Schemas

An abstraction of the fabric manufacturing process is to first **spin** the **fibres** into **yarn** and then **weave** this yarn into **fabric**. A schema of this process is shown below. In reality, the process is more detailed as it may contain intermediate tasks, such a dying of threads and loom preparation. In Figure 10, the representation of the process is shown.

Fibre	A **fibre** is a unit thread of a natural or manufactured matter that forms the basic element of fabrics and other textile structures.
Spinning	**Spinning** is the process of transforming multiple fibres into yarn. A spinning device is used in the process.
Yarn	**Yarn** is a long continuous length of interlocked fibres, suitable for use in the production of textiles, sewing, crocheting, knitting, weaving, embroidery, or rope making. Yarn is produced by spinning raw fibres of wool, flax, cotton, hemp, or other materials to produce long strands.
Weaving	**Weaving** is a way to fasten multiple parallel threads of yarn that are extended by tension with a perpendicular, interwoven, and much longer thread. Most types of weaving require a minimum of equipment.
Fabric	A **fabric** is a material made through weaving, knitting, crocheting, or bonding that may be used in the production of further goods (garments, etc.).

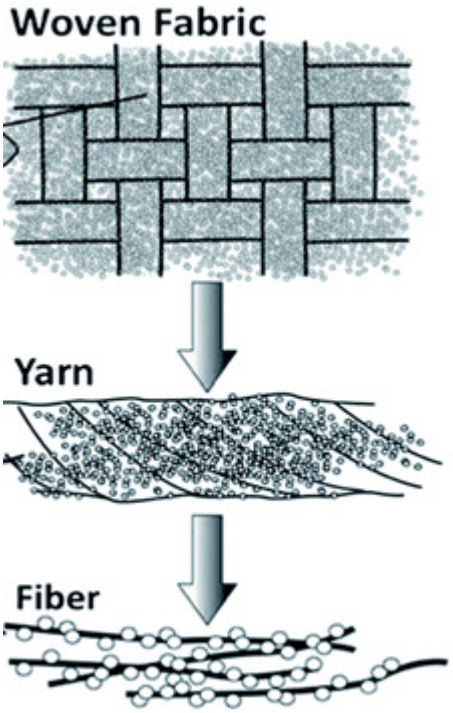


Figure 10. A schema of the fabric manufacturing process.

Individual activities are modelled in more detailed schemas. In Figure 11, the activity of weaving is analysed in actions.

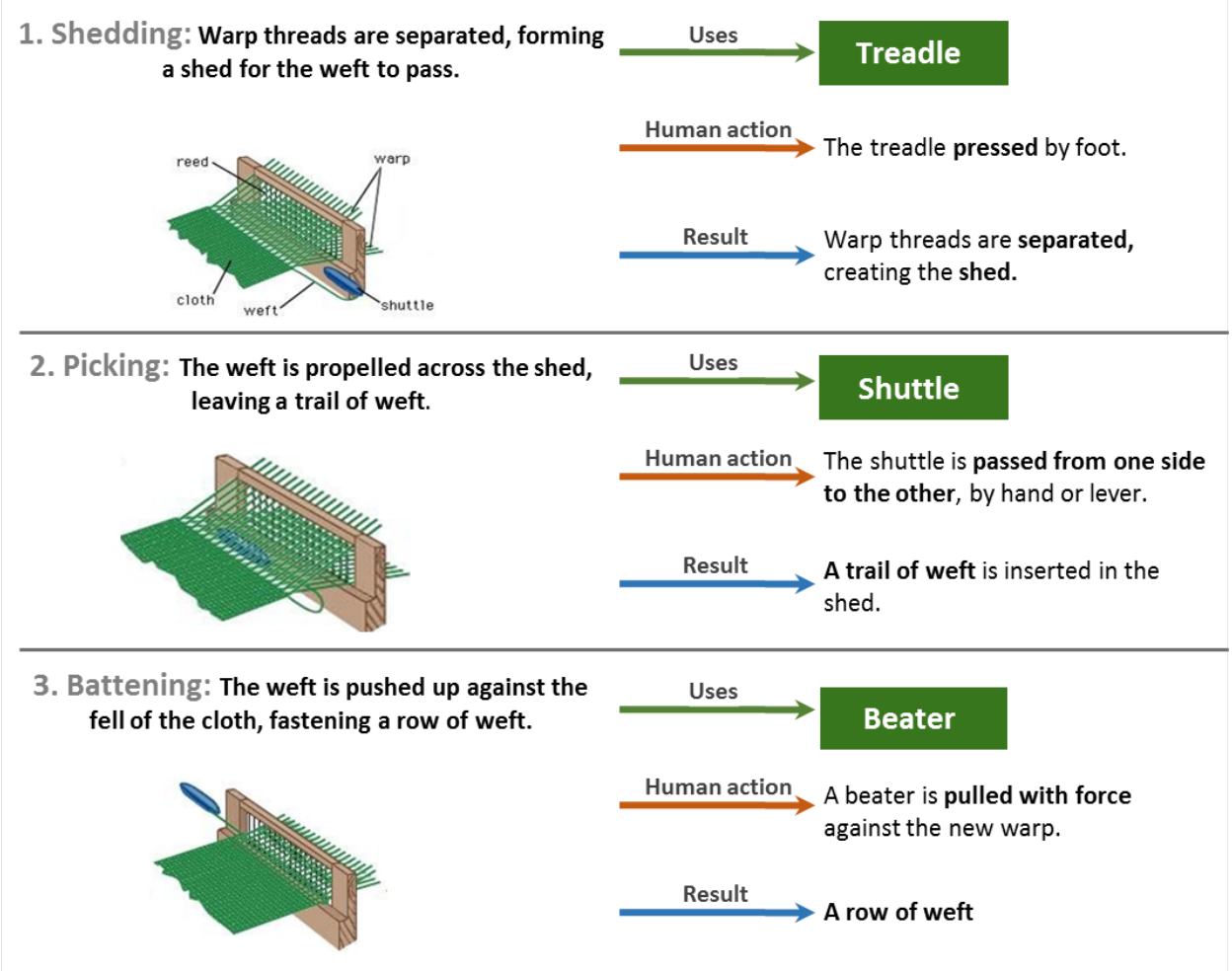
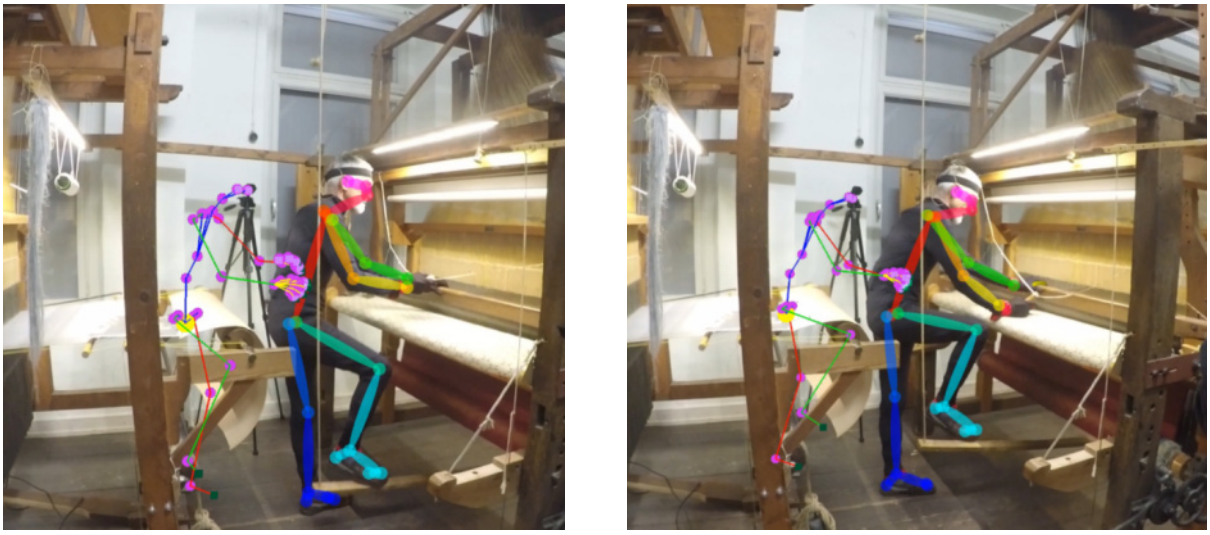


Figure 11. A schema of the weaving process.

The recording of the weaver's actions is segmented to form a MV. The loom is broken down into simple machine components (e.g. pedal, shuttle, beater). We claim that an appropriate combination of machine components with motion can transfer human expertise to the digital world, offering a generic approach to the representation of human operated machinery. To demonstrate this approach, the following steps are followed:

- Motion Capture (MoCap) of humans using a machine or tool (weaving with a loom).
- Machine or tool model acquisition (3D reconstruction).
- Implementation of Virtual Humans to operate the machine.
- Segmentation of MoCap recordings into a MV.
- Segmentation of the machine into 3D models of simple machines (i.e. treadle, shuttle, beater).
- Association of machine components with a Virtual Human to reproduce part of machine motion and, together with VH motion, part of the weaving process.
- Motion Retargeting from the recording of the craftsman operating the machine to the VH operating a model of the machine in the virtual world.
- Visualisation of human motion and emulation of machine motion while weaving.

The result of visualising human motion into a virtual world using the motion vocabulary acquired by actual craftspeople using the loom is presented in the Figures 12 and 13.



Treadle press Beating

Figure 12. Pose estimation of a human during weaving.

Figure 13. Emulation of a VH operating a loom.

5.3 Context

To demonstrate contextual knowledge representation, we consider the silk textile manufacturing workshops of Krefeld. Krefeld is a city in North Rhine-Westphalia, Germany, founded on the remains of the Roman military camp of Gelduba, sometime before 1105 (Figure 14). The silk workshops of Krefeld grew after the mid-1750s in a district of the town, which became later known as the **"Crown Prince District"** (Figure 15).

The vicinity of Krefeld, Düsseldorf, Cologne, and the Lower Rhine region, provides an understanding of **economic context**. Rhine has been a vital and navigable waterway for carrying trade and goods deep inland; its importance since the Roman Empire is evident by the castles and fortifications along it.

The growth of Krefeld began in the 17th century. Many **religious refugees** settled in and around the town, in a territory ruled by the House of Orange, which offered "religious asylum".

During the 1700s the economic situation was dire, particularly for peasants in state that now make up Germany. In the Lower Rhine region, **linen manufacturing** provided jobs and foreign exchange and was supported by the state, during the reign (1740-1786) of Friedrich the Great, King of Prussia. Feudalism and the putting-out system gave way to mercantilism and workshops.

The **Industrial Revolution** diminished the income and social status of hand-weavers in the Lower Rhine regions, similarly to many other places in Europe, but with the exception of Krefeld. The changes in the international economy were among the main factors prompting Krefeld's industry to **shift from linen to silk**. Between 1800-1820, Krefeld's textile industry started to abandon linen production and shifted to silk textile production. Krefeld became the epicentre of silk and velvet textile production in the early 1800s and was named as **"Town like Silk and Velvet"**. The region around Krefeld became and remains an industrial area.

This growth brought the need for more workers and prosperity brought regional growth of the workforce and **urbanisation**. Young men were attracted by higher earnings and ample employment opportunities, resulting from industrial growth (Figure 16). Neighbouring regions converted gradually from linen to silk. Industrial growth is evident by the history of the city infrastructures and transportation, which enabled regional sales and exports (Figures 17, 18, 19, 20). Most silk-weaving workshops were located at the southern end of the Crown Prince District, in close proximity to the train station, central post office, and freight transport. The industry sold its products across Germany and exported to the Vatican and the U.S.A.

Even when silk weaving became mechanised, in the late 1800s, manual weaving in Krefeld workshops prevailed, due to their ability to manufacture **ecclesiastical textiles**. Such textiles were originally woven in linen and wool, but later on in silk, velvet and also gold and silver threads. The Krefeld community **actively promoted** the manufacturing of silk ecclesiastical garments, as **religious art** (Figure 21). This retained the need for manual weavers, because these expensive textiles were not woven on mechanical looms.

The decline of the industry started with the Second Vatican Council (1962 – 1965), requiring the clergy to wear simpler robes. Over time, the number of skilled manual weavers decreased. During the 1980s only Andreas Friedenberg, was still employed in the Gotzes Company - the last surviving silk weaving

workshop in Krefeld. After his death in 1989, the weaving workshop closed and only sales were maintained. In 1992, the company was recorded as defunct.

The last owner of the company acted to preserve its workshop, in its original location for posterity. This led to the formation of an Association of Friends of Haus der Seidenkultur (HdS) which in 2000 was donated money by cultural trusts in Krefeld to acquire the building and all its contents Volunteers from the run the weaving workshop as a museum. Today, Mingei works with HdS in the preservation of this endangered craft instance.

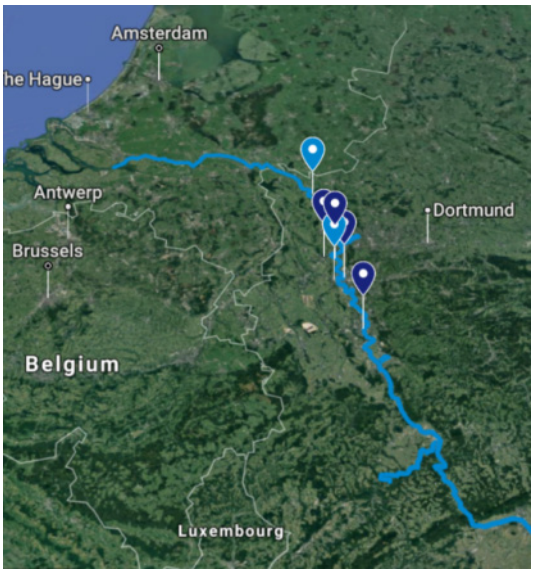


Figure 14. Rhine and locations in the vicinity of Krefeld (light blue lines, superimposed on map). Pinpointed locations in light blue are the cities of Krefeld, Cologne, Düsseldorf and, in dark blue, the locations of Roman settlements of Xanten, Neuss, Gelduba.

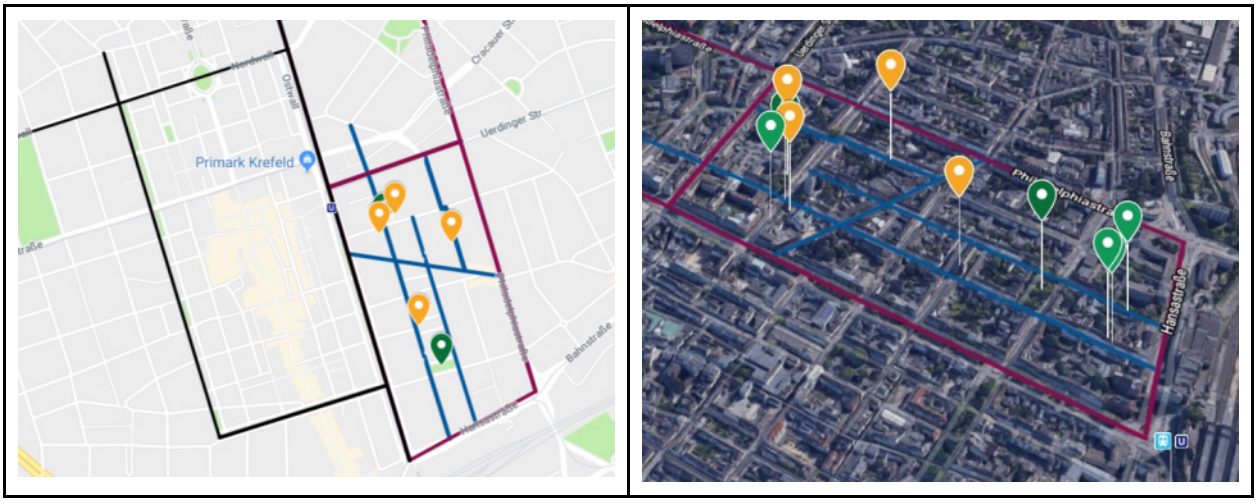


Figure 15. Maps of Krefeld today, showing the Historical City Centre in black and the Crown Prince District, in purple. Pinpointed are city infrastructures (in yellow), parks (in dark green), and silk workshops of the Gotzes company.

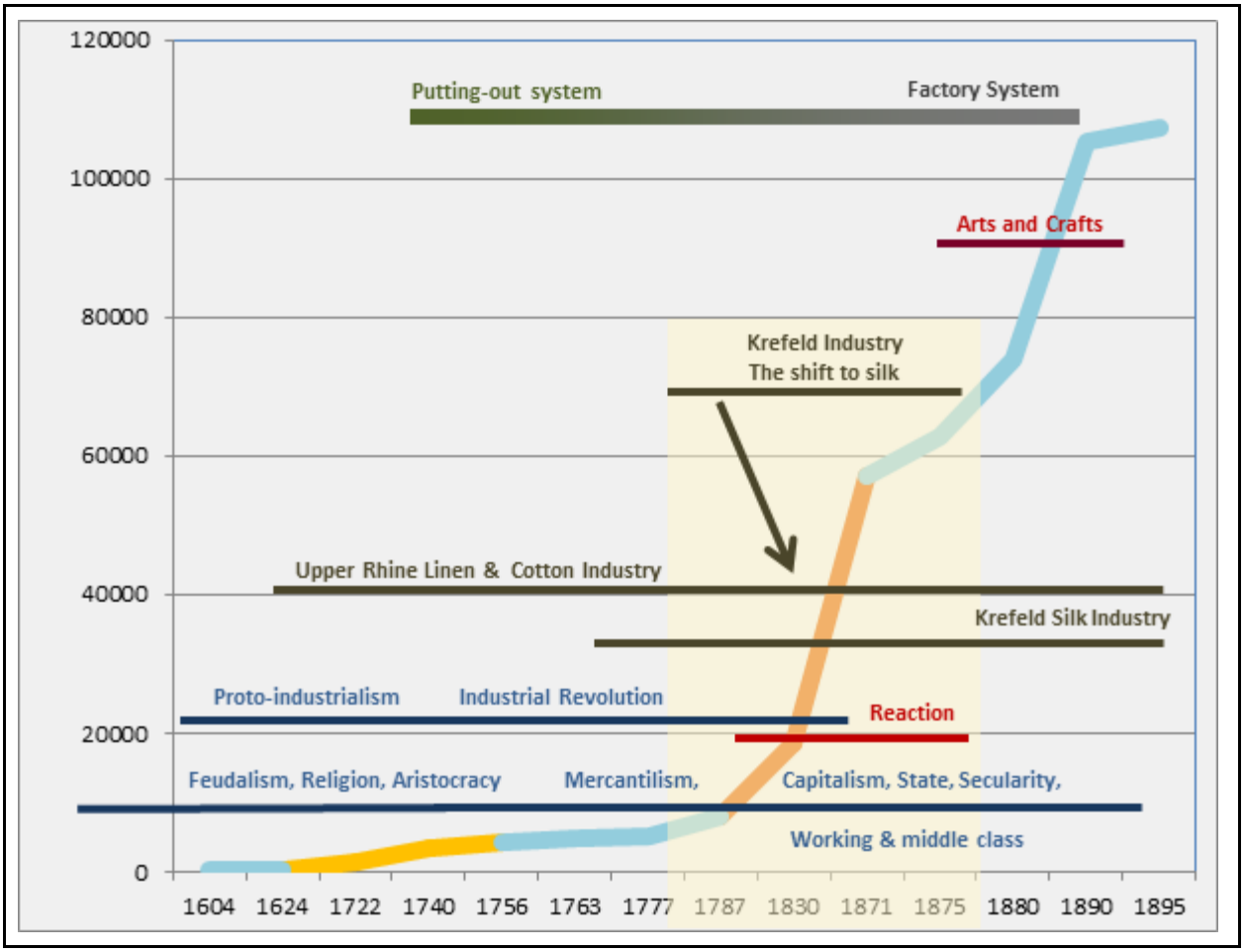


Figure 16. Population of Krefeld from 1604 to 1895, roughly annotated with historic periods and eras. The population graph is based on knowledge inventory; historical annotations are indicative.

1819	Inner area of Krefeld completed, based on plans by master builder Adolph von Vagedes.
1835	Design work starts for a 7th expansion of the rapidly growing Krefeld.
1843	Prussian government approves the plans of the Düsseldorf government building officer Franz Anton Umpfenbach, for an expansion in an easterly direction covering what is now known as the **"Crown Prince District"**.
1872	Development in Luisenstrasse, main street of "Crown Prince District" completed. 23% of Krefeld's population employed in the textile industry.

Figure 17. The urban expansion of Krefeld.

1899	Electricity station in Canalstrasse.
1893	Waterworks at two deep wells provide high quality drinking water.
1875	Central sewage to the Rhine.
1900	Significant increase in the amount of mail. Reichspost sets up additional post offices, in individual town districts.
1908	Central sewage renewed with a purification stage.
1908	Urban canal system enables sewage disposal.

Figure 18. Events in the history of Krefeld city infrastructures.

1849	Krefeld included in rail link Homberg– Uerdingen – Krefeld – Viersen.
1853	Routes to Aachen and Oberhausen.
1856	Route to Cologne.
1868	Establishment of the Krefeld Railway Company.
1868	Routes to Hüls, Moers, and St. Tönis.
1898	Route to Düsseldorf - long distance train.
1900	Electrically powered trams.
1906	Creation of river port. Attracts companies unrelated to the textile industry.
1907	New train station.

Figure 19. Events in the transportation history of Krefeld.

1850s	Catholic Church, Stephanskirche.
1864	Secondary school, Luisenplatz.
1868	Orphanage, on the eastern side of Kronprinzenstrasse.
1872-4	Protestant church, Friedenskirche.

Figure 20. Events in the history of educational and religious infrastructures of Krefeld.

	Event	Significance	Impact
1852	Exhibition of religious art, by Franz Bock.	Cassareto company presented its new "mediaeval fabrics" to a wide public.	Defined niche market.
1880	The mechanical loom for silk put manual weavers into dire straits.	The ecclesiastical textile industry still needed manual weavers, because ecclesiastical textiles are not mass produced. It was not economical to use the mechanised looms to produce small quantities of very high quality fabrics interwoven with gold and silver threads.	Weaving ecclesiastical textiles still provided employment.
1887	Participation of Krefeld entrepreneurs in "Exhibition of Religious Fine-Art, Weaving and Embroidery from the Past". Location: Königliche Webschule (Royal School of Weaving). Patronage: Archbishop of Cologne.	The purpose of the exhibition was to promote *"the production of religious textiles"*.	In the following decades, more weaving workshops for ecclesiastical textiles appeared in Krefeld.

Figure 21. Ecclesiastical textile marketing events relevant to the Krefeld industry.

6. Conclusions

Preservation of HCs calls for a systematic process of their **representation** and **presentation.** To this end, this chapter has defined the basic requirements for knowledge inventory regarding craft understanding, craft materials, practice and context. Furthermore, it explored how to: (a) cover tangible and intangible HC dimensions; (b) adhere to knowledge digitisation standards for CH documentation; (c) digitally represent knowledge and semantics. To this end, experiments and use cases of the proposed approach were presented. As research towards a validated protocol for craft presentation and representation is still in progress, we will further elaborate and validate the proposed approach.

A technological limitation of this work is the ability to record or represent "felt" sensory knowledge, on craft practice. A practitioner interprets her own qualia[5], to perceive the environment. Examples are the haptic sensation of a plaster in pottery or the sensation of heat and smell in glassmaking. A theoretical limitation is the representation and assessment of artistic content embedded in craft products. Although the representation of the artistic dimensions is elaborated in multiple ways by including e.g. the principles of composition in art (unity, balance, movement, rhythm, etc.), there will always be a difficulty in representing how someone becomes an artist and produces new art.

[5] Qualia are subjective, conscious experiences or "the ways things seem to us" (Dennett 1988).

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