



## Deliverable 6.5 – Report on Mingei pilots

<b>Release Date</b>	8.02.2022
<b>Version</b>	1.2
<b>Dissemination Level</b>	Public

<b>Project Number</b>	822336
<b>Project Acronym</b>	Mingei
<b>Project Title</b>	Representation and Preservation of Heritage Crafts

<b>Deliverable Number</b>	D6.5
<b>Deliverable Title</b>	Report on Mingei Pilots
<b>Deliverable Type</b>	Report
<b>Dissemination Level</b>	Public
<b>Contractual Delivery Date</b>	Date
<b>Actual Delivery Date</b>	31.05.2022
<b>Work Package</b>	WP6 – EXPERIENCE, LEARN & EXPRESS: Narratives and storytelling for novel craft experiences in CHIs
<b>Authors</b>	Xenophon Zabulis, Nikolaos Partarakis, Effie Karuzaki, Carlo Meghini, Danae Kaplanidi, Arnaud Dubois, Cynthia Beisswenger, Dieter Blatt, Chris Ringas, Eleana Tasiopoulou, Danae Kaplanidi, Dimitrios Menychtas, Alina Glushkova, Brenda Elizabeth Olivas Padilla, Sotiris Manitsaris, Dick van Dijk, Ammar Qammaz, Meia Wippoo, Aggeliki Tsoli, Antonis Argyros, Catherine Cuenca, Anne-Laure Carre, Arnaud Dubois, Ilka Neumann, Vito Nitti, Evropi Stefanidi, Ilia Adami, Antonios Chatziantoniou, Valentina Bartalesi, Daniele Metilli, Nikolaos Patsiouras, Paraskevi Doulgeraki, Ulrike Denter, Hansgeorg Hauser
<b>Number of pages (incl. cover)</b>	166



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 822336.

<http://www.mingei-project.eu/>

## Executive summary

This deliverable reports on the three Mingei Pilots which regard the digitalization, preservation and presentation of the crafts of silk weaving, mastic cultivation and glass blowing respectively. Firstly, an overview of the overall methodology adopted will be provided. As the readers will find out, the adopted methodology can be parted into six steps:

1. **Craft Understanding.** It entails exhaustive ethnographic and archival research, as well as interviews with people (which we call ‘Living Treasures’). This means that the researchers will dive into dusty archives to collect textual, photographic and audio documentation, perform interviews to collect oral testimonies, and organize and study them all to extract knowledge. The aim is to deeply understand the process followed in each craft, the actions taken in each step of the process and the conditions before, and the expected result after each process step.
2. **Data collection** is the recording of physical objects and the human actions leading to the transformation of materials into articles of craft. The collected data are acquired from media objects, which is an abstraction for digital recordings such as images, video, 3D scanners, and Motion Capture (MoCap) and their technical meta-data. In the case of the Mastic pilot, drones have also been used to photograph mastic villages, so that their 3D reconstruction was made possible.
3. **Craft representation** refers to the definition of semantic meta-data, or basic knowledge elements. These are the tools and affordances used in the crafting process, as well as the related objects, places, events, and materials. Also, motion capture is segmented, tagged and retargeted into virtual humans in this step. All the semantic data, the links among the entities and the links to external entities are stored in the MOP, essentially creating a craft representation in the digital world.
4. **Process Representation.** This step refers to the representation of the crafting process in terms of steps and interrelating conditions between them that prescribe the crafting process. To this end, UML activity diagrams are used to formally represent the craft processes schemas, which are then encoded in the MOP. To represent the relationships among the process schema steps, the UML transition types Transition, Fork, Merge, Join, and Branch are adopted. Both processed schemas and process instances are modelled and inter-correlated.
5. **Craft presentation and preservation** refers to the experience built on top of this rich semantic representation, with the represented knowledge network made available through the WWW and the MOP in hypertext format. Semantic links are provided in the form of URI for external resources for digital items curated in MOP, while knowledge elements are linked to media objects of relevance. In this way, users can experience a rich interlinked knowledge network, in which they can easily discover much information on the underlying heritage crafts and their practising. For locations, embedded, dynamic maps are provided through OpenStreetMap, while timeline and calendar views can be dynamically created for the represented events. In this way, MOP visitors can explore all the desired dimensions of a craft and, by following the hyperlinks they are interested in, learn about everything they truly want to know, without being lost. Finally, documentation pages have been created which contain links to digital assets, textual presentation of metadata, and previews of the associated digital assets. For locations and events, specific UI modules are provided, and timeline and calendar views are automatically created.

6. **Exploitation.** The digitization of the crafts paved the way for creating engaging cultural experiences, that have the potential to have an impact on interest growth and tourism, which can support Heritage Crafts communities and institutions. Also, the pilot outcomes will attract new apprentices through training and demonstrations that guarantee long-term preservation. In this step of the proposed methodology, we present how each pilot’s results are exploited to promote the craft and ensure its publicity and preservation over time.

After the overall methodology is explained, a detailed report on the work of each pilot follows, showing how each methodology step was applied to it. The pilots chosen are:

#### **Pilot 1: Silk weaving.**

In this pilot, silk weaving is demonstrated in the context of textile manufacturing as practised by the Community of the Haus der Seidenkultur, a former silk factory that was turned museum where the traditional craft of jacquard weaving is still practised. To deeply understand the craft, Mingei collected knowledge from multiple sources such as archives, books, audiovisual material, digital representations, documentaries, interviews with craft practitioners, as well as pertinent essays that were provided by the HdS museum collaborators and personnel. We specifically studied the ‘Jacquard’ type of loom, being a loom featuring a special attachment, that, based on a “chain of cards” can automatically decide which coloured yarn should be chosen at any point throughout the weaving process for the desired pattern to be woven. This way, the ‘Jacquard’ attachment automates the weaving process and allows for complex patterns to be woven easily and without mistakes in massive. It is considered the first form of programming, and a predecessor of computers. We also paid attention to how these patterns were transferred from paper designs to actual punched cards fed to the ‘Jacquard’ attachment and to the symbols those patterns contain, as they usually unveil interesting stories, myths and legends.

The outcomes of this pilot can be summarized as:

- a) Applications that enhance the museum visit experience include the presentation of socio-historic context through narratives. More specifically, a museum tour guide has been developed on top of ten hot spots in the museum each one connected to relevant narrations and audio visual presentations that unveiled the hidden treasures of the craft of textile manufacturing. The application guides visitors through the chosen hot spots in the museum and presents audio-visual content, based on Silk Narratives that were also produced in the context of this pilot. Narrations by VHs enhance the presentation of narratives and contribute to the suspension of disbelief. In addition, scannable items and artefacts in the museum allow the user to access more information that is not included in the museum application per se. In addition to the museum tour guide, two visualizations were considered for presenting digitization outcomes and visualizing the socio-historic context. The first one regards the projection of digitization outcomes in interactive form, while the second regards the provision of information on the socio-historic context of the museum through interactive timelines. Both visualizations have currently been installed at FORTH premises.
- b) Applications and concepts that are inspired by traditional crafts to create new products and services. In this context, a handbag inspired by traditional crafts has been crafted, featuring cloth pieces of common motifs used by the Haus der Seidenkultur. Each motif has its history – a series of symbols that evolved in time and were artistically woven together to form

traditional ecclesiastical fabrics. The bag followed a minimal design approach based on the abstract style of Piet Mondrian was, and features a solid big base to ensure that it stands when placed on a surface and a long strap to be worn on the women's shoulder. An AR application has been built that can recognize the motifs on the bag and augment the virtual space around the bag with a canvas to present the stories behind those motifs. These stories relate to the history of Europe and the social and historic dimension of textile weaving. The bag is also a portal to a web of information provided through the MOP, as users can be transferred to the corresponding MOP web page through a virtual button entitled "view more info" on the virtual canvas. The crafted handbag serves one of the most important goals of HdS which is to raise awareness regarding the unique CH possessed by the museum and at the same time connect its legacy with European history and tradition.

- c) Innovative means for Web-based access to information and content for learning, education, and training. First of all, a dedicated web page delivered in three variations (for the public, researchers, and kids), summarizes all the key accomplishments of this pilot. The page is initiated through a page index that guides visitors to the main results delivered online, including rich audio-visual information supported by multimodal narratives. The MOP also provides access to historic narratives, which can be accessed in alternative means by studying (a) the narration text, (b) the key events presented in the narrative, (c) the main human participants, (d) the locations of events, and (e) the chronologic sequence of events. Secondly, a virtual museum application has been built that displays 3D reconstructions of historic Silk ecclesiastical garments in an image gallery carousel, where users can navigate and read the annotated information for each one of them. Thirdly, an interactive timeline visualization is delivered, which presents silk fabulae regarding historical and social events related to the craft of Silk in Krefeld. As the presented content is streamed directly from the MOP, it gets automatically generated with minimal technical effort. Finally, two games 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 have been created.

#### **Pilot 2: Mastic cultivation and chicle production.**

This pilot regards the representation of the mastic cultivation and chicle production handicrafts. Its main goal is to enable craft training and demonstration in the environment of an ethnographic heritage museum. To understand the craft, Mingei conducted extensive research, including:

- a) Archival research, which focused on the archive that Piraeus Bank Group Cultural Foundation (PIOP) acquired by Chios Mastic Growers Association,
- b) Photographic research, including photographs from fifteen categories, indicatively mentioning the Chios Mastic Growers Association, geographical and geological maps and diagrams, photographs of women at work, historical depictions of Chios and its mastic villages, mastic cultivation and processing (for market and chicle production), machines, objects and tools used, photographs related to customs and traditions and others
- c) Audiovisual material studied includes documentaries produced by television channels and cinematographers, documentation videos of history researchers and ethnographers, including interviews with mastic producers, men, and women that used to work at the Chios Mastic Growers Association and advertisement clips of the ELMA chewing gum. Finally, we studied



- d) (d). Audio material, including interviews with former employers at the Chios Mastic Growers Association, radio advertisements of the ELMA chewing gum and recordings of traditional songs regarding mastic cultivation and songs sung during traditional feasts were studied.

In the Mastic Pilot, stories are exploited as the primary means of transferring knowledge in the museum context. In this vain, the craft understanding activity gave birth to eight personas, the profiles and stories of which are an assortment of the material studied. Their stories (narratives) are intended to be narrated by the museum to its visitors to transmit the rich tradition of mastic, making visitors part of the social establishment of the craft. Virtual avatars incarnating those personas have been created using references from the ethnographic research, using a VH creation software and 3D modelling software for clothes and accessories to attain a high level of realism. The natural human movement was recorded using a motion-capturing suite, and voice recordings were used for the narrations rather than automatically generated voices. The result was high-quality virtual narrators whose outfit resembles that of workers in the mastic factory and that look, move and sound natural.

Moreover, in the context of the Mastic pilot, many reconstructions have taken place, including the mastic villages of Chios, which were reconstructed from aerial images acquired via a drone, the mastic factory machines that were used in the production of the mastic chicle, the mastic oil, and the mastic resign drops for the market. For reconstructing the mastic machines and the tools used in mastic cultivation, the actual machines and tools exhibited at the Chios Mastic Museum were scanned and photographed, turned into 3D models and were further post-processed to produce high-quality realistic 3D models. All the reconstructions have been stored in the MOP in the context of craft representation and preservation, along with the documentation, audio, audiovisual and photographic material collected.

The processes of mastic cultivation and chewing gum production, along with the processes performed by mastic growers and by the Chios Gum Mastic Growers Association have been modelled, and their semantic representation has been published to the MOP.

Specifically, for the mastic cultivation processes, the pilot has also modelled the cultivation activities. For the latter, individual motions have been captured using a motion capturing suite, both in the fields and indoors. The moves were further processed to correct occlusions and errors, stored in .bvh format and retargeted to a virtual human avatar that can demonstrate the craft in a virtual field.

Like all the pilots, the digital assets produced in the Mastic pilot are hosted in the MOP repository and are provided online in conventional and open formats. Also, the represented knowledge network is available through the WWW and the MOP in hypertext format. Semantic links are implemented as hyperlinks that lead to the pages of cited entities, essentially building a knowledge network for visitors to dive in. The craft of mastic cultivation is demonstrated in a virtual environment depicting a mastic tree field where a virtual worker replicates the moves captured during the craft documentation process. The virtual worker also manipulates virtual tools that were reconstructed, or whose 3D models have been built in the context of this pilot. The processed gestural know-how of the captured craft practitioner is used not only for replicating the movements of the practitioner but also for setting digitized craft tools in motion

using a technical approach for attaching tools to VHs and inferring tool motion from human motion.

To present the craft, the following applications have been built:

- a) A virtual mastic factory, that hosts all the 3D models of the mastic machines used for the chicle production, along with virtual storytellers that stand in front of the machines and are capable of narrating their story to the visitors. Users can navigate through the virtual space of the factory, discover the mastic machines and hear the narrator's stories about their personal and work lives, their duties in the factory, their education etc, as well as learn about the operation of the machines, and how each process was performed without them in the past. In this way, visitors can virtually travel back in time to that era and learn how people lived and worked.
- b) A virtual mastic field is a virtual environment resembling a mastic field, where a virtual farmer demonstrates the mastic cultivation and mastic collection processes, and the tools needed in each of these processes.
- c) Airborne, which is an immersive flight simulator installed both in an immersive projection room at FORTH premises and also in the multimedia room of the museum, consisting of three touch-enabled walls, supports people tracking, and body-based interactions. In this room, users can virtually fly over various mastic villages of Chios, stopping at each village and retrieving multimedia and text information related to it. The application is also built for standard PCs.
- d) An AR application that augments the mastic factory exhibition at the Chios Mastic Museum with narrations by Virtual Humans. The installation is comprised of four tablet devices each of them covering a specific area of the museum containing several hot spots. By selecting a hotspot, a virtual storyteller appears in the factory through the tablet camera, ready to narrate their life story, their daily life and work at the factory and provide information about the task performed in each hotspot (space or machine).
- e) A craft training application for mastic harvesting was created and installed in the museum's multimedia space. The application enables users to come in touch with the mastic harvesting process in the fields, by encouraging them to mimic the craft actions given as on-screen instructions.
- f) Finally, an AR application has been built for visitors to experience mastic cultivation in the field through their mobile devices, in the rural space outside the museum. The application facilitates an AR-capable device to recognize metallic sculptures that exist in the rural space of the museum. Through the camera, these sculptures become alive to present typical cultivation activities.

### **Pilot 3: Glass blowing.**

This pilot presents the process of producing a glass carafe, and specifically a copy of a glass carafe dated in 1842, made by Georges Bontemps. To deeply understand the craft of glass blowing, a thorough study on literature resources was conducted, along with background research that allowed the comprehension of basic vocabulary and notions. The ethnographic research involved audiovisual recordings and interviews with the practitioners and fieldwork observation to dive deep into the individualities of the crafting process and understand the intricate interweaving of local traditions and individual lives in cultural transmission. This pilot has an extra requirement concerning the other pilots, (but relevant to other crafts as well), being the viscous nature of hot

glass. In other words, the glass state (hot/cold) prohibits the pause of the crafting process during some sequences of tasks, meaning that more specific conditions are needed to model the glass blowing process. In line with the other pilots, a lot of data was collected, digitally recorded, post-processed, and curated in the Mingei Online Platform (MOP). Such data include objects and actions, audiovisual recordings, photographic documentation and 3D reconstructions of tools, products, and workspaces and captured (with the use of a full-body motion capturing suite) practitioner and apprentice crafting actions. To study and capture the process of recreating the studied artefact, fourteen carafes were crafted at the premises of CERFAV (Centre européen de recherches et de formation aux arts verriers). The process was documented using audiovisual and photographic material, and the craftsmen's moves were captured using a full-body motion capturing suite. The documentation of the process lead to activity diagrams that describe the process of carafe making step by step, which our team also semantically represented in the MOP. After the process schema modelling, the pilot also modelled one process of creating a carafe according to this schema. The process is modelled as a series of events that have a chronological order, and each event, i.e. each step of the process is linked to one or more documentation material of the specific event, such as photographs or audiovisual recordings.

To digitally preserve the craft knowledge, this pilot has modelled the tools and the machines used throughout the carafe creation process as well as the craftsmen's moves. The tools were mostly metallic, which means their 3D documentation was challenging. Also, the pilot has modelled all the machinery used in the glass blowing process. Especially for the creation of 3D models of machinery, the acquired audiovisual documentation acquired during the ethnographic research was used and the machines were created from scratch. Virtual Humans were also created in the context of this pilot using a combination of software.

In the context of presenting the craft of glass blowing, three applications were implemented and interconnected to present synchronized content. The main application is a simulation of the crafting process for creating a glass carafe and combines the knowledge of the crafting process with the modelling of the workshop, the tools, and the machines. It features a realistic virtual workshop that hosts all the machinery modelled along with the virtual humans and the tools. VHs essentially demonstrate the craft by manipulating the tools and performing the animations of the craftsmen's moves that were recorded during the ethnographic fieldwork at CERFAV. The presentation is made in such a way that the user feels like they stand next to real craftsmen during a carafe production and can explore the 3D scene as they wish. The second application presents close-up views of the gestures of the glassblowing VH to enhance the understanding of the audience regarding specific crafting gestures used in the making process. Finally, the third application presents the tools used in each step of the process to enhance the understanding between craftsmanship, gestures, and tools. To experience glassblowing gestures, an interactive installation was created as well at which the user can watch a video of an expert performing the gestures and then try to imitate his moves.

The results of this pilot including the aforementioned applications were deployed in the context of a periodic exhibition at the premises of the museum of CNAM in a dedicated space.

## Keywords

Heritage Crafts, Traditional Crafts, Craft Representation, Craft Preservation, Craft Presentation, Virtual Reality, Mixed Reality, Augmented Reality, Interaction, Knowledge Representation, Multimodal Narratives, Human Motion Visualisation

## Document History

Date	Version	Author/Editor	Affiliation	Comment
28.06.2021	0.1	Nikolaos Partarakis	FORTH	Initial draft
29.07. 2021	0.2	Mingei consortium	Mingei	Comments on the initial draft
02.08. 2021	0.3	Effie Karuzaki	FORTH	Revised draft
03.09. 2021	0.4	Mingei consortium	FORTH	Comments on the revised draft
16.10. 2021	0.5	Effie Karuzaki	FORTH	Revised draft
16.11. 2021	0.6	Mingei consortium	Mingei	Comments on the revised draft
16.12. 2021	0.7	Nikolaos Partarakis	FORTH	Revised draft
22.01.2022	0.8	Mingei consortium	ARMINES	Final comments
08.02.2022	0.9	Nikolaos Partarakis	FORTH	Final version
05.05.2022	1.0	Ilia Adami	FORTH	Version that includes the evaluation results
25.05.2022	1.1	Nikolaos Partarakis	FORTH	Version that includes the online pilots
31.05.2022	1.2	Margerita Antona	FORTH	Final QA reviewed version

## Abbreviations

<b>HC</b>	Heritage Craft
<b>MoCap</b>	Motion Capture
<b>CH</b>	Cultural Heritage
<b>CHI</b>	Cultural Heritage Institutions
<b>CIDOC-CRM</b>	CIDOC Conceptual Reference Model
<b>LHTs</b>	Living Human Treasures
<b>CC0</b>	Creative Commons
<b>CrO</b>	Crafts Ontology
<b>MOP</b>	Mingei Online Platform
<b>AR</b>	Augmented Reality
<b>VR</b>	Virtual Reality
<b>MR</b>	Mixed Reality
<b>VH</b>	Virtual Humans
<b>TC</b>	Traditional Crafts



## Table of Contents

Keywords.....	8
Table of Contents .....	11
List of figures.....	18
1. Introduction .....	25
2. Background and Related Work .....	27
2.1 Digital representation of Traditional Crafts .....	27
2.2 Interactive technologies for CH .....	28
2.2.1 Augmented Reality.....	28
2.2.2 Virtual Humans.....	29
2.2.3 Mixed reality .....	29
2.2.4 X-Reality .....	30
2.3 Importance of Intangible Cultural Heritage for sustainable tourism .....	30
3. The methodology adopted in the Mingei pilots .....	31
3.1 Craft understanding .....	31
3.2 Data collection .....	32
3.2.1 Audiovisual recordings.....	32
3.2.2 Documentation of tools, machinery, and workspaces .....	32
3.2.3 Motion capture .....	32
3.3 Craft representation .....	33
3.4 Process representation .....	33
3.5 Craft presentation and preservation .....	34
3.6 Exploitation .....	34
4. Pilot 1: Silk weaving.....	35

4.1	Craft understanding .....	35
4.1.1	Knowledge collection and literature review .....	35
4.1.2	Understanding silk weaving .....	36
4.1.3	Weaving jacquard patterned fabrics .....	38
4.1.4	Silk loom preparation.....	40
4.1.5	Formulation of historic narratives .....	40
4.2	Data collection .....	41
4.2.1	Photographic documentation .....	41
4.2.2	Ultra-high resolution surface scanner .....	42
4.2.3	3D digitization of ecclesiastical vestments .....	42
4.2.4	Video documentation of craft practitioners .....	43
4.2.5	MoCap of craft practitioners.....	44
4.2.6	MoCap of narrators.....	45
4.3	Craft representation .....	45
4.3.1	Visual tracking from audiovisual craft documentation .....	45
4.3.2	Visual tracking from audiovisual archives.....	47
4.3.3	MoCap segmentation.....	49
4.3.4	Motion retargeting.....	49
4.4	Process representation .....	51
4.5	Craft presentation and preservation .....	52
4.5.1	Digital preservation.....	52
4.5.2	Craft documentation.....	53
4.5.3	Craft demonstration.....	54
4.6	Exploitation .....	55

4.6.1	Enhancing the museum visit experience .....	55
4.6.1.1	Museum tour guide – Narratives in the museum .....	55
4.6.1.2	Digital information visualization in the museum .....	56
4.6.2	A handbag inspired by traditional crafts.....	57
4.6.3	Web-based access to immersive visualizations .....	58
4.6.3.1	Historic narratives .....	60
4.6.3.2	Virtual Museum – Discover the ecclesiastical garments of Krefeld.....	62
4.6.3.3	Interactive Timeline.....	62
4.6.3.4	Craft games.....	63
5.	Pilot 2: Mastic cultivation & chicle Production .....	64
5.1	Craft understanding .....	64
5.1.1	Creation of personal stories of mastic factory workers.....	65
5.1.2	Analysis of the industrial production of mastic chicle .....	65
5.1.3	Narratives.....	66
5.2	Data collection: endurant entities .....	66
5.2.1	Reconstruction of mastic villages .....	66
5.2.2	Reconstruction of mastic factory machines .....	66
5.2.3	Modelling of mastic cultivation tools.....	67
5.2.4	Modelling the mastic factory .....	68
5.2.5	Virtual factory workers .....	69
5.3	Data collection: perdurant entities.....	72
5.3.1	MoCap of mastic cultivation activities.....	72
5.3.2	MoCap of narrations from factory workers.....	73
5.4	Craft representation .....	74

5.5	Process representation .....	76
5.5.1	Processes performed by mastic growers.....	77
5.5.2	Processes performed by the Chios Gum Mastic Growers Association.....	79
5.6	Craft presentation and preservation .....	79
5.6.1	Digital preservation.....	79
5.6.2	Craft documentation.....	79
5.6.3	Presentation of craft actions.....	80
5.6.4	Presentation of craft actions in virtual environments.....	80
5.7	Exploitation .....	81
5.7.1	Geographical context presentation .....	81
5.7.2	Virtual storytellers.....	82
5.7.3	The exhibition at the Chios Mastic Museum .....	84
5.7.4	Training on the gestural know-how of mastic cultivation .....	84
5.7.5	Augmenting the mastic factory exhibition with narrations by Virtual Humans.....	85
5.7.6	Presentation of geographic context .....	86
5.7.7	Augmentation of the mastic field using mobile devices.....	87
5.7.8	Preliminary evaluation of the Mastic Pilot .....	87
5.8	Craft understanding .....	90
5.9	Data collection .....	90
5.9.1	Audiovisual recordings.....	91
5.9.2	Documentation of tools, machinery, and workspaces .....	91
5.9.3	Motion capture .....	93
5.9.4	Data curation.....	93
5.10	Craft representation .....	94

5.11	Process representation .....	95
5.11.1	Process schema representation .....	95
5.11.2	Specific process representation .....	96
5.12	Craft presentation and preservation .....	97
5.12.1	Digital preservation for glassblowing .....	97
5.12.2	Glassblowing documentation .....	98
5.12.3	Craft demonstration.....	99
5.12.3.1	Workshop .....	99
5.12.3.2	Implementation of Virtual Humans & animation .....	100
5.12.3.3	Tool usage.....	101
5.12.3.4	Workshop demonstration .....	101
5.12.4	Glassblowing training.....	103
5.13	Exploitation .....	104
5.13.1	Preliminary evaluation .....	106
6.	Evaluation of installations at pilot sites .....	108
6.1	Silk pilot evaluation results .....	109
6.1.1	UEQ results.....	110
6.1.2	Ad-hoc questions results.....	112
6.1.3	Net Promoter Score (NPS) .....	114
6.1.4	Other comments .....	114
6.2	Mastic pilot evaluation results.....	115
6.2.1	Mastic narrations application .....	115
6.2.1.1	UEQ results .....	117
6.2.1.2	Open-ended questions .....	118

6.2.1.3	Ad-hoc questions.....	120
6.2.1.4	Net Promoter Score.....	123
6.2.2	Mastic landscapes application .....	123
6.2.2.1	UEQ results .....	124
6.2.2.2	Open-ended questions .....	125
6.2.2.3	Ad-hoc questions.....	127
6.2.2.4	Net Promoter Score.....	128
6.2.3	Mastic gestures application .....	128
6.2.3.1	UEQ results .....	129
6.2.3.2	Open-ended questions .....	131
6.2.3.3	Ad-hoc questions.....	132
6.2.3.4	Net Promoter Score (NPS).....	133
7.3	Glass pilot questionnaire results.....	133
6.2.4	UEQ results.....	134
6.2.5	Open-ended questions.....	136
6.2.6	Ad-hoc questions .....	137
7.	Web-based communication of the pilots .....	141
7.1	Glass .....	141
7.1.1	Researchers and Academics.....	141
7.1.2	craft education and training .....	142
7.1.3	Exhibition .....	143
7.1.4	Kid's corner .....	144
7.2	Mastic.....	145
7.2.1	Researchers and Academics.....	146



7.2.2	craft education and training .....	147
7.2.3	Exhibition .....	150
7.3	Silk .....	152
7.3.1	Researchers and Academics.....	153
7.3.2	craft education and training .....	154
7.3.3	Kid’s corner .....	155
7.3.4	Exhibition .....	156
8.	Discussion and lessons learned.....	158
8.1	Methodology structure .....	158
8.2	Collaboration.....	158
8.3	Replicability.....	158
8.4	Potential improvements .....	159
	References.....	160

## List of figures

Figure 1: Proposed methodology.....	31
Figure 2. The three stages of weaving. ....	38
Figure 3. Loom with Jacquard attachment. ....	38
Figure 4. Transfer of a pattern to squared paper. ....	39
Figure 5. Translating the design into punched cards.....	39
Figure 6. Punched cards for the Jacquard attachment.....	40
Figure 7. Silk loom preparation.....	40
Figure 8. Photographic documentation of ecclesiastical garments of HdS. ....	42
Figure 9. Ultra-high-resolution scan of silk fabrics. ....	42
Figure 10. (a) Original images of an ecclesiastical vestment made from silk and gold brocade and (b) photogrammetric 3D reconstruction, (c) online videos showing 3D garment reconstructions. ....	43
Figure 11. (a) All of the recording cameras in action, (b) Representative frames of the weaving process along with the estimated 3D skeletal (body/hands) pose of the expert. ....	44
Figure 12. Examples of tasks of textile manufacturing.....	45
Figure 13. Visual tracking examples.....	47
Figure 14. Representative sequences of tracking a single or both hands of an expert during the weaving process as described in HdS at Krefeld documentaries. ....	49
Figure 15. Animation sequences.....	50
Figure 16. (a) Importing the mocap file into MotionBuilder., (b) Matching the avatar with the actor. ....	51
Figure 17. Process schema representation in MOP.....	52
Figure 18: Screenshot of the MOP.....	53
Figure 19. Examples of the animated virtual avatar for the silk pilot. ....	54
Figure 20. Excerpt from the Museum tour guide application for the HdS museum.....	56
Figure 21. Physical installation of Discover the ecclesiastical garments of Krefeld – Photo was taken from installation at FORTH premises. ....	56

Figure 22. Interactive Timeline – projected information on multiple adjacent walls ( <i>left</i> ) and projected annotation of a selected element ( <i>right</i> ) – Photo taken from installation at FORTH premises.....	57
Figure 23. The AR app is presenting information on the recognized pattern.....	58
Figure. 24 Web-based dissemination of results. ....	59
Figure 25. A presentation of a socio-historic narrative in MOP. ....	61
Figure 26. Screenshots of Virtual Museum application UIs – Image gallery of 3D reconstructions of vestments (left) and annotated information of selected vestment (right).....	62
Figure 27. Annotated information of selected events drawn from the MOP. ....	62
Figure 28 – (a) Design Pattern Game, (b) Punch card game.....	63
Figure 29: Village reconstruction using aerial images acquired by a drone.....	66
Figure 30. Photographic documentation of chicle production machines together with photogrammetric reconstruction results and post-processing in Blender 3D [24].....	67
Figure 31. Renderings of 3D models of mastic cultivation tools in Blender 3D [24]. ....	68
Figure 32. Mastic factory using HDRP in Unity. ....	69
Figure 33. Creating the look of the virtual workers.....	69
Figure 34. (a) Placing & conforming an imported 3D mesh of a dress, (b) Posable functionalities to test the skinning values, (c) Testing the skinning values and the collision between the body and the garment or accessory.....	71
Figure 35. (a) Checking bone positions., (b) Rigged model assuming poses. ....	72
Figure 36. Recording narrations with the help of (a) a Female narrator, and (b) a male narrator. ..	74
Figure 37. Presentation of (a) 3D objects and (b) 3D reconstructions, in MOP. ....	75
Figure 38. Representation in MOP of (a) Events, (b) Persons, and (c) Locations. ....	76
Figure 39. UML diagram of the cultivation process.....	77
Figure 40. Examples of animating a VH using BVH input from MoCap recordings. ....	80
Figure 41: Demonstration of the mastic cultivation activities by a VH .....	81
Figure 42. Airborne deployed in an immersive projection room. ....	82

Figure 43. Airborne is accessed in its standalone version through a desktop PC. ....	82
Figure 44. (a) Virtual factory with machines, (b) Examples of narrator VHs is the virtual factory....	83
Figure 45. An instance of the main screen of the interactive installation.....	84
Figure 46. Craft training through replication of the gestural know-how of the mastic cultivator....	85
Figure 47. A view of the available hot spots for a specific area of the museum.....	85
Figure 48. A VH appears through AR on the screen showing the available narrations.....	86
Figure 49. An instance of the main screen of the interactive installation.....	87
Figure 50. Mobile app navigation example. ....	87
Figure 51. The carafe is on display at the museum of CNAM.....	89
Figure 52. A collection of glassblowing tools at the museum of CNAM.....	89
Figure 53. 3D models of glass workshop tools. ....	92
Figure 54. 3D models of glass workshop machines. ....	92
Figure 55. Digital assets. ....	94
Figure 56. Process schema representation in MOP.....	96
Figure 57. Process representation in MOP. ....	97
Figure 58. Computer-aided, VR presentation of glassblowing processes. Top: marvering. Middle: shaping. Bottom: illustration of the glass deformation during glassblowing.....	99
Figure 59. Artificial lighting. ....	100
Figure 60. Animating the Virtual Human. ....	101
Figure 61. Main application screen.....	102
Figure 62. Close-up views of the glassblowing process. ....	103
Figure 63. Overview of the tools used in each step.....	103
Figure 64. left- An instance of the main screen of the interactive installation, right – instructions. ....	104
Figure 65. Building up the installation at CNAM.....	105

Figure 66. Craft workshop presentation.....	106
Figure 67. left- Craft training screen view, right – craft training – user view.....	106
Figure 68: Age distribution of respondents – Virtual Museum Tour application.....	110
Figure 69: Aggregate means and variance per UEQ scale – Museum Tour application.....	111
Figure 70: Frequency for ad-hoc questions 1-3 – Virtual Museum Tour application.....	113
Figure 71: Frequencies for ad-hoc questions 4-5 – Virtual Museum Tour application .....	113
Figure 72: Frequencies for ad-hoc questions 7-8 – Virtual Museum Tour application .....	113
Figure 73: Age distribution of post-interaction questionnaire respondents – Mastic narrations ..	117
Figure 74: Country of origin distribution of post-interaction questionnaire respondents – Mastic narrations.....	117
Figure 75: Aggregate means and variance per UEQ scale – Mastic narrations application.....	117
Figure 76: Frequency for ad-hoc questions 1-3 – Mastic narrations application.....	121
Figure 77: Frequency for ad-hoc questions 4-6 – Mastic narrations application.....	121
Figure 78: Graphs displaying frequencies of answers for ad-hoc questions 7-9 – Mastic narrations application.....	122
Figure 79: Graph displaying frequencies of answers for ad-hoc questions 10 – Mastic narrations application.....	122
Figure 80: Age distribution of respondents – Mastic landscapes application.....	124
Figure 81: Country of origin distribution of respondents – Mastic landscapes application .....	124
Figure 82: Aggregate means and variance per UEQ scale-Mastic landscapes application .....	124
Figure 83: Frequency for ad-hoc questions Q1-3 – Mastic landscapes application .....	127
Figure 84: Frequency for ad-hoc question Q4 – Mastic landscapes application.....	128
Figure 85: Age distribution of post-interaction questionnaire respondents – Mastic gestures application.....	129
Figure 86: Country of origin distribution of post-interaction questionnaire respondents – Mastic gestures application.....	129
Figure 87: Aggregate means and variance per UEQ scale-Mastic gestures application .....	130

Figure 88: Frequency for ad-hoc questions Q1-3 – Mastic gestures application .....	133
Figure 89: Age distribution of post-interaction questionnaire respondents – Glass interactive application.....	134
Figure 90: Country of origin distribution of post-interaction questionnaire respondents – Glass interactive application .....	134
Figure 91: Aggregate means and variance per UEQ scale-Glass interactive application .....	135
Figure 92: Frequency for ad-hoc questions Q1-3 – Glass application .....	139
Figure 93: Frequency for ad-hoc questions Q4-6 – Glass application .....	139
Figure 94: Frequency for ad-hoc questions Q7-8 – Glass application .....	139
Figure 95. A segment of the glass pilot landing page. ....	141
Figure 96. Glass pilot – for researchers and academics.....	142
Figure 97. Glass pilot – education and training material.....	143
Figure 98. A segment of the CNAM exhibition page. ....	144
Figure 99. Online presentation of the virtual glassblowing workshop.....	144
Figure 100. Glassblowing comic book.....	145
Figure 101. A segment of the mastic pilot landing page. ....	146
Figure 102. A segment from step 5 on the researchers and academics page.....	147
Figure 103. Online craft education for the Mastic cultivation.....	149
Figure 104. A segment of the thematic tourism page of the Mastic pilot. ....	150
Figure 105. A segment of the Mastic museum exhibition page. ....	151
Figure 106. Presentation of experiences available on site. ....	152
Figure 107. A segment of the Silk pilot landing page. ....	153
Figure 108. A segment from step 3 on the researchers and academics page.....	154
Figure 109. Segments from the education and training page. ....	155
Figure 110. A segment of the kids' corner page. ....	156



Figure 111. A segment of the exhibition page.....	157
---	-----

## List of tables

Table 1. Repetitions and mean durations of gestures extracted from the tasks recorded at HdS. ..	49
Table 2. Recordings of mastic cultivation activities with a MoCap suit. ....	73
Table 3. Tasks recorded at CERFAV.....	93
Table 4: UEQ results per item (Mean, variance, std. dev.) – Museum Tour application .....	111
Table 5: Median, mode, and inter-quartile ranges for ad-hoc questions – Museum Tour application .....	112
Table 6: Frequency of answers for questions Q1-3 – Virtual Museum Tour application.....	112
Table 7: Frequency of answers for questions Q4-8 – Museum Tour application.....	113
Table 8: UEQ results per item (Mean, variance, std. dev.) – Mastic narrations application.....	118
Table 9: Categories of comments and number of comments per category for question “List what you liked the most” – Mastic narrations application.....	119
Table 10: Categories of comments and number of comments per category for question “List what you liked the least” – Mastic narrations application .....	119
Table 11: Median, mode, and inter-quartile ranges for ad-hoc questions – Mastic narrations application.....	120
Table 12: Frequency of answers for questions Q1-5 – Mastic narrations application.....	121
Table 13: Frequency of answers for questions Q6-10 – Mastic narrations application.....	121
Table 14: UEQ results per item (Mean, variance, std. dev.) – Mastic landscapes application.....	125
Table 15: Categories of comments and number of comments per category for question “List what you liked the most” – Mastic landscapes application.....	126
Table 16: Categories of comments and number of comments per category for the question “List what you liked the least” – Mastic landscapes application .....	126
Table 17: Median, mode, and inter-quartile ranges for ad-hoc questions – Mastic landscapes application.....	127
Table 18: Frequency of answers for questions Q1-4 – Mastic landscapes application.....	127
Table 19: UEQ results per item (Mean, variance, std. dev.) – Mastic gestures application.....	130

Table 20: Categories of comments and number of comments per category for the question “List what you liked the most” – Mastic gestures application .....	131
Table 21: Categories of comments and number of comments per category for the question “List what you liked the least” – Mastic gestures application .....	132
Table 22: Median, mode, and inter-quartile ranges for ad-hoc questions – Mastic gestures application.....	132
Table 23: Frequency of answers for questions Q1-4 – Mastic landscapes.....	132
Table 24: UEQ results per item (Mean, variance, std. dev) – Glass interactive application .....	135
Table 25: Categories of comments and number of comments per category for question “List what you liked the most” – Glass interactive application .....	136
Table 26: Categories of comments and number of comments per category for question “List what you liked the least” – Glass interactive application.....	137
Table 27: Median, mode, and inter-quartile ranges for ad-hoc questions – Glass application .....	138
Table 28: Frequency of answers for questions Q1-3 – Glass application.....	138
Table 29: Frequency of answers for questions Q4-8 – Glass application.....	138

## 1. Introduction

Mingei is implementing the tools and thus, creating the necessary conditions to preserve and support the transmission of HCs and associated CH knowledge, as well as, to support research in this domain of CH. These tools are stemming from the following Mingei Activities:

- **An HC representation protocol:** Mingei is implementing a **representation protocol** that will allow the gathering, annotating, and semantically organising digital assets and derived knowledge (reported in D1.3). Non-digitised essential components of HCs such as skills and actions are being captured by **mature technological components**. Abstract crafts values, such as contextual information, are described using vocabularies and the CrO that is being implemented for this purpose.
- Mingei is implementing technologies to offer **access to HC representations and tools** for querying, storytelling, and experiencing HCs through preserved knowledge. These tools are co-designed with stakeholders.
- Mingei is exploring the potential of contributions to specific use cases in different learning contexts: informal education and leisure, formal education and HC-oriented, and Cultural Tourism. Pilots are **covering diverse HCs**, present multiple tangible and intangible HC dimensions, and exhibit **complementarity**. This complementarity regards the **characteristic attributes, values and dimensions** that define HCs. The pilots address a **wide thematic range**: *materials, HC products, handicraft skills and use of tools or machinery, endangered and indigenous crafts, traditional, artisan and industrialized crafts, indoors and outdoors practice, gender and age roles, intergenerational learning, societal and economic impact, cultural and regional identity, as well as, tradition and personal creativity.*

At the same time, Mingei has as a primary **stakeholder the general public** as the preserved CH belongs to all people. The individual benefit of stakeholders reinforces the benefit of the primary, as stakeholder gains are co-related; i.e. HC research can provide new content for museums, while increased visitation funds HC research. Stakeholders include:

- **HC communities** benefit from documentation, preservation, growth of interest, and educational tools.
- **Museums, CHIs, and CCIs** will obtain novel content and attractive ways to present it.
- **CH researchers and professionals** will obtain knowledge repositories and tools that support new research.
- **Cultural tourism and associated businesses** will obtain new content, stories, and marketing capabilities.

Also, reviving or reenacting processes, locations, places and traditions connected with crafts may provide new dimensions and enhance the museum visit experience.

In this deliverable, an extensive report on the three Mingei pilots namely ‘Silk Weaving’, ‘Mastic Cultivation & Gum Production’ and ‘Glass Making’, is provided. In the following sections, the deliverable will firstly provide the background and discuss the related work on preserving cultural heritage and on the technologies used, and then it will analyse the overall methodology adopted for understanding, documenting and preserving the three crafts chosen for the Mingei pilots. Afterwards, a detailed report will take place on each pilot, which will present pilot-specific

information on craft understanding, data collection, craft representation, process representation, craft presentation and preservation as well as the results of each pilot, how are they exploited to demonstrate the craft and attract more people to it.

## 2. Background and Related Work

### 2.1 Digital representation of Traditional Crafts

A staggering amount of research on the digitization of artefacts and archives has taken place in the last two decades [1, 2, 3, 4]. This enormous effort has led to sophisticated digitization techniques of artefacts and documents, as well as, guides of good practice for digitization streamlining [5]. Moreover, efforts in the preservation of digital assets have produced standards in digitization formats and enabled the production of knowledge bases open to the public for general knowledge or application development, i.e. Europeana. More recently, the CH community has an advanced interest in capturing, modelling, and digitally preserving intangible aspects of CH.

HCs are recognized as a form of CH by prominent organizations. In 2003, UNESCO adopted a Convention for the Safeguarding of Intangible Cultural Heritage (ICH), and in its authoritative text [6] it enumerates traditional craftsmanship as an independent category of Intangible ICH. HCs comprise a scientifically challenging domain of CH because it includes both tangible and intangible faces qualifying HCs as “the most tangible manifestation of intangible cultural heritage” [6]. HCs exhibit a wide thematic range of CH topics of historical, societal, anthropological, and ethnographic interest.

To date, research efforts on HCs have been scattered through materials and places of production and very few have treated the topic of HCs as a source of renovation and innovation of knowledge. Despite its importance in the mid-19th century, scientific literature on the preservation and curation of HCs started to emerge recently; only a few studies are treating the topic in an integrated manner, given its multifaceted nature. Efforts toward appropriate treatment have emerged, through the collaboration of a wide range of experts by UNESCO [6], providing a theoretical basis for this effort. Besides case studies, there has been no effort devoted to the representation of all HC dimensions and the curation of the corresponding digital assets.

The multifaceted nature of HCs has provided a range of definitions that are explored in seminal attempts to define theoretically the notions and contexts of HCs [7, 8]. Though a crisp definition is elusive it is conceded that HCs are characterized, as a minimum, by (a) traditional materials and technologies of their manipulation, (b) a certain type of product (c) dextrous use of tools and or hand-operated machinery to make or repair useful things and (d) a type of making that involves knowledge and application of traditional designs.

HCs have both tangible and intangible dimensions. Tangible dimensions regard artefacts & buildings, clothing, tools and machinery, documents & archives, as well as the materials and the physical environment of practice. Their digitization has been addressed by past digitization projects and breadth of methods and best practice guides are now available. Intangible Dimensions of HCs have also multiple faces that include the required skills, the learning process, as well as the cultural, religious, social, economic, and creative faces [8].

There exists a theoretical and technological gap that calls for: (a) a formalized process for the representation of HCs coping with challenges that stem from the representation of the multidimensional nature of HC and the diverse range of experts involved and (b) a technological



This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 822336.

<http://www.mingei-project.eu/>

infrastructure that supports these goals, copes with the large data volume and avails collaboration between these experts.

## 2.2 Interactive technologies for CH

Cultural Heritage Institutions seek new ways to attract and engage new visitors. One of the ways to obtain competitive advantage is the investment and implementation of interactive experiences on-site [55]. Over the years, several technologies have emerged each of which provides forms of interaction and various levels of immersion but also poses requirements in terms of space, setup, and deployment. In this sub-section of the deliverable, the most prominent of these technologies are presented.

### 2.2.1 Augmented Reality

AR has a significant influence on visitor experience [58], and exhibit the potential of providing craft experiences to museum visitors. The conventional use of AR is to interactively visualize digital assets in place with physical exhibits [56]. Museum visits can also be enhanced via the inclusion of Virtual Humans (VHs) [57] in the augmented content, as demonstrators and narrators. This enhancement is significant because AR offers more advantages to museum visitors considering that information can be overlaid upon video frames captured by a camera. AR has been applied to make it possible to visualize incomplete or broken real objects as they were in their original state by the superimposition of the missing parts [87]. The ARCO system [88], [89] provides customized tools for Virtual Museum (VM) environments, ranging from the digitization of museum collections to the tangible visualization of both museum galleries and artworks. In [90], Virtual Humans (VHs) are used in an AR setting to present narratives on the everyday life of workers in a mastic factory narrated by the workers themselves appearing virtually within the exhibition.

AR has also been reinforced by advances in mobile computing and display technologies [59, 60]. Today, commercial applications are developed in a wide range of disciplines that include physical, industrial, and handicraft interaction [61, 62]. AR systems use the display of the device to implement a transparency metaphor, in which the live feed from the camera is used as if the device is transparent and the user is looking through the screen's glass. In this illusion, the system realistically augments the feed with objects and events that are not present in the physical environment. In this task, the estimation of the location and orientation, of the device, is crucial and is largely based on the visual input from the camera. Robustness is supported by markers, which provide spatial references [63]. The proliferation of unique key point features largely alleviated the requirements for markers or increased the flexibility in the appearance of markers to match the aesthetic needs of the installations [64]. More immersive experiences are provided by untethered AR headsets.

A common denominator in the degree of immersion is the compatibility of the appearance of the displayed content with the physical environment, True AR describes the condition of an AR experience that is not distinguishable from reality due to the high level of realism [65, 66]. Several True AR examples can be found in [68, 69, 70, 71]. In True AR, Visual realism requires, at least, the treatment of geometric and photometric consistency. Geometric consistency requires that the virtual objects and VHs must be spatially registered in the environment to give the impression that is part of it. It is thus required that occlusions are treated when augmenting virtual objects in the video feed and, thus, a 3D model of the environment facilitates the solution of this problem [72,



73]. Photometric consistency dictates that the virtual content must be lit as if immersed in the light of the real environment. To solve this problem, highlights, shadows, and brightness are rendered in consistency with the physical environment [74]. AR systems also facilitate the implementation of virtual museums [75]. Many AR approaches emerged, each one focusing on individual aspects of augmenting physical exhibits with digital content [76]. In [78, 80] the importance of immersion for CH applications is underscored. In [77], a pipeline for highly realistic digital asserts, suitable for AR applications, is proposed. In [81], antiquities were showcased through tours of the archaeological site using Meta AR glasses. Components for the development of AR applications for CH are proposed in [79].

### 2.2.2 Virtual Humans

VHs are able on simulating verbal and nonverbal communication. This type of interface is made possible with the help of multimodal dialogue systems, which extend common speech dialogue systems with additional modalities just like in human-human interaction [82]. The visual representation of a character including its perceivable behaviour, from a decoding perspective, such as facial expressions and gestures, belongs to the domain of Computer Graphics and likewise implicates many open issues concerning natural communication. However, employing virtual characters as personal and believable dialogue partners in multimodal dialogues entails several challenges, because this requires not only a reliable and consistent motion and dialogue behaviour but also nonverbal communication and affective components. Besides modelling the “mind” and creating intelligent communication behaviour on the encoding side, which is an active field of research in artificial intelligence [83], the visual representation of a character including its perceivable behaviour, from a decoding perspective, such as facial expressions and gestures [84], belongs to the domain of computer graphics and likewise implicates many open issues concerning natural communication [85, 86]. Concluding, building realistic VHs was traditionally a great challenge requiring a professional motion capturing studio and heavy resources in 3D animation and design. Lately, workflows for the implementation of VHs have been proposed, based on current technological trends in wearable mocap systems and advancements in software technology for their implementation, animation, and visualization [14].

### 2.2.3 Mixed reality

MR relies on a combination of VR, AR, and the real environment. It essentially refers to the merging of real and virtual worlds to produce new environments and visualizations where physical and digital objects co-exist and interact in real time. According to Milgram and Kishino’s virtuality-continuum, real-world and virtual world objects are presented together on a single display (e.g. the screen of a mobile phone) [15] that displays the visual representation of both the real and the virtual space [16]. An example of the use of MR techniques in a museum environment is the Situating Hybrid Assemblies in Public Environments (SHAPE) project [17] which uses hybrid reality technology to enhance users’ social experience and learning in the museum and other exhibition environments, concerning cultural artworks and to their related contexts. Several studies demonstrate that the use of new and combined media enhances how culture is experienced. In this regard, CH uses such technologies for different purposes, including education, exhibition enhancement, exploration, reconstruction, and virtual museums. Among the multiple manifestations of MR for cultural Heritage most relevant to this work is the usage of augmented artefacts to access and interact with information and artefacts [e.g. 91]. Previous approaches include multimodal interfaces to augment

physical CH artefacts with information [92, 93], CH inspired games that employ physical items and digitizations of physical items and sites [94, 95, 96], informative art displays [97, 98, 99, 100] and immersive mixed reality environments for CH [101].

#### 2.2.4 X-Reality

AR, VR, and MR applications when coexisting in a physical context are referred to as X-Reality (Extended Reality) or XR applications [18]. The use of such technologies has the potential to enrich the information of cultural heritage artefacts and museum exhibits and turn passive visitors into active participants engaged in an interactive and immersive blend of physical and virtual as if it was a single, unified world [19].

### 2.3 Importance of Intangible Cultural Heritage for sustainable tourism

The wealth and variety of expressions and forms of ICH are steadily becoming a principal motivation for travel around the world. Many forms of ICH tourism are associated with a longer duration of stay than tangible CH sites (i.e. archaeological sites), which is required for appreciating and experiencing ICH [20]. The UN-World Tourism Organization (UNWTO) recognizes that an important challenge lies in identifying, protecting and safeguarding ICH by investing in sustainable tourism development, in consultation with local communities and other stakeholders [21]. In this context, community participation and engagement through inclusive co-design, and co-curation activities will increase the acceptance and participation of local communities, which are central to the success of tourism services. As recommended, stakeholders will “enjoy the benefits of tourism development” and “establish projects with communities” [21]. Trends in the Cultural and Creative Industries [22] show that availing content electronically, on-site and via the WWW, increases interest and financial impact. In line with the Faro Convention, technical approaches for ICH should demonstrate the value of HCs in “sustainable development, cultural diversity and contemporary creativity”[23], meaning that profits contribute to and motivate the preservation of HCs. By providing the ways HC representations and competitive, educational, and compelling tourism experiences, it is possible to increase the visibility of HCs and preserve this form of ICH as a “shared source of remembrance, understanding, identity, cohesion and creativity”[23]. These properties follow the UNWTO recommendation to actively support “initiatives that follow international best practice for documentation, the use of information technologies and the communication of ICH values”[21].

### 3. The methodology adopted in the Mingei pilots

An articulated approach to the documentation and representation of crafts is proposed in [39, 40 and 41]. The methodology adopted stems from the application of the Mingei Protocol for craft digitisation as presented in the Mingei deliverable D1.3. The technical implementation of the approach for the formal and digital representation of the crafting process is supported by the Mingei Online Platform (MOP) [35], where digital assets and semantic meta-data are organized in a formal representation compatible with contemporary digital preservation standards. The proposed approach is articulated in a sequence of phases, as illustrated in Figure 1. Following this methodology, the representation maintained by the MOP includes knowledge that is represented in (conceptual) layers that correspond to representation tasks as outlined in the next subsections.

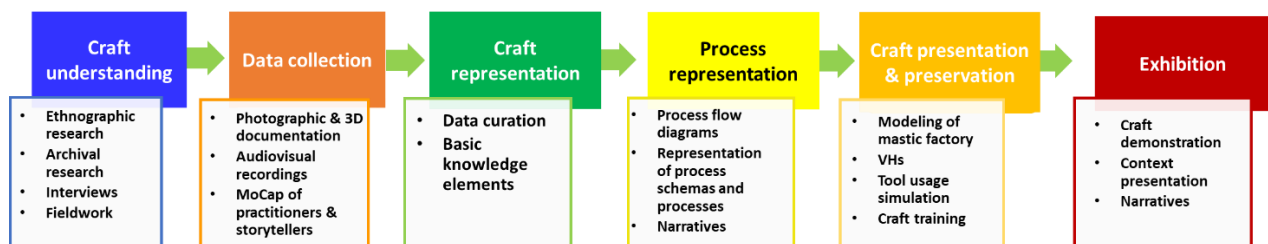


Figure 1: Proposed methodology

#### 3.1 Craft understanding

*Craft understanding* identifies the workflow of the crafting processes, the location of practice, the involved objects, and its actors. It *begins with the collection of existing knowledge of the following categories*:

- Basic knowledge including (a) curated text, (b) curated material, and (c) formal representation
- Existing content includes (a) archives, (b) bibliographic research outcomes, (c) audiovisual material, and (d) digital representations
- Contextual information (1) brief description of the craft (2) geographical location and range of the craft, (3) selected and representative communities concerning the craft, (4) craft workers / skilled workers / handicrafts education, (5) gender roles, (6) equipment, (7) craft products, (8) craft traditions including oral tradition / story telling / work songs / myths & legends, (9) social practices / social dimension, (10) economic dimension, (11) design dimension, (12) artistic dimension, (13) rituals, (14) festive events, (15) religious dimension, (16) learning / education / transmission of knowledge, (17) geography of workshops, (18) emic (inside) Presentation
- Narrative interviews with craft practitioners

The digital assets hosted in the MOP repository are provided online in conventional and open formats. Each asset has a unique IRI to be directly integrated by third parties. Our knowledge is available to the Semantic Web via the MOP and the SPARQL endpoint exposed. Furthermore, to ensure compatibility with online knowledge sources, definitions of terms are imported to MOP through linking to terms from the Getty Arts and Architecture thesaurus and the UNESCO thesaurus. For further exploitation of semantic knowledge encoded in MOP an EDM export facility has been

also been implemented allowing (a) export of data in semantic compatible to EDM format and (b) formulate SPARQL queries to the MOP SPARQL endpoint to receive EDM formatted results.

## 3.2 Data collection

In this step, the components of the crafting process are digitally recorded, post-processed, and curated on an online platform. The collection of data was a timely process involving various scientific disciplines and technical tools including photographic documentation, 3D digitization, video documentation of craft practitioners, MoCap of craft processes and narrators, etc.

These digital assets record objects and actions, acquired from documenting photographically and in 3D materials, tools, products, and workspaces and recording practitioner crafting actions, in recording sessions. The organization of these sessions is facilitated by the vocabulary and storyboard, in identifying the objects, sites, and practitioner actions to be digitized. Moreover, some of the photographic and video assets may be recorded in combination with ethnographic fieldwork.

A requirement relevant to the glasswork, but also relevant to other crafts, is that the viscous nature of hot glass prohibits the pause of the crafting process during some sequences of tasks. As such, motion files may contain multiple process steps and actions

### 3.2.1 Audiovisual recordings

Pertinent assets regard conventional audiovisual data acquired from the ethnography such as audio and video interviews photographic documentation, as well as documentation to be used for craft representation including photographs and video documentation of objects, spaces, and demonstrations.

Audiovisual recordings of the crafting process are important for overview and ethnographic study, as well as for documenting significant aspects of the process with a local spatial expression, such as tool gripping postures, detailed and minute manipulations, and so on. Moreover, multiple and/or wide-angle bird view cameras can be employed to capture the motion of multiple practitioners and their movement within.

### 3.2.2 Documentation of tools, machinery, and workspaces

The documentation of tools, machinery, and workspaces is both photographic and in 3D. We refer to [117] for the photographic documentation of static artefacts and scenes, and to [118] for their 3D documentation. The 3D documentation of metallic tools and glassware can be challenging. We distinguish between the potential historic significance of an object and its utility as a tool, wherein the latter solely their geometrical structure can be sufficient. In some cases, the 3D model of tools can be easily modelled or even provided by the manufacturer. The use of synthetic models can simplify the digitization tasks and significantly reduce scanning costs.

### 3.2.3 Motion capture

The applicability of Motion Capture (MoCap) and video modalities depends on the type of environment. Inertial MoCap [103] is more suitable than optical [104] in the cluttered space of

workshops, due to reduced installation requirements and independence to occlusions. Nevertheless, inertial MoCap is not sufficiently sensitive to minute motions. A practical issue was that it was difficult for the practitioner to manipulate objects with the gloves of the suit. To solve that, latex gloves were worn on top of the suit's gloves to add friction. Markerless methods exhibit the least accuracy [33, 34], but require only a camera. We found markerless motion recording suitable mainly in obtaining key hand postures and body gestures.

### 3.3 Craft representation

In this step, semantic meta-data are defined, and new knowledge elements are extracted. For example, appropriate fragments from the raw data are chosen to be processed, and then those fragments are fed to specialized computer algorithms and software tools to generate higher-level results (e.g. motion files from raw video sources). Motion capture is segmented, tagged and retargeted into virtual humans to be used for demonstrating the craft (as a whole or in steps) and as storytellers. To associate frames and segments from motion recordings with postures and gestures respectively, the AnimIO annotation editor is employed, which facilitates body-member specific annotation of motion recordings. To represent tool and machine usage, motion recordings and 3D models are combined. The objects and actions of the crafts are semantically represented and linked to semantic metadata and digital assets such as locations, tools, persons etc. Also, reference postures and gestures are identified from motion recordings. All the semantic data, the links among the entities and the links to external entities are stored in the MOP, essentially creating a craft representation in the digital world

### 3.4 Process representation

In this step, UML activity diagrams are used to formally represent the craft processes schemas, which are then encoded in the MOP. Activity diagrams were chosen first because they can be refined hierarchically, allowing the increase of representation detail at later stages, and secondly because their visual nature was found to support the collaboration with practitioners. The representation of the crafting process was made in terms of steps and interrelating conditions between them, essentially forming a set of “instructions”, i.e. steps and relations between them. To represent the relationships among the process schema steps, the UML transition types Transition, Fork, Merge, Join, and Branch are adopted in the ontology. More specifically, the progression of sequential steps is modelled by a Transition link. Forks are used to represent the initiation of two parallel tasks. In Merge transition, two or more control paths unite and Join connecting steps that should be completed before the transition to the next step. Merge and Join transitions are structurally similar, but a join is a synchronization across a set of parallel flows, while in a merge only a single flow is active. Finally, Branch transitions connect a step with a decision step that accepts tokens on one incoming edge and selects one outgoing alternative. Branch nodes control the flow of a process by selecting one of several alternatives, based on the outcome of a condition evaluation. Two kinds of processes are modelled: Processed schemas and process instances. Process Schemas are generic instructions on how to perform the craft – such as food recipes or generic instructions. Process instances model the exact steps followed by a craftsman at a specific time, such as a specific execution of a recipe made by a specific chef and at a specific point in time. The MOP UI enables the instantiation of processes schemas, via the entry and chronological ordering of events, accompanied by the recordings that document them (such as photos, videos etc)

### 3.5 Craft presentation and preservation

The represented knowledge network is available through the WWW and the MOP in hypertext format. Semantic links are implemented as hyperlinks that lead to the pages of cited entities. Contents are also organized and presented thematically, per class type. A keyword-based search is also provided. Documentation pages contain links to digital assets, textual presentation of metadata, and previews of the associated digital assets. For locations and events, specific UI modules are provided. For locations, embedded, dynamic maps are provided through OpenStreetMap [38]. Time-line and calendar views are available for events.

The vocabularies formulated in the first step of the craft representation are provided as illustrated vocabularies of tools, 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.

Processes are presented containing links to the recordings of the knowledge elements for the tools and materials involving the participating practitioners, the date, the tools employed, and the location of the recording. If the process follows a process schema, a link to that schema and its preview are also provided. The hierarchy of process steps is presented using insets, each one presenting textual information and previews of the available digital assets. To present step organization, insets are dynamically unfolded to any depth of the process hierarchy, associated with image previews and embedded videos. Variations include images and textural descriptions.

### 3.6 Exploitation

The multifacet representation achieved from the proposed methodology is explored in a plethora of interactive presentations and demonstrations. In this step, we present how each pilot's results are exploited to promote the craft and ensure its publicity and preservation over time. These may include games and applications in various installations or virtual worlds, museum exhibits and virtual museum installations, creating augmented art objects etc. Through these, people all over the world can get in touch with the craft, be taught by virtual avatars, learn about its origins and history and deeply understand its value. This step is essentially the touch point of Mingei with the people, aspiring to, attract cultural tourism, promote the cultural crafts and preserve them through time, inspiring the next generations.



## 4. Pilot 1: Silk weaving

Pure silk, one of the oldest known natural fibres, is still highly fashionable even after thousands of years. The history of Krefeld is closely linked to this magical material. Today there is a small museum, called Haus der Seidenkultur, which shows how the history of silk has shaped the development of the town over the past three centuries. At the beginning of the 17th century, Krefeld came under the rule of the Netherlands, and the town became an island of religious tolerance. Consequently, in a period in which the denomination of the population was determined by the denomination of the ruler, Mennonites from near and far came to Krefeld and settled there. This immigration had far-reaching consequences that have shaped the profile of the town right up to the present day.

The religious refugees brought with them linen processing skills and as they were also mostly successful businessmen they laid the foundation stone for economic growth and prosperity. The von der Leyen family, immigrants from Radevormwald, also contributed significantly to the development of the “Town like Silk and Velvet”. Originally linen weavers, they increasingly changed the emphasis of their business to silk weaving.

In 1702 Krefeld became Prussian and silk weaving became the most important economic factor with sales to the Prussian court in Berlin flourishing. In this period the silk weavers were out-workers who received orders to weave fabrics from merchants and traders. The looms were set up in front of the light window in the typical small cottages, some of which still exist today. The head of the household was normally the weaver and other family members helped with tasks such as reeling the thread onto the bobbins for the shuttle. On one of the main avenues of the town, there is a monument to the weavers “Meister Ponzelaar”. He wears a frock coat (his Sunday best) in the local dialect “Laakesseroock”, a high-necked waistcoat, a small collar with a silk scarf, and a “Jraduutkapp” (a black cap). At the end of the week, he takes the finished fabric on the beam to the merchant’s office together with a bag containing any thread leftover. There he was paid and received a new prepared warp beam and thread for the week ahead. Such weavers were a typical sight in the town until the beginning of the 19th century. Their craft required rapid comprehension and rhythmic movement of hand and foot.

In 1785 Edward Cartwright invented his first mechanical loom and continued to make improvements to it. The enhanced looms then went on sale in 1820. With the advent of mechanization, the silk entrepreneurs started to build factories where all the machines were powered by one source of energy and the workers were responsible for more than one loom.

### 4.1 Craft understanding

#### 4.1.1 Knowledge collection and literature review

*Craft understanding is initiated with the collection of existing knowledge in the following categories:*

- Basic knowledge including (a) curated text, (b) curated material, and (c) formal representation
- Existing content includes (a) archives, (b) bibliographic research outcomes, (c) audiovisual material, and (d) digital representations
- Contextual information (1) brief description of the craft (2) geographical location and range of the craft, (3) selected and representative communities concerning the craft, (4)

craft workers / skilled workers / handicrafts education, (5) gender roles, (6) equipment, (7) craft products, (8) craft traditions including oral tradition / story telling / work songs / myths & legends, (9) social practices / social dimension, (10) economic dimension, (11) design dimension, (12) artistic dimension, (13) rituals, (14) festive events, (15) religious dimension, (16) learning / education / transmission of knowledge, (17) geography of workshops, (18) emic (inside) Presentation

- Narrative interviews with craft practitioners

In the case of textile manufacturing, the literature was studied including the curated text of the museum, and pertinent essays from museum collaborators and personnel were provided by HdS. The original texts were in German, some published and some from the museum's records, and translated by HdS in the context of the project. In almost all cases, both the English and German texts are provided. Furthermore, three documentaries were studied that are productions of HdS. The two documentaries contain demonstrations of the weaving process, performed by the community of volunteers of HdS. The third is a guided walkthrough in the city of Krefeld at places of relevance to the silk workshops of Krefeld.

#### 4.1.2 Understanding silk weaving

Weaving is a way to fasten multiple parallel threads that are extended by tension with a perpendicular, interwoven and much longer thread. Most types of weaving require a minimum of equipment. Machinery introduced over time aims to ease and accelerate the process of weaving.

The yarn that comes from the spinning mill is rewound onto the warp beam of the loom before being used for weaving. In warping, the warp threads from the warping creel that have been sorted by the gathering reed are wound onto the warping drum. After warping, the spooled warp threads are wound onto a large metal roll, the warp beam of the loom.

A loom is any device that holds the warp threads at a reasonable tension and facilitates the interlacement of yarn. A shed is the area formed when some, but not all, of the warp threads, are lifted. When the weft thread is passed through the shed, it is over some threads and under the rest. The basic mechanism that forms this shed is the heddle. A heddle is a hole that the warp threads pass through. When the heddle goes up, the warp thread associated with that heddle also does.

Passing a string through a heddle is a task similar to passing a string through a needle. Thus, setting up the threads through the heddles is a tedious and time-consuming task. It is thus important to perform it as scarcely as possible. Estimation of thread quantities is an important part of loom preparation. The weaver must be able to repair a broken thread so that passing the string through the heddle is avoided.

Depending on the way of creating tension for the warp threads, different kinds and types of looms have been invented, i.e. the blackstrap loom, the drawloom, or the conventional handloom where bars are attached to each thread to create tension.

Up to the invention of the heald, individual warps were lifted by fingers, to insert perpendicularly the weft. The heddle mechanized the lifting of warps. The upper heald frames are connected by a cord passing over a roller, and the lower heald frames are connected to treadles. By depressing one treadle, one heald frame is raised and the other lowered, separating the warp threads. This



separation creates an opening, or the shed, that facilitates the insertion of the weft. Depending on which heddles are lifted in each warps different structures, or weaves, can be woven.

A way to introduce the weft thread was by hand. The weft is wound around a rod that is called pirn and, while it is interwoven through the warp, it is unravelled from the pirn. The idea of winding the weft yarn onto a stick that could carry it faster through the shed from side to side led to the development of shuttles. Pressing the weft into place, firmly and evenly, across the width of the fabric is not easy to be performed by hand. This tool is required to be:

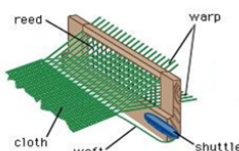
- flat to be entered into an open shed,
- smooth to glide easily along the warp threads,
- firm so as not to bend under pressure,
- long to reach across the warp and beyond to be held, and
- bladelike and blunt on one side to reach deeply into the angle of the opened shed.

These requirements led to the beater-in or batten, which for a sword-like appearance is called the “weavers sword” [42]. Weaving is summarized as a repetition of these three actions:

- Shedding: warp threads are separated by raising or lowering healds to form a clear space where the weft should pass.
- Picking: weft is passed across the loom. This is implemented by hand, shuttle, air-jet, or rapier.
- Beating-up or battening: the weft is pushed up against the fell of the cloth by the beater.

In Figure 2, the three stages of weaving are illustrated.

**1. Shedding:** Warp threads are separated, forming a shed for the weft to pass.



Uses

**Treadle**

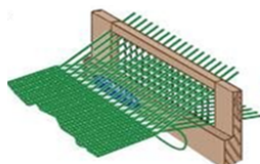
Human action

The treadle is pressed by foot.

Result

Warp threads are separated, creating the shed.

**2. Picking:** The weft is propelled across the shed, leaving a trail of weft.



Uses

**Shuttle**

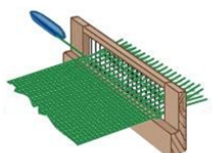
Human action

The shuttle is passed from one side to the other, by hand or lever.

Result

A trail of weft is inserted in the shed.

**3. Battening:** The weft is pushed up against the fell of the cloth, fastening a row of weft.



Uses

**Beater**

Human action

A beater is pulled with force against the new warp.

Result

A row of weft

**Figure 2. The three stages of weaving.**

#### **4.1.3 Weaving jacquard patterned fabrics**

The Jacquard attachment is a device fitted to a loom that simplifies the process of manufacturing textiles with complex patterns. The machine was controlled by a “chain of cards”; that is some punched cards laced together into a continuous sequence. Multiple rows of holes were punched on each card, with one complete card corresponding to one row of the design. An example of a loom with a Jacquard attachment is presented in Figure 3. Loom with Jacquard attachment.



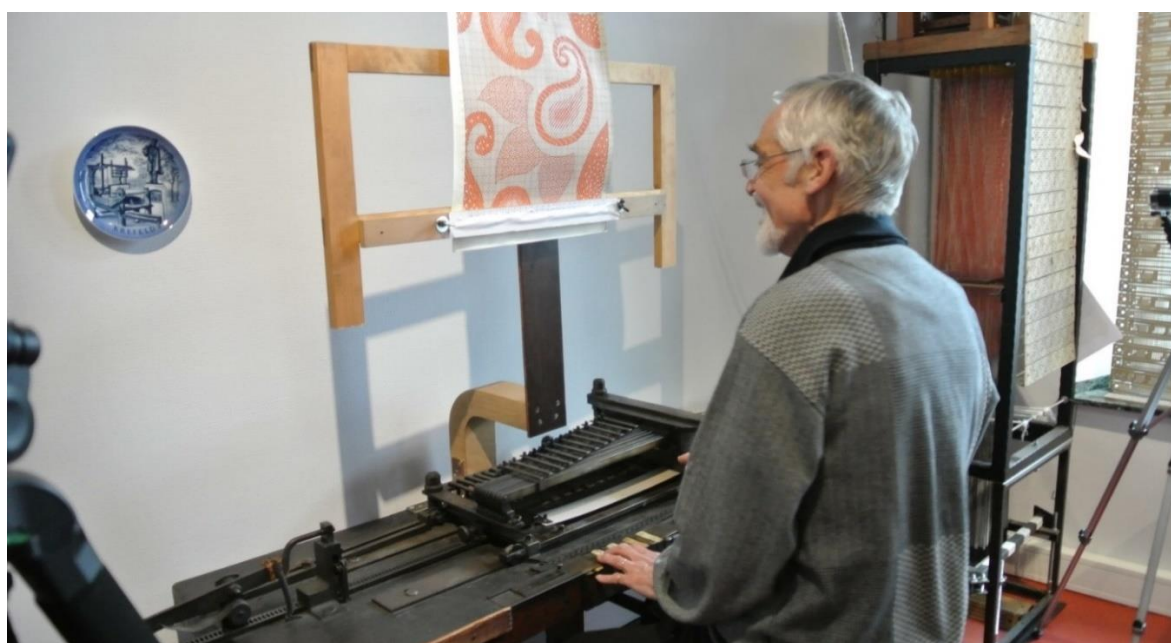
**Figure 3. Loom with Jacquard attachment.**

To create patterned fabrics using a Jacquard loom, the fabric design is first sketched and transferred to squared paper (see Figure 4).



**Figure 4. Transfer of a pattern to squared paper.**

A skilled worker translates the design into punched cards, using a machine for punching cards, as shown in. Each complete card represents one row of the weft pattern. The holes created in the cards encode the selection of threads to be lifted when the shuttle passes for that particular row, for the implementation of the pattern. Technically, the holes allow the hooks to pass through which, in turn, trigger the heddles to be lifted. Cards are laced together in a chain and introduced to the loom.



**Figure 5. Translating the design into punched cards.**



In Figure 6, punched designs for the Jacquard attachment are shown. The act of lifting some of the warp threads so that the weft passes only below those can be better understood when looking at a woven fabric, from both sides.



Figure 6. Punched cards for the Jacquard attachment.

#### 4.1.4 Silk loom preparation

Extensive instructions are provided in the HdS, Film Project, “Einrichten des Golwebstuhles”, (“Setting up the Gold Loom”) where the preparation of the silk or gold loom is presented. In this documentary, visual documentation of the required tasks was studied. In the HdS, Film Project, “Stadtspaziergang auf Seiden Pfaden” (“Hanging by a thread”), 2018, guidelines were studied relevant to the estimation of the amount of thread required depending on the size of the fabric to be manufactured (see Figure 7).



Figure 7. Silk loom preparation.

#### 4.1.5 Formulation of historic narratives

The major outcome of the craft understanding activities is the creation of text-based narratives produced as the result of the rationalization of knowledge. Rationalization has been useful for identifying several topics of interest. For each of these topics, a text-based narrative has been

created. The narratives include technical and contextual knowledge — historic, economic, societal, traditional, gender roles, teaching methods, etc. — relative to the textile manufacturing at Krefeld. Narratives transmit craft knowledge through stories that contain both tangible and intangible dimensions of a craft, along with the information that highlights its historical and societal significance in conjunction with the major historical events. Overall the following narratives have been defined:

- From Jacquard weaving to computer science
- History of haus der seidenkultur: construction of the building
- Krefeld from Its Origins to Town Like Silk and Velvet
- Hubert Gotzes Weaving Workshop
- About the name Krefeld
- History of the Family Hubert Gotzes jr.
- The story of the Jacquard invention
- Silk pilot Context
- Vocational Training in Krefeld
- History of the company Hubert Gotzes Inc. in Chicago
- The story of the cloth in the shrine of Charlemagne and its motif
- Ecclesiastical Fabric Weaving in Krefeld
- Ecclesiastical textiles
- Chronicle of the Casaretto Family
- Founding of the association of friends
- In the house with tricky nooks and crannies
- Origins of the “Crown Prince District”
- A foundation for 100 years

The objective of the creation of these narratives regards the identification of information (Persons, Events, Locations) represented and linked to the acquired digital documentation. Ultimately this process leads to the formulation of a semantic representation of these narratives. Pertinent data collection activities relevant to the use case under consideration are presented in section 4.2.

## 4.2 Data collection

The collection of data was a timely process involving various scientific disciplines and technical tools including photographic documentation, 3D digitization, video documentation of craft practitioners, MoCap of craft processes and narrators, etc. The following sections provide a summary of these activities.

### 4.2.1 Photographic documentation

Photographic documentation focused on museum exhibits that have unique historical value. More specifically, we took photos of patterns in books, paintings, manuscripts, garments, and fabrics as well as close-up photos of the various parts of the looms. The photographs collected comprise about 20 textile manufacturing documents with instructions, 110 overview photographs of looms and HdS workshops, 80 loom detail photographs, 10 photographs of silk threads, 50 photographs of plants used in the manufacturing of colour pigments, and 5 sets of photographs of detailed ecclesiastical



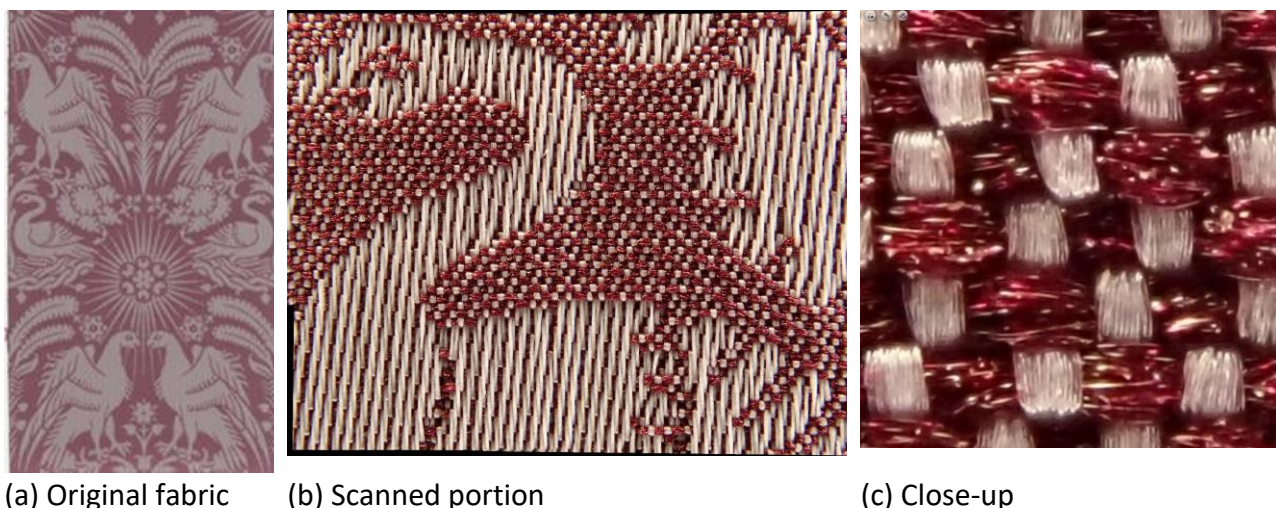
garments (about 800 photographs). In addition, photo sets of reputed artefacts of HdS regard ecclesiastical garments (Figure 8).



**Figure 8. Photographic documentation of ecclesiastical garments of HdS.**

#### 4.2.2 Ultra-high resolution surface scanner

For the acquisition of ultra-high-resolution scans of textiles, a contactless scanner and its software were designed and implemented. The scanner regards the photographic digitization of planar and approximately planar surfaces and is proposed as a cost-efficient alternative to off-the-shelf solutions. The result is 19.8 Kppi, micrometre scans. Accurate surface mosaics are obtained based on novel image acquisition and image registration approach that actively seeks registration cues by acquiring auxiliary images and fusing proprioceptive data in the correspondence and registration tasks [43]. Results can be seen in Figure 9.



(a) Original fabric

(b) Scanned portion

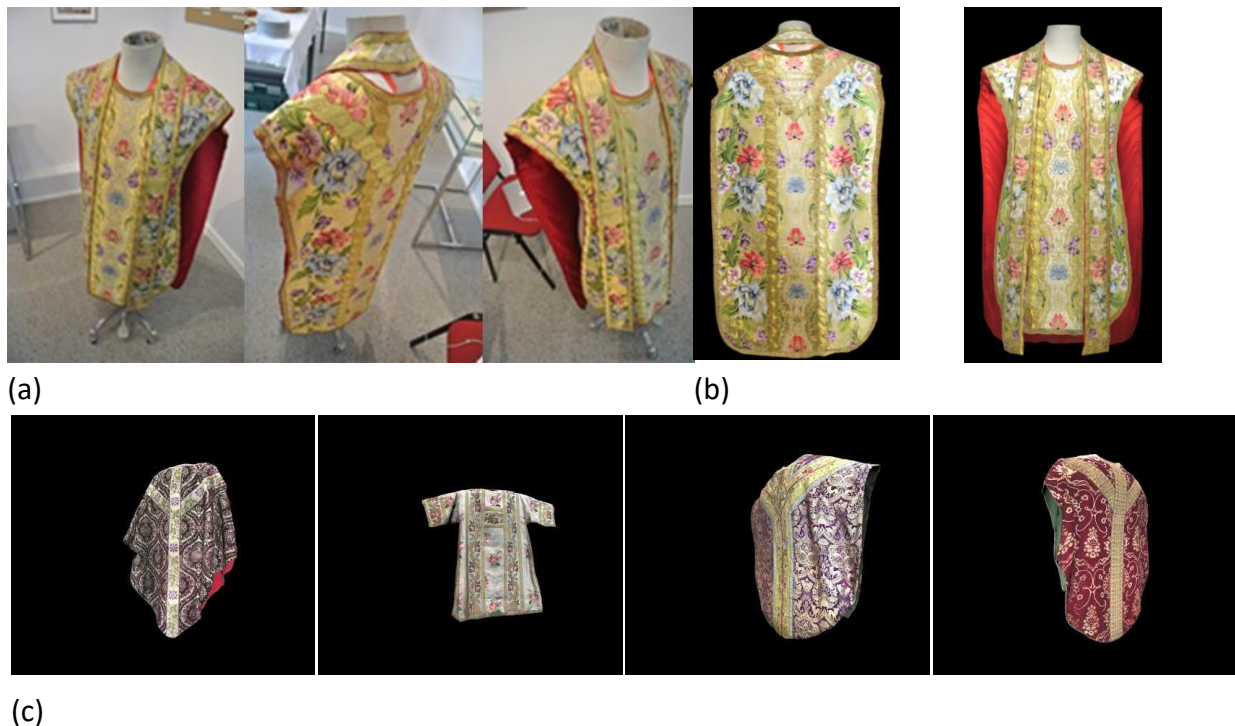
(c) Close-up

**Figure 9. Ultra-high-resolution scan of silk fabrics.**

#### 4.2.3 3D digitization of ecclesiastical vestments

Reputed artefacts of HdS were digitized such as ecclesiastical garments. In figure Figure 10 (a) the acquired photographic documentation is presented while Figure 10 (b) presents the 3D digitization

results on this dataset. Furthermore, Figure 10 (c) presents four more examples of garments digitized and hyperlinked to the YouTube channel of the Mingei project.



**Figure 10. (a) Original images of an ecclesiastical vestment made from silk and gold brocade and (b) photogrammetric 3D reconstruction, (c) online videos showing 3D garment reconstructions.**

#### 4.2.4 Video documentation of craft practitioners

Recording by a human expert was performed during silk weaving. More specifically, the expert was recorded as he went through the different stages of the loom and silk preparation as well as the weaving process itself. For acquiring video documentation, in terms of equipment, we used three cameras for data acquisition. One digital camera (Nikon J1) with a 10-30mm lens that captured single images of resolution 3872 x 2592 as well as full HD (1920 x 1080) video at 60fps and two GoPro cameras with an ultra-wide lens capable of 2.7K (2704 x 1520) video footage at 70fps (see Figure 11, a). To ensure that the footage is free of motion blur, we captured the scene at a high frame rate and additionally used tripods and a gimbal.

The data we collected can be used without much further processing as a standalone audio/visual material depicting the expert performing the actions and commenting on his thought process as he is executing them. More importantly, we captured videos of high resolution at a high frame rate from various viewpoints to ensure an unobstructed view of the expert that can be used to perform human hand and body pose estimation and extract the motion patterns of the expert. The latter type of data acquisition posed several challenges. Due to the physically tiring process of operating a heavy loom by a single expert, only a few repetitions of each task in the weaving process could be performed and recorded. This is not a limitation for the video footage but it makes motion reconstruction harder since more repetitions of motions generally mean more robust reconstruction. A second challenge was the size and positioning of the looms. State-of-art 3D human pose estimation algorithms from visual data are typically trained using frontal full views of human



bodies where major identifying features of the body (face, arms, fingers) are visible and self-occlusions are limited. For instance, having two different frontal views of the body during the weaving process would have been ideal. In the case of the weaving room at Krefeld, all of the machines have several moving parts, are positioned and mounted on walls, and occlude the front side of the expert making it impossible to capture frontal views of the body. We ended up recording the expert using back views of his body from specific angles to be able to simultaneously capture his body and his feet that play an active part in the operation of the looms pushing against pedals and levers (see Figure 11, b).

The capturing procedure resulted in a dataset of approximately 100GB of pictures and videos where we recorded the artistic procedures of painting and selecting the tiling patterns, punching cards compatible with the Jacquard looms, and the preparation (winding and unwinding) of silk, and the final weaving procedure.



**Figure 11. (a) All of the recording cameras in action, (b) Representative frames of the weaving process along with the estimated 3D skeletal (body/hands) pose of the expert.**

#### 4.2.5 MoCap of craft practitioners

MoCap of Craft practitioners took place between April 2<sup>nd</sup> and 4<sup>th</sup>, 2019 at the HdS Museum, Krefeld, Germany. During that time, one expert was recorded performing the following tasks related to silk weaving: the creation of the punch cards, wrapping of the beam, preparation of the beam, and jacquard weaving with looms of different sizes (small, medium, and large). These are illustrated in Figure 12.

Creation of the punch cards



Small size loom

Wrapping of the beam



Medium size loom

Preparation of the beam



Large size loom





Figure 12. Examples of tasks of textile manufacturing.

#### 4.2.6 MoCap of narrators

MoCap of narrators is used to provide realistic animations of Virtual Humans acting as museum storytellers. To this end, the narration is captured as performed by a human and the acquired motion is retargeted to the VH as presented later on in this paper. To do so the Rokoko equipment and software were used. For the narration moves to be more realistic, the stories during the recordings were also narrated, and used the voice was synchronously recorded. In this way, the synchronization of voice and movement in the narrations was a lot easier, and it also guaranteed a more natural narration.

### 4.3 Craft representation

Data recorded using the aforementioned technical equipment and methodologies generated a large dataset to be post-processed. Post-processing in this context is considered the process of selecting the appropriate fragments from the raw data to be processed and then feeding these fragments to specialized computer algorithms and software tools to generate higher-level results (e.g. motion files from video sources). The outcomes are then represented in MOP.

#### 4.3.1 Visual tracking from audiovisual craft documentation

For visual tracking, the OpenPose [54] library and the MocapNET [45] body tracking software was used. On the Krefeld datasets we observe that, when all limbs are visible, motions tend to translate well into the armature. On the other hand, failure frames mostly consist of several limbs being occluded and not visible in the camera observations. Invisible joints lead to missing 2D joint estimations and missing 2D estimations, in turn, mean empty lines and columns in the NSDM matrices of MocapNET and not enough structural information for a clearly defined solution. This is particularly evident in datasets during the punching cards where despite the positioning of the cameras feet often are occluded going out of the field of view. This particular case could be remedied with specialized classes that handle joint estimation without feet. It should also be noted that both OpenPose, as well as MocapNET, handle input as standalone frames and that means that no temporal information is leveraged to mask possibly noisy input.

To further improve results despite the integration of newer improved versions of the 2D and 3D pose estimation software, motion interpolation could smooth 2D and 3D output. Finally, the curator could add missing points to reduce motion artefacts. Visual tracking examples are presented in Figure 13.



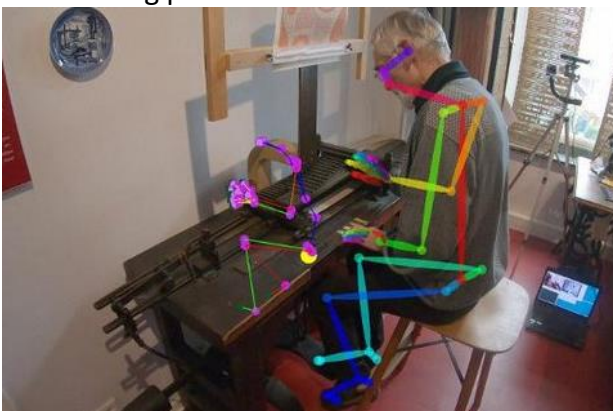
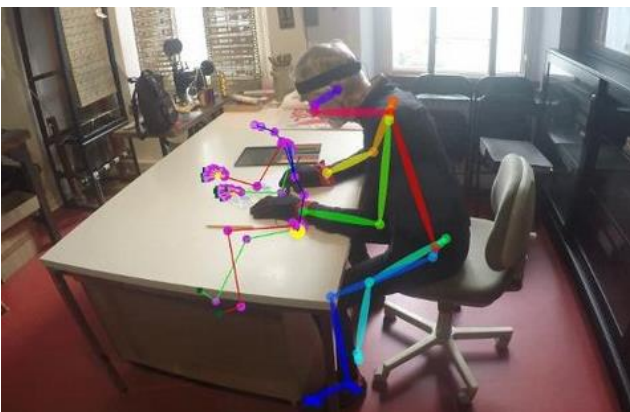
An instance of occlusions of the right foot that can negatively affect tracking.



Body Tracking frames from the weaving machine process. Note that hands at this step are considered always to be open palms and are visualized because they are a part of the final model.

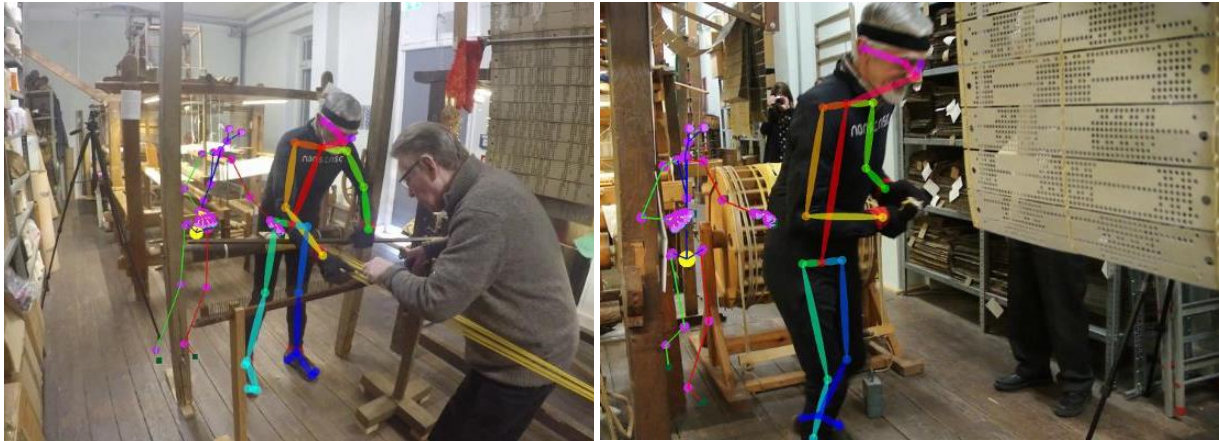


Frames from the thread winding process.



Frames from the drawing and preparation of the punched cards for the looms.





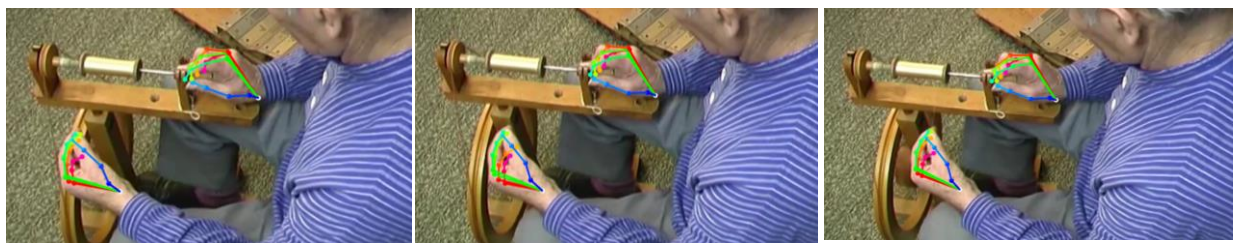
Frames from thread separation and loom preparations.

**Figure 13. Visual tracking examples.**

### 4.3.2 Visual tracking from audiovisual archives

The audiovisual archives post-processed with visual tracking algorithms included the set of documentaries created by HdS showcasing the silk weaving process to the public. The documentaries include interviews of members of HdS describing the whole process as well as demonstrations of preparing and operating the looms. Given that the focus of these documentaries has been to provide broad knowledge regarding silk weaving and be an immersive experience for the viewer, recording experts' weaving is only part of the storytelling. For instance, the recording of experts is interleaved with historical data about silk weaving or only a small area of the body of the expert is visible during weaving to showcase the loom. To handle effectively these data, clips of the original videos that depict only the operation of the looms need to be selected and potentially be enhanced with information from the accompanying audio regarding the semantics of the recorded motion.

To track the 3D motion of the expert from videos, we use a python/C++ implementation of tracking algorithms [46, 47] that make use of a GPU for estimating the locations of the hand joints on the image as well as the 3D skeletal pose of the hand. In our experiments, we have used an NVIDIA GeForce GTX 1080 GPU. We then import the estimated 3D skeletons in the Open Source modelling software Blender and use the internal functionality to output the data in .bvh format. In Figure 14, we see representative clips of the weaving process as described in the documentaries.



Sequence 1





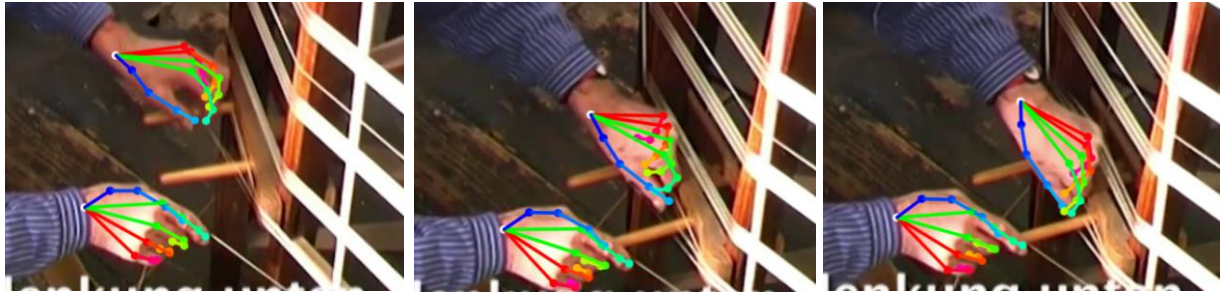
Sequence 2



Sequence 3



Sequence 4



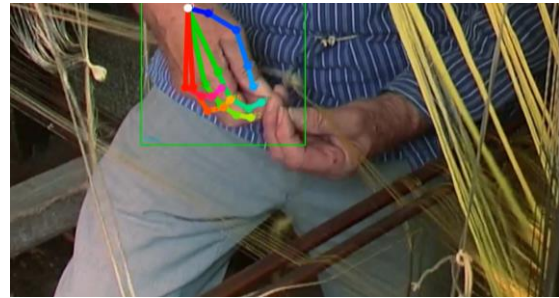
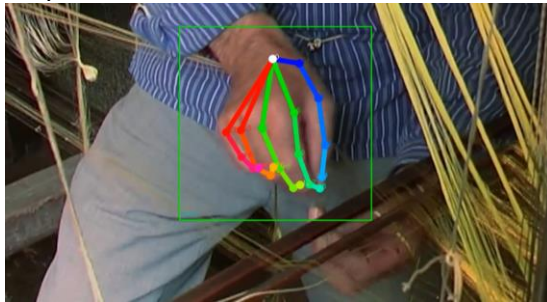
Sequence 5



Sequence 6



Sequence 7



Sequence 8

**Figure 14. Representative sequences of tracking a single or both hands of an expert during the weaving process as described in HdS at Krefeld documentaries.**

### 4.3.3 MoCap segmentation

After the correction and noise removal from the MoCap data, the data was segmented by gestures. The recordings initially were done by tasks, being one recording a whole task, these recordings were afterwards segmented by gestures. One task could have only one gesture that is repeated several times or might have more gestures that are repeated throughout the task. For example, jacquard weaving consisted of the sequential repetition of three gestures. Table 1 illustrates the number of gestures extracted from each task, how many repetitions were recorded from each, and its mean duration. In general, the goal was to collect a minimum of three repetitions per gesture.

Task	Gestures	Repetitions	Mean duration
Creating a card	Gesture 1	110	5.55
Beam preparation	Gesture 1	3	34.14
	Gesture 2	2	58.39
	Gesture 3	4	79.25
	Gesture 4	3	8.97
	Gesture 5	3	323.03
Wrapping the beam	Gesture 1	124	4.89
Weaving (small size loom)	Gesture 1	11	2.38
	Gesture 2	11	5.33
	Gesture 3	11	4.04
Weaving (medium size loom)	Gesture 1	35	1.16
	Gesture 2	35	2.07
	Gesture 3	35	2.20
Weaving (large size loom)	Gesture 1	16	0.75
	Gesture 2	16	1.18
	Gesture 3	15	2.37

**Table 1. Repetitions and mean durations of gestures extracted from the tasks recorded at HdS.**

### 4.3.4 Motion retargeting

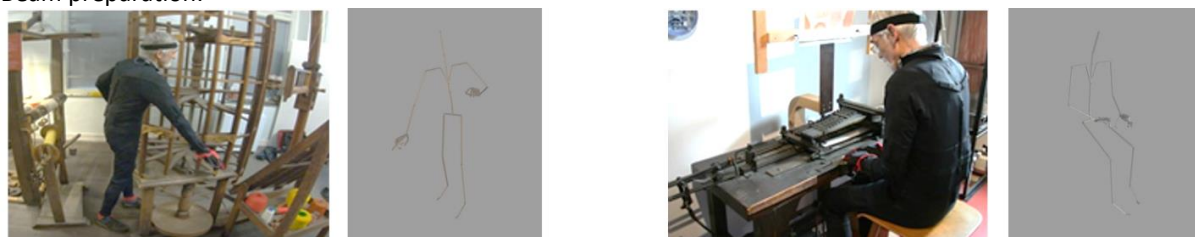
The processing of MoCap input was initiated with the selection of the most accurate of the available sequences. To this end, each sequence was reviewed and a selection has been made based on the accuracy and quality of the motion, avoiding, when possible, noises and sliding. In total, 16 files



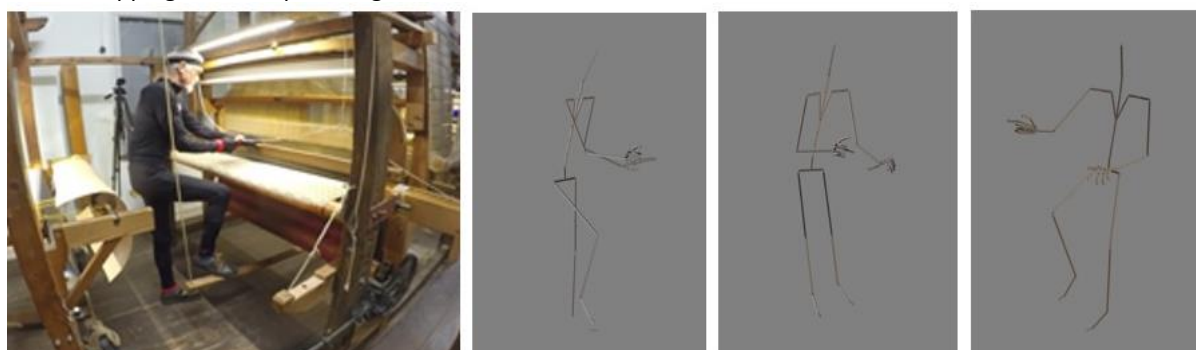
were selected. Figure 15 presents the Silk pilot animation files. The process is segmented into 6 sub-processes and in total, 16 sequences were used.



Beam preparation.



Beam wrapping and card punching.



Weaving Large size loom



Weaving medium size loom



Weaving small size loom

**Figure 15. Animation sequences.**

The next step has been done on Autodesk MotionBuilder software [48] is dedicated to animation and the direct integration of motion capture technologies. The process requires different steps (see Figure 16) :

- Creation of an "actor" in MotionBuilder with skeleton definition corresponding to the BVH hierarchy.
- Transposition of the received animations (.bvh files) on the actor
- Synchronization of the avatar with the actor by adjusting the 2 models so that the measurements match and the animations are correctly reproduced (retargeting).

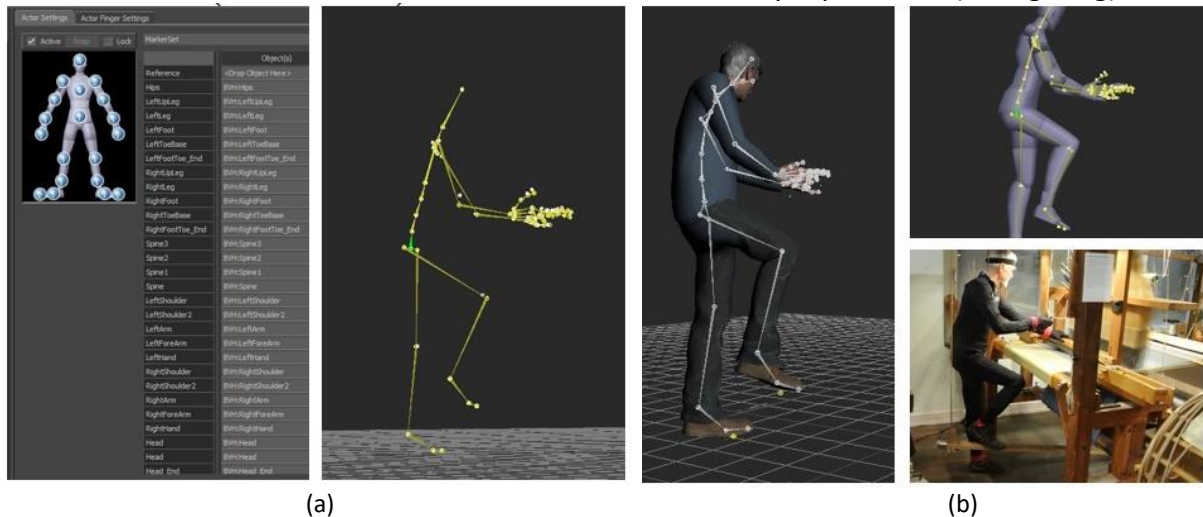


Figure 16. (a) Importing the mocap file into MotionBuilder., (b) Matching the avatar with the actor.

#### 4.4 Process representation

Artefact creation is considered a process that is based on a schema. This *process schema* is conceptual and can be demonstrated or verbally described, i.e. as instructions. When a practitioner follows this archetype, we say that the executed process followed this schema. To refer to individual stages of creation, we say that process schemas and processes are comprised of *step schemas* and *steps*, respectively. Step schemas and steps are decomposed into smaller step schemas and steps, respectively. This decomposition leads to a hierarchy that starts from a coarse description down to a finer analysis of its steps.

An activity diagram is a flow chart that models workflows and can depict sequential and concurrent activities. Activity diagrams and notations are borrowed from the specification [49]. In this work, they are used with a slightly different meaning: while in the UML, the basic actions of an activity diagram are computational actions performed by a machine, in the present context the basic actions of an activity diagram are actions performed by humans or natural phenomena. Consequently, we use the following transition types *Transition*, *Fork*, *Merge*, *Join*, and *Branch*, and denote them as in UML.

The representation of the Craft of Silk weaving in MOP is presented in Figure 17.

## Silk schema

[Schema preview](#)

### Process schema description

Step	Step description	Execution order	Substeps
0. Silk thread making		Leads to 1. Pattern Design	8
1. Pattern Design		Leads to 2. Point paper design	1
2. Point paper design		Leads to 3. Card Punching	1
3. Card Punching		Leads to 4. Warp preparation	1
4. Warp preparation		Leads to 5. Fitting	2
5. Fitting		Leads to 6. Weaving	6
6. Weaving		Leads to 7. Finishing Weaving	4
7. Finishing Weaving			4

**Figure 17. Process schema representation in MOP.**

## 4.5 Craft presentation and preservation

### 4.5.1 Digital preservation

As explained in the previous sections, all knowledge elements are created through form-filling operations using the MOP. Each type of element has a dedicated Webform, where meta-data is edited. Furthermore, facilities to create links with other knowledge elements are provided. Links are provided in the form of URI for external resources or in the form of semantic links for digital items curated in MOP. Moreover, knowledge elements are linked to media objects of relevance. Examples of represented knowledge items are shown in Figure 18.



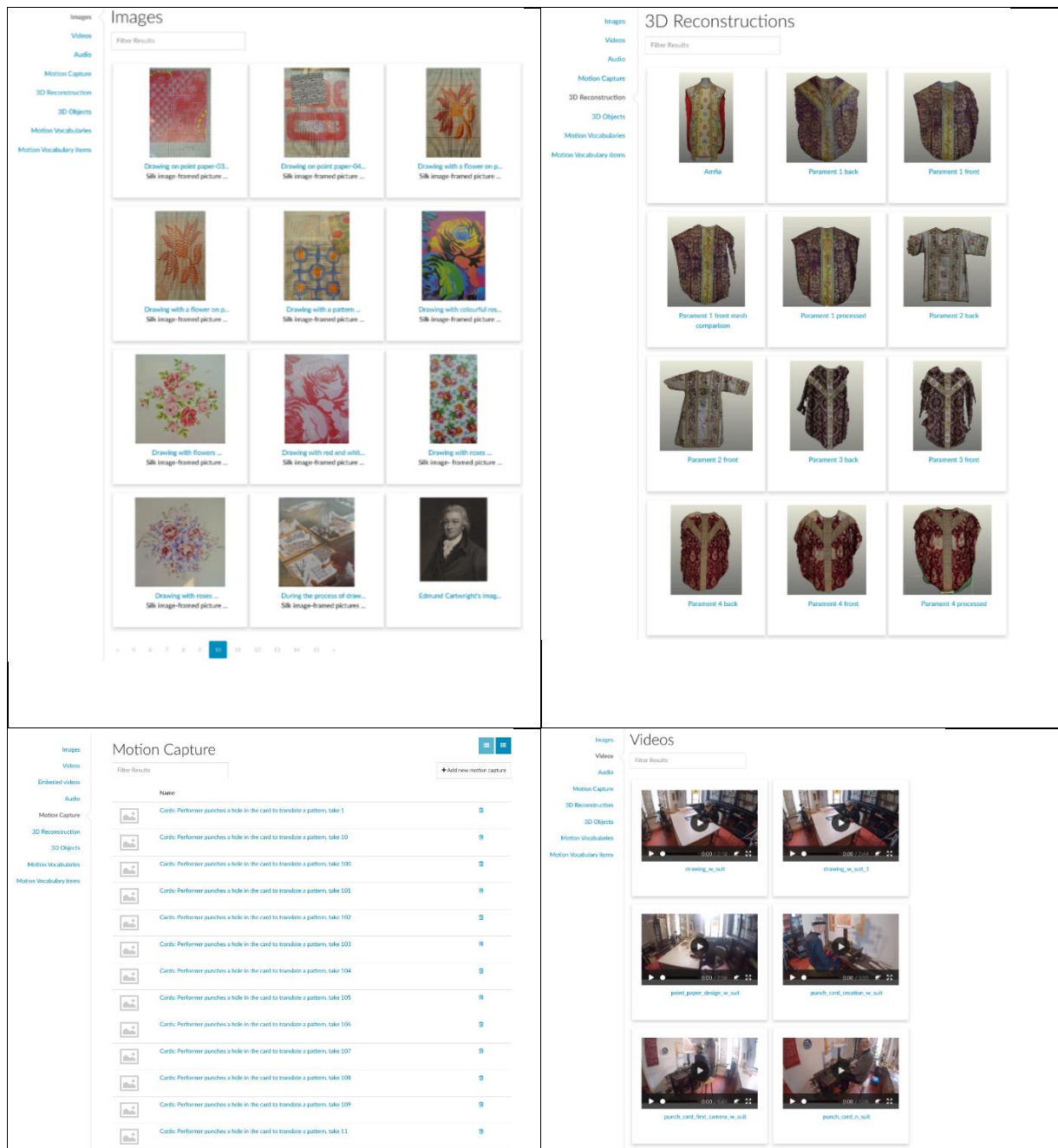


Figure 18: Screenshot of the MOP.

The digital assets hosted in the MOP repository are provided online in conventional and open formats. Each asset has a unique IRI to be directly integrated by third parties. Our knowledge is available to the Semantic Web via the MOP and the SPARQL endpoint exposed. Furthermore, to ensure compatibility with online knowledge sources, definitions of terms are imported to MOP through linking to terms from the Getty Arts and Architecture thesaurus [50] and the UNESCO thesaurus [51]. For further exploitation of semantic knowledge encoded in MOP a Europeana Data Model (EDM)[52] export facility has been also been implemented allowing (a) export of data in semantic compatible to EDM format and (b) formulate SPARQL queries [53] to the MOP SPARQL endpoint to receive EDM formatted results.

#### 4.5.2 Craft documentation

The represented knowledge network is available through the WWW and the MOP [36] in hypertext format. Semantic links are implemented as hyperlinks that lead to the pages of cited entities. Contents are also organized and presented thematically, per class type. A keyword-based search is also provided. Documentation pages contain links to digital assets, textual presentation of metadata, and previews of the associated digital assets. For locations and events, specific UI modules are provided. For locations, embedded, dynamic maps are provided through OpenStreetMap [38]. Time-line and calendar views are available for events.

Process presentations are presented containing links to the recordings of the knowledge elements for the tools and materials involving the participating practitioners, the date, the tools employed, and the location of the recording. If the process follows a process schema, a link to that schema and its preview are also provided. The hierarchy of process steps is presented using insets, each one presenting textual information and previews of the available digital assets. To present step organization, insets are dynamically unfolded to any depth of the process hierarchy, associated with image previews and embedded videos. Variations include images and textural descriptions.

### 4.5.3 Craft demonstration

#### 4.5.3.1 Presentation of craft actions

Figure 19 presents examples of the animated avatars created for silk weaving. Videos of the results can be also found at the following link: [http://miralab.com/mingei\\_preliminary-results](http://miralab.com/mingei_preliminary-results).

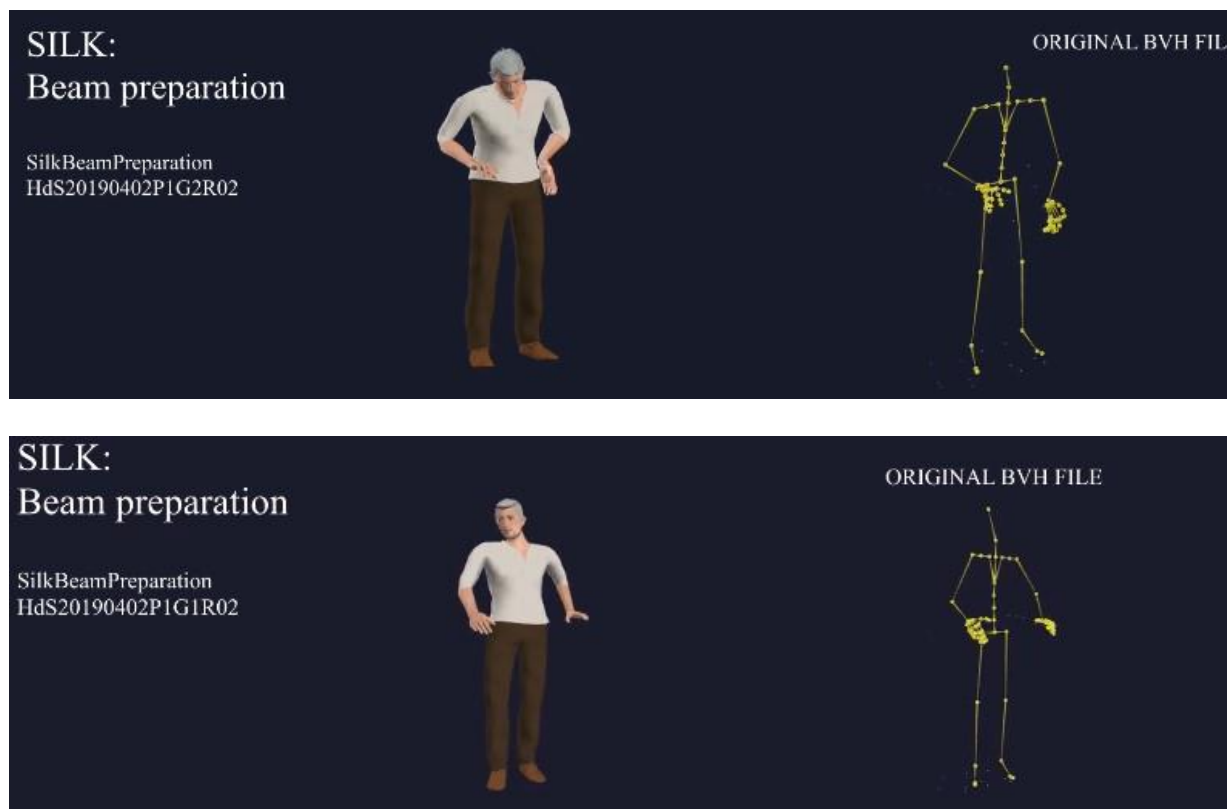


Figure 19. Examples of the animated virtual avatar for the silk pilot.

#### 4.5.3.2 Implementation of virtual humans & animation

The virtual human bodies and clothes are created to obtain one unified and optimized model, enhancing the visual impact of the characters with texture mapping and material editing. The 3D generation of the virtual bodies has also to take into consideration the total number of polygons used to create the meshes to keep a balance between the 3D real-time simulation restrictions and the skin deformation accuracy of the models

Avatars are created with a combination of different software: Adobe Fuse CC/Mixamo [30] is used for creating the body character, the clothes, the hair, and the rigging. The generated model is then imported into Autodesk 3DS max [29] for mesh geometry optimization. Manual methods, by using the editable poly tools are preferred since it allows keeping the regularity of the topology while the automatic methods generate a mess geometry which is not suitable for skin deformation nor a regular UV texture map generation.

### 4.6 Exploitation

The multifacet representation achieved from the proposed methodology is explored in a plethora of interactive presentations and demonstrations. These are categorized in this pilot as follows: (a) applications that enhance the museum visit experience including the presentation of socio-historic context through narratives, (b) applications and concepts that are inspired by traditional crafts to create new products and services, and (c) innovative means for Web-based access to information and content for learning, education, and training.

#### 4.6.1 Enhancing the museum visit experience

##### 4.6.1.1 Museum tour guide – Narratives in the museum

A dedicated museum tour guide application has been built that presents narrations regarding the socio-historic context of the museum exhibitions while guiding visitors in the museum (see Figure 20). The application is built on top of ten hot spots in the museum each one connected to relevant narrations and audio-visual presentations that unveiled the hidden treasures of the craft of textile manufacturing. The structure of the museum tour guide application follows that of the actual museum tour conducted by a live person guide. Thus, it includes 10 stations in the museum, each corresponding to a physical area in the museum. The content is formulated based on the MOP Silk Narratives and other digitized material curated by HdS.

The narrations of the VH tour guide are recorded in two languages, German and English and they are accompanied by subtitling in the respective language. To enhance the suspension of disbelief, the VH's animations were custom-made using the MoCap suit and recording the movements of a real person while narrating each narration individually in both languages. Furthermore, all audio-visual content is narrated and subtitled in both languages.

A comprehensive user-based evaluation of the Museum Tour Guide was planned and carried out as part of T6.5 activities to assess its overall usability and user experience. The evaluation involved the participation of public visitors at the HdS museum, who provided their feedback after using the Museum Tour Guide application during their visit to the museum via post-interaction questionnaires. The results of this evaluation are reported in paragraphs 6 and 7.1.

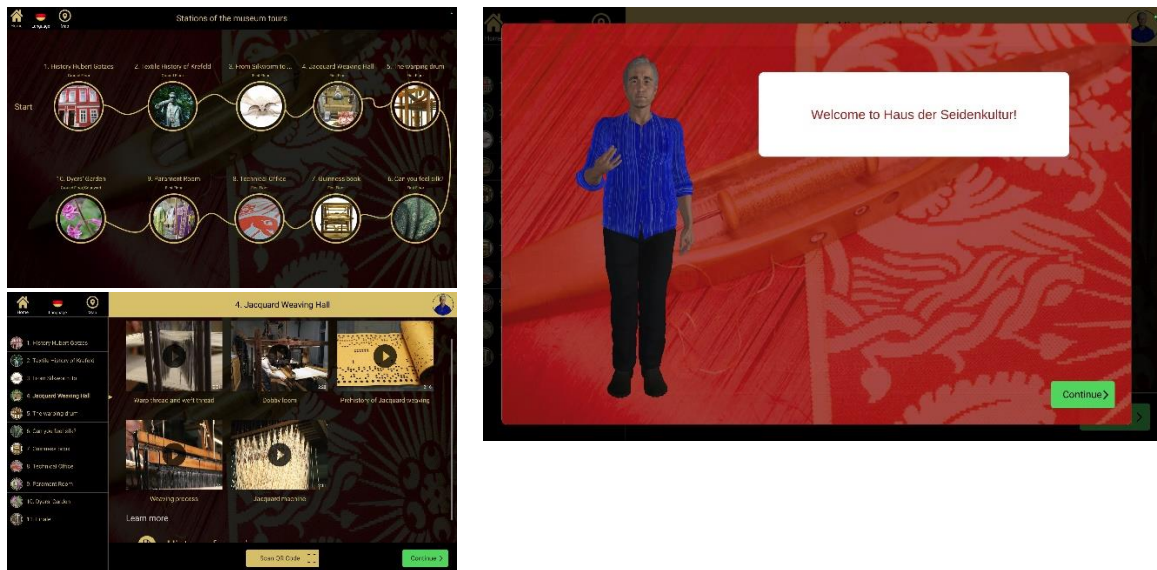


Figure 20. Excerpt from the Museum tour guide application for the HdS museum.

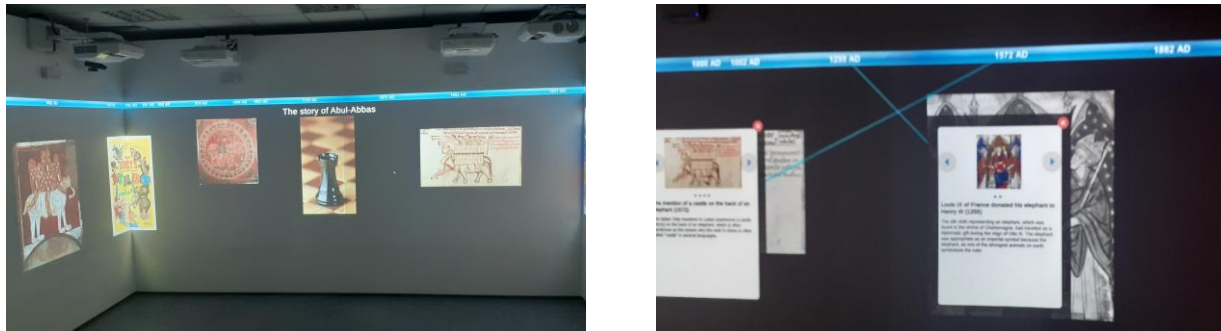
#### 4.6.1.2 Digital information visualization in the museum

Two visualizations were considered for presenting digitization outcomes and visualizing the socio-historic context. The first visualization (Figure 21) regards the projection of digitization outcomes in interactive form while the second regards the provision of information on the socio-historic context of the museum through interactive timelines (see Figure 22).



Figure 21. Physical installation of Discover the ecclesiastical garments of Krefeld – Photo was taken from installation at FORTH premises.





**Figure 22. Interactive Timeline – projected information on multiple adjacent walls (*left*) and projected annotation of a selected element (*right*) – Photo taken from installation at FORTH premises.**

#### 4.6.2 A handbag inspired by traditional crafts

The idea of creating a contemporary accessory was born by studying the historical patterns and transforming them into text-based narratives. This was in line with one of the most important goals of HdS which is to raise awareness regarding the unique CH possessed by the museum and at the same time connect its legacy with European history and tradition. The design of the handbag was a challenging task. By closely studying the HdS patterns, the following issues were encountered that needed a careful design approach: (a) the patterns are almost monochromatic, (b) patterns are woven in bright yet intense colour variations that require careful combinations, (c) due to the intense iconographic elements of the patterns the risk of creating a cluttered visual result is high.

Taking into account the above issues, a careful study of visual aesthetics was needed to decide upon the design approach to be followed. Initially, taking into account that the handbag should contain several patterns the size of the bag was decided to be approximately forty centimetres to thirty-five centimetres. For the bag, a minimal design approach was followed with a solid big base to ensure that it stands when placed on a surface and a long strap to be worn on the women's shoulder but still be visible. The patterns were constrained into a strict geometric approach with some form of separator between the patterns. A black stripe for example could provide a good separator between colourful patterns. Negative space (visually empty space) was also employed. The final design was based on geometric abstraction as manifested in the art creation of the 20<sup>th</sup> century could and more specifically on the abstract style of Piet Mondrian.

Crafting the handbag was by itself an interesting process considering the identified requirements and concepts. One of the major challenges was the selection of the appropriate material for the handbag. From the outer side, a neutral material that can be easily hand-painted and provides a mental connection to art artefacts was preferred. To, this end it was decided that unpainted cotton canvas would be used. Cotton canvas is a strong fabric used in painting and can be painted in various media. At the same time is a material that can support the overlaying of delicate textile fabrics like the ones provided by HdS.

The interior of the handbag should provide stiff support to the exterior so as for the bag to “stand by its own” when placed on a surface and provide a smooth surface to the exterior to eliminate possible deformations of the patterns. It is important that the patterns remain visible and with

limited deformation to support the recognition algorithms. Another, requirement for the interior is to be waterproof. This is a practical provision to support the actual usage of the artefact as a handbag. For the interior, a stiff, waterproof synthetic material was used. The same combination of canvas and stiff waterproof synthetic material was used for the handbag straps to give the same feeling as the rest of the handbag.

The selection of patterns was made to create maximum visual contrast. The rationale for the selection of pattern placement is twofold. **First, we were interested in visual stimuli** thus placement should produce stimulus input to the eye of the viewer and this is done through contrast variations. In the case of patterns with limited contrast to each other negative space is integrated to support the visual differentiation of patterns. **Second, we are interested in the visual contrast** of the greyscale representation of patterns. Such visual contrast is needed to assist the image processing algorithms in differentiating patterns that are not separated through negative space and thus could coexist in the visual field of an application.

Each motif has its history – a series of symbols that evolved in time and were artistically woven together to form traditional ecclesiastical fabrics. A few years ago some of these motifs were still being manually woven on wooden Jacquard hand-loom which were up to two hundred years old. Our AR application is providing **three layers** of pattern recognition. The **first layer** regards the bag which has its own story, its creation. The **second layer** regards multiple patterns which reveal the story of textile weaving in Krefeld. The **third layer** is the stories of the patterns have a story of their own (see Figure 23).

The AR app is augmenting the virtual space with a canvas to present those stories. Furthermore, as these stories relate to the history of Europe and the social and historic dimension of textile weaving the bag is also a portal to a web of information provided through the MOP. To reach this information a button entitled “view more info” navigates the user to the respective webpage of the MOP and from where the journey to European History may begin.



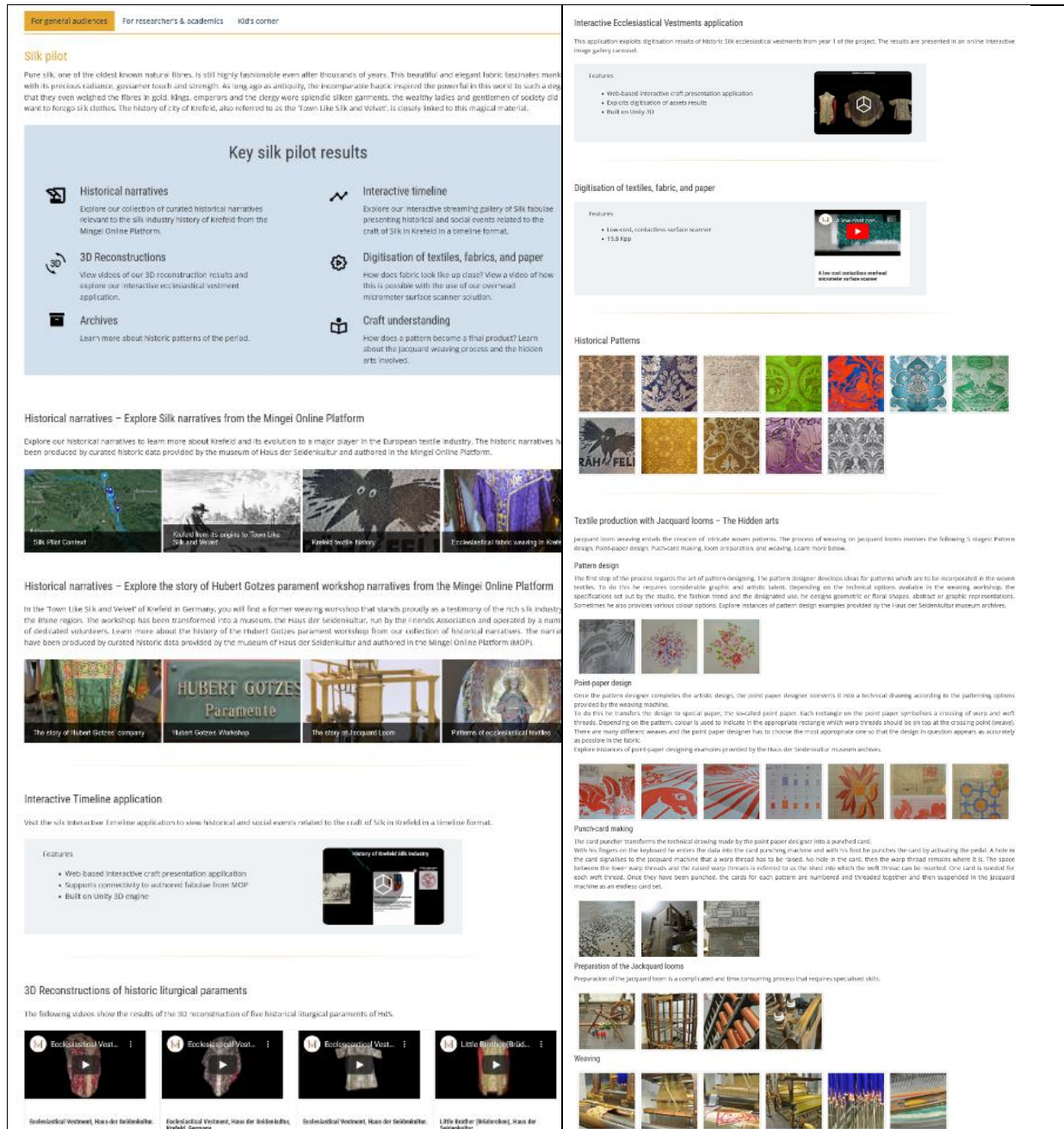
Figure 23. The AR app is presenting information on the recognized pattern.

#### 4.6.3 Web-based access to immersive visualizations

Web-based access is supported through a dedicated web page that summarizes all the key accomplishments of the proposed methodology for the use case of textile manufacturing. This page is structured using a modern long page approach initiated through a page index that guides visitors

to the main results delivered online. These include rich audio-visual information supported by multimodal narratives available online. The web page can be seen in Figure. 24.

To address the needs of the widest possible user population the Web page has three variations: (a) for the general public, (b) for researchers and academics, and (c) for kids. Further to the aforementioned Web-based information, more details on the available web-based visualization are presented in the following sections.



The screenshot displays a web-based dissemination of results, organized into several sections:

- For general audiences / For researchers & academics / Kids corner**: Navigation tabs at the top.
- Silk pilot**: Introduction to the silk pilot project, highlighting its historical significance and the use of 3D reconstructions.
- Key silk pilot results**: A central section with four main categories:
  - Historical narratives**: Explore our collection of curated historical narratives relevant to the silk industry history of Krefeld from the Mingei Online Platform.
  - Interactive timeline**: Explore our interactive streaming gallery of Silk focuses presenting historical and social events related to the craft of Silk in Krefeld in a timeline format.
  - 3D Reconstructions**: View videos of our 3D reconstruction results and explore our interactive ecclesiastical vestment application.
  - Archives**: Learn more about historic patterns of the period.
- Historical narratives - Explore Silk narratives from the Mingei Online Platform**: A section with four sub-narratives:
  - Silk Pilot Context**
  - Krefeld from its origins to 'Town Like Silk and Velvet'**
  - Krefeld textile history**
  - Ecclesiastical fabric weaving in Krefeld**
- Historical narratives - Explore the story of Hubert Gotzes parament workshop narratives from the Mingei Online Platform**: A section with four sub-narratives:
  - The story of Hubert Gotzes company**
  - Hubert Gotzes Workshop**
  - The story of Jacquard loom**
  - Patterns of ecclesiastical vestments**
- Interactive Timeline application**: A section with a video player and a list of features:
  - Web-based interactive craft presentation application
  - Supports connectivity to software fabricae from MOP
  - Built on Unity 3D engine
- 3D Reconstructions of historic liturgical paraments**: A section with four sub-reconstructions:
  - Ecclesiastical Vestment, Haus der Seidenkultur, Krefeld, Germany**
  - Ecclesiastical Vestment, Haus der Seidenkultur, Krefeld, Germany**
  - Ecclesiastical Vestment, Haus der Seidenkultur, Krefeld, Germany**
  - Little Booklet/Büchlein, Haus der Seidenkultur**
- Interactive Ecclesiastical Vestments application**: A section with a video player and a list of features:
  - Web-based interactive craft presentation application
  - Exports digitisation of assets results
  - Built on Unity 3D
- Digitisation of textiles, fabric, and paper**: A section with a video player and a list of features:
  - Low-cost, contactless surface scanner
  - IOS App
- Historical Patterns**: A grid of various historical textile patterns.
- Textile production with Jacquard looms - The Hidden arts**: A section with a video player and a list of features:
  - Pattern design
  - Point paper design
  - Punch-card making
  - Preparation of the Jacquard looms
  - Weaving

Figure. 24 Web-based dissemination of results.

#### 4.6.3.1 Historic narratives

Access to Historic narratives is provided through the MOP where the text-based narratives formulated are semantically represented and connected to the represented socio-historic information as presented in Figure 25. The narrative can be accessed in alternative means by studying (a) the narration text, (b) the key events presented in the narrative, (c) the main human participants, (d) the locations of events, and (e) the chronologic sequence of events.



## The Krefeld textile industry

Narration

Krefeld textile history Narration

Presentation

Krefeld textile history presentation

## Krefeld textile history presentation

The "Crown Prince District"

Prussian government in Berlin approves the plans for the 7th expansion of Krefeld. These plans set out the expansion in an easterly direction covering what is now known as the "Crown Prince District".

## Decline of Ecclesiastical Textile Industry

Many workshops producing ecclesiastical fabrics in Krefeld had to close down. Despite the severe losses suffered by the ecclesiastical fabric business as a result of the Second Vatican Council the Gottes company was able to hold out for a long time at its original location. Over time, the number of skilled manual weavers declined. In 1989, the last weaver dies, the Gottes company, closes the weaving workshop and just maintains sales.



Haus der Seidenkultur's logo

## The shift to silk

Krefeld's industrial dynamism stood in marked contrast to the helplessness of many longlabing linen centers unable to cope with the prospective loss of their main outlet, the English market. In the course of the 18th century, this export market virtually dried up, supplanted by the meteoric rise of a resilient Northern Irish linen trade. Disbanded by governmental subsidies and a protective tariff, the Ulster linen industry not only collapsed in its secondary within Great Britain but soon became a formidable competitor in the world of Europe. The Krefeld textile industry moved toward the manufacture of silk products, as its principal source of employment. The former linen industry provided a solid basis from which to launch this change. Silk baring found no serious difficulties in gathering an able workforce. The linen weavers, in and around Krefeld, eagerly turned to silk weaving. The new trade offered them prospects of considerably higher earnings and more regular employment opportunities. Social and husband collaborations among the city effectively barred all outsiders from entry into Krefeld's silk and velvet trades. These close knit ties had been evolved by this energetic and ambitious minority in response to persecution. The old linen industry provided a solid basis from which to launch this change ("Drawing thus the linen trade," writes Gerhard von Berckbrugg, "Very [i.e., the von der Leyens] struck roots with their silk industry on ground prepared by the Jülich linen merchant-manufacturers). The strategic importance of an existing industrial framework in creating "external economies" (external economies of scale for the newly developing trade is well established. Here it became most apparent in the sphere of early labour recruitment. Krefeld confined, unsurprisingly, Adam Smith's contention on how minor the differences between working on linen and other products were.

## The growth of Krefeld

The growth of Krefeld began in that century, partially because Krefeld was one of few towns spared the horrors of the Thirty Years' War (1618-1648). During the 17th century Mennonite settlers transformed the "insignificant little town" of Krefeld into a bustling capital of the linen trade. Protestant minorities, such as the Mennonites, were excluded from political office and landownership. Though family connections, they created a network or transfer system for commodities, money, and information which endowed them with considerable economic advantages that were collaboratively exploited (as in an association). The Rhishish political environment and system provided tolerance and protection, was socially open and allowed the economic success of minorities.

## The 7th expansion of Krefeld

Düsseldorf government building officer Franz Anton Ungerhausen drew up the designs for the 7th expansion of Krefeld. A strict geometric road network was planned. The existing road diagonally traversing the Linien Strasse, was retained as the historical main line. Linienstrasse and Althofstrasse were developed as new public squares. Street naming: the streets running north to south were given the names of members of the Prussian royal family, "Crown Prince Street" was a reference to the then Crown Prince Friedrich Wilhelm IV who visited Krefeld in 1853. The other street names also refer to members of Prussian nobility, Luisenstrasse (Louise of Prussia), Mariannestrasse (Marlene of Orange-Nassau), Elisabethstrasse (Blaschke of Bielefeld).

## A new hope

Despite the end of the Gottes enterprise, it was important to the entrepreneur that the last Krefeld silk weaving workshop with its lacquered looms in their authentic place should be preserved for posterity. He contacted the town of Krefeld and initiated a process which finally led to the Association of Friends acquiring the property and its contents from the Maus family with the aid of funds made available by the Kulturstiftung NRW and the Sparkassenstiftung Krefeld (Krefeld Cultural trust) in 2002. Since that year, the Association of Friends has run the former weaving workshop for ecclesiastical textiles as a museum consisting mainly of volunteers. The active volunteers and the members of the Association of Friends now strive to finally bring the history of the premises alive. Visitors and joint paper designers amongst others contribute to this by demonstrating what was once like to work in the weaving workshop at Hubert Gottes. The former cutting and embroidery rooms are now the setting for temporary exhibitions and demonstrations of former craftspeople which are in most cases connected with the history of the building or the "Town like Silk and Velvet". Apart from gaining impressions of past history, there is always something new to see and experience as the Haus der Seidenkultur, the Stargewerke (Weaver of the Town Council) and Paul Gerhard Schulze (Stress Artist) and Dr. Stevanus (Bishop, Director of the Museums in Burg Linn) collaborate to preserve the industrial monument and became founding members of the Association of Friends.

## Metropolization of Krefeld

The population increased due to the influx of young men attracted to Krefeld by the higher earnings and ample employment opportunities resulting from industrial growth. Textile operatives were recruited from amongst the local population. Locals succeeded in raising off the influx of outsiders into this realm, which they considered their exclusive preserve. Newcomers were pressed into the "industrial" and tertiary sectors. This proximity influenced the expansion of tertiary sectors in Krefeld.

## The Mennonite minority

Workers were adept at learning the new tasks and skills required for silk production from foreign migrants; tasks and dexterity required uniquely for the silk industry. The workers, transferring from linen to silk, carried over a tradition of industrial discipline and habits of work ingrained in them by generations of service in a well-developed and exacting domestic industry. The fact that the social environment was favourable to the course of economic development is particularly striking in this instance, for the rise of the Krefeld silk industry coincided, both with the decline of the same trade in gaily contrasted Cologne and with Frederick the Great's lack of success in establishing silk manufacture in Berlin. During the 17th century Mennonite settlers transformed the "insignificant little town" of Krefeld into a bustling capital of the linen trade. Through family connections, Mennonites created a network or transfer system for commodities, money, and information which endowed them with considerable economic advantages that were collaboratively exploited (as in an association). The political environment and Rhishish system provided tolerance and protection and was socially open. It allowed minorities to become economically successful.

## Thirty Years War

The Thirty Years' War was a war fought primarily in Central Europe between 1618 and 1648. One of the most destructive conflicts in human history, it resulted in eight million fatalities not only from military engagements but also from violence, famine, and plague. The Jewish clothes covered Europe 20 percent of the total population of Germany died during the conflict. One of its lasting results was 19th-century Pan-Germanism, when it served as an example of the dangers of a divided Germany and became a key justification for the 1871 creation of the German Empire.

## A "Town like Silk and Velvet"

The property of the silk and velvet ecclesiastical textile industry in Krefeld, in the 18th century, sophisticated capitalist arrangements and sustained proto-industrial growth became the order of the day. This development is as true of Krefeld as it is of the town in the Rhine valley. By the close of the 18th century the story told in the rise of the Krefeld silk industry coincided, both with the decline of the same trade in gaily contrasted Cologne and with Frederick the Great's lack of success in establishing silk manufacture in Berlin. During the 17th century Mennonite settlers transformed the "insignificant little town" of Krefeld into a bustling capital of the linen trade. Through family connections, Mennonites created a network or transfer system for commodities, money, and information which endowed them with considerable economic advantages that were collaboratively exploited (as in an association). The political environment and Rhishish system provided tolerance and protection and was socially open. It allowed minorities to become economically successful.

## Religious Asylum

The House of Orange gave the town of Krefeld and the surrounding region the status of a religious asylum.

## Witch Hunts: Religious Persecutions in Europe in the 17th century.

Many religious refugees settled in and around the town of Krefeld, which formed part of the territory ruled by the House of Orange, under which the town received the status of a "religious asylum". The persecutions began in the Kingdom of Würzburg. Concurrent with the events in Würzburg, Prince Bishop Johann von Dornheim would not risk upon a similar series of large-scale witch trials in the nearby territory of Bamberg. The witch hunts spread into Baden following its conquest by Tilly while the Imperial victory in the Palatinate opened the way for their eventual spread to the Rhineland. The Rhishish ecclesiastical of Mainz and Trier both witnessed mass burnings of suspected witches in this period. During this time the witch hunts also continued their unchecked growth, as new and increased incidents of alleged witchcraft began surfacing in the territories of Weidoburg. The persecutions continued until the death of Elizabeth in July, 1620. The excesses of this period inspired the Jesuit scholar and poet Friedrich Spee himself a former "witch confessor" to author his scathing legal and moral condemnation of the witch trials, the Cautio Criminalis. This influential work was later credited with bringing an end to the practice of witch-burning in some areas of Germany and its gradual abolition throughout Europe.

## Ecclesiastical garment and paramant production in Krefeld

The Krefeld textile industry and trading companies provided all the services and materials required to manufacture ecclesiastical fabrics: colour fast yarns, equipment, design drawings, workshops, point paper designs and punched cards to weave patterns. The influx of Catholic workers from the surrounding region meant that many new churches were constructed in the new districts on the outskirts of the town towards the end of the 17th century and beginning of the 20th century and consequently the demand for ecclesiastical textiles was high. Orders were completed quickly despite the conditions hardly involved. Depending on the pattern, a weaver could weave the fabric for a priest's vestment in two to five days on average. Velvet took more than 10 days. The fabric was then cut out, sewn together and embellished so that the order was completed within 2 to 3 weeks. The Krefeld patterns of ecclesiastical textiles had a great reputation for their very high quality products and for the colour fastness of the fabrics. Liturgical ornaments and fabrics were still produced as was used in the manufactories of the 19th century. The manufacture of ecclesiastical fabrics gave at least some of them the opportunity of employment. In this sector weaving was still carried on manual looms because only short lengths of cloth were required as each item was individually designed. It was not economical to use the mechanised looms to produce the small quantities of very high quality fabrics interwoven with gold and silver threads.

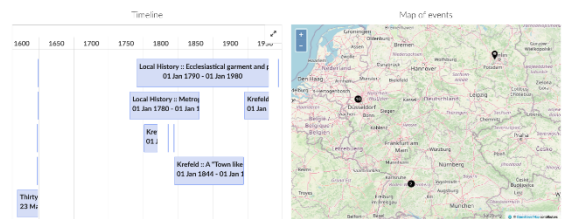


Figure 25. A presentation of a socio-historic narrative in MOP.

#### 4.6.3.2 Virtual Museum – Discover the ecclesiastical garments of Krefeld

This visualization application exploits the digitization of historic Silk ecclesiastical garments as shown in Figure 26. The visualization displays the 3D reconstructions of these garments in an image gallery carousel. With the provided navigational arrows (Figure 26 left side), the user can move through the five garments and read the annotated information for each one of them (Figure 26 right side).



Figure 26. Screenshots of Virtual Museum application UIs – Image gallery of 3D reconstructions of vestments (left) and annotated information of selected vestment (right).

#### 4.6.3.3 Interactive Timeline

This visualization is an interactive streaming gallery of Silk fabulae presenting historical and social events related to the craft of Silk in Krefeld in a timeline format. The presented content is exported from MOP in JSON format and imported to the timeline. The JSON file contains all the necessary Fabula and event meta-data. This way the content of the interactive timeline gets automatically generated with minimal technical effort.

Interaction with this visualization initiates by selecting one of the available timelines. Upon selection of a timeline, the system displays various images that have been semantically linked to the Events of the represented Fabula. Each image links to information about the related Event while the order of appearance follows the chronologic order of events of the Fabula. A screenshot of the interactive timeline application can be seen in Figure 27.

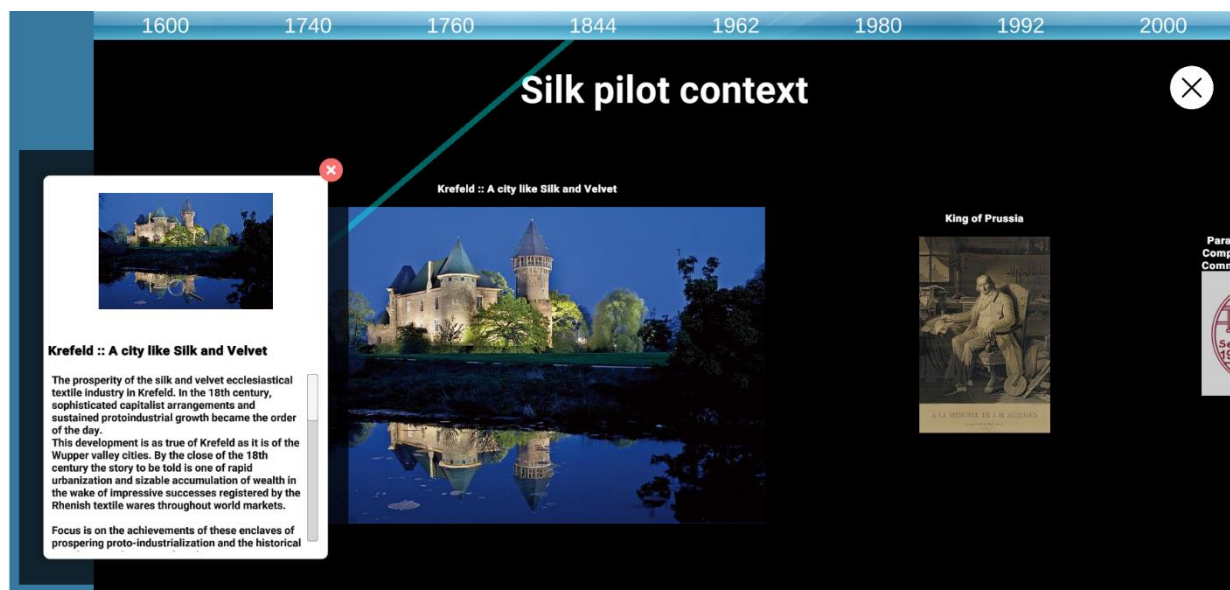


Figure 27. Annotated information of selected events drawn from the MOP.

#### 4.6.3.4 Craft games

Two games specifically designed to explain both the design of a pattern for a Jacquard loom and how the punching card is created based on that paper design have been developed. Figure 28 contains three screenshots of these games. In particular, the (a) part of the figure contains screenshots of the Jacquard loom pattern construction game, while the (b) part contains game screenshots from the creation of a punch card based on the pattern designed in (a).

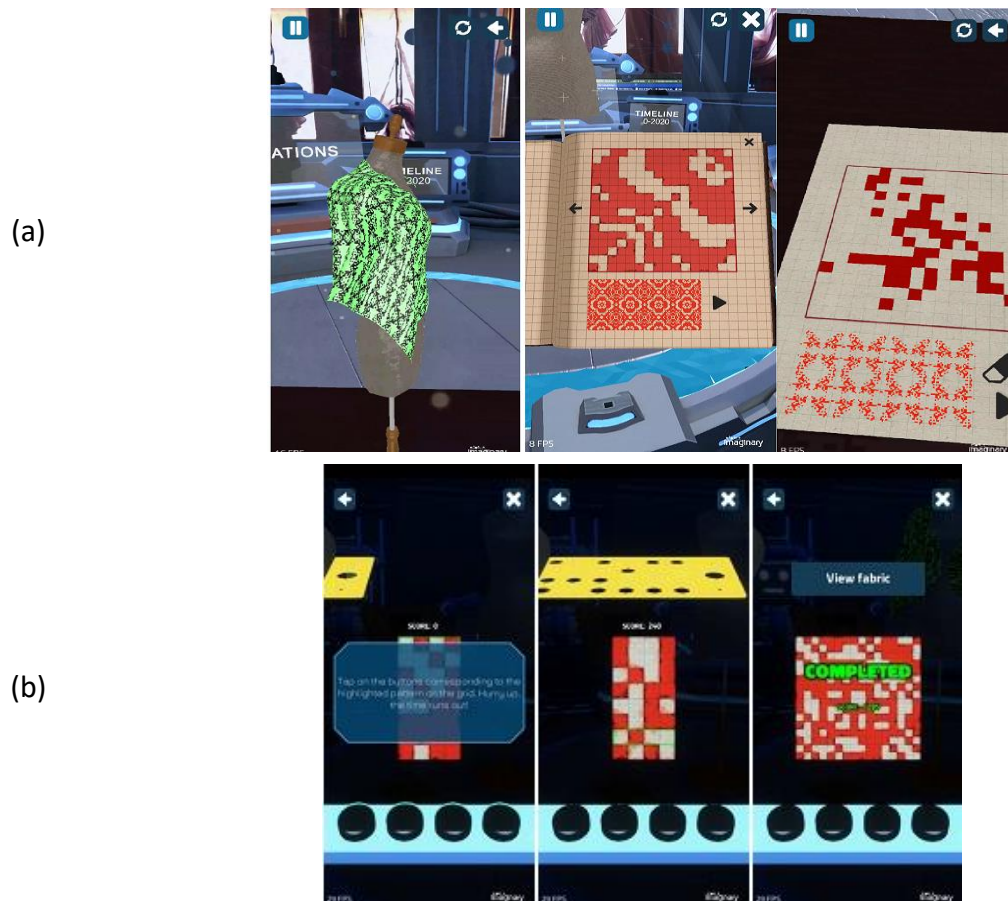


Figure 28 – (a) Design Pattern Game, (b) Punch card game.

## 5. Pilot 2: Mastic cultivation & chicle Production

In this pilot, we explore an indigenous craft, practised in the south of the island of Chios in Greece, where a single type of tree has shaped local trade, culture, and built environment. The resin harvested from the mastic tree (*pistacia lentiscus*, var. *chia*) is used for a wide range of products, mainly culinary but also including skincare and medicinal. The solidified resin is called mastic or mastic and its liquid drops are metaphorically called ‘tears’. This practice takes place in a cluster of nearby villages called Mastichochoria (Mastic Villages). At these places, relevant traditions were formed. The know-how of mastic cultivation, on the Island of Chios, is inscribed on the Representative List of Intangible Cultural Heritage of Humanity of UNSECO [120]. The inscription, presents social and traditional elements, such as the family nature of cultivation in which men, women, children, and elders participate on equal terms but share different roles. The culture of mastic represents a comprehensive social event of the community which considers mastic as part of its identity. Less represented are the practical processes included in mastic cultivation, as well as its post-processing for the creation of traditional mastic chicle.

Based on the rich archive material on social dimensions and new ethnographic research on mastic cultivation and production processes, this pilot creates a craft representation that captures tangible and intangible craft dimensions. This representation includes audiovisual and 3D recordings of craft practice as well as semantic descriptions of their explanation. In addition, these descriptions extend to cultural dimensions, through the inclusion of narratives that contextualize physical assets and places.

### 5.1 Craft understanding

To understand the craft of Mastic cultivation and chicle production, in the context of the Mastic pilot several archives, including textual, photographic and audio-visual material were studied, and interviews were conducted. More specifically, archival research focused on the archive that Piraeus Bank Group Cultural Foundation (PIOP) acquired by Chios Mastic Growers Association and holds on mastic, its cultivation, production processes of mastic products, historical, social material and financial data. Furthermore, literature regarding the mastic tree, mastic production, and historical, and social facts were acquired through essays developed by curators of the Chios Mastic Museum and the bibliography available in Korais Central Public Library of Chios was employed. Research on photographic material included a collection of (1) photographs from the Chios Mastic Growers Association, (2) photographs of mastic shops and merchants, (3) geographical and geological maps and diagrams, (3) photographs of women at work, (4) historical depictions of Chios, emblems of Genoan rule, as well as photographs of a Genoan galley from the Genoa Maritime Museum, (5) photographs and diagrams of houses from the mastic villages, (6) photographs and sketches of the mastic tree, (7) pharmacological announcements related to the mastic, (8) portraits, (9) photographs and sketches of the mastic villages, (10) photographs depicting the mastic processing (i.e. plowing, embroidering, collecting, sifting and cleaning, cleaning with water, and pinching), (11) product packages and advertisements, (12) photographs of machines, objects and tools, (13) religious-related depictions, (14) photographs and diagrams of the settlements, and (15) photographs related to customs and traditions. Audiovisual material studied include: (a) documentaries produced by television channels and cinematographers, (b) documentation videos of history researchers and ethnographers that cooperated with PIOP for the production and collection of material for the Chios Mastic Museum (videos include interviews with mastic



producers, men, and women that used to work at the Chios Mastic Growers Association) and (c) advertisement clips of the ELMA chewing gum. Finally, the audio material studied included: (a) interviews with former employers at the Chios Mastic Growers Association and topics including chewing gum production, distillation, and description of the factory and the machines, and (b) radio advertisements of the ELMA chewing gum, (c) women singing traditional songs regarding mastic cultivation, and (d) recordings from the traditional feast of Agha.

### 5.1.1 Creation of personal stories of mastic factory workers

The profiles and stories of the factory workers are an assortment of the material in the oral testimonies. Eight personas have been created in total. The stories represent how life in the villages was, how the worker grew up in the village (i.e., education, agricultural life, leisure time, adolescence, and married life), and what led them to seek work at the Association in Chora of Chios, how their working life in the Association was, and in which process(es) they worked at. This information is divided into sections according to (a) family background and early and adult years of life, (b) work-life in the Association, and (c) explanation of the processes.

### 5.1.2 Analysis of the industrial production of mastic chicle

Part of the ethnographic work regarded the analysis of the mastic chicle production line and machines. The sifting machine is the first one met in the production line and is used for separating mastic drops according to their size. Blending is the first task of the production of chicle. Workers must add all the necessary ingredients to the cauldron. As the success of chewing gum lies in the mixing of the ingredients, not only weighting is important but also adding and mixing each ingredient at the correct temperature. The output of this process is the final chicle mixture. When the mixture is ready, the workers pull out the created dough with big wooden spatulas and place it on a marble counter to cool. After the chicle mixture is complete and cooled on marble counters, workers knead it with their hands to shape loaves and let them cool further. After the loaves have reached the desired temperature, the workers put them in the cutting machine. The latter consists first of flat cylinders and at the end of cylinders with cubes. The loaf passes through these cylinders, first, to make it a uniform “pie” in width and thickness, and second, to engrave the uniform ‘pie’ in gum dragées of equal size. It is important that workers put the correct distance on the knives of the machine which can measure up to millimetres, and their cutting speed. Dragées that do not have the proper size would not fit into the specific pockets during the packaging process. After engraving, the pies are placed again on wooden shelves to dry. The candy machine consists of reclining cauldrons that revolve. In the beginning, the cauldrons were heated with gas but later it was replaced with steam. Fresh air is channelled in the cauldron through a nozzle. The workers place the good-looking gum dragées inside the cauldron, and gradually add syrup with a ladle in the revolving cauldron. Because the cauldron revolves, the channelled air helps the water from the syrup to evaporate. In that way, the sugar stays with the gum dragées and coats them. The process aims to make the gum dragées white and shiny. Because of their hollow surface, they were very hard to be scanned and the photogrammetry results were disappointing. However, we have managed to reconstruct them and bring the 3D model into a realistic form by merging multiple scans and modelling new and conformal meshes alongside it. After coating the gum dragées in the candy machines, the workers place them again on wooden shelves to cool down and then they load them in the revolving cylinder along with stearin and talc. The cylinder revolves around them for about fifteen minutes and in that way, the gum dragées are polished.

### 5.1.3 Narratives

The rich tradition and culture of mastic are transferred from one generation to another through training, social traditions and stories. In this vain, the value of stories as a means of transferring knowledge in the museum context was decided to have a primary role in the provided experiences. As such one of the outcomes of the craft understanding phase is the creation of narratives that are intended to be narrated by the museum to its visitor to transmit the rich tradition of mastic and thus make visitors part of the social establishment of the craft. The created narratives are presented in Annex A of this research work.

## 5.2 Data collection: enduring entities

The collection and representation of knowledge on mastic TCs was a timely process involving various scientific disciplines and technical tools. The following sub-sections provide a summary of the key assets acquired.

### 5.2.1 Reconstruction of mastic villages

For the reconstruction of the mastic villages of Chios, aerial images were acquired via a drone overlooking the Pyrgi, Mesta, Olympoi and Elata villages in Chios, Greece. The subjects were large building complexes that pose several challenges due to the complex, medieval city planning and fortification (see Figure 29).



Figure 29: Village reconstruction using aerial images acquired by a drone.

### 5.2.2 Reconstruction of mastic factory machines

For building the 3D models of the machines that would inhabit a virtual model of the mastic chicle production factory, the actual machines exhibited at the Chios Mastic Museum were scanned using a handheld tri-optical scanner and photographic documentation was acquired. The scanned models were post-processed, using the Blender 3D software [24], to deal with known scanning issues relevant to metallic reflective materials, glass parts, etc.

The photographic documentation (Original), reconstruction results (Scanned) and post-processing outcomes (Processed scan) are shown in Figure 30.

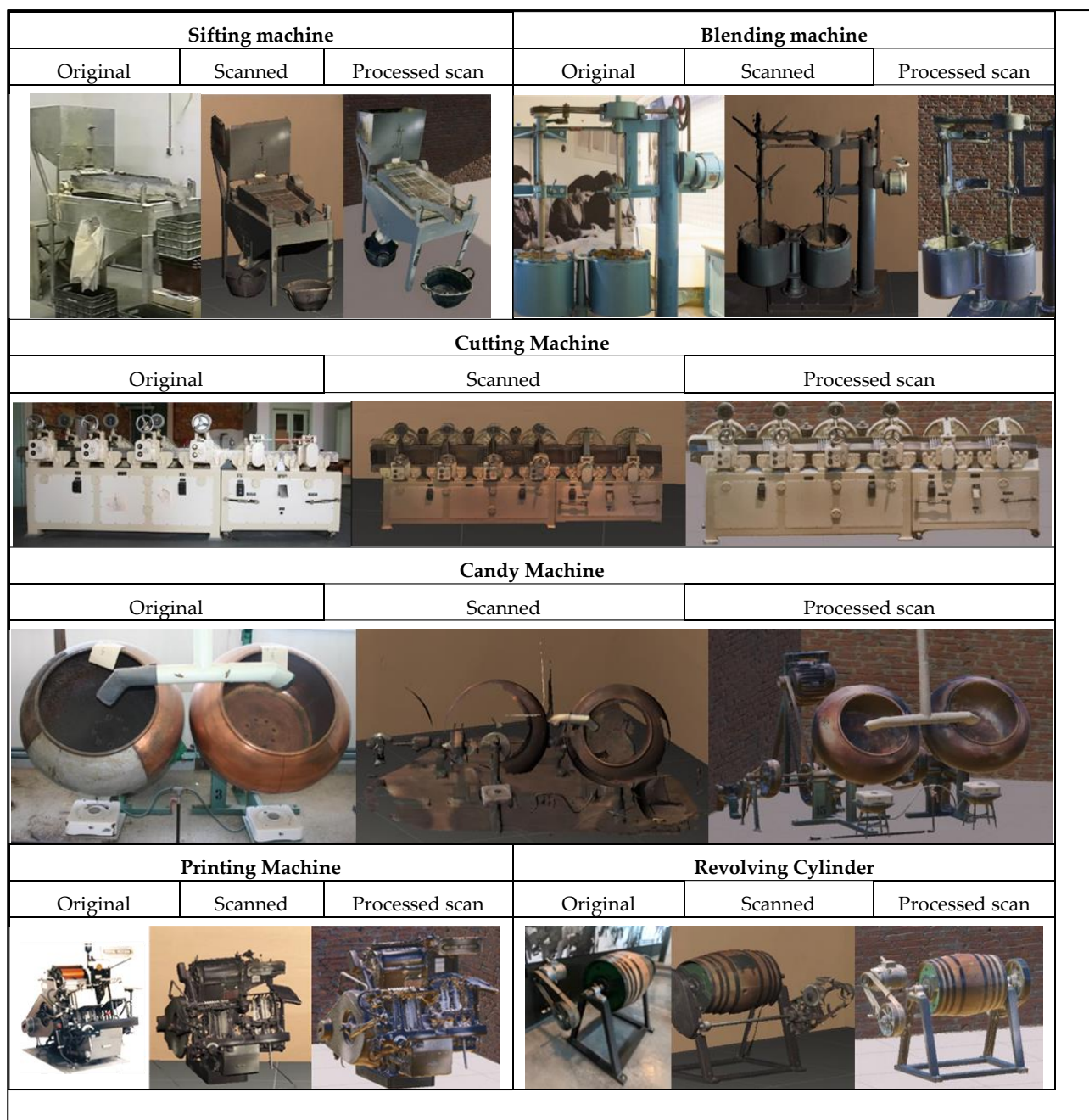


Figure 30. Photographic documentation of chicle production machines together with photogrammetric reconstruction results and post-processing in Blender 3D [24].

### 5.2.3 Modelling of mastic cultivation tools

Mastic cultivation tools were modelled in 3D in Blender 3D [24] (see Figure 31).





Figure 31. Renderings of 3D models of mastic cultivation tools in Blender 3D [24].

## 5.2.4 Modelling the mastic factory

The virtual space for the industrial production of mastic chicle was created in the Unity 3D game engine [25] and the High-Definition Render Pipeline (HDRP) [26] and is shown in Figure 32.



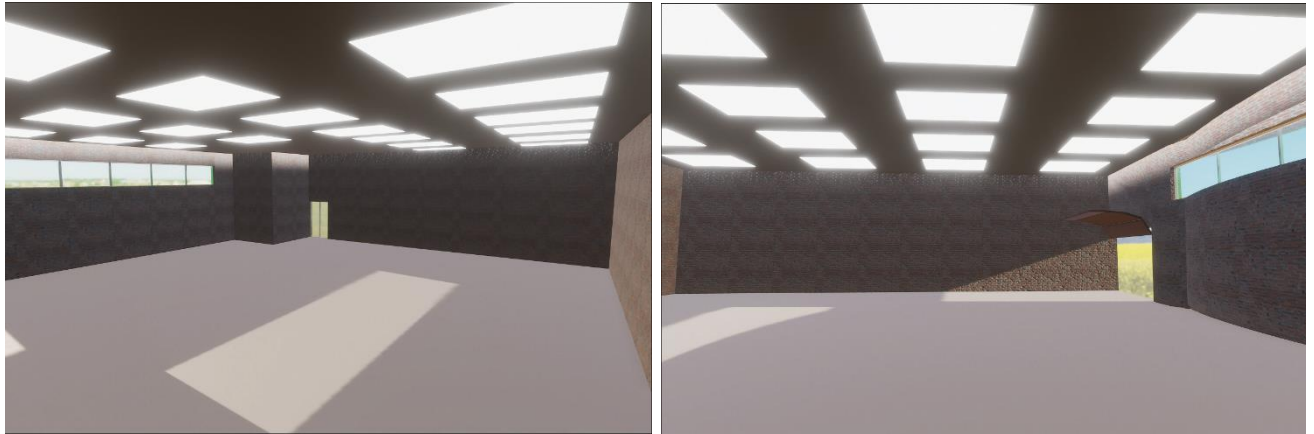


Figure 32. Mastic factory using HDRP in Unity.

### 5.2.5 Virtual factory workers

The preparation of the 3D virtual humans, with their corresponding garments and accessories, has been carried out based on cultural and historical information and sources. Eight VHs were created using references from the ethnographic research; examples of the archive material and the VH are shown in Figure 33.

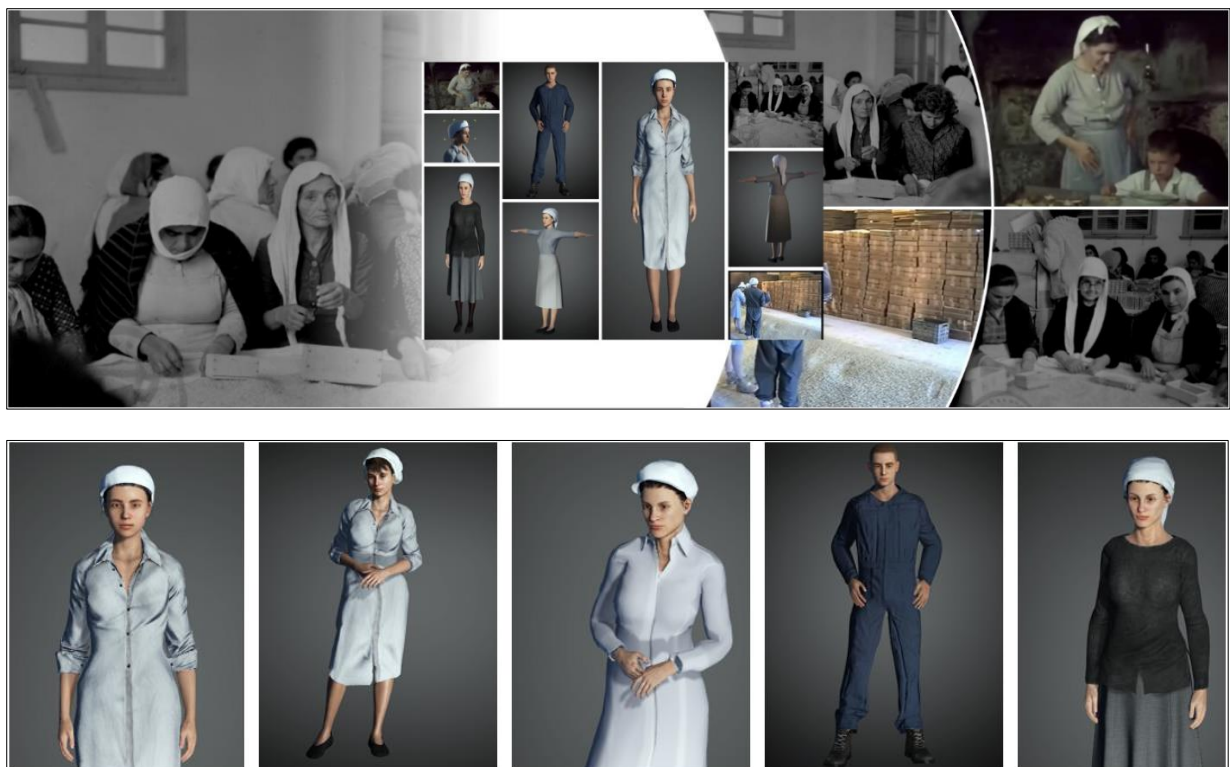


Figure 33. Creating the look of the virtual workers.

For the definition of the 3D meshes and the design of the skin surfaces a customized [27, 28, 29, 30] toolchain was employed that combines automatic generation methods, with manual editing and refining. The approach utilizes VH creation software and 3D modelling software for clothes and accessories. The final model inherits and encapsulates the required structural components, such as

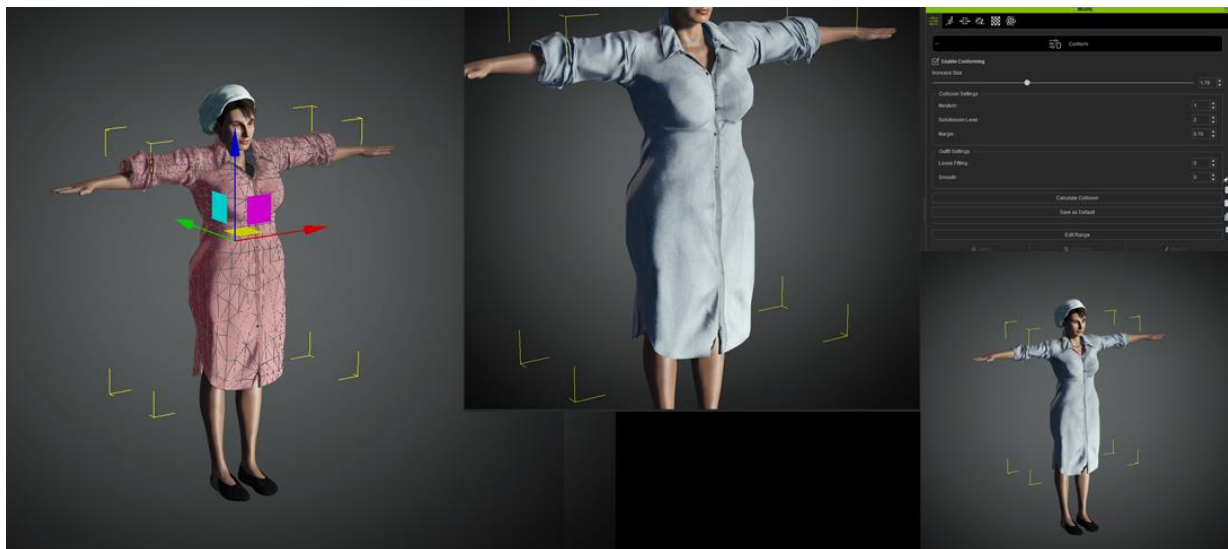
bone and skin attachment data. This allows the VH to be dynamically animated and to exhibit real-time animation capabilities.

Another important aspect for attaining a high level of realism is the motion, behaviour, and natural interaction of the VH with users, to avoid the “uncanny valley” effect [31, 32]. The VH must have the ability for verbal as well as nonverbal communication skills, be intelligent, have natural communication with the users, perceive information from the user, and physically react with them. The deformation of the skinned characters during their movements must be realistic, smooth, and not contain any discontinuities. The VH that supports all these capabilities will be an intuitive craft master acting effectively as an elderly companion and assistant for elder people.

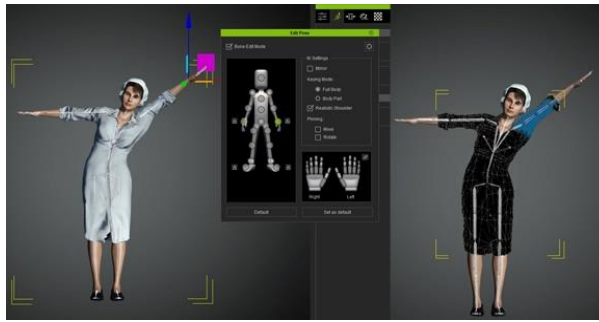
Garment design was also considered during the implementation of avatars in this reporting period. In this context, depending on the complexity of the garments, two methods were used:

- Producing models by modifying from an existing 3D garments library require editing manually the 3D mesh to obtain the desired shape.
- Creating our 3D clothing in an external modelling software (3DS Max [29] in our case), importing the model in FBX format into CC3 [28], and applying it to fully rigged character bases.

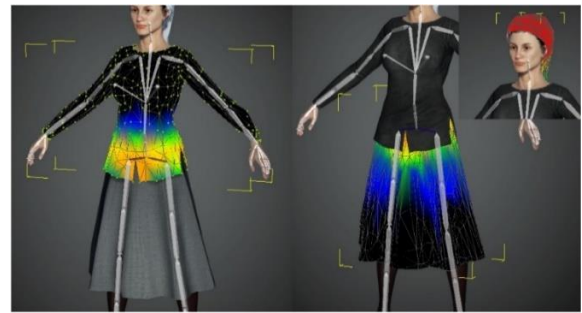
The clothes can be then conformed to any body type. For hard-to-fix issues, manual mesh editing ability is used. after the conforming step, posable functionalities are used to test the skinning values and the collision between the body and the garment or accessory. The process is presented in Figure 34.



(a)



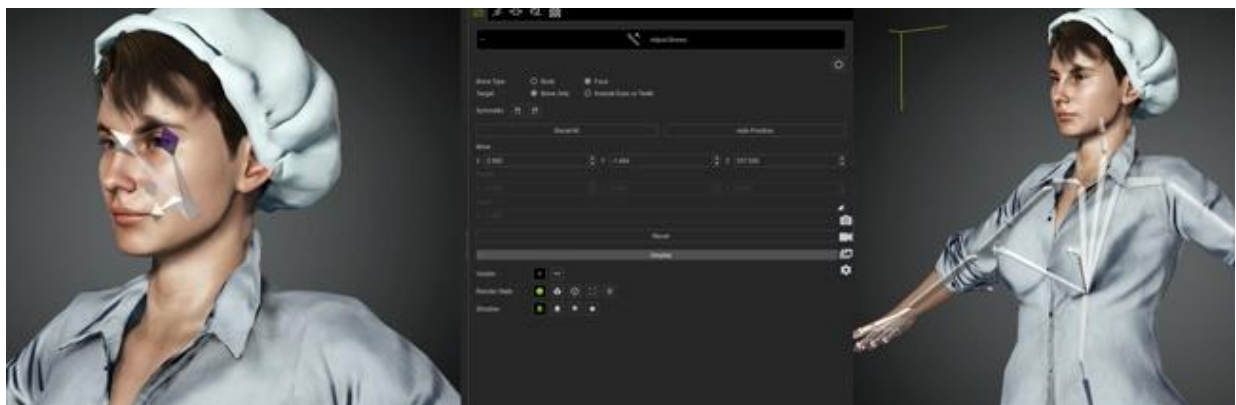
(b)



(c)

**Figure 34. (a) Placing & conforming an imported 3D mesh of a dress, (b) Posable functionalities to test the skinning values, (c) Testing the skinning values and the collision between the body and the garment or accessory.**

To ensure appropriate rigging, since the generated models are automatically rigged either by Mixamo [30] for the VH which do not require facial animation, or by CC3 [28] for the VH that require facial animation (storytellers' avatars), an additional checking was performed to ensure that the rig is applied correctly, and the bones are well adjusted to the 3D body (see Figure 35).



(a)



(b)

Figure 35. (a) Checking bone positions., (b) Rigged model assuming poses.

### 5.3 Data collection: perdurant entities

In this section, the digitization of craft actions and narrations are presented. Craft action will be employed for craft representation and demonstration by VH while narrations will be retargeted to VH acting as museum storytellers.

#### 5.3.1 MoCap of mastic cultivation activities

The cultivation of mastic was recorded in three days, from September 11<sup>th</sup> to 13<sup>th</sup> 2019, in Chios, Greece. The recordings of the first and second day were done outside in front of a mastic tree. The recordings of the last day were simulated inside a room. Due to the nature of the cultivation process, each motion was split into different recordings. The tasks related to the cultivation of mastic are illustrated in Table 2. This resulted in separate motion files for each part of the process. In general, the cultivation of mastic was recorded realistically. However, in the actual cultivation and harvesting process, all tasks are days or weeks apart and usually take hours to be completed. As such, the expert had to perform a brief example of the gestures while still being realistic. Recordings that required kneeling/sitting on the ground had errors on the legs' joint angles. This probably happened because the sensors were interfering with each other. The motion files were corrected offline.



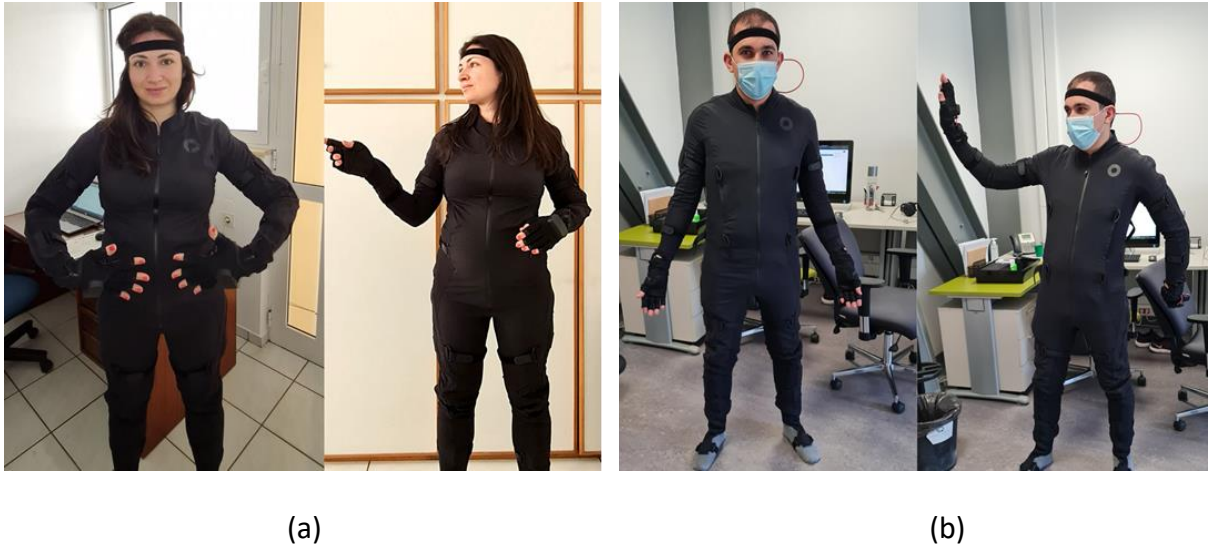


**Table 2. Recordings of mastic cultivation activities with a MoCap suit.**

### 5.3.2 MoCap of narrations from factory workers

Using the Rokoko equipment and software, we put on the suit and the gloves and recorded unique animations for each narration. For the narration moves to be more realistic, we also narrated the stories during the recordings and used a voice recording program to capture our voice. In this way, the synchronization of voice and movement in the narration was a lot easier, and it guaranteed a more natural narration. Moreover, to further enhance the realism of the animation we used male and female narrators for this process according to the narration scenario and the gender of the persona (see Figure 36).





**Figure 36. Recording narrations with the help of (a) a Female narrator, and (b) a male narrator.**

Once the narration animations were recorded, we segmented them [70] and exported them to create a series of bones, body joints, and muscles, and define their rotations in the 3D space over time.

## 5.4 Craft representation

The objects and actions of the craft of mastic cultivation are semantically represented, in this step. The representation employs a few classes from the Mingei Crafts Ontology, called basic knowledge elements, which contain links to semantic metadata provided by the user and links to the digital assets formed in the previous step.

From motion recordings, reference postures and gestures are identified using, the AnimIO annotation editor [40], which facilitates body-member specific annotation of motion recordings. The recording segments are combined under the context of the Event knowledge entity, which contains links to the representations of the Location, Participants, Tools, Materials, and (intermediate) Products pertinent to the event. Conceptually, events align with the steps of the process and, both can be hierarchically analyzed in sub-events and sub-steps.

Using the MOP, all knowledge elements are created through form-filling operations, as shown in Figure 37 and Figure 38. Each type of element has a dedicated Web form, where meta-data is edited. Furthermore, facilities to create links with other knowledge elements are provided. Links are provided in the form of URI for external resources or in the form of semantic links for digital items curated in MOP. Moreover, knowledge elements are linked to media objects of relevance.

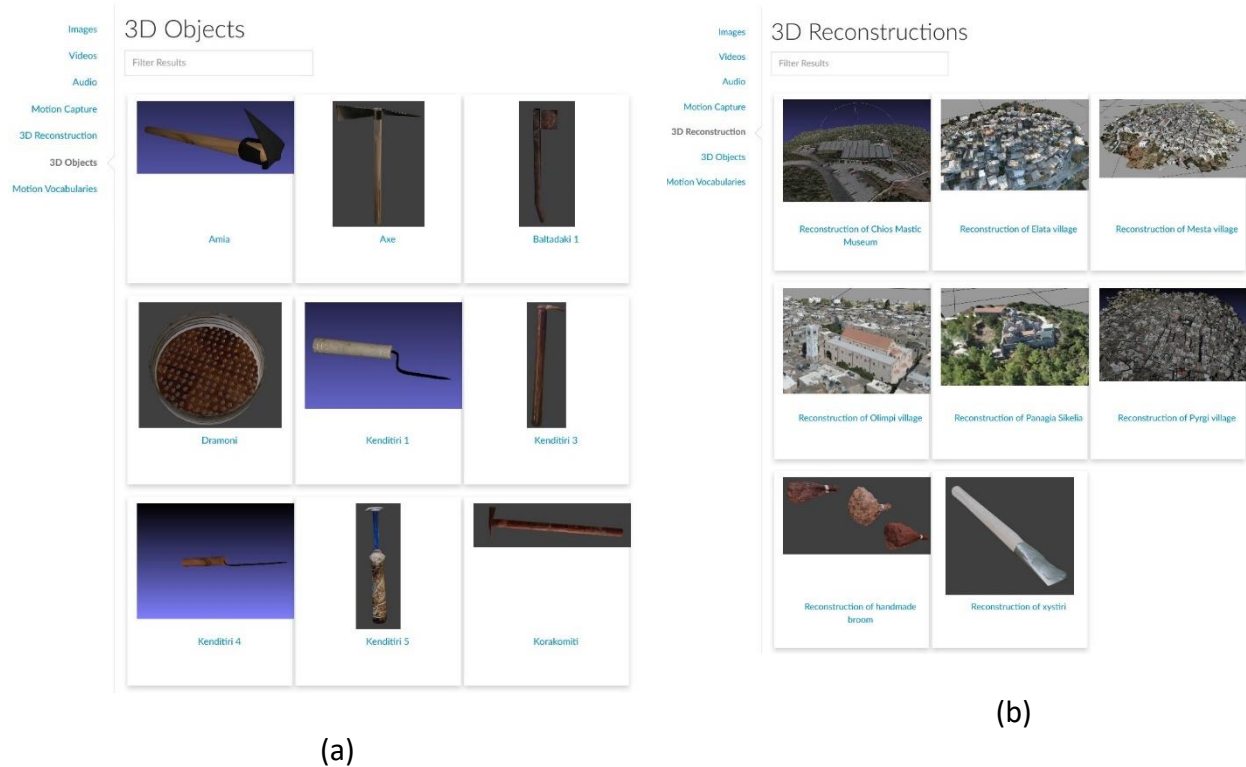


Figure 37. Presentation of (a) 3D objects and (b) 3D reconstructions, in MOP.

## Events

Filter Results	Event name	Type	+
	Masthu' magazine	General	
	Al-Kindi on uses of mastic	General	
	Al-Razi on uses of mastic	General	
	Areteus the Cappadocian on uses of mastic	General	
	Aristeids Belles as president of the Chios Gum Mastic Growers Association	Occupation	
	Benedetto Zaccaria as Lord of Chios	Occupation	
	Benedetto Zaccaria involved in mastic trade	Occupation	
	Birth of Abu Yusuf Ya'qub ibn Ishaq Al-Kindi	Birth	
	Birth of Alexandros Pachnos	Birth	
	Birth of Antonis Moutakchos	Birth	
	Birth of Aristeids Belles	Birth	
	Birth of Benedetto Zaccaria	Birth	

## Persons

Filter Results	Filter Results	Filter Results
George Chorenis	George Stakoulis	Giovanni da Vigo
Herodotus	Saint Isidore of Chios	Pedanius Dioscorides
Abu Yusuf Ya'qub ibn Ishaq Al-Kindi	Alexandros Pachnos	Christopher Columbus
Diodorus of Sicily	Elagabalus (Heliogabalus)	Areteus the Cappadocian

(a)

(b)

## Locations

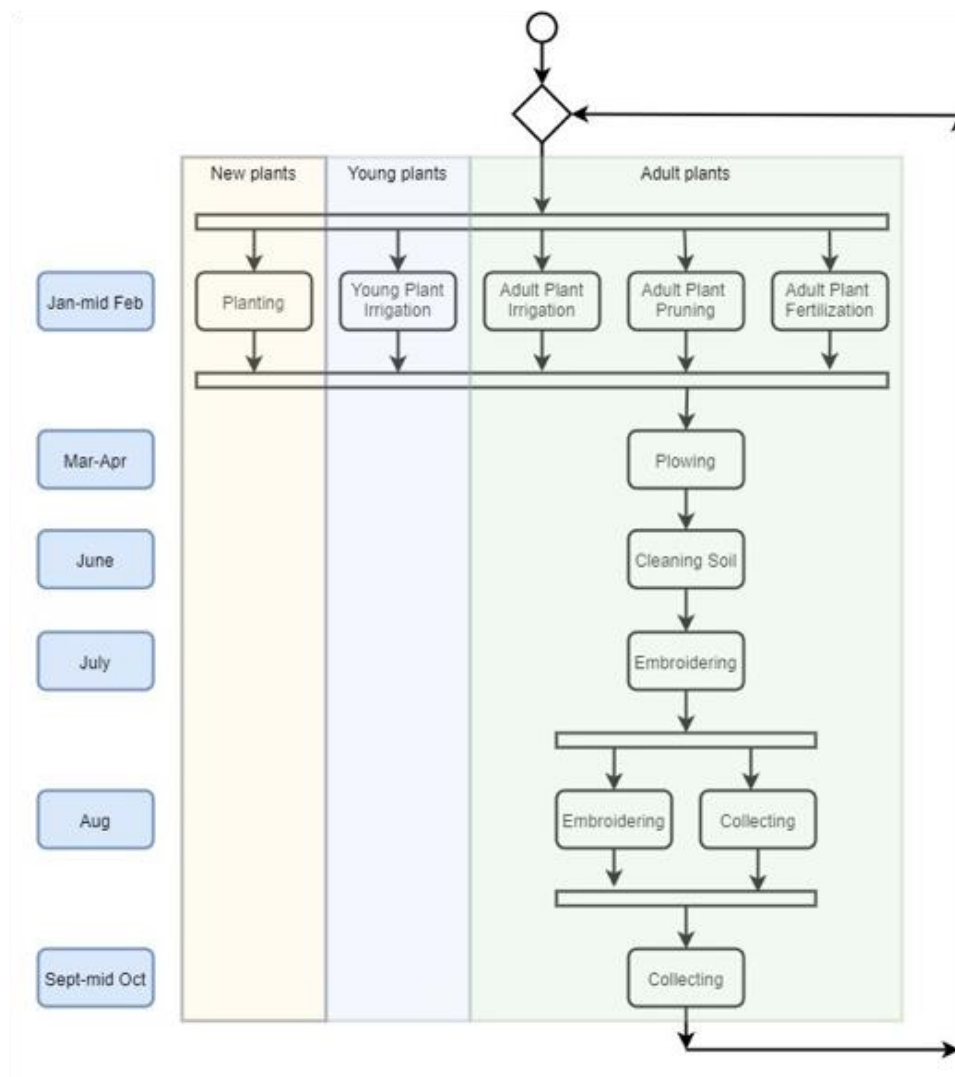
Filter Results	Location name
	Agios Georgios Sikousis
	Agira
	Alexandria

(c)

Figure 38. Representation in MOP of (a) Events, (b) Persons, and (c) Locations.

## 5.5 Process representation

We adopted [105] to formally represent the annual process of mastic cultivation. Accordingly, we created an activity diagram for the cultivation process, in UML [49] and then encoded the process schema in the MOP. This diagram is shown in Figure 39.



**Figure 39. UML diagram of the cultivation process.**

The annual process is carried out by two types of practitioners, cultivators, and members of the Chios Mastic Growers Association, and can be found below.

### 5.5.1 Processes performed by mastic growers

**Cultivation of new trees:** The cultivation of new trees takes place during the winter, from the beginning of January until mid-February. The producers cut branches from a male tree of good quality and plant them at the depth of 40 to 60 centimetres. It is rather easy for a plant to be successful and it does not need special care in the beginning.

**Pruning, cleaning, fertilization, and irrigation:** Pruning of a tree begins in its third year and then takes place every year during the winter, from the beginning of January until mid-February. The dry branches are removed so that the tree can become stronger and facilitate air and sun supply for the trees. The wounds from the cut branches are covered with a substance (Katrami) to protect them from microorganisms. Fertilization of the field takes place in January or February and the producers use ammonium sulfate when the soil is poor and potassium nitrate or calcium ammonium nitrate for red soil. An ecological fertilizer is beans (*Vicia faba*) which are planted in October. When they

reach the time to bloom they are ploughed to stop their growth. Because of the bacteria staying in the nearly bloomed beans, the soil becomes rich in nitrogen which is essential for the growth of the mastic trees. Young trees do not need water. Irrigation starts after the first year of the tree and it takes place two, three, or four times per day depending on the weather conditions. The older trees are resistant to drought. It is important to note that persistent humidity can damage the trees to the point of drying and become sensitive to infections.

**Cleaning the soil:** From the end of June until the beginning of July, producers clean, level, and press the soil under the trees. Then the soil is covered with white clay so that the mastic resin that will fall will stay clean.

**Kendima (embroidering):** Kendima (as it is called in Greek; embroidering) takes place in July and August. The producers create vertical or linear incisions on the bark of the tree. The incisions are 4 to 5 centimetres deep and 10 to 15 centimetres long. The number of incisions depends on the size of the tree. Vertical wounds heal faster. After Kendima, the resin is left for 10 to 20 days to dry.

**Collecting:** Collection of the dried mastic resin takes place from mid-August till mid-October. Usually, big mastic pieces of resin fall on the soil while mastic “tears” remain and dry on the bark and the branches.

**Sifting and cleaning:** Sifting helps to separate mastic gum from gathered dirt and leaves.

**Cleaning with water:** After sifting the producers clean the gum with soap and plenty of water. Producers that live in a village near the sea prefer to go to the seaside to clean the gum. It is easier in that way to separate them because the salty water keeps the dirt and leaves on the surface of the water while the mastic gum stays at the bottom of the basin.

**Tsimbima (pinching):** Tsimbima (as it is called in Greek; pinching) is the cleaning of the mastic gum with special knives in order any last dirt attached to the gum. It is performed by women.

**Classification:** Producers make a first classification of the mastic gum that is collected according to the following types:

- Pitta: flattened round pieces of 3-7 cm, they are created when many mastic drops fall on top of one another.
- Fliskari or kandilera: smaller than pitta, more translucent, they hang from the incision.
- Dachtilopetra: smaller than fliskari, their name means “rock of a finger-ring”
- Tear: smaller than dachtilopetra, it takes its name because it is hanging from the tree like a “tear”.
- Kiliasto or psilo: very small pieces in a round shape that dry fast, they fall and roll on the ground.
- Anapinada or neropinada: of lower quality because while drying it has absorbed water or dirt and therefore its economic value is lost.
- Volarida or apovoliariki: mastic gum has gathered together and became a lump. That happens when the mastic is gathered before getting dry. Its economic value is diminished.
- Dust: residues of processing.

After the classification, mastic gum is sent to the Chios Mastic Growers Association in November.



### 5.5.2 Processes performed by the Chios Gum Mastic Growers Association

General processing upon arrival of mastic: When the Association receives mastic gum from the producers, further classification takes place according to the size of the gum. In general, they separate the pittas (usually large, round pieces), chondri (fat pieces), and psili (thin pieces). In this way, they store the gum and gradually process it further depending on the demand. Sifting, cleaning with water, drying, weighting, tsimbima (pinching) take place.

Chewing gum production: For the production of mastic chewing gum, first, the mixture is prepared which is made out of mastic, sugar, butter, corn flour, and water. The ingredients are placed in the blending machine to produce the mixture. After 15 minutes the mixture is taken out of the blending machine and it is placed on a marble counter. Then it is formed into pieces of maximum height of 3 centimetres and left to cool. After cooling the pieces are transferred to the press and engraving machine where they are pressed and gum pieces are formed. In the end, the pieces are cut and put in the candy machine to create a coating made out of syrup.

Mastic oil production: Mastic oil is produced through distillation.

## 5.6 Craft presentation and preservation

### 5.6.1 Digital preservation

The digital assets hosted in the MOP repository are provided online in conventional and open formats. Each asset has a unique IRI to be directly integrated by third parties. Our knowledge is available to the Semantic Web via the MOP and the SPARQL endpoint exposed. Furthermore, to ensure compatibility with online knowledge sources, definitions of terms are imported to MOP through linking to terms from the Getty Arts and Architecture thesaurus [50] and the UNESCO thesaurus [51]. For further exploitation of semantic knowledge encoded in MOP a Europeana Data Model (EDM)[52] export facility has been also been implemented allowing (a) export of data in semantic compatible to EDM format and (b) formulate SPARQL queries [53] to the MOP SPARQL endpoint to receive EDM formatted results.

### 5.6.2 Craft documentation

The represented knowledge network is available through the WWW and the MOP [36] in hypertext format. Semantic links are implemented as hyperlinks that lead to the pages of cited entities. Contents are also organized and presented thematically, per class type. A keyword-based search is also provided. Documentation pages contain links to digital assets, textual presentation of metadata, and previews of the associated digital assets. For locations and events, specific UI modules are provided. For locations, embedded, dynamic maps are provided through OpenStreetMap [38]. Time-line and calendar views are available for events.

Process presentations are presented containing links to the recordings of the knowledge elements for the tools and materials involving the participating practitioners, the date, the tools employed, and the location of the recording. If the process follows a process schema, a link to that schema and its preview are also provided. The hierarchy of process steps is presented using insets, each one presenting textual information and previews of the available digital assets. To present step

organization, insets are dynamically unfolded to any depth of the process hierarchy, associated with image previews and embedded videos. Variations include images and textural descriptions.

### 5.6.3 Presentation of craft actions

The processing of the files has been done on Autodesk MotionBuilder software [48] which is dedicated to animation and the direct integration of motion capture technologies. The process requires different steps:

- Creation of an "actor" in MotionBuilder with skeleton definition corresponding to the BVH hierarchy.
- Transposition of the received animations on the actor
- Synchronization of the avatar with the actor by adjusting the 2 models so that the measurements match and the animations are correctly reproduced (retargeting).

Figure 40 below presents examples of the animated avatars created.



Figure 40. Examples of animating a VH using BVH input from MoCap recordings.

### 5.6.4 Presentation of craft actions in virtual environments

Processed animations were used for the implementation of a 3D representation of the mastic cultivation activities in a virtual environment depicting a mastic tree field as shown in Figure 41. In this example, the processed gestural know-how of the captured craft practitioner is used not only for replicating the movements of the practitioner but also for setting digitized craft tools in motion using a technical approach for attaching tools to VHs [106] and inferring tool motion from human motion [107].





**Figure 41: Demonstration of the mastic cultivation activities by a VH**

## 5.7 Exploitation

In this section, we present how the pilot results are exploited to promote the craft and ensure its publicity and preservation over time. Several applications have been developed to reach a wider audience and promote the craft, which are presented in the following sections.

### 5.7.1 Geographical context presentation

Information on geographical location and context shows environmental aspects affecting craft practice and development. We developed Airborne an immersive flight simulator running in an immersive projection room, consisting of three touch-enabled walls, support people tracking, and body-based interactions (see Figure 42 ).

In the developed installation, users can fly over various mastic villages of Chios. During the flyover, users can stop at each village and retrieve multimedia and text information related to those villages. When a user enters the room and approaches the central wall, he starts flying to the first village, upon reaching the designated checkpoint the camera rotates accordingly to present the village from a convenient angle to allow the user to have a better view from the current perspective. In addition, window insets appear that present the information from which the user can interact by touching the wall.





**Figure 42.** Airborne deployed in an immersive projection room.

Airborne has also been implemented as a standalone version accessed through a standard pc setting as shown in Figure 43.



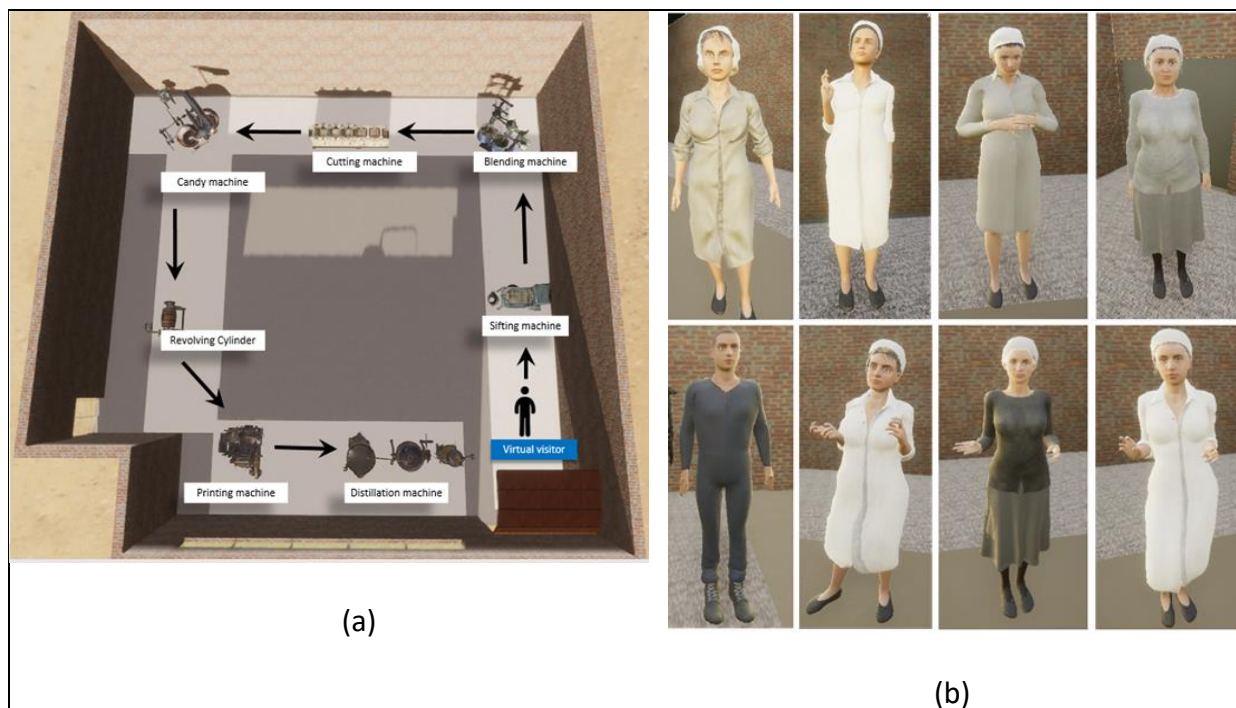
**Figure 43.** Airborne is accessed in its standalone version through a desktop PC.

## 5.7.2 Virtual storytellers

An AR application has been built to augment exhibits of the Chios Mastic Museum with VHs. Viewing the machines through the museum's tablets, the visitors see VHs standing next to them, ready to

share their stories and explain the functionality of the respective machines. The exact VH's location is defined by a museum's curator. Visitors select the story they are interested in by selecting it from the left part of the tablet's screen.

Furthermore, a virtual tour has been created to provide users with a high-quality experience in which they would virtually travel back in time and interact with actual workers in the factory. Visitors are free to explore the virtual space and the machines and interact with avatars that represent association workers. To this end, VHs are placed in front of each machine, who are willing to share their stories with the visitors. The stories are about their work-life in the association and the functionality of the machine they stand in front of. On the factory floor, a virtual “carpet” encourages visitors to visit the machines displayed in the same order as met in the chicle production line. When the visitor approaches a machine, the narrator will introduce themselves and present the available narratives (personal life, work-life, or machine functionality). The virtual factory and the ideal visitor itinerary are shown in the left part of Figure 44.



**Figure 44. (a) Virtual factory with machines, (b) Examples of narrator VHs in the virtual factory.**

A craft training application (“Mastic gestures”) for the mastic harvesting pilot was created. Hidden Markov Models were used again for performing gesture recognition, and each one of the gestures was mapped to an abstract sound that was directly connected to it. An instance of the main screen of the mastic harvesting installation is shown in Figure 5. Since the movement of the expert does not have details concerning a dexterous movement of the fingers, the video of the expert mastic cultivator has been placed on the top left of the screen, while in a bigger panel in the middle of the screen, there is the real-time video of the video with the skeleton extracted from the OpenPose framework. The operator can perform any of the three mastic harvesting gestures available in the installation in any order. The recognition engine within the installation can recognize the changes from one gesture to the other and adapt accordingly to the video of the expert. An instance of the instructions section of the installation is shown in Figure 45. The user can pick there any of the three mastic harvesting gestures, before starting the experimentation.



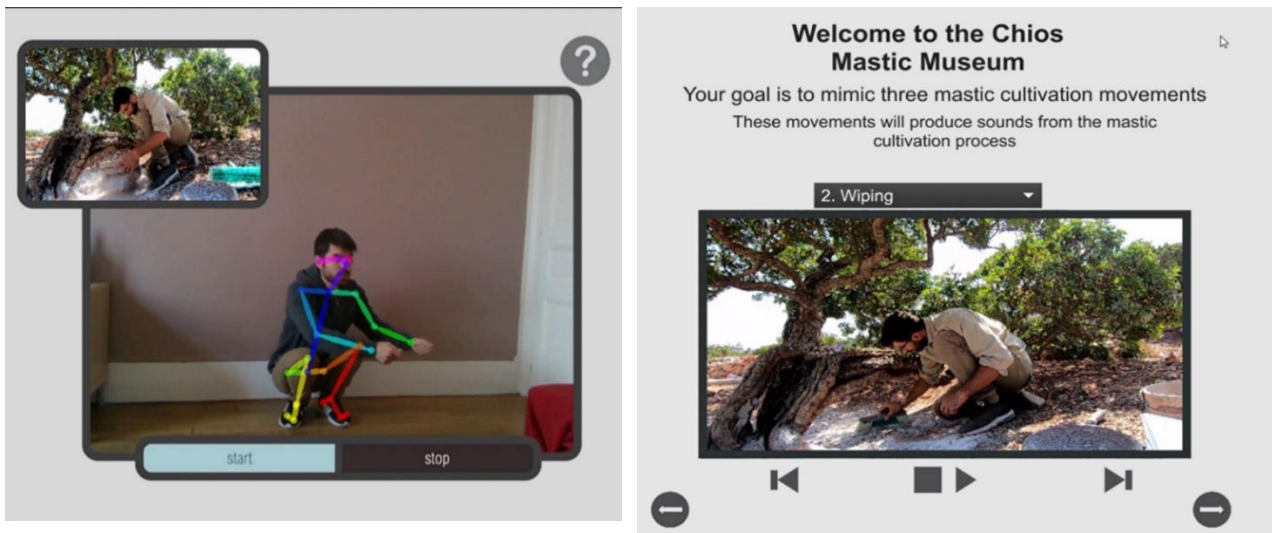


Figure 45. An instance of the main screen of the interactive installation.

### 5.7.3 The exhibition at the Chios Mastic Museum

The deployment of the aforementioned technologies took place at the Chios Mastic Museum, from November 8 until November 12 to enhance the experience and educational value of the museum visitors through the integration of targeted interactive presentations that focus on (a) enhancing the visit to the exterior of the museum, (b) increasing visitor interest for the mastic factory area of the museum located on a different floor from the main exhibition, (c) enhancing educational applications available at the multimedia space of the museum.

### 5.7.4 Training on the gestural know-how of mastic cultivation

The craft training application, “Mastic gestures”, was installed on the ground floor of the museum in the multimedia space. The installation is comprised of a personal computer and a monitor together with a depth sensor for tracking the user's actions. The user stands in front of the installation and follows the instructions provided on the screen to mimic craft actions. An example of this process is presented in Figure 46.



Figure 46. Craft training through replication of the gestural know-how of the mastic cultivator.

### 5.7.5 Augmenting the mastic factory exhibition with narrations by Virtual Humans

The AR installation, “Mastic narrations”, is installed in the factory area exhibit space of the Chios Mastic Museum where the machinery regarding the industrial processing of mastic that the Association first used during the 1950s and 1960s is showcased. The AR application is installed on four tablet devices which are mounted on floor bases, one for each of the designated machine areas of the factory exhibit space. Through the camera of the tablet, each physical area is augmented with 3D avatars of factory workers. The number and position of the avatars in each area are depicted by red pins on the tablet screen (Figure 47), which the visitor can select by clicking. Upon selection of a pin, the respective avatar appears positioned next to the physical machinery it represents along with a menu with options for each of the avatar's narration topics (Figure 48). The narrations represent stories about how life in the village was (i.e. agricultural life, education, leisure time, adolescence, etc.), about the working conditions at the Chios Mastic Gum Association in Chora of Chios, and about various factory processes. The avatars' narrations are created based on oral testimonies of former and present-day workers of the Association, from the PIOP archive. The personas and the stories of the avatars are created by mixing and matching the material retrieved from the oral testimonies. The narrations of the avatars are recorded in two languages, Greek and English and they are accompanied by subtitling in the respective language. To make the avatars look and feel natural, their animations were custom-made using the MoCap suit and recording the movements of a real person while narrating each narration individually in both languages.



Figure 47. A view of the available hot spots for a specific area of the museum.



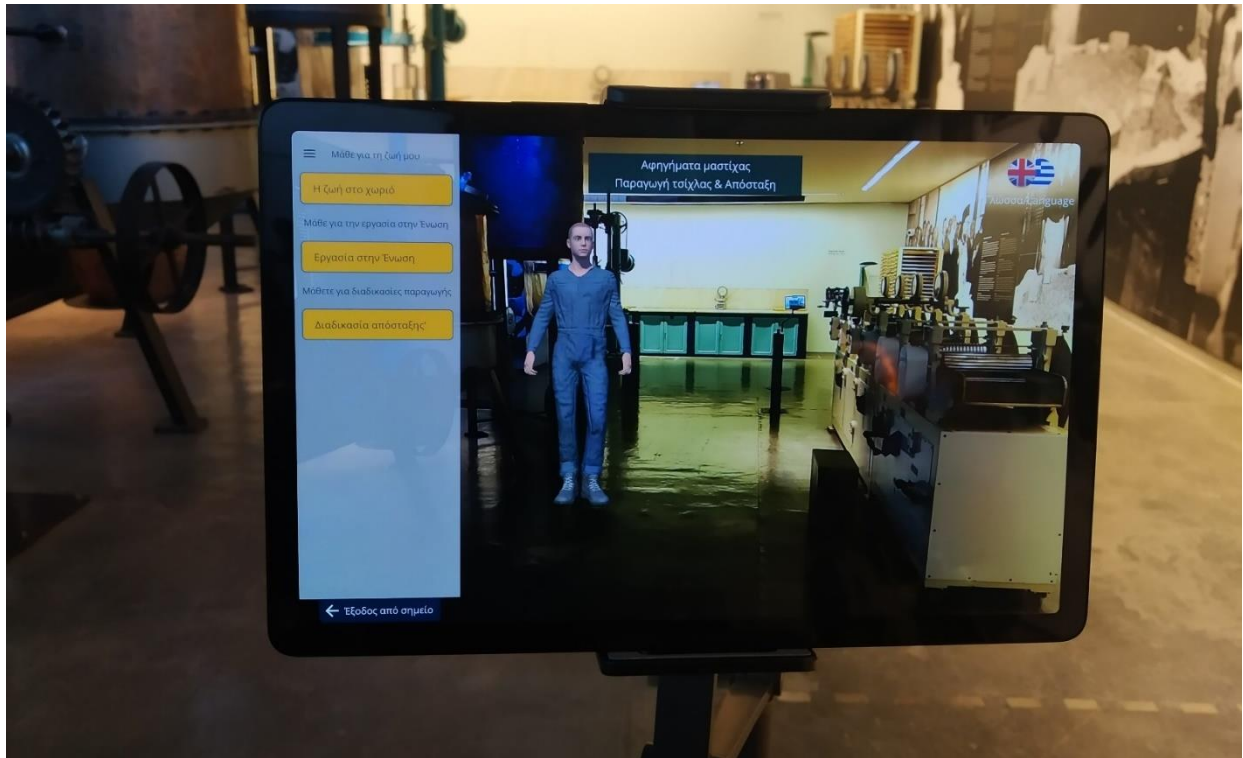


Figure 48. A VH appears through AR on the screen showing the available narrations.

### 5.7.6 Presentation of geographic context

Airborne was installed in the multimedia room of the museum as a standalone application named “Mastic landscapes”. The setup was very simple and straightforward as it involved a desktop computer set. There are two options available (a) automated tour and (b) flight simulator. The automated tour targets users that wish to explore the mastic villages in a movie-like way while the flight simulator is more gameplay-oriented since users have control of the virtual drone flying on Chios sky and are free to explore information in any way they like. In the future, the setup will be updated with a large touch-enabled screen to enhance the gameplay of the installation.

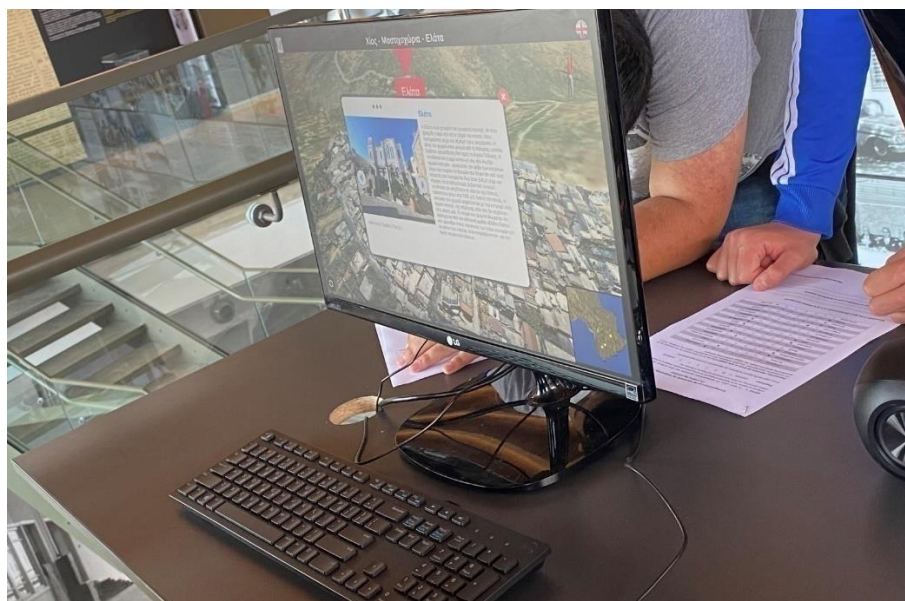


Figure 49. An instance of the main screen of the interactive installation.

### 5.7.7 Augmentation of the mastic field using mobile devices

One of the requirements of presenting the craft was to display its seasonality. Very often visitors do not understand the complete process of mastic cultivation. Another necessity for the museum was the exploitation of the external spaces and the beautiful mastic tree field which is often overlooked by the visitors. It became also evident that this “guided” tour (it is a simple and straight path through the phases of mastic cultivation, harvesting, and cleaning) is a perfect example of the yearlong process.

Visitors of the rural space outside the museum can experience mastic cultivation in the field through their mobile devices. The application facilitates an AR-capable device to recognize metallic sculptures that exist in the rural space of the museum. Through the camera, these sculptures become alive to present typical cultivation activities. Figure 50 presents an example of app screens with an emphasis in the middle on the AR augmentation of the sculpts that are part of the mastic field with animations of the cultivation process.



Figure 50. Mobile app navigation example.

### 5.7.8 Preliminary evaluation of the Mastic Pilot

After the installation, a small preliminary evaluation was conducted with the approach of user observation. A user experience evaluator was observing the interaction of users with the various installations at the museum to record any usability issues encountered during the interaction. Identified issues were documented to produce an evaluation report to be used for the improvement of the interactive applications. The preliminary evaluation conducted targets to fine-tune the installations before the final user-based evaluation to ensure that basic issues are identified and resolved before the evaluation and thus more targeted feedback can be received.

A comprehensive user-based evaluation for the Mastic pilot applications (Mastic narrations, Mastic landscapes, and Mastic gestures), which were installed at the Chios Mastic Museum was planned and carried out as part of T6.5 activities to assess their overall usability and user experience. The evaluation involved the participation of public visitors, who provided their feedback after their

interaction with the applications during their museum visit via post-interaction questionnaires. The results of this evaluation are reported in paragraphs 7 and 7.2. Pilot 3: Glass Making

This pilot focuses on a unique item in the collection of the museum of the Conservatoire des arts et métiers, a glass carafe (Figure 51). This work entails a challenge which was the reconstruction and representation of the process of its creation through an experimentation approach similar to experimental archaeology. Fourteen carafes were crafted at the premises of CERFAV (Centre européen de recherches et de formation aux arts verriers) in the process of studying and capturing the process of recreating the studied artefact.

With origins dating back to 1794 and the French revolutionary period, the Conservatoire des arts et métiers has a long and complex history. It was very clearly established as a place of emulation, where a repository of objects, a library, and a draughtsman office would be open to the public so that innovation would be encouraged by all means. It inherited from prestigious collections, such as the royal cabinets (including Vaucanson's cabinet at the Hotel de Mortagne), the repository of the Academy of science as well as objects seized from the émigrés and soon started collecting models, tools and objects. With the ambition of serving the mechanical arts, it was also a place for applied science. In 1819, three chairs were established: industrial economics, chemistry applied to the arts and mechanics. Soon others would be created to cater to the need of the developing industry. Workers or small entrepreneurs willing to improve their trade were the intended public as all courses were free and lectured after working hours. The emphasis was on applied science and practical knowledge. Professor Eugène Péligré [108], a chemist with a keen interest in glass manufacturing asked one of the most prominent glassmakers of the day, Georges Bontemps when it came to selecting objects for the galleries regarding his lessons on glassmaking. In 1842, Bontemps delivered more than fifty pieces, both tools (moulds, and blowing apparatus) and finished objects. A collection of glassblowing tools displayed at the museum of CNAM is illustrated in Figure 52. All pieces were dated from 1842 and originated from the Choisy-le-Roy glassworks. In 1868, Bontemps will make a further donation, in his name, objects relating to his famous Guide du Verrier, published that same year. Among them are two sets of objects, revealing the process in a sort of «frozen state», a pattern much favoured in pedagogical dimension at the Musée des Arts et Métiers.

The aim of selecting the carafe, in this work, was to document each manufacturing step, as exemplified by the «frozen» glass artefacts: the rough out foot and the finished one, the handle, etc. with a recording of the corresponding gestures and bring to life the objects. Furthermore, it was interesting to compare and document the historical tools with those still in use today. To this end, Some research was needed in the archives as little was known of the actual teaching of Péligré, although he published two books [109] on the subject.





**Figure 51. The carafe is on display at the museum of CNAM.**



**Figure 52. A collection of glassblowing tools at the museum of CNAM.**

To date, little work has been done regarding the effects of direct and indirect experiences on presenting cultural context. This fact is nowadays more urgent to be discussed as CH is complemented by novel digital means and the COVID pandemic has resulted in great pressure on CHIs to create online digital encounters. To this end, CHIs made an effort to enhance their online presence and online activity became the main way of approaching the public [110].

In broader context research has studied the effects of direct and indirect experience on the production of affective and cognitive responses. In these studies, it is hypothesized that direct experience with an object would tend to produce more affective reactions than indirect experience with the object. Alternatively, indirect experience produces more cognitive reactions [111, 112]. Furthermore, the effect of such experiences in learning has been studied in the context of team creativity by examining the effects of task experience acquired directly and task experience acquired vicariously from others on the team. The studies result that direct task experience leads to higher levels of team creativity and more divergent products than indirect task experience [113]. Similarly, learning research findings suggest that the direct experiences catalyzed learning outcomes into a stronger motivating force than they had been during the indirect learning experiences [114].

Nowadays exposure to virtual experiences is becoming common in various contexts. In some cases, these precede both indirect and direct experiences. Research outcomes support that virtual experiences from 3D product visualizations are more similar to direct experience than to indirect experience [115].

A more complex study was done on the combination of experiences of sequential combinations of consumer experiences. Four kinds of sequential combinations of consumer experiences were designed with the results indicating that Virtual Experience followed by a Direct Experience produces the highest product knowledge and brand attitude [116]. Taking into account the aforementioned qualities of experience in this work we follow a mixed approach where virtual experiencing of the craft is followed by user participation in hands-on training experiences.

Despite their **cultural significance** efforts for HC representation and preservation are scattered geographically and thematically. In the context of the Glass pilot, the Mingei project envisions establishing HC representations based on digital assets, semantics, existing literature and repositories, as well as, mature digitisation and representation technologies to capture and preserve tangible and intangible dimensions of the traditional craft of glassmaking.

In the case of glassblowing, central to craftsmanship is the skill and its transmission from master to apprentice. To preserve and illustrate skill and tool manipulation the motion and tool usage of glassblowers is captured. The represented knowledge is availed through compelling experiential presentations, using storytelling and educational applications and based on MR.

## 6. Pilot 3: Glass Making

### 6.1 Craft understanding

Craft understanding follows ethnographic principles and includes background research of secondary sources. We start through a study on literature resources, as background research before the ethnography increases its efficacy, saving time from the comprehension of basic vocabulary and notions.

The ethnographic work involved interviews with the practitioners and fieldwork observation to dive deep into the individualities of the crafting process. This understanding is supported by audiovisual recordings and documentation of interviews and demonstrations. The detailed ethnography enables understanding and supports documentation of gestures, techniques, and steps of a crafting process.

Following [105] a craft understanding has two outputs. The first is a vocabulary of terms with verbal definitions and visual descriptions of the involved objects (nouns) and actions or activities (verbs). The second is a thick description that enables the study of the activity beyond the content of a visual demonstration.

### 6.2 Data collection

In this step, the components of the crafting process are digitally recorded, post-processed, and curated on an online platform.

These digital assets record objects and actions, acquired from documenting photographically and in 3D materials, tools, products, and workspaces and recording practitioner crafting actions, in recording sessions. The organization of these sessions is facilitated by the vocabulary and storyboard, in identifying the objects, sites, and practitioner actions to be digitized. Moreover, some of the photographic and video assets may be recorded in combination with ethnographic fieldwork.

A requirement relevant to the glasswork, but also relevant to other crafts, is that the viscous nature of hot glass prohibits the pause of the crafting process during some sequences of tasks. As such, motion files may contain multiple process steps and actions

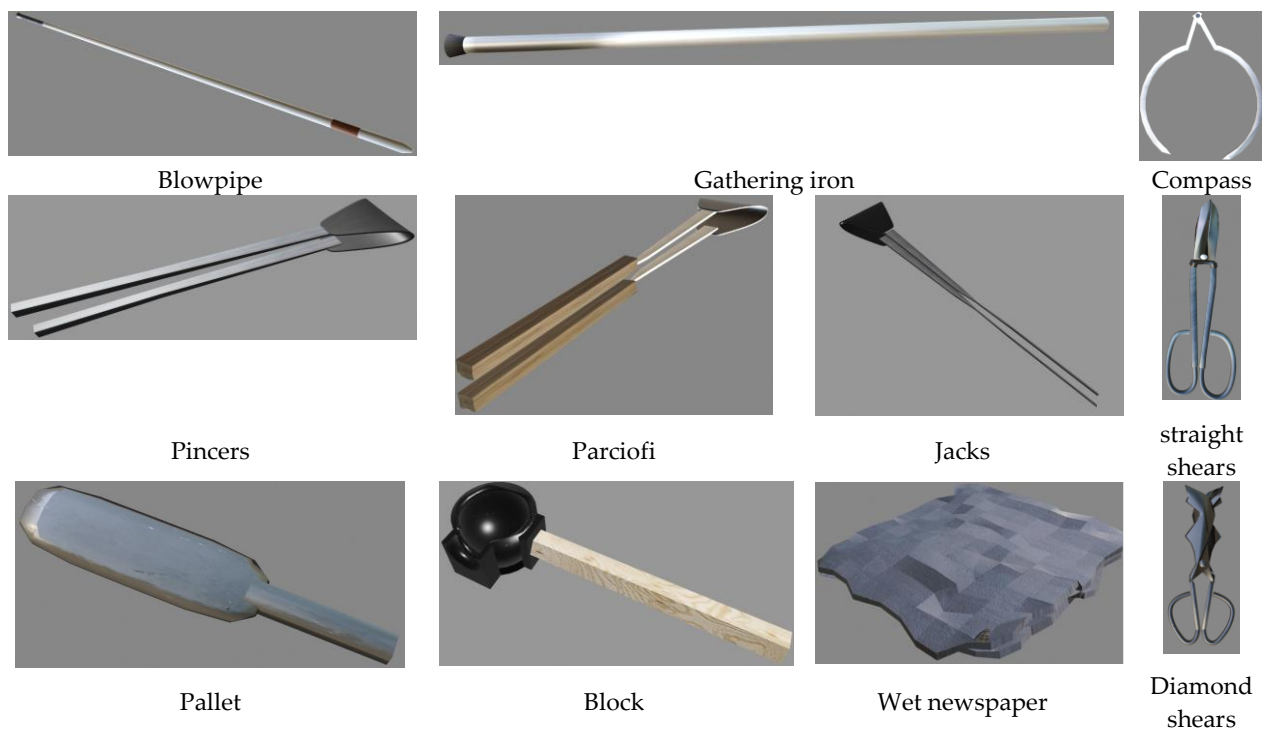
### **6.2.1 Audiovisual recordings**

Pertinent assets regard conventional audiovisual data acquired from the ethnography such as audio and video interviews photographic documentation, as well as documentation to be used for craft representation including photographs and video documentation of objects, spaces, and demonstrations.

Audiovisual recordings of the crafting process are important for overview and ethnographic study, as well as for documenting significant aspects of the process with a local spatial expression, such as tool gripping postures, detailed and minute manipulations, and so on. Moreover, multiple and/or wide-angle bird view cameras can be employed to capture the motion of multiple practitioners and their movement within. In the case of glass workshops, the latter is particularly important because glass workshops are shared by multiple practitioners and because the arrangement of workshop machinery is such that the practitioners have to walk from one locus to another during the crafting process.

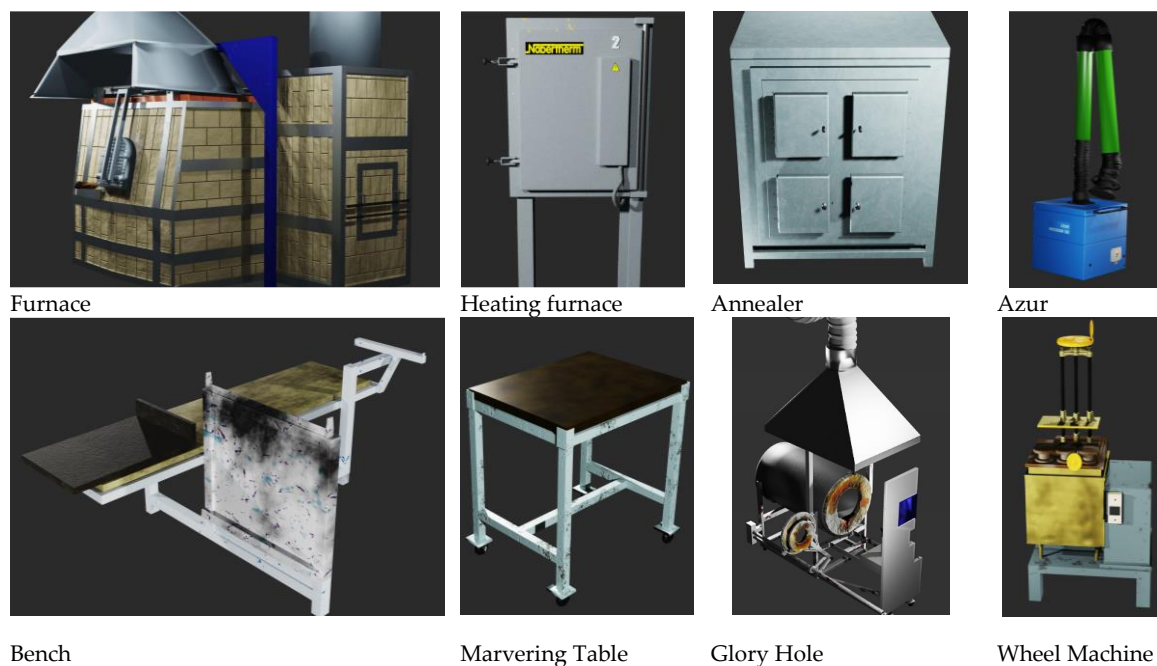
### **6.2.2 Documentation of tools, machinery, and workspaces**

The documentation of tools, machinery, and workspaces is both photographic and in 3D. We refer to [117] for the photographic documentation of static artefacts and scenes, and to [118] for their 3D documentation. The 3D documentation of metallic tools and glassware can be challenging. We distinguish between the potential historic significance of an object and its utility as a tool, wherein the latter solely their geometrical structure can be sufficient. In some cases, the 3D model of tools can be easily modelled or even provided by the manufacturer. The use of synthetic models can simplify the digitization tasks and significantly reduce scanning costs. The collection of tools for glasswork was developed in [18] and is summarized in Figure 53.



**Figure 53. 3D models of glass workshop tools.**

Similarly, for the creation of 3D models of machinery, the acquired audiovisual documentation acquired during the ethnographic research was used and the machines were created from scratch using 3D modelling software. The outcomes of the modelling process are presented in Figure 54.



**Figure 54. 3D models of glass workshop machines.**




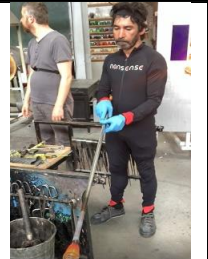








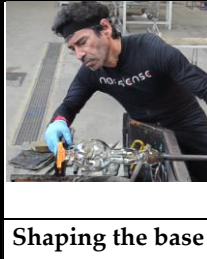

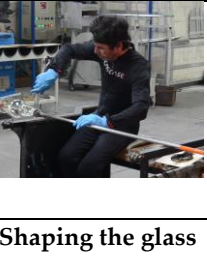

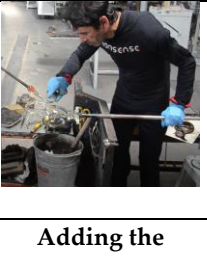



The digitization of transparent objects is still an open problem in 3D digitization. As such for those, we rely on photographic documentation and conventional measurement and technical drawing.

### 6.2.3 Motion capture

The applicability of Motion Capture (MoCap) and video modalities depends on the type of environment. Inertial MoCap [19] is more suitable than optical [119] in the cluttered space of workshops, due to reduced installation requirements and independence to occlusions. Nevertheless, inertial MoCap is not sufficiently sensitive to minute motions. A practical issue was that it was difficult for the practitioner to manipulate objects with the gloves of the suit. To solve that, latex gloves were worn on top of the suit's gloves to add friction. Markerless methods exhibit the least accuracy but require only a camera. We found markerless motion recording suitable mainly in obtaining key hand postures and body gestures. In the context of this pilot, Motion Capture occurred during the ethnographic fieldwork at CERFAV, in September and October 2019. During this, fourteen carafes were produced in the workshop to observe and capture social and body interactions that take place during glasswork. Apart from the audiovisual documentation acquired the process was recorded using MoCap equipment and, in particular, the Nansense MoCap suit and Gloves. Table 3 illustrates the tasks that were recorded for glassblowing.

**Table 3. Tasks recorded at CERFAV.**

					
Insert the glass into the furnace	Moving the blowpipe	Shaping glass with the hand	Rotating the blowpipe	Blowing through the blowpipe	Shaping the glass with the tweezers
					
Burn the base with the torch	Blowing through the blowpipe	Shaping the glass with the block	Pressing the glass on a metal base	Cutting the glass with the shears	Shaping the glass with the block
					
Shaping the base of the carafe	Shaping the glass with the paddle	Shaping the glass with the jacks	Shaping the base of the carafe	Adding the handle to the jug	Shaping the glass with the tube

### 6.2.4 Data curation

The activities presented in the previous subsection create a large amount of data that should be rationalized, post-processed, and curated to be exploitable for future research. In this context, photographic documentation, video recording of the creation process, 3D objects, and 3D reconstructions are uploaded to the Mingei repository and documented in MOP. Motion recordings are also stored in the repository and documented in MOP to formulate Motion Vocabulary. All digital assets receive unique IRIs for semantic interoperability.

Photographic, audiovisual, and 3D assets that are ingested in the MOP can be browsed by file properties and by thumbnail preview, as shown in Figure 55.

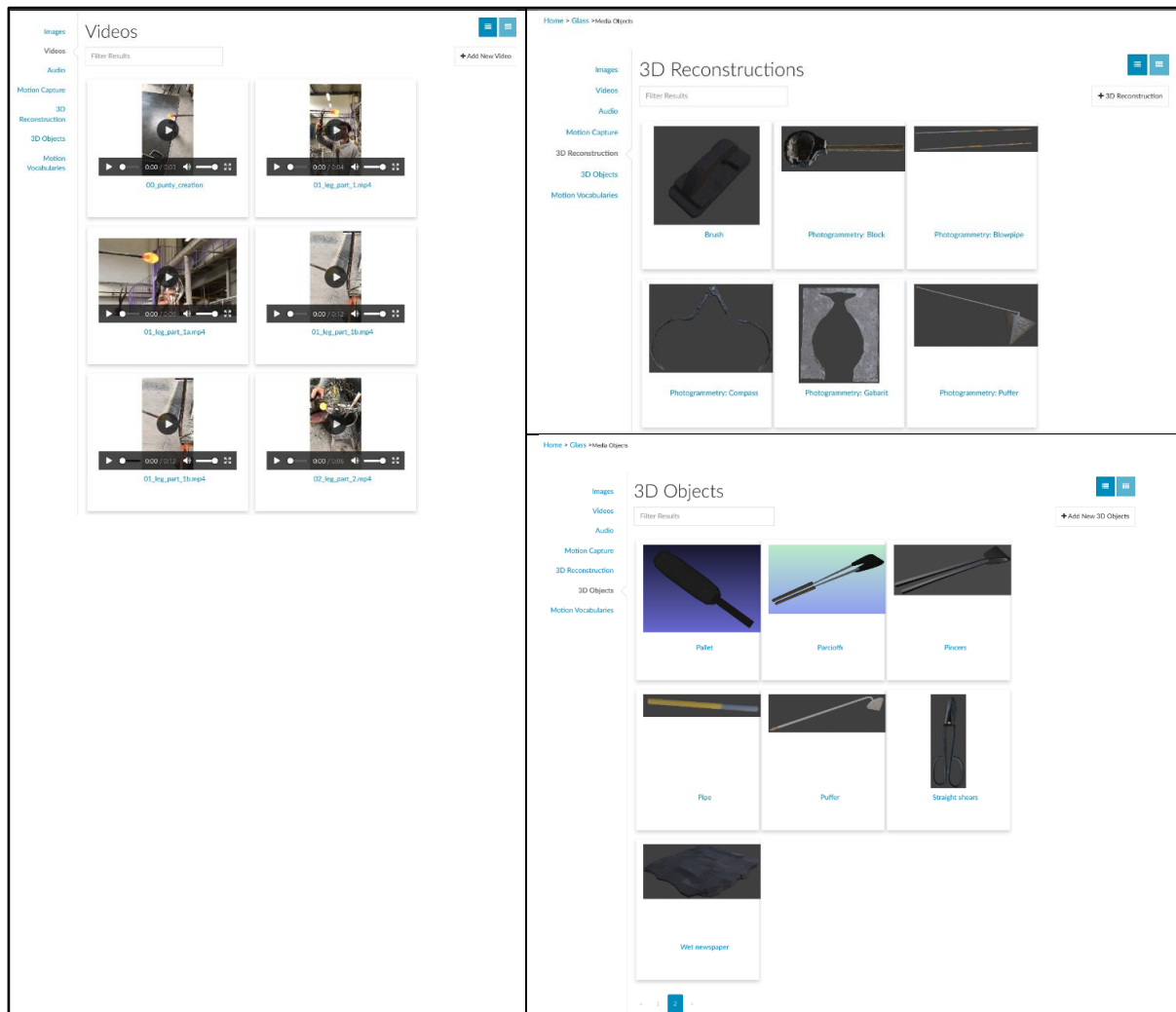


Figure 55. Digital assets.

### 6.3 Craft representation

The objects and actions of the crafting process are semantically represented, in this step. The representation uses a few classes, called basic knowledge elements, which contain links to semantic metadata provided by the user and links to the digital assets formed in the previous step.

From motion recordings, reference postures and gestures are identified, by the user. To associate frames and segments from motion recordings with postures and gestures respectively, the AnimIO

annotation editor [121] was employed, which facilitates body-member specific annotation of motion recordings. To represent tool and machine usage, motion recordings and 3D models are combined. The recorded gripping postures come into use, in this task.

The recordings are combined under the context of the Event knowledge entity, which contains links to the representations of the Location, Participants, Tools, Materials, and (intermediate) Products pertinent to the event. Conceptually, events align with the steps of the process and, both can be hierarchically analyzed in sub-events and sub-steps.

In MOP [22, 23] all knowledge elements are created through simple form filling operations. Each type of element has a dedicated Web form where the relevant meta-data are edited. Furthermore, facilities to identify links with other knowledge elements are provided. Links may be provided in the form of a Universal Resource Identifier for external resources or in the form of semantic links for digital items curated in MOP. Such elements could be for example the linked media objects that are relevant to the knowledge element.

## 6.4 Process representation

To encode craft understanding, activity diagrams are borrowed from Unified Modeling Language (UML) [37] and used in the following sense. While UML represents computational actions that transform data, in this work, physical actions that transform materials are represented. The transition types Transition, Fork, Merge, Join, and Branch are adopted and denoted as in UML.

Activity diagrams can be defined hierarchically, allowing the increase of representation detail at later stages. Moreover, their visual nature was found to support the collaboration with practitioners. Activity diagrams are essential in representing transitions between process steps, in which distinct tools are employed and actions take place. and, in particular, decision points and parallel tasks in the process.

The progression of sequential steps is modelled by a Transition link. Forks are used to represent the initiation of two parallel tasks. In Merge transition, two or more control paths unite and Join connecting steps that should be completed before the transition to the next step. Merge and Join transitions are structurally similar, but a join is a synchronization across a set of parallel flows, while in a merge only a single flow is active. Finally, Branch transitions connect a step with a decision step that accepts tokens on one incoming edge and selects one outgoing alternative. Branch nodes control the flow of a process by selecting one of several alternatives, based on the outcome of a condition evaluation.

### 6.4.1 Process schema representation

In this step, the activity diagram is transcribed into a transition graph. The MOP UI facilitates the structure and enables the instantiation of process schemas and their steps. Data fields are used to enter appellations, informal descriptions, and step order. Transitions are instantiated via dynamic UI components that adapt to transition type. An example of a represented process schema is presented in Figure 57.











Glass schema <a href="#">edit name</a>					Schema preview
Process schema description <a href="#">edit description</a> Investigative glass process that was possibly used by George Bontemps to create a glass carafe.					
Tip: How to model your process schema <ul style="list-style-type: none"> <li>First define each of the steps of the process schema using the '+ Add step' button.</li> <li>Once you define the steps, you can then use the 'Specify' link to define their execution order parameters (i.e. specific order relationships among the steps).</li> <li>Lastly, for each defined step, you can specify any substeps by clicking on its name and following the same procedure.</li> </ul>					
+ Add step					
Step	Step description	Execution order <sup>?</sup>	Substeps		
0. Blowpipe cleaning	The blowpipe is cleaned from any residuals from past use.	Leads to 1. Blowing and Shaping <a href="#">edit order</a>	0	<a href="#">edit info</a>	
1. Blowing and Shaping	A bubbling action is performed by the glass blower using a blowpipe and which results in the creation of a bubble of air within a liquid quantity of glass that has been just fathered from the workshop furnace.	Leads to 2. Leg and foot laying <a href="#">edit order</a>	5	<a href="#">edit info</a>	
2. Leg and foot laying	The leg and the foot of the carafe are constructed.	Leads to 3. Transfer to punty <a href="#">edit order</a>	3	<a href="#">edit info</a>	
3. Transfer to punty	The glass body is transferred from the blowpipe to the punty.	Leads to 4. Cervix refining <a href="#">edit order</a>	3	<a href="#">edit info</a>	
4. Cervix refining	Cervix is refined.	Leads to 5. Cord laying <a href="#">edit order</a>	0	<a href="#">edit info</a>	
5. Cord laying	A glass cord is laid for decoration.	Leads to 6. Beak cutting <a href="#">edit order</a>	4	<a href="#">edit info</a>	
6. Beak cutting	Creation of the beak.	Leads to 7. Handle laying <a href="#">edit order</a>	3	<a href="#">edit info</a>	
7. Handle laying	The glass handle is created by laying.	Leads to 8. Finishing carafe <a href="#">edit order</a>	3	<a href="#">edit info</a>	
8. Finishing carafe	The carafe is finished for stability.	Leads to 9. Annealing <a href="#">edit order</a>	3	<a href="#">edit info</a>	
9. Annealing	Controlled cooling of glass a heat avoids the formation of cracks, increases its ductility, and reduces its hardness,	Specify	2	<a href="#">edit info</a>	

Figure 56. Process schema representation in MOP.

## 6.4.2 Specific process representation

Process representations account for the events that took place during the execution of a process schema. Intuitively, a process is an individual flow of events, out of those possible in the activity diagram. The MOP UI enables the instantiation of process representation, via the entry and chronological ordering of events, accompanied by the recordings that document them. An example of a process representation in MOP is presented in Figure 57.



The screenshot displays the Mingei Online Platform (MOP) interface for the 'Carafe making process'. The top navigation bar includes links for Home, Silk, Mastic, Glass, Global, Cinema, and Help. The breadcrumb trail shows 'Home > Glass > Processes > Carafe making process'.

The main heading is 'Carafe making process'. Below it, there are tabs for 'View', 'Authoring', 'Related media objects', and 'Process preview'. The 'View' tab is active, showing a detailed description of the process: 'This is the process of making a carafe Bontemps' style.'

Key information provided includes:

- Participants:** Jean-Pierre Mateus (role: Glassmaker), Dominique Jamis (role: Assistant)
- Location:** Vannes-le-Château
- Material(s):** Glass, Water
- Tool(s):** Annealing furnace, Glory Hole, Marver, Bench, Punty, Wet Newspaper, Jacks, Shears, Blowpipe

Below this information, there is a section for 'Related process media' with a link to 'View all 27 process media'. Three video thumbnails are shown, labeled 'Carafe\_procedure\_01', 'Carafe\_procedure\_02', and 'Carafe\_procedure\_03'.

On the right side, the 'Process steps' section lists 9 steps, with '2. Leg and foot laying' selected. This step is described as: 'The carafe leg and foot are gathered, attached on the carafe and shaped by the master blower and his assistant.'

Below the step list, there is a 'Step related media' section with a link to 'View all 4 step media'. It shows three video thumbnails labeled 'Leg\_and\_foot\_laying...'.

The 'Substeps' section for '2. Leg and foot laying' shows a link to 'View all 55 substep media'. It includes a detailed description of the 'Leg laying' substep: 'The glass master starts creating the carafe base. The assistant takes out of the furnace a new molten blob of glass and he is checking the exact position that should be played. The glass master places the molten glass on the inflated glass and cuts it with metal shears. He pushes the molten glass on the inflated glass using the wide side of the jacks. He wipes the glass with the wet paper. After that, he uses a metal pallet in order to flatten the base of the carafe.'

Below this, there are three video thumbnails labeled '01\_leg\_part\_1.mp4', '01\_leg\_part\_1a.mp4', and '01\_leg\_part\_1b.mp4'. Further substeps include 'Leg gathering and overhead drop', 'Leg shaping', 'Foot laying', 'Foot gathering and overhead drop', and 'Foot shaping'. A 'Verification' section at the bottom states: 'The glass master checks that the foot base has the correct size according to his tool.'

The verification section includes two video thumbnails labeled 'leg\_and\_foot\_verific...'.

Figure 57. Process representation in MOP.

## 6.5 Craft presentation and preservation

### 6.5.1 Digital preservation for glassblowing

The digital assets hosted in the MOP repository are provided online in conventional and open formats. Each asset has a unique IRI to be directly integrated by third parties. Our knowledge is available to the Semantic Web via the MOP and the SPARQL endpoint exposed. Furthermore, to ensure compatibility with online knowledge sources, definitions of terms are imported to MOP through linking to terms from the Getty Arts and Architecture thesaurus [50] and the UNESCO thesaurus [51]. For further exploitation of semantic knowledge encoded in MOP an EDM export facility has been also implemented allowing (a) export of data in semantic compatible to EDM

format and (b) formulate SPARQL queries to the MOP SPARQL endpoint to receive EDM formatted results.

### 6.5.2 Glassblowing documentation

The represented knowledge network is available through the WWW and the MOP in hypertext format. Semantic links are implemented as hyperlinks that lead to the pages of cited entities. Contents are also organized and presented thematically, per class type. A keyword-based search is also provided. Documentation pages contain links to digital assets, textual presentation of metadata, and previews of the associated digital assets. For locations and events, specific UI modules are provided. For locations, embedded, dynamic maps are provided through OpenStreetMap [38]. Time-line and calendar views are available for events.

The vocabularies formulated in the first step of the craft representation are provided as illustrated vocabularies of tools, 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.

Processes are presented containing links to the recordings of the knowledge elements for the tools and materials involving the participating practitioners, the date, the tools employed, and the location of the recording. If the process follows a process schema, a link to that schema and its preview are also provided. The hierarchy of process steps is presented using insets, each one presenting textual information and previews of the available digital assets. To present step organization, insets are dynamically unfolded to any depth of the process hierarchy, associated with image previews and embedded videos. Variations include images and textural descriptions.

In some cases, through the post-processing of the original digital assets, we can provide simplified visualizations for illustrative purposes. Such visualizations reduce the information provided for example by a video recording of the essential parts of the craft to be presented. A collection of enhanced iconic abstractions of tool usage gestures is presented in Figure 58. For example, in the first row of Figure 58, the picking up of hot glass material is presented in the first two figures while the other two present the creation of form using a hand-held tool. Using the same rationale several steps are also visualized in this figure in a form of abstraction that presents only the tools and their interaction with matter.

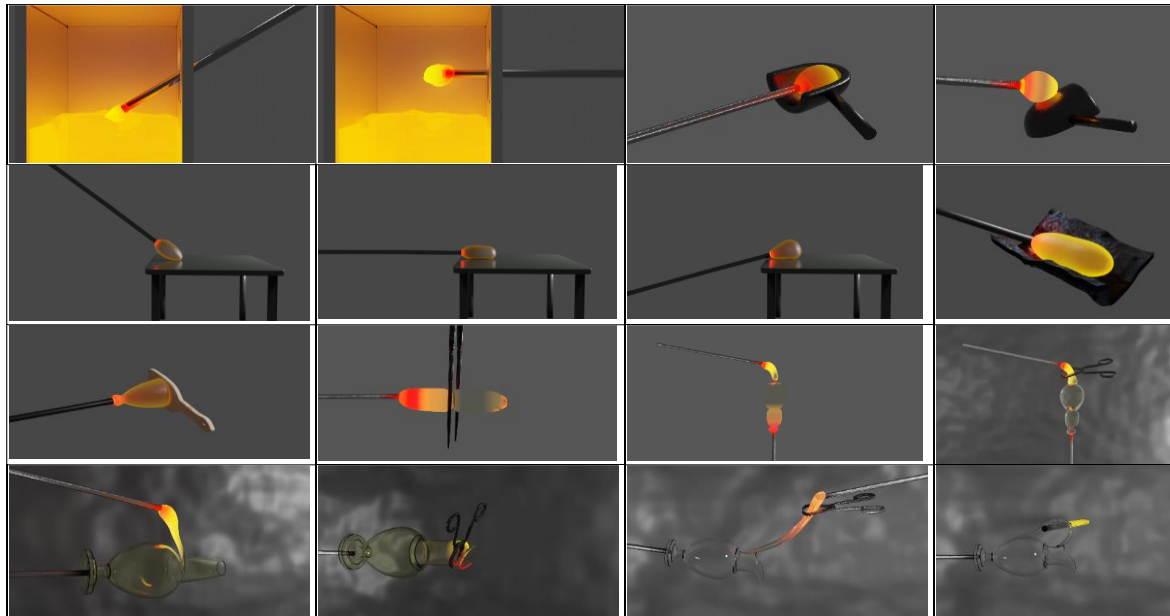


Figure 58. Computer-aided, VR presentation of glassblowing processes. Top: marvering. Middle: shaping. Bottom: illustration of the glass deformation during glassblowing.

### 6.5.3 Craft demonstration

#### 6.5.3.1 Workshop implementation in 3D

For the implementation of the workshop in 3D, the High Definition Rendering Pipeline (HDRP) offered by Unity3D [26] game engine was used. HDRP offers various features that contribute heavily to how realistic a scene can look, like physically accurate lighting, and multiple out-of-the-box material types (Subsurface Scattering, Anisotropy, Iridescence, Specular Colour, and Translucency), and several post-processing effects (Ambient Occlusion, Auto-exposure, and Screen Space Reflections). Lighting in HDRP is physically accurate and uses lighting units such as lumens, lux, and candela. The environment was set up to use an HDRI Sky for the skybox and the ambient lighting. The fog was also added to give some density to the atmosphere and interact with the sunlight within the workshop. Machinery modelled as presented above was also imported and instantiated in the scene based on reference photographic material. The lighting plan is using lightmaps for all static geometry with the use of Mixed Lights, which provide real-time direct lighting but its indirect is baked. For dynamic geometry, e.g., characters, Light Probes will be used in the next iteration. Extra care was put into creating semi-transparent materials. Reflections were also added to the scene with the use of Reflection Probes. The overall artificial lighting of the 3D workshop is shown in Figure 59.



**Figure 59. Artificial lighting.**

### 6.5.3.2 Implementation of Virtual Humans & animation

The virtual human bodies and clothes are created to obtain one unified and optimized model, enhancing the visual impact of the characters with texture mapping and material editing. The 3D generation of the virtual bodies has also to take into consideration the total number of polygons used to create the meshes to keep a balance between the 3D real-time simulation restrictions and the skin deformation accuracy of the models

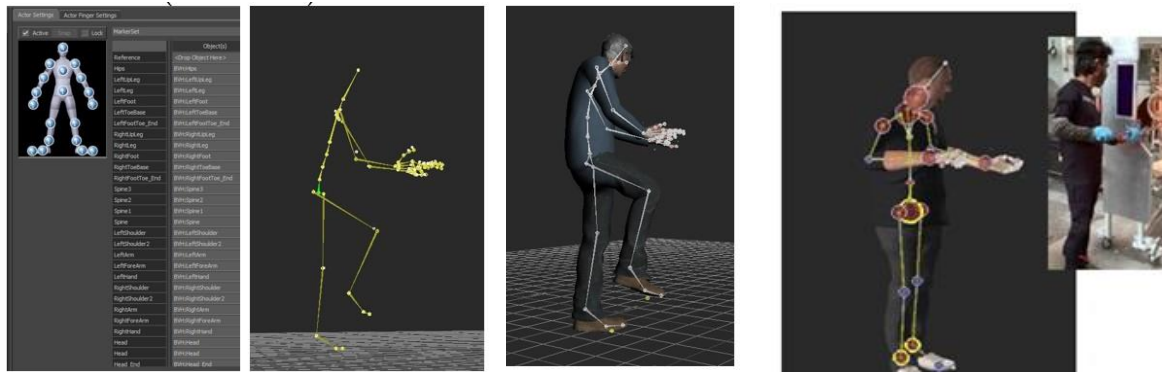
Avatars are created with a combination of different software: Adobe Fuse CC/Mixamo [30] is used for creating the body character, the clothes, the hair, and the rigging. The generated model is then imported into Autodesk 3DS max [29] for mesh geometry optimization. Manual methods, by using the editable poly tools are preferred since it allows keeping the regularity of the topology while the automatic methods generate a mess geometry which is not suitable for skin deformation nor a regular UV texture map generation.

The processing of the files has been done on Autodesk MotionBuilder software [48] which is dedicated to animation and the direct integration of motion capture technologies. The process requires the following steps:

- Creation of an "actor" in MotionBuilder with skeleton definition corresponding to the Biovision Hierarchy (BVH).
- Transposition of the received animations (.bvh files) on the actor
- Synchronization of the avatar with the actor by adjusting the 2 models so that the measurements match and the animations are correctly reproduced (retargeting).

Screenshots from the procedure of animating a virtual actor are presented in Figure 60.





**Figure 60. Animating the Virtual Human.**

### 6.5.3.3 Tool usage

Tool Handling during animations is implemented using animation rigging, which enables users to animate a mesh with the use of a skeleton, as well as other use cases like runtime rigging. Runtime rigging is when a skeletal animation is modified during gameplay using constraints as a post-process. Useful scenarios include attaching hands to props or aiming the head in reaction to a gameplay event like a character passing by. Rig Constraints are also used to affect objects in reaction to the skeleton's motion.

### 6.5.3.4 Workshop demonstration

For craft presentation and to facilitate the installation presented in the next section three applications were implemented. These applications present synchronized content and thus they integrate a software mechanism for their interconnection. The main application (see Figure 61) is a simulation of the crafting process for creating a glass carafe as modelled in the previous sections and combines the knowledge of the crafting process with the modelling of the workshop, the tools, and the machines. Furthermore, it integrates the implemented VHs and their animations as recorded during the ethnographic fieldwork at CERFAV.



**Figure 61. Main application screen.**

The second application (see Figure 62) presents close-up views of the gestures of the glassblowing VH to enhance the understanding of the audience regarding specific crafting gestures used in the making process.

The third application presents the tools used in each step of the process to enhance the understanding between craftsmanship, gestures, and tools. For example, as shown in Figure 63 for the shaping and glassblowing process steps a blowpipe, newspaper, and a block are used. The tools are presented on the top of the application's screen while the abstraction of the process is presented in section 4.3.3. is presented on the bottom side of the screen.

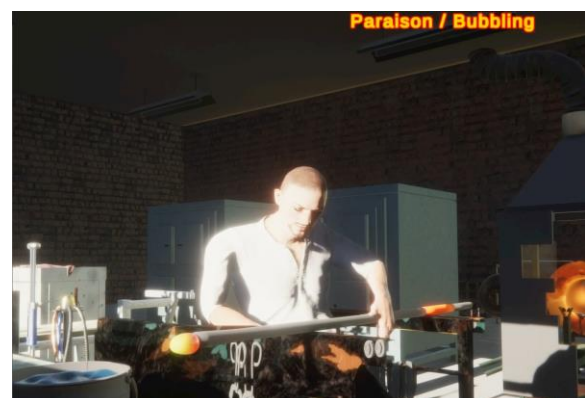
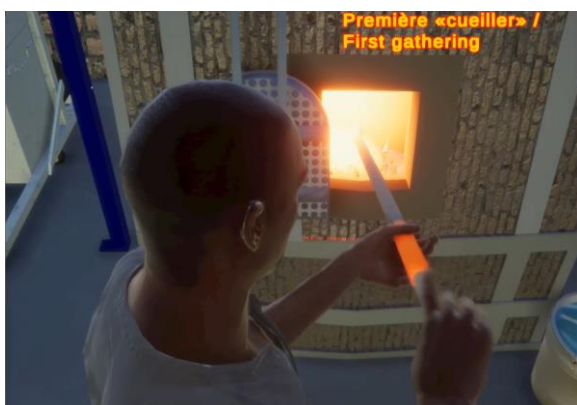




Figure 62. Close-up views of the glassblowing process.

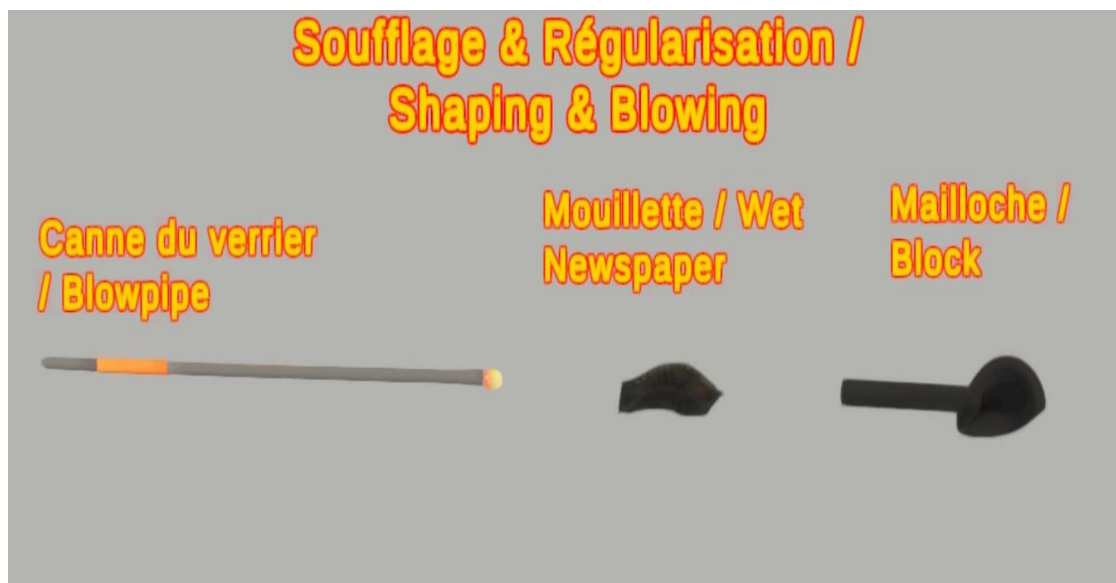


Figure 63. Overview of the tools used in each step.

#### 6.5.4 Glassblowing training

To experience glassblowing gestures, an interactive installation was created, with the use of MAX/MSP 8, a visual programming framework, in combination with python programming, as well as an RGB-D Intel Realsense camera for the real-time tracking and recognition of the gestures of the user. The information that was used from both videos from the gesture recognition engine was the upper body joints (shoulders, elbows, wrists, neck), as extracted from the OpenPose [54] framework. OpenPose is a system for real-time human joint detection, with the use of Deep Learning architectures.

On the screen, a big frame with the video of the expert glassblower appears, while a smaller one with the video of the visitor places on the top-left of the screen. The user can either start experimenting directly or choose the question mark sign on the top of the installation screen, to see the instructions before starting imitating. An instance of this instructions screen is shown in Figure 64. On that screen, the user can see a video of each one of the gestures, before starting

experimenting. When the imitation starts, the grey bar right up the expert's video starts getting red. The speed of this bar getting red concerns how good the gesture recognition results are.

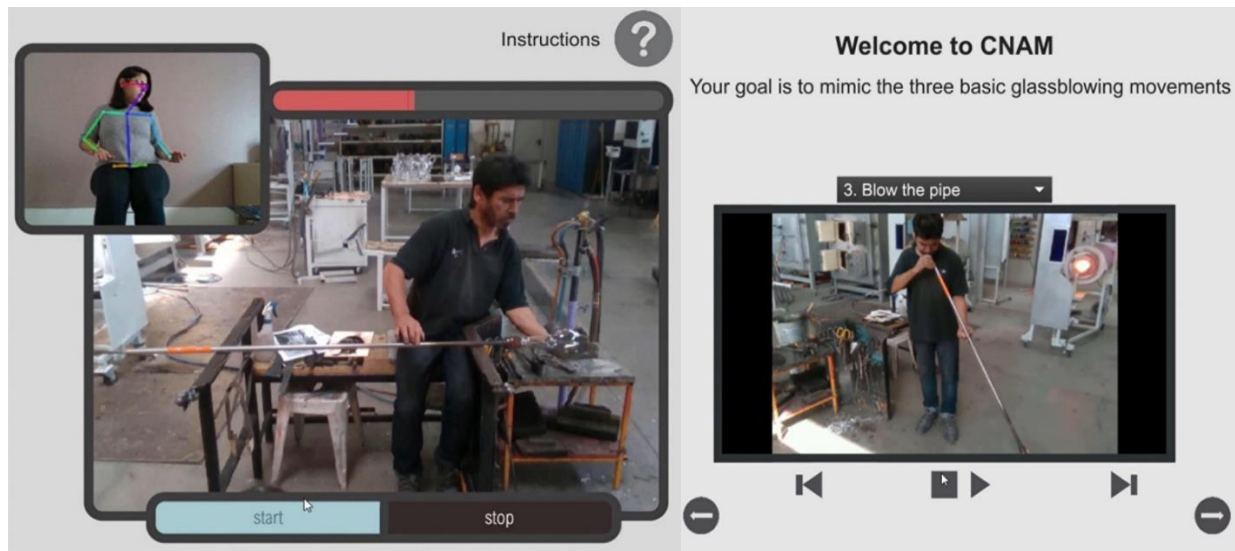


Figure 64. left- An instance of the main screen of the interactive installation, right – instructions.

## 6.6 Exploitation

The results of this pilot were deployed in the context of a periodic exhibition at the premises of the museum of CNAM, which is where the worlds of academics and professional activity come together. It is the only higher education establishment dedicated to life-long professional training.

In this context, a dedicated space at the cathedral which is part of the museum was dedicated for the exhibition. The space is a chapel of the cathedral located within the main exhibition of the museum. The installation is comprised of a special construction capable of hosting three large displays created through back projection in thin synthetic fabric. Furthermore, for craft training, a bench has been installed in front of the main display together with a glassblowing pipe to be used by visitors. The installation has integrated hosting spots for the glass carafes and pieces of the carafe created during the ethnographic fieldwork. Special lighting was integrated within to present the interaction of glass with light and to create an atmosphere. Figure 65 presents the building of the installation structure.





**Figure 65. Building up the installation at CNAM.**

After the completion of the physical part of the installation, the software was installed in the computers hosting each projection and their intercommunication was set up. Furthermore, the computers were programmed to communicate with the projectors to open and close automatically thus saving resources, and protecting the projection equipment. Figure 66 presents the craft presentation applications installed and running within the installation space.

In the computer hosting the glassblowing presentation, a second application was installed which is dedicated to crafting training. This application allows users to mimic craft gestures using the tools and the bench. The scenario that was set up was that the presentation application sequence is executed first and then the main projection switches to the craft training applications so that users test what they learned from the craft presentations. To do so, an application was used to control the order of execution of the craft presentation and craft training applications.

Examples of users interacting with the craft training application are presented in Figure 67. On the left side, a back view of the application and user is presented while on the right side we present how users are experiencing the interaction.

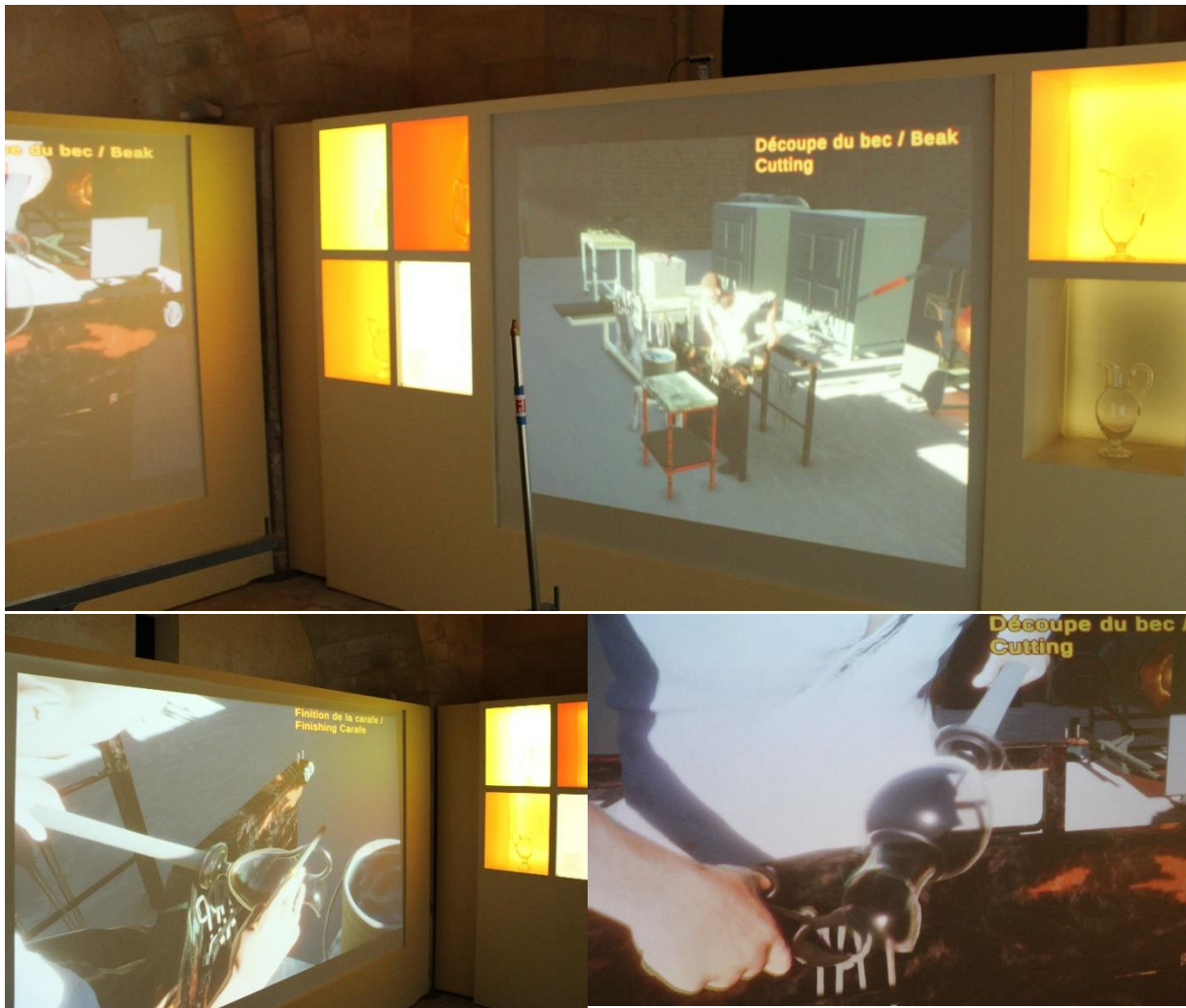


Figure 66. Craft workshop presentation.



Figure 67. left- Craft training screen view, right – craft training – user view.

### 6.6.1 Preliminary evaluation

After the technical validation of the installation, a short preliminary evaluation with end-users provided by the museum was conducted. The objective of the preliminary evaluation was to identify

whether the educational goals set up by the museum are facilitated through the installation and identify possible usability issues.

The first part of the preliminary evaluation was conducted with users from the education department of the museum invited to experience the installation and mimic the craftsperson actions using the bench and tools provided. The results of this evaluation resulted in changes to the UI of the training application in order (a) to provide real-time help to users to guide them through the training process and (b) to enhance the feedback of the system during user operation to enhance the understanding of both successful and non-successful interaction. More specifically, an identified issue regarded the feedback that should be provided when the user is starting to perform a gesture where there was a time frame with no additional information from the system resulting in users quitting an operation with the feeling that they were not doing the correct gestures.

The second part of the evaluation was done through inspection methods on all users. A user experience evaluator was monitoring the interaction of the users with the system and recorded identified usability issues. More of them were minor details of the UI that were improved. The most severe issue identified was a cold start effect resulting from the lack of sufficient information from the system when moving from the craft demonstration part to the craft training part. For this reason, introductory screens were designed and installed to assist users when the training session started. Furthermore, another issue that regarded the time scheduling of the installation regarded the occurrence of switches between apps while the users were interacting with the training. This was considered a major usability issue and was resolved on-site.

After the conclusion of this preliminary evaluation and the resolution of the identified issues, the installation was inspected by a user-experience expert.

A comprehensive user-based evaluation of the Glass installation was planned and carried out as part of T6.5 activities to assess its overall usability and user experience. The evaluation involved the participation of public visitors, who provided their feedback after their interaction with the applications via post-interaction questionnaires. The results of this evaluation are reported in paragraph 7.3.

## 7. Evaluation of installations at pilot sites

As mentioned earlier, user-based evaluations of the applications which were installed at the three pilot sites were carried out with the participation of museum visitors to assess their overall usability and user experience. Specifically, the visitors were asked to provide their feedback in an anonymous format via post-interaction questionnaires after spending some time interacting with the applications. The applications that were included in these pilot evaluations were the following:

- Silk pilot: Museum tour guide – mobile application
- Mastic pilot: Mastic narrations – AR application, Mastic gestures – gestural know-how application, and Mastic landscapes (Airborne) – geographical context application
- Glass pilot: Craft workshop presentation and craft training application

The post-interaction questionnaires were constructed individually for each one of the above installations and according to the specific parameters each application needed to evaluate. The questionnaires were divided into parts and included both close and open-ended questions providing quantitative and qualitative data.

The first part of the questionnaire, which was common to all the questionnaires, was based on the standardised and well-established questionnaire User Experience Questionnaire (UEQ) [122], which measures the user experience of interactive products and applications. The scales included in the UEQ cover a comprehensive impression of user experience, including both classical usability aspects such as efficiency, perspicuity, and dependability, as well as user experience aspects, such as originality and stimulation.

The questionnaire contains 26 items in the form of semantic differentials, i.e. pairs of opposite adjectives, which can be rated on a 7-point Likert scale. The 26 items correspond to the six scales:

- *Attractiveness*: Overall impression of the product. Do users like or dislike the product?
- *Perspicuity*: Is it easy to get familiar with the product? Is it easy to learn how to use the product?
- *Efficiency*: Can users solve their tasks without unnecessary effort?
- *Dependability*: Does the user feel in control of the interaction?
- *Stimulation*: Is it exciting and motivating to use the product?
- *Novelty*: Is the product innovative and creative? Does the product catch the interest of users?

However, for the needs of the evaluation of the pilot installations, only the following four of the six scales were used: *Attractiveness*, *Perspicuity*, *Stimulation*, and *Novelty*. This reduced the number of items to 18. This decision was made because the efficiency and the dependability scales included items that were irrelevant to the functionality included in our applications as they pertain more to task-oriented systems. The results of the UEQ were calculated based on the data analysis tool provided by the authors [123].

The second part and third parts of the questionnaires included ad-hoc questions which differed from installation to installation.



In the questionnaires for the evaluation of the installations that are examined to remain on the pilot sites as long-term fixtures (i.e. the application for the Silk pilot at the Haus der Seidenkultur and the installations at the Museum of Mastic in Chios) an additional question was used, that of the Net Promoter Score. The Net Promoter Score [124] is a loyalty metric typically used in customer surveys that aims to quantify customers' overall satisfaction with a product or service and the likelihood of someone recommending the product, or service to a friend or colleague. The metric comprises of a single item question, "How likely are you to recommend this application/installation to a relative or a close friend" and it is measured on a scale from 0-10. However, in recent years this single item question has been used in the HCI field as a complementary metric to other usability metrics [125].

The questionnaires were translated into the native language of the pilot site in addition to the English version, i.e. in Deutsch for the Silk pilot in Krefeld, Germany, in Greek for the Mastic pilot in Chios island, and French for the Glass pilot in CNAM, Paris.

## 7.1 Silk pilot evaluation results

The post-interaction questionnaire for the Museum Tour Guide application comprised of the following three parts:

*Part A:* This part included the 16 items of the UEQ questionnaire corresponding to the scales of attractiveness, perspicuity, stimulation, and novelty.

*Part B:* This part included 3 ad-hoc questions answered on a 5-item Likert scale format: Not at all, very little, neutral, somewhat, and very much. These questions aimed at measuring the visitors' prior knowledge of the represented craft, their impression on whether the application helped them learn about the craft and their impression of whether the museum tour made them want to learn more about the craft, respectively. Specifically, these questions were phrased as follows:

1. Before this museum tour, how knowledgeable were you about the craft of jacquard weaving?
2. How much did this museum tour help you learn more about the craft of jacquard weaving?
3. How much do you think this museum tour made you want to learn more about the craft of jacquard weaving?

*Part C:* This part included 5 more ad-hoc questions answered on a 5-item Likert scale format: Very unsatisfied, unsatisfied, neutral, satisfied, very satisfied.

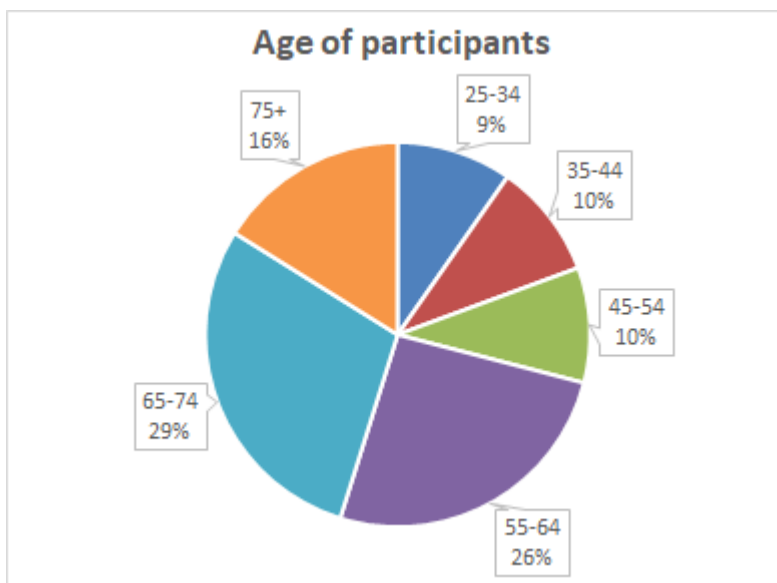
In this part, the visitors were asked to indicate their level of satisfaction with the following technical and design aspects of the application:

4. The overall structure of this Museum Tour application
5. The ease of using this Museum Tour application
6. The quality of the content of the videos provided in the Tour
7. The museum guide (avatar) of the application
8. The educational value of the Museum Tour

*NPS question:* On a scale from 0 (Not at all likely) to 10 (Extremely likely), how likely are you to recommend this Museum Tour application to a friend or a family member visiting the museum? Circle the number that corresponds to your score.

*Comments:* At the end of the questionnaire, space was allocated for the addition of any other comments the visitors would like to make about the Museum Tour Guide application they experienced.

Thirty-four public visitors responded to the post-interaction survey questionnaire after using the Museum Tour Guide application. Thirty-two respondents were from Germany and two were from other countries, Spain and France. The respondents were all adults and the majority of them (65%) were above the age of 45, as it is depicted in Figure 68.



**Figure 68: Age distribution of respondents – Virtual Museum Tour application**

### 7.1.1 UEQ results

The UEQ does not produce an overall score for the user experience. Rather, it aggregates the results per scale used in the questionnaire, i.e. in the case of the pilots, attractiveness, perspicuity, stimulation, and novelty. The results of the aggregated means and variance for these four scales for the Museum Tour Guide application are depicted in Figure 69, whereas the results per each of the semantic differential items are presented in Table 4.

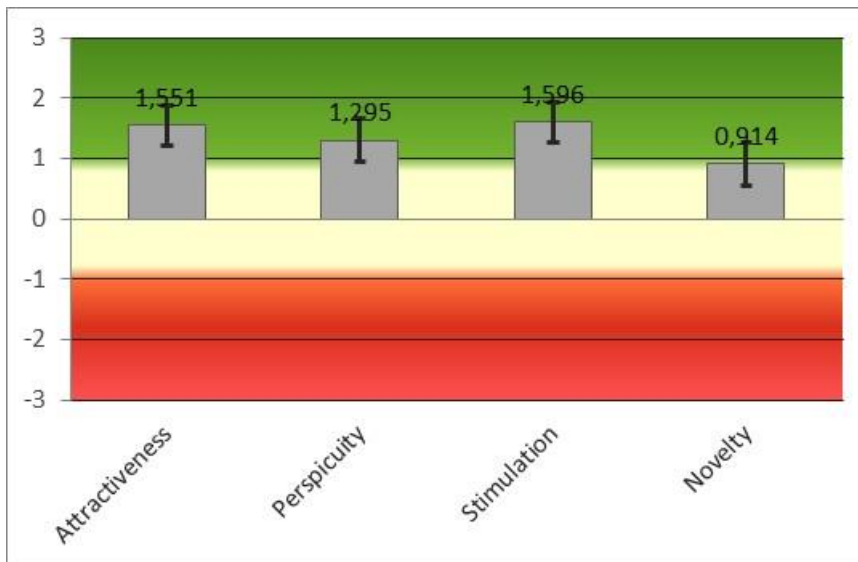


Figure 69: Aggregate means and variance per UEQ scale – Museum Tour application

Item	Mean	Variance	Std. Dev.	N	Left	Right	Scale
1	2,1	0,4	0,6	33	annoying	enjoyable	Attractiveness
2	1,7	0,9	0,9	32	not understandable	understandable	Perspicuity
3	1,1	1,7	1,3	32	creative	dull	Novelty
4	1,2	1,3	1,1	32	easy to learn	difficult to learn	Perspicuity
5	1,5	1,4	1,2	33	valuable	inferior	Stimulation
6	1,5	1,6	1,3	33	boring	exciting	Stimulation
7	2,0	1,2	1,1	33	not interesting	interesting	Stimulation
8	0,8	2,1	1,5	32	inventive	conventional	Novelty
9	1,8	1,2	1,1	33	good	bad	Attractiveness
10	1,3	1,7	1,3	33	complicated	easy	Perspicuity
11	1,5	1,8	1,3	31	unlikable	pleasing	Attractiveness
12	1,0	1,5	1,2	32	usual	leading edge	Novelty
13	1,3	2,2	1,5	32	unpleasant	pleasant	Attractiveness
14	1,3	1,1	1,0	31	motivating	demotivating	Stimulation
15	1,0	2,1	1,4	32	clear	confusing	Perspicuity
16	1,3	1,3	1,1	32	attractive	unattractive	Attractiveness
17	1,4	1,9	1,4	32	friendly	unfriendly	Attractiveness
18	0,7	1,5	1,2	32	conservative	innovative	Novelty

Table 4: UEQ results per item (Mean, variance, std. dev.) – Museum Tour application

Values between -0,8 and 0,8 represent a more or less neutral evaluation of the corresponding scale, values > 0,8 represent a positive evaluation and values < -0,8 represent a negative evaluation. From the results presented in the table, we can see that only in one of the items in the novelty scale (conservative/innovative) the mean score was just under 0,8, however, the overall novelty scale still received a positive result. In fact, all scales measured received scores well above the neutral zone, reflecting the positive impression of the respondents in regards to the perceived stimulation, attractiveness, perspicuity, and novelty of the application.

### 7.1.2 Ad-hoc questions results

As mentioned earlier, 8 ad-hoc questions were included in the post-interaction questionnaire for the Museum Tour Guide application. The first 3 questions (Q1-Q3) aimed at measuring the visitors' prior knowledge of the subject, whether they think the application helped them learn more about it, and whether they think it intrigued them in learning more. These 3 questions were measured on a 5 item Likert-scale with the following options: Not at all, a little, neutral, somewhat, and very much. The other 5 questions (Q4-Q8) aimed at measuring the visitors' impression of the structure of the virtual tour, its ease of use, the quality of the content, the impression of the Virtual Character of the museum tour guide, and the overall educational value of the application. The 5-item Likert scale used for these questions had the following scales: Very unsatisfied, unsatisfied, neutral, satisfied, and very satisfied.

As all the ad-hoc questions were scored on a 5 item Likert scale, the data collected was treated as ordinal and thus the results are reported in the median, mode, and inter-quartile ranges and frequency (%). Respective data is shown in Table 5, Table 6, and Table 7, while the data is shown in bar charts in Figure 70, Figure 71, and Figure 72.

<b>Part B: Questions 1-3</b>	<b>N</b>	<b>Median</b>	<b>Mode</b>	<b>IRQ (Q3-Q1)</b>
Q1: Before this museum tour, how knowledgeable were you about the craft of jacquard weaving?	33	4	4	1.5 (2.5-4)
Q2: How much did this museum tour help you learn more about the craft of jacquard weaving?	34	4,5	5	1 (5-4)
Q3: How much do you think this museum tour made you want to learn more about the craft of jacquard weaving?	32	4	4	1(5-4)
<b>Part C: Questions 4-8 - level of satisfaction with the following</b>	<b>N</b>	<b>Median</b>	<b>Mode</b>	<b>IRQ (Q3-Q1)</b>
Q4: Overall structure of this Museum Tour application	33	4	4	1.5 (4,5-3)
Q5: Ease of using this Museum Tour application	34	4	4	1 (4-3)
Q6: Quality of the content of the videos provided in the Tour	33	4	4	1 (5-4)
Q7: Museum guide (avatar) of the application	33	4	4	1 (4-3)
Q8: Educational value of the Museum Tour	34	4	4	1 (5-4)

**Table 5: Median, mode, and inter-quartile ranges for ad-hoc questions – Museum Tour application**

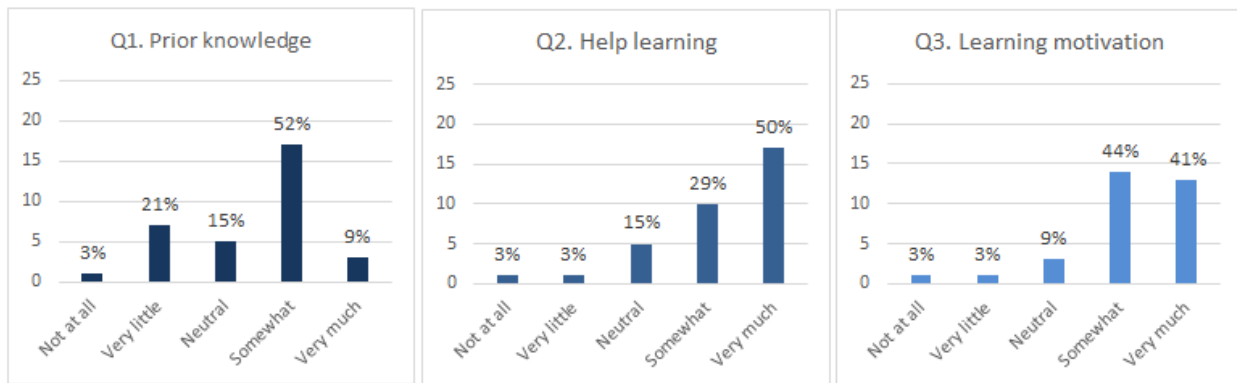
	<b>Q1 Freq. (%)</b>	<b>Q2 Freq. (%)</b>	<b>Q3 Freq. (%)</b>
Not at all	3%	3%	3%
Very little	21%	3%	3%
Neutral	15%	15%	9%
Somewhat	52%	29%	44%
Very much	9%	50%	41%

**Table 6: Frequency of answers for questions Q1-3 – Virtual Museum Tour application**

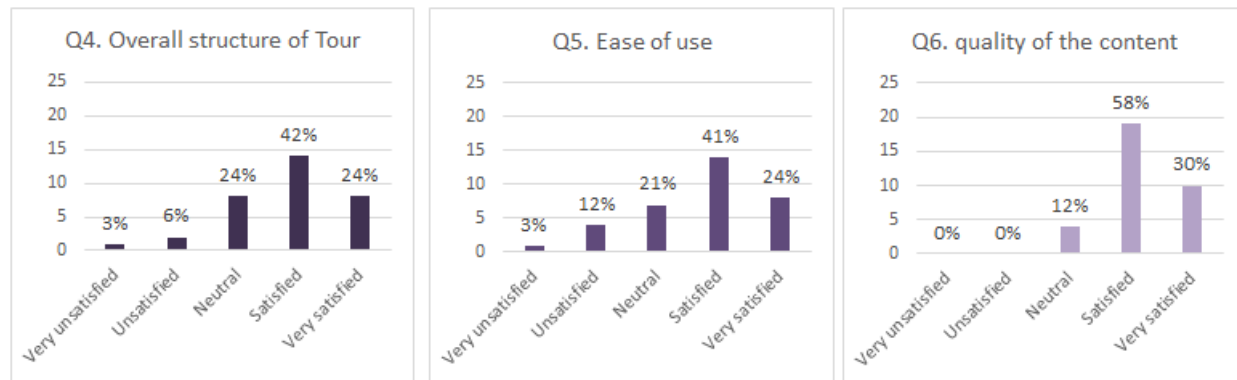
	<b>Q4 Freq. (%)</b>	<b>Q5 Freq. (%)</b>	<b>Q6 Freq. (%)</b>	<b>Q7 Freq. (%)</b>	<b>Q8 Freq. (%)</b>
Very unsatisfied	3%	3%	0%	0%	0%
Unsatisfied	6%	12%	0%	12%	0%
Neutral	24%	21%	12%	27%	3%
Satisfied	42%	41%	58%	52%	62%
Very satisfied	24%	24%	30%	9%	35%



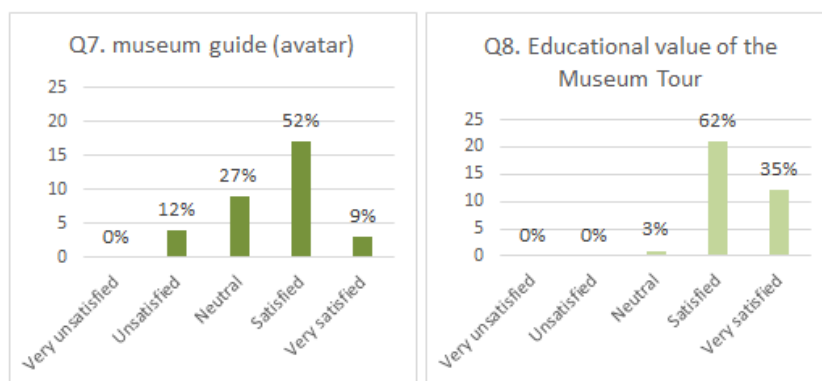
**Table 7: Frequency of answers for questions Q4-8 – Museum Tour application**



**Figure 70: Frequency for ad-hoc questions 1-3 – Virtual Museum Tour application**



**Figure 71: Frequencies for ad-hoc questions 4-5 – Virtual Museum Tour application**



**Figure 72: Frequencies for ad-hoc questions 7-8 – Virtual Museum Tour application**

From the data presented in the tables, it is shown that the central tendency (*median*) of the respondents in Q2 was 4,5 and for Q3-Q8 was 4. Whereas, the most frequent value (*mode*) in the answers was 5 for Q2 and 4 for Q3-8. This means that the majority of the respondents have rated positively all aspects of the application.

Looking at the graphs, it can be seen that even though the majority of the respondents, 61%, were people who were somewhat very knowledgeable about the represented craft (Q1), the majority of

them, 79%, thought that the application helped them learn more about it (Q2). Moreover, the majority of the respondents, 85%, also thought that the application made them want to learn more about the craft, which is an indication that the application intrigued the sample of visitors in learning more about the craft (Q3). This conclusion is also supported by the answers received about the level of satisfaction regarding the educational value of the museum tour application, which was also scored very highly by the vast majority of the respondents, 97% (Q8).

Concerning the level of satisfaction with the ease of use of the application, 65% of the respondents answered that they were satisfied or very satisfied with it (Q5), whereas only 17%, which translates to 5 out of the 34 respondents to this question scored in the lower range 1 and 2. The respondents also seemed to be very satisfied with the quality of the content of the tour (i.e. audio-visual content and narrations), with 88% rating their satisfaction as 4 and 5 on the scale (Q6). One of the respondents made a comment that best reflects this sentiment “I have never had such complex contents presented in such a detailed manner in any other museum”. Furthermore, 66% of the respondents also rated high their level of satisfaction with the overall structure of the Tour. Whereas regarding the museum guide, although the majority of the respondents, 61%, rated high the avatar tour guide, 27% were neutral about it, neither positive nor negative, and only 12% were unsatisfied with it, which corresponds to 4 people out of the 33 who answered this question.

### 7.1.3 Net Promoter Score (NPS)

The NPS for the Museum Tour Guide application was calculated after subtracting the percentage of detractors (those who gave a score of 6 or less on the 10-item rate scale) from the promoters (those who gave a score of 9 or 10 on the rating scale). Based on the global NPS standards, any score above 0 is considered a “good” score, (50 and above is excellent, while 70 and above is world-class). The NPS of the museum tour was **41**, which is considered a rather positive score, as it shows that there are more advocates (promoters) willing to recommend the virtual tour to others than critics (detractors).

### 7.1.4 Other comments

In the last section of the questionnaire, space was provided for the respondents to leave any general comments they had about the Museum Tour Guide application. 22 of the visitors who responded to the questionnaire wrote comments in this section. The majority of the comments regarded suggestions for improvements and minor problems encountered during the operation of the tablet and the application. The most representative of these comments and the actions taken to correct any reported problems are discussed next.

Specifically, some of the suggestions had to do with providing physical markers in the museum to mark more clearly the path of the tour. As one visitor pointed out it would have been helpful if there were clear indications at which point in each station one should stand, while three other visitors pointed out that labelling was missing i.e. signs to show where to go next, to mark entrances and exits points of stations, etc. One person even suggested for the avatar be incorporated into the map of the building to guide the visitors through the map. A digital map of the museum with notations on where exactly each station is positioned in the building is provided as a button option at the top of the application, but it is possible that some people would have preferred physical labels in addition to the digital indication of where each station is at the museum. As adding physical labels

in the corridors and the rooms is not an option for the museum, it was decided to include additional information about the location of each station in the museum on the Avatar screen in the form of a diagram or a picture in the updated version of the application.

Another aspect of the tour that some of the visitors commented about was that the volume of the videos varied making it necessary for the visitors to adjust it from the tablet side buttons. This problem has to do with the fact that the recordings of the video narrations and the recordings of the Avatar narrations and the after production editing were not done with the same equipment and software (i.e. microphones, video compilers, etc.). As a result, there was indeed some variation. To alleviate this problem, in the updated version of the application, the Avatar narrations audio files were edited in speciality software to match the volume of the video narrations audio files, so that the visitors won't have to adjust the volume during the tour.

Other minor problems had to do with the video player, which seemed to take a little longer than usual to start in some instances. This problem has to do with the allocation of the RAM of the Android tablet to background services. In any case, to reduce this effect, compression was applied in all the videos to ensure that there will be no delays.

Overall, the problems reported in the comments section were minor and were addressed in their majority in the newer version of the application.

## 7.2 Mastic pilot evaluation results

For the Mastic pilot, evaluations were conducted for the three application installations: Mastic narrations, mastic landscapes, and mastic gestures. For each application, a separate questionnaire was constructed. The description of each of the questionnaires and the results per application are presented next.

### 7.2.1 Mastic narrations application

**Part A:** This part included the 16 items of the UEQ questionnaire corresponding to the scales of attractiveness, perspicuity, stimulation, and novelty that measure user experience and usability. Furthermore, in this section, two open-ended questions were added, “List what you liked the most about the mastic narrations applications” and “List what you liked the least about the mastic narrations applications”.

**Part B:** This part included 5 ad-hoc questions answered on a 5-item Likert scale format: Not at all, a little, neutral, somewhat, very much.

These questions aimed at measuring the visitors' prior knowledge about the life of mastic growers, their impression on whether the application helped them learn about the life of mastic growers, and their impression of whether the application made them want to learn more about the mastic growers, their impression on whether the application enhanced their overall museum experience, and whether they considered the use of avatars as an appropriate medium to convey the mastic growers narrations, respectively. Specifically, the questions were phrased as follows:

1. How knowledgeable were you about the life of mastic growers before using this interactive application?
2. How much do you think this interactive application helped you learn more about the life of mastic growers?
3. How much do you think this interactive application made you want to learn more?
4. How much do you think that this interactive application enhanced your overall museum visit experience?
5. Do you think that the virtual characters (avatars) used in this application were appropriate mediums to convey narratives?

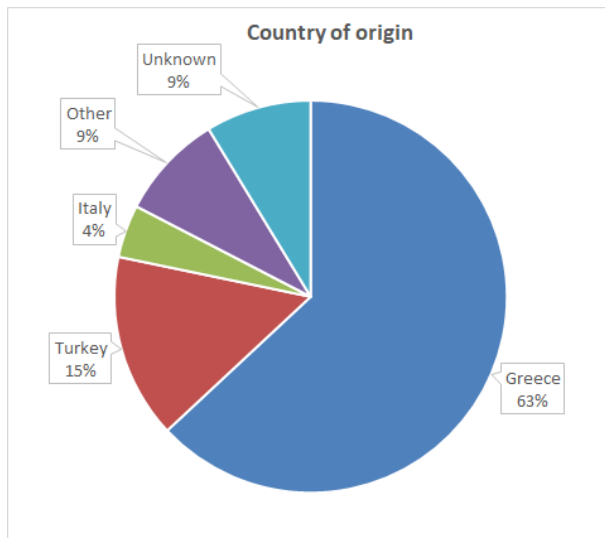
**Part C:** This part included 5 more ad-hoc questions answered on a 5-item Likert scale format: Very unsatisfied, unsatisfied, neutral, satisfied, very satisfied

In this part, the visitors were asked to indicate their level of satisfaction with various technical and design aspects of the application. Specifically, with the following:

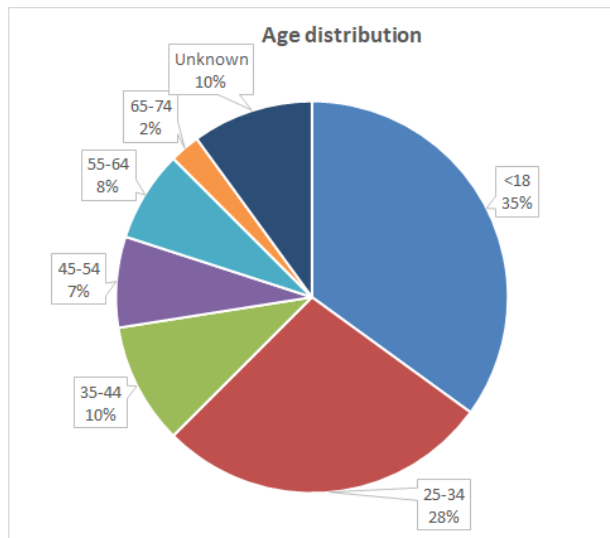
6. Design and animation of virtual characters (avatars)
7. Quality of the content of the narrations
8. The educational value of narrations
9. Authenticity of narrations
10. Overall satisfaction with this interactive museum application

**NPS question:** On a scale from 0 (Not at all likely) to 10 (Extremely likely), how likely are you to recommend this interactive application to a friend or a family member visiting the museum? Circle the number that corresponds to your score.

A total of 45 visitors to the Chios museum answered the post-interaction questionnaire. The age and country distribution are depicted in Figure 73 and Figure 74 respectively.



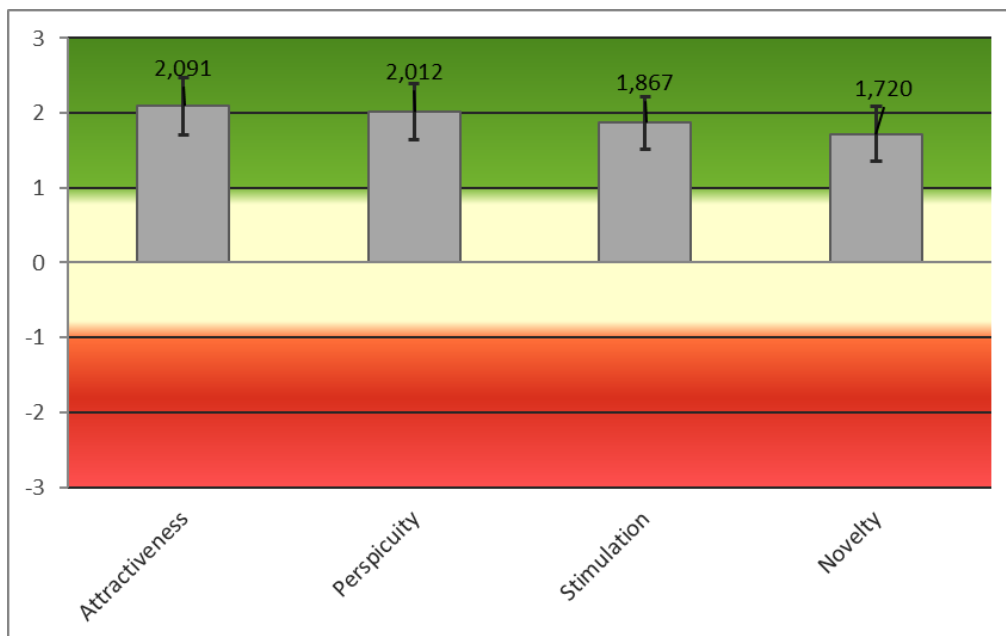
**Figure 73: Age distribution of post-interaction questionnaire respondents – Mastic narrations**



**Figure 74: Country of origin distribution of post-interaction questionnaire respondents – Mastic narrations**

#### 7.2.1.1 UEQ results

The results of the aggregated means and variance for these four scales are depicted in Figure 75, whereas the results per each of the semantic differential items are presented in Table 8.



**Figure 75: Aggregate means and variance per UEQ scale – Mastic narrations application**

Item	Mean	Variance	Std. Dev.	No.	Left	Right	Scale
1	1,6	1,9	1,4	41	annoying	enjoyable	Attractiveness
2	2,0	2,0	1,4	42	not understandable	understandable	Perspicuity
3	1,8	2,2	1,5	42	creative	dull	Novelty



4	2,3	1,3	1,2	42	easy to learn	difficult to learn	Perspicuity
5	1,9	1,7	1,3	41	valuable	inferior	Stimulation
6	1,5	1,9	1,4	41	boring	exciting	Stimulation
7	2,0	1,8	1,4	40	not interesting	interesting	Stimulation
8	1,5	2,7	1,6	41	inventive	conventional	Novelty
9	2,2	1,5	1,2	41	good	bad	Attractiveness
10	1,6	2,8	1,7	41	complicated	easy	Perspicuity
11	2,1	2,1	1,5	42	unlikable	pleasing	Attractiveness
12	1,8	2,8	1,7	41	usual	leading edge	Novelty
13	2,1	2,2	1,5	41	unpleasant	pleasant	Attractiveness
14	2,0	1,7	1,3	41	motivating	demotivating	Stimulation
15	2,1	2,0	1,4	42	clear	confusing	Perspicuity
16	2,0	2,1	1,5	42	attractive	unattractive	Attractiveness
17	2,3	1,7	1,3	41	friendly	unfriendly	Attractiveness
18	1,9	2,6	1,6	42	conservative	innovative	Novelty

**Table 8: UEQ results per item (Mean, variance, std. dev.) – Mastic narrations application**

From the results depicted in the above figure and table, it can be concluded that the visitors that responded to the post-interaction questionnaire, rated the Mastic narrations application rather positively on all four scales, as the means for all the items were well above 0.8 which is considered the middle zone. The highest rating was scored on the attractiveness scale, followed by perspicuity, stimulation, and novelty with small differences between them. The overall positive impression depicted in the UEQ results is also reflected in the comments respondents wrote in the two open-ended questions, the analysis of which is presented next.

### 7.2.1.2 Open-ended questions

In this post-interaction questionnaire, two open-ended were provided:

1. List what you liked the most about this interactive application
2. List what you liked the least about this interactive application

The question “List what you liked the most about the application” received comments from 30 of the 45 respondents, with some leaving more than one comment per question. Some comments were removed from the analysis as they were not specific to the application, but the entire factory area exhibit. The remaining comments were aggregated and then categorised manually.

Table 9 and Table 10 present the most representative comments per identified category (*left column*) and the number of individual comments received in each category (*right column*).

List what you liked the most about this interactive application	
Categories	Number of individual comments
<b>Avatars:</b> avatars liven up the history, narration style (not robotic), integration of avatars in the physical space, avatar narrates its own story, beautiful avatars	9
<b>Innovation:</b> innovative, the fact that you can interact with the exhibit, the creativity and innovation of it, where the interaction	9

meets the human element, standing next to an avatar that is narrating his story, innovative “videos” (narrations), VR aspect, AR layer, seeing people interacting with the exhibit	
<b>Ease of use:</b> easy guidance, understandable, simplicity of vocabulary used, intuitive application, simple in the description (narrations)	7
<b>Experience:</b> “homely” personal stories, avatars narrating their own personal story (makes it more real), wonderful and authentic stories from everyday life, personal stories of the factory workers, simple stories that make them feel more familiar	6
<b>Learning:</b> the directness of it, learning about the entire process from production to consumption, informative about the process (mastic), information that cannot be seen/read otherwise, an animation showing everything part to part, a good initiative to make the process clear for visitors	6

**Table 9: Categories of comments and number of comments per category for question “List what you liked the most” – Mastic narrations application**

The “List what you liked the least about this interactive application”, received comments from 19 of the respondents. Three of those comments were removed from the analysis as they were irrelevant and two were actually positive comments, i.e nothing to list in this question. There was a total of 14 comments in this section relevant to the application.

List what you liked the least about this interactive application	
Categories	Number of individual comments
<b>Technical issues:</b> room for improvement in the rhythm and intonation of the narrations, subtitles were not synchronized correctly in all the avatars, the stands (mobility), sometimes the speech was delayed, bigger fonts on PINs	7
<b>Other:</b> missing hint that screen is touchable, “video” avatar may take time to listen-can be summarized, would have liked if 3D objects appeared next to the avatars, would have liked in avatars were moving to show how work was done	7

**Table 10: Categories of comments and number of comments per category for question “List what you liked the least” – Mastic narrations application**

The majority of comments regarding technical issues were collected during the evaluation of the first version of this application and were all correct. Specifically, changes in the content of the narrations were made to improve the flow of the information, the audio recordings were done anew to improve intonation and reflect the changes in the content of the narrations, any problems with subtitle synchronization were corrected, and the narration components were compressed to ensure that there would be not lagging observed. Furthermore, the stands holding the tablets that host this application were made more stable by applying adhesive tape on their bases. Other minor changes were made in the UI, such as making the fonts of the PINs larger and adding functionality to show the ‘Select language’ UI when the application was idle for a couple of minutes as a hint that the user can interact with the tablet. Lastly, significant changes were made in the administrative side of the application to facilitate the museum staff in carrying out the steps needed to set up the application every morning more easily and effectively.

Overall, the comments collected in this section showed that visitors found the application easy and simple yet innovative and powerful in conveying personal stories about the factory workers.

### 7.2.1.3 Ad-hoc questions

This section of the post-interaction questionnaire for the Mastic narrations questionnaire included 10 questions. The first 5 questions (Q1-Q5) aimed at measuring the visitors' prior knowledge of the subject, whether they think the application helped them learn more about it, whether they think it intrigued them in learning more, whether it enhanced their overall museum visit, and whether they found the use of avatars as storytellers appropriate. These 5 questions were measured on a 5 item Likert-scale with the following options: Not at all, a little, neutral, somewhat, and very much. The other 5 questions (Q6-Q10) aimed at measuring the visitors' impression of the ease of use, the quality of the 3D representation, the quality of the information about the mastic villages, and their overall level of satisfaction with it. The 5-item Likert scale used for these questions had the following options: Very unsatisfied, unsatisfied, neutral, satisfied, and very satisfied.

As all the ad-hoc questions were scored on a 5 item Likert scale, the data collected was treated as ordinal and thus the results are reported in the median, mode, and inter-quartile ranges and frequency (%). Respective data is shown in Table 11, Table 12, and Table 13 while the data is shown in bar charts in Figure 76, Figure 77, Figure 78, and Figure 79.

Part B: Questions 1-5	N	Median	Mode	IRQ (Q3-Q1)
Q1: How knowledgeable were you about the life of mastic growers before using this interactive application?	44	2	2,1	2 (3-2)
Q2: How much do you think this interactive application helped you learn more about the life of mastic growers?	44	5	5	1 (5-4)
Q3: How much do you think this interactive application made you want to learn more?	44	4	4	2 (5-3)
Q4: How much do you think that this interactive application enhanced your overall museum visit experience?	44	5	5	1 (5-4)
Q5: Do you think that the virtual characters (avatars) used in this application were appropriate mediums to convey narratives?	44	4	5	1,5 (5-3,5)
Part C Questions 6-10 - level of satisfaction with the following:	N	Median	Mode	IRQ (Q3-Q1)
Q6: Design and animation of virtual characters (avatars)	44	4	4	1 (5-4)
Q7: Quality of the content of the narrations	44	5	5	1 (5-4)
Q8: Educational value of narrations	44	5	5	1 (5-4)
Q9: Authenticity of narrations	44	4	5	1 (5-4)
Q10: Overall satisfaction with this interactive museum application	44	5	5	1 (5-4)

**Table 11: Median, mode, and inter-quartile ranges for ad-hoc questions – Mastic narrations application**

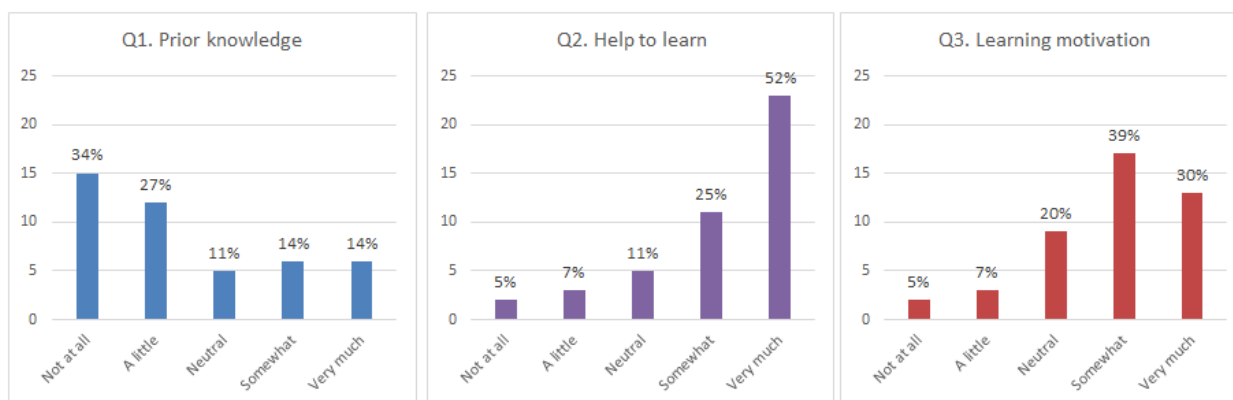
	Q1 Freq. (%)	Q2 Freq. (%)	Q3 Freq. (%)	Q4 Freq. (%)	Q5 Freq. (%)
Not at all	34%	5%	5%	2%	2%
Very little	27%	7%	7%	2%	5%
Neutral	11%	11%	20%	9%	18%

Somewhat	14%	25%	39%	32%	32%
Very much	14%	52%	30%	55%	43%

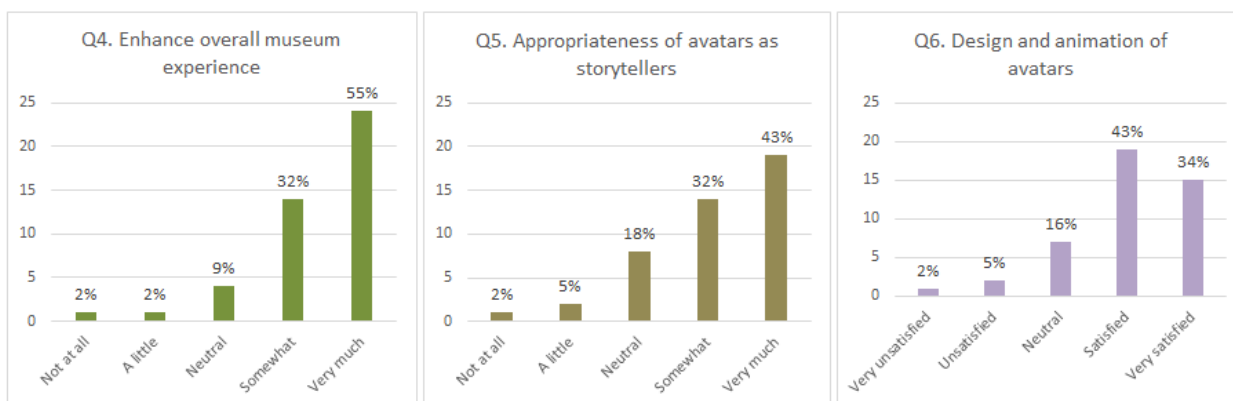
**Table 12: Frequency of answers for questions Q1-5 – Mastic narrations application**

	Q6 Freq. (%)	Q7 Freq. (%)	Q8 Freq. (%)	Q9 Freq. (%)	Q10 Freq. (%)
Very unsatisfied	2%	2%	2%	0%	2%
Very little	5%	7%	2%	2%	7%
Neutral	16%	7%	9%	9%	5%
Somewhat	43%	30%	32%	41%	30%
Very much	34%	55%	55%	48%	57%

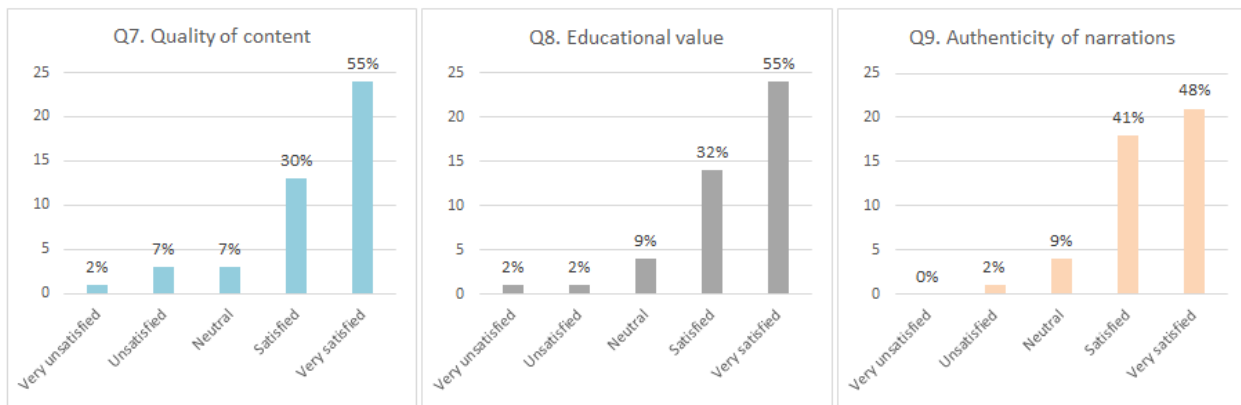
**Table 13: Frequency of answers for questions Q6-10 – Mastic narrations application**



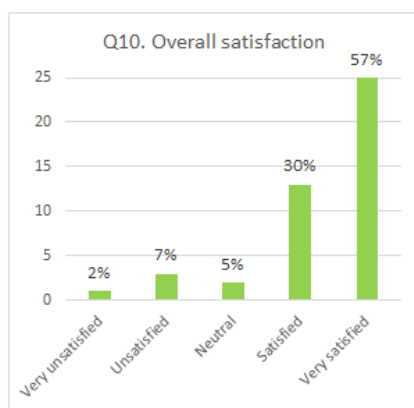
**Figure 76: Frequency for ad-hoc questions 1-3 – Mastic narrations application**



**Figure 77: Frequency for ad-hoc questions 4-6 – Mastic narrations application**



**Figure 78: Graphs displaying frequencies of answers for ad-hoc questions 7-9 – Mastic narrations application**



**Figure 79: Graph displaying frequencies of answers for ad-hoc questions 10 – Mastic narrations application**

From the data presented in the tables, it is shown that the central tendency (*median*) of the respondents in Q2, Q4, Q7, Q8, and Q10 was 5 and for the rest of the questions, Q3, Q5, Q6, and Q9 it was 4. Whereas the most frequent value (*mode*) in the answers for Q3 and Q6 was 4, and for the rest Q2, Q4, Q5, Q7, Q8, Q9, and Q10 was 5. This means that the majority of the respondents rated positively all aspects of the application.

Looking at the graphs, it can be seen that 61% of the respondents had little or no prior knowledge about the life of mastic growers (Q1), however, 77% of the respondents thought that the application helped them learn more about the mastic growers (Q2). This result coincides with the sentiment of the majority of the respondents, 87%, who rated their level of satisfaction with the educational value of the application positively (Q8). Furthermore, 39% of the respondents thought that the application made them want to learn more (intrigued learning).

A high percentage of the respondents, 87%, also thought that the application enhanced their overall museum visit experience. 77% of the respondents found the avatars appropriate mediums for storytelling, with only 3 people rating them negatively. Interestingly enough the negative ratings on the avatars were by respondents in the age group of under 18.



All other aspects of the application, such as the quality of the content (Q7), the authenticity of narrations (Q9), and the overall satisfaction (Q10), were also rated positively by the vast majority of the respondents, 85%, 89%, and 87% respectively.

#### 7.2.1.4 Net Promoter Score

The calculated NPS for the Mastic narrations application was calculated **42**, which is considered a positive score, as it shows that there are more advocates (promoters) willing to recommend the virtual tour to others than critics (detractors). Specifically, 60% of the 43 respondents to this question answered 9 or 10 on the likeliness to recommend this application to their relatives and friends, and 29% answered 6 and below, while the remaining 11% of the respondents answered with an 8 or 7, falling in the “passives” category. The NPS score for this application is yet another indication that proves that the visitors had a positive user experience with this Mingei installation.

### 7.2.2 Mastic landscapes application

The questionnaire for the Mastic landscapes Mingei installation consisted of the following three parts:

**Part A:** The first part of this questionnaire included the same 16 items of the UEQ questionnaire corresponding to the scales of attractiveness, perspicuity, stimulation, and novelty, as the other installation questionnaire. Additionally, this section also included the two open-ended questions were “List what you liked the most about the mastic narrations applications” and “List what you liked the least about the mastic narrations applications” like the questionnaire of the Mastic narrations.

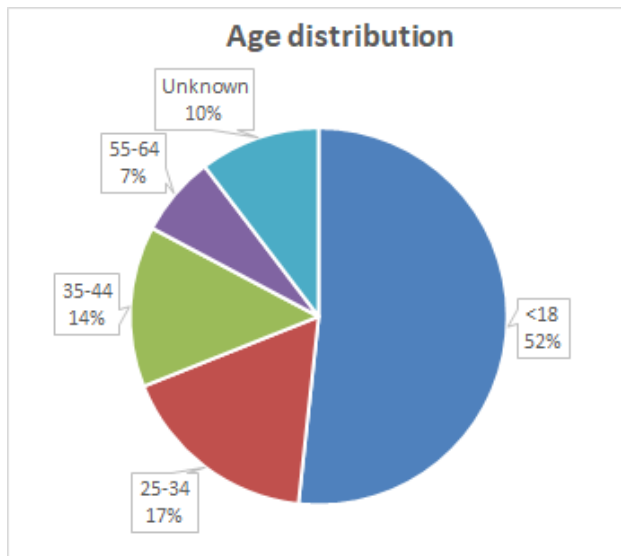
**Part B:** This part included 4 ad-hoc questions answered on a 5-item Likert scale format: Very unsatisfied, unsatisfied, neutral, satisfied, very satisfied.

In this part, the visitors were asked to indicate their level of satisfaction with various technical and design aspects of the application. Specifically, with the following:

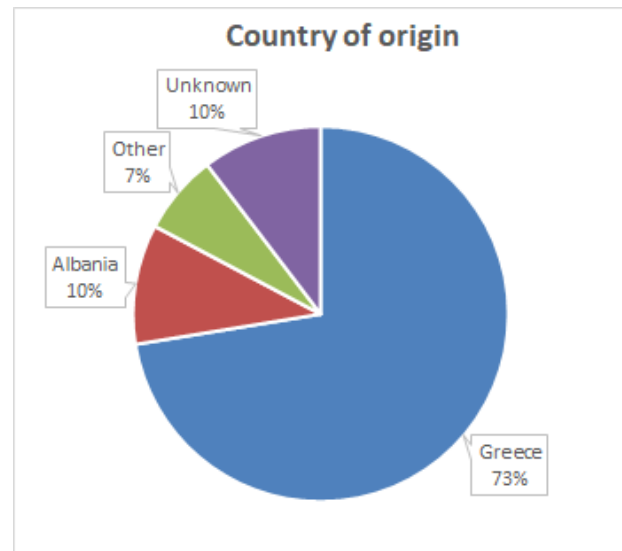
1. Ease of using this interactive application
2. Quality of virtual representation of the traditional villages
3. Quality of content presented in each traditional village
4. Overall satisfaction with this interactive museum exhibit

**NPS question:** On a scale from 0 (Not at all likely) to 10 (Extremely likely), how likely are you to recommend this interactive application to a friend or a family member visiting the museum? Circle the number that corresponds to your score.

A total of 30 visitors to the Chios museum answered this post-interaction questionnaire after interacting with this application. The age and country distribution are depicted in Figure 80 and Figure 81 respectively.



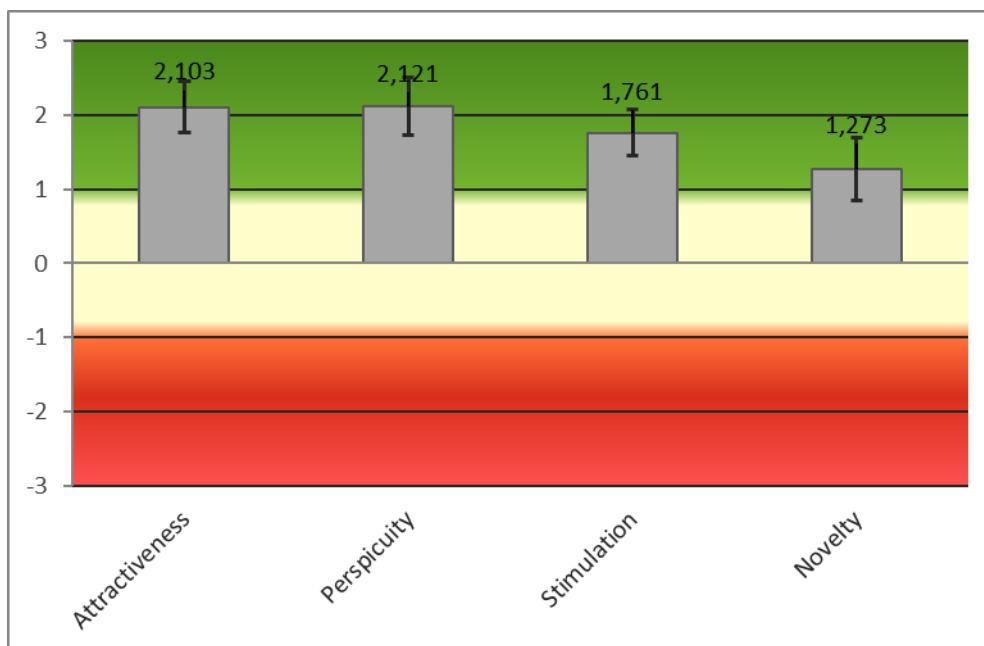
**Figure 80: Age distribution of respondents – Mastic landscapes application**



**Figure 81: Country of origin distribution of respondents – Mastic landscapes application**

### 7.2.2.1 UEQ results

The results of the aggregated means and variance for the four UEQ scales are depicted in Figure 82, whereas the results per each of the semantic differential items are presented in Table 14.



**Figure 82: Aggregate means and variance per UEQ scale-Mastic landscapes application**

Item	Mean	Variance	Std. Dev.	No.	Left	Right	Scale
1	2,1	0,7	0,9	29	annoying	enjoyable	Attractiveness
2	2,4	0,7	0,9	29	not understandable	understandable	Perspicuity
3	1,5	1,8	1,3	28	creative	dull	Novelty

4	2,0	2,1	1,5	29	easy to learn	difficult to learn	Perspicuity
5	2,1	1,6	1,3	28	valuable	inferior	Stimulation
6	1,3	1,1	1,1	28	boring	exciting	Stimulation
7	1,7	0,8	0,9	29	not interesting	interesting	Stimulation
8	1,1	3,0	1,7	28	inventive	conventional	Novelty
9	2,2	1,3	1,1	29	good	bad	Attractiveness
10	2,1	1,7	1,3	29	complicated	easy	Perspicuity
11	2,2	1,4	1,2	29	unlikable	pleasing	Attractiveness
12	1,1	3,2	1,8	29	usual	leading edge	Novelty
13	2,1	1,2	1,1	28	unpleasant	pleasant	Attractiveness
14	1,9	1,4	1,2	28	motivating	demotivating	Stimulation
15	2,1	1,9	1,4	29	clear	confusing	Perspicuity
16	1,9	1,6	1,3	29	attractive	unattractive	Attractiveness
17	2,1	1,3	1,2	29	friendly	unfriendly	Attractiveness
18	1,3	3,5	1,9	29	conservative	innovative	Novelty

**Table 14: UEQ results per item (Mean, variance, std. dev.) – Mastic landscapes application**

The results of the UEQ scales and individual item scores of the Mastic landscapes application depicted in the above figure and table respectively show that the visitors that responded to the post-interaction questionnaire, rated also rather positively this Mingei installation on all four scales. None of the items received a mean of <0.8. The scale with the highest score was stimulation, followed by perspicuity, attractiveness, stimulation and novelty.

### 7.2.2.2 Open-ended questions

In this post-interaction questionnaire, two open-ended were provided:

1. List what you liked the most about this interactive application
2. List what you liked the least about this interactive application

The Mastic landscapes application received comments from 23 respondents in the “List what you liked the most about this interactive application” section and from 22 respondents in the “List what you liked the least about this application” section.

The answers to these questions were aggregated and then categorised manually. Some respondents left more than one comment. Table 15 and Table 16 present the categories and their most representative comments (*left column*) and the number of comments received per category (*right column*).

List what you liked the most about this interactive application	
Categories	Number of individual comments
<b>Information:</b> the content of mastic villages, the pictures shown, informative app	7
<b>3D environment design:</b> the 3D model of the villages, the design of the villages, very beautiful design, love the visuals	7
<b>Experience:</b> “Super cool!”, very interesting application, that you get some connection to the geographical site of the island	7

<b>Interaction:</b> very interactive with the drone, the manual piloting over the villages, the way it operated, easy and simple to use	5
<b>Other comments:</b> nothing negative to report (transferred from the “list what you liked the least” question)	6

**Table 15: Categories of comments and number of comments per category for question “List what you liked the most” – Mastic landscapes application**

From the written comments in the second question, 16 of them regarded elements that the respondents didn’t like or suggestions for improvements, while 6 of them were positive comments regarding the fact that they had nothing to list as negative. These 6 comments were transferred to the list of positive comments and were counted as such. The categories of the comments received are presented in the tables below along with the number of individual comments in each category. It is important to note, that some of the comments about the manual piloting mode not functioning correctly or not being available were collected during the first round of evaluation. At that time, this mode was partially functional, as it was added as a feature at the very last moment. In the second round of evaluation, this interaction mode was fully functional and no more negative comments were received about it.

List what you liked the least about this interactive application	
Categories	Number of individual comments
<b>Information:</b> the lack of extra information on the 3D map, few POIs on the island, quality of the image	6
<b>Experience:</b> the lack of free navigation in the 3D environment, waiting for the drone to complete the circle around the village before moving on	3
<b>Interaction:</b> the manual pilot mode was not working, the control of the drone was abrupt	2
<b>Suggestions:</b> more information about the villages such as a 360° picture, perhaps use a different metaphor for the flying instead of the drone-like something that is connected to the content of the app, additional features like zoom in and out and navigation inside the 3D village, add more villages (e.g.: Thymiana, Kallimasia, Nenita, etc.), would love to see real drone footage of the towns or street views	5

**Table 16: Categories of comments and number of comments per category for the question “List what you liked the least” – Mastic landscapes application**

From the two tables with the positive and the negative comments, it is obvious that the positive comments far exceeded the negative ones, which is an indication that the respondents to the questionnaire had an overall positive user experience with this application regarding the information, the interaction, and the experience provided by it. As far as the negative problems, as already mentioned various improvements were made regarding the manual piloting and the information presented in each village. Furthermore, various adjustments to the lighting of the 3D village scenes and the height of the flight were done to improve the display of the 3D graphics. Finally, it was noted by the museum staff that some visitors were not sure how to start with the application, so instructions were added to the opening screen of the application, to alleviate this problem.

### 7.2.2.3 Ad-hoc questions

This section of the post-interaction questionnaire for the Mastic landscapes questionnaire included 4 questions that aimed at measuring the visitors' impression of the ease of use, the quality of the 3D representation, the quality of the information about the mastic villages, and their overall level of satisfaction with it. The 5-item Likert scale used for these questions had the following options: Very unsatisfied, unsatisfied, neutral, satisfied, and very satisfied.

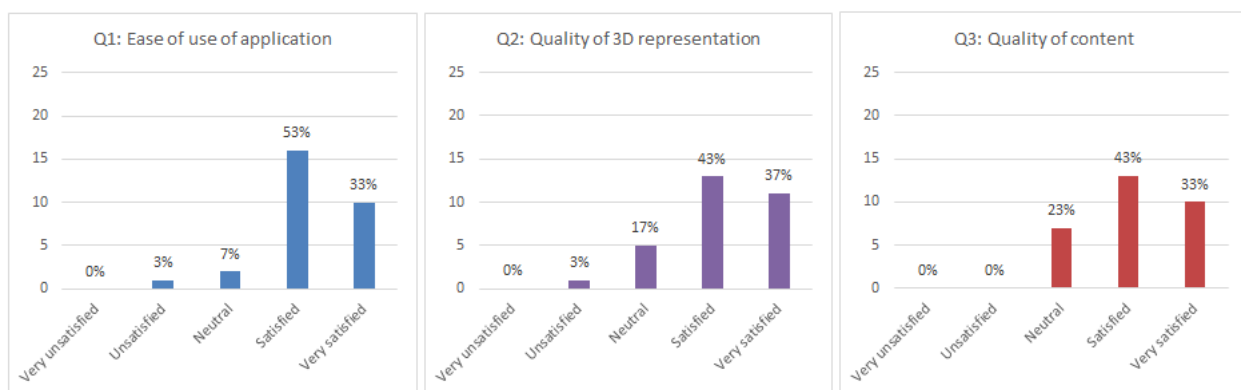
As all the ad-hoc questions were scored on a 5 item Likert scale, the data collected was treated as ordinal and thus the results are reported in the median, mode, and inter-quartile ranges and frequency (%). Respective data is shown in Table 17 and Table 18 while the data is shown in bar charts in Figure 83 and Figure 84.

Part B: Questions 1-4	N	Median	Mode	IRQ (Q3-Q1)
Q1: Ease of using this interactive application	30	4	4	1 (5-4)
Q2: Quality of virtual representation of the traditional villages	30	4	4	1 (5-4)
Q3: Quality of content presented in each traditional village	30	4	4	1 (5-4)
Q4: Overall satisfaction with this interactive museum exhibit	30	5	5	1 (5-4)

**Table 17: Median, mode, and inter-quartile ranges for ad-hoc questions – Mastic landscapes application**

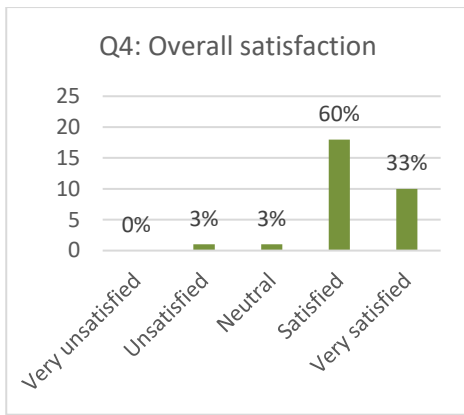
	Q1 Freq. (%)	Q2 Freq. (%)	Q3 Freq. (%)	Q4 Freq. (%)
Very unsatisfied	0%	0%	0%	0%
Very little	3%	3%	0%	3%
Neutral	7%	17%	23%	3%
Somewhat	53%	43%	43%	60%
Very much	33%	37%	33%	33%

**Table 18: Frequency of answers for questions Q1-4 – Mastic landscapes application**



**Figure 83: Frequency for ad-hoc questions Q1-3 – Mastic landscapes application**





**Figure 84: Frequency for ad-hoc question Q4 – Mastic landscapes application**

From the data presented in the tables, it is shown that the central tendency (*median*) and the most frequent value (*mode*) of the respondents in all the questions was 4 in all four questions. This means that the majority of the respondents were satisfied with the ease of use of the application, the quality of the 3D representation of the represented mastic villages, the quality of content, and the overall satisfaction with this interactive application.

Specifically, looking at the graphs, it can be seen that 88% of the respondents were satisfied with the ease of use of the application (Q1), and 80% of the respondents were satisfied with the 3D representation of the mastic villages (Q2), and 76% with the quality of the information provided for each of the mastic villages (Q3). Lastly, 93% of the respondents rated very high the overall satisfaction with this interactive application.

#### 7.2.2.4 Net Promoter Score

The NPS for the Mastic landscapes application received a positive score of **38**, with 55% of the 29 respondents to this question answering 9 or 10 on the likeliness to recommend this application to their relatives and friends scales, and 17% answering 6 and below, while the remaining 23% of the respondents answered with an 8 or 7, falling in the “passives” category.

### 7.2.3 Mastic gestures application

The questionnaire for the Mastic landscapes Mingei installation consisted of the following three parts:

**Part A:** The first part of this questionnaire included the same 16 items of the UEQ questionnaire corresponding to the scales of attractiveness, perspicuity, stimulation, and novelty, as the other installations’ questionnaires. Additionally, this section also included the two open-ended questions “List what you liked the most about the mastic narrations applications” and “List what you liked the least about the mastic narrations applications”.

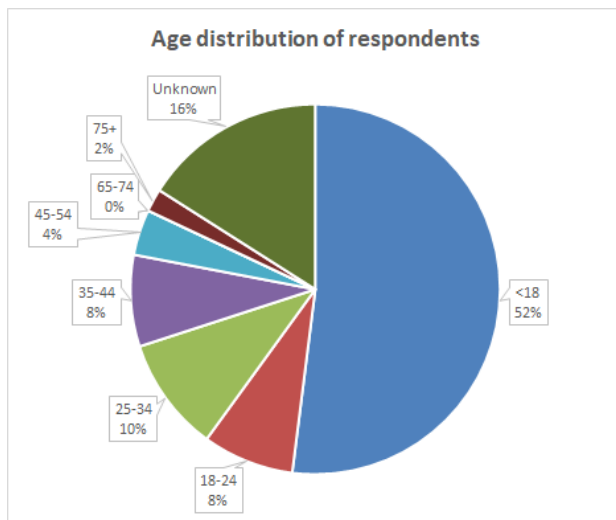
**Part B:** This part included 3 ad-hoc questions answered on a 5-item Likert scale format: Very unsatisfied, unsatisfied, neutral, satisfied, very satisfied.

In this part, the visitors were asked to indicate their level of satisfaction with various technical and design aspects of the application. Specifically, with the following:

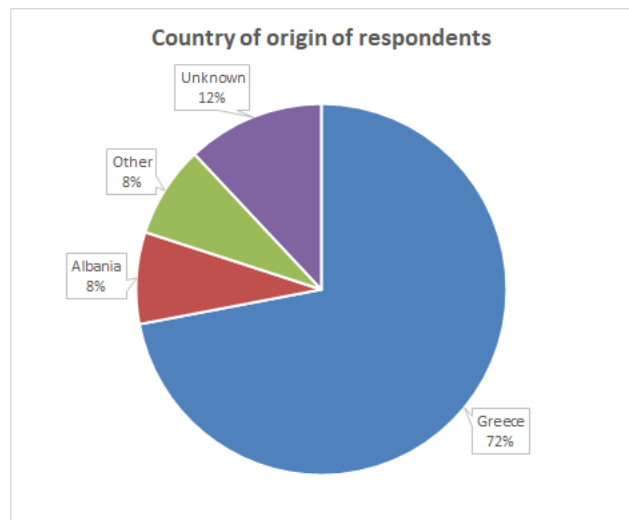
1. Ease of applying the gestures as they were shown by the mastic grower in the video
2. Ease of understanding whether you performed the gesture correctly or incorrectly
3. Overall satisfaction with this interactive application

**NPS question:** On a scale from 0 (Not at all likely) to 10 (Extremely likely), how likely are you to recommend this interactive application to a friend or a family member visiting the museum? Circle the number that corresponds to your score.

A total of 50 visitors to the Chios museum answered this post-interaction questionnaire after interacting with this application. The age and country distribution are depicted in Figure 85 and Figure 86 respectively.



**Figure 85: Age distribution of post-interaction questionnaire respondents – Mastic gestures application**



**Figure 86: Country of origin distribution of post-interaction questionnaire respondents – Mastic gestures application**

### 7.2.3.1 UEQ results

The results of the aggregated means and variance for the four UEQ scales are depicted in Figure 87, whereas the results per each of the semantic differential items are presented in Table 19.

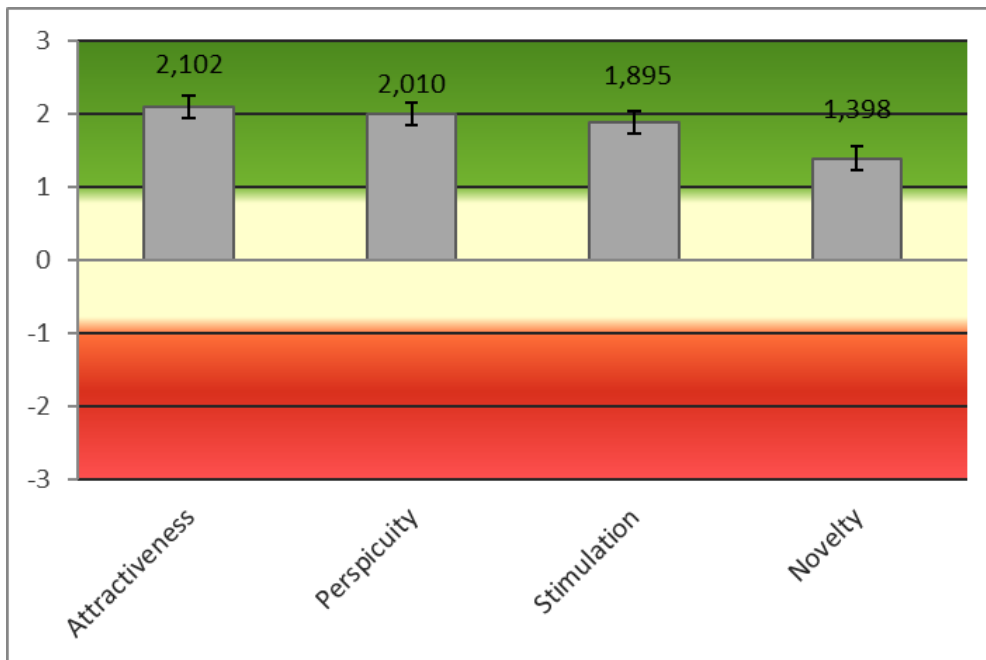


Figure 87: Aggregate means and variance per UEQ scale-Mastic gestures application

Item	Mean	Variance	Std. Dev.	No.	Left	Right	Scale
1	2,0	1,3	1,1	50	annoying	enjoyable	Attractiveness
2	2,0	2,0	1,4	50	not understandable	understandable	Perspicuity
3	2,0	2,5	1,6	49	creative	dull	Novelty
4	2,1	2,0	1,4	50	easy to learn	difficult to learn	Perspicuity
5	2,0	1,6	1,2	49	valuable	inferior	Stimulation
6	1,7	1,8	1,3	50	boring	exciting	Stimulation
7	2,1	1,8	1,3	49	not interesting	interesting	Stimulation
8	0,7	5,4	2,3	49	inventive	conventional	Novelty
9	2,3	1,3	1,1	49	good	bad	Attractiveness
10	1,9	1,5	1,2	50	complicated	easy	Perspicuity
11	2,1	1,8	1,3	50	unlikable	pleasing	Attractiveness
12	1,7	3,5	1,9	50	usual	leading edge	Novelty
13	2,1	2,0	1,4	50	unpleasant	pleasant	Attractiveness
14	1,8	1,6	1,3	50	motivating	demotivating	Stimulation
15	2,1	1,6	1,3	50	clear	confusing	Perspicuity
16	2,0	1,8	1,3	50	attractive	unattractive	Attractiveness
17	2,3	2,1	1,5	49	friendly	unfriendly	Attractiveness
18	1,2	4,9	2,2	50	conservative	innovative	Novelty

Table 19: UEQ results per item (Mean, variance, std. dev.) – Mastic gestures application

From the results of the UEQ scales and individual items, it can be concluded that the visitors that responded to the post-interaction questionnaire, rated also rather positively this Mingei installation on all four scales. Only one semantic differential item (inventive/conventional) from the novelty scale received a mean of 0,7 which falls in the upper limits of the neutral sentiment zone.

Nonetheless, cumulatively the novelty scale received a positive mean of 1,398. The scale with the highest score was attractiveness, followed by perspicuity, stimulation, and novelty.

### 7.2.3.2 Open-ended questions

In this post-interaction questionnaire, two open-ended were provided:

1. List what you liked the most about this interactive application
2. List what you liked the least about this interactive application

The Mastic gestures application received comments from 40 of the 50 respondents in the “List what you liked the most about this interactive application” section and from 33 of the 50 respondents in the “List what you liked the least about this application” section. Some respondents left more than one comment.

The answers to these questions were aggregated and then categorised manually. Table 20 and Table 21 present the categories and their representative comments (*left column*) and the number of comments per category received (*right column*).

List what you liked the most about this interactive application:	
Categories	Number of individual comments
<b>Experience:</b> an entertaining way (mimicking) to learn about the process of mastic gathering, the computer made us workers of mastic, the connectivity of the installation with the facts, the sounds, very interesting application, clever idea, it was authentic, learning the moves, getting a rough feeling of how the procedure is done, easy and entertaining depiction of the real cultivation	18
<b>Interaction/gestures:</b> the embroidery gesture, the sifting gesture, the fast response to the movements, the way the movements were explained, being able to collect the mastic out of the soil	17
<b>Novelty:</b> the implementation of new technology, resourceful application, creative, innovative, very interesting	6
<b>Other:</b> Everything was great, “even though I am experienced in the field, it was amazing”	13

**Table 20: Categories of comments and number of comments per category for the question “List what you liked the most” – Mastic gestures application**

From the 33 respondents that wrote comments on the second question, 26 of the comments regarded elements that the respondents didn’t like or suggestions for improvements, while 16 of the comments listed there were actually positive comments regarding the fact that they had nothing to list as negative. These 17 positive comments were transferred and analysed in the first question.

In the table below, the elements that were reported as the least liked by the respondents and the suggestions for improvements are presented in categories:

List what you liked the least about this interactive application	
Categories	Number of individual comments

<b>Interaction:</b> the video was changing gestures all the time, easily mixed my moves (I did the embroidering and the sifting video and sound were activated), the sounds, the interaction could have been better	10
<b>Experience:</b> quality of the video, the colours of the skeleton were confusing me, the resolution of the image, having to kneel to do the gestures, I would prefer more things concerning the interactive education	9
<b>Technical issues:</b> camera issues	2
<b>Suggestions:</b> add more gestures, very nice idea but could have been enriched with more content, not having two characters in the installation (the user and cultivator) but having the avatar of the user as the cultivator, it would have been better having a platform for the visitor to sit so that they don't get dirty	5

**Table 21: Categories of comments and number of comments per category for the question “List what you liked the least” – Mastic gestures application**

From the two tables with the positive and the negative comments, it is obvious that the positive comments far exceeded the negative ones, which is an indication that the respondents to the questionnaire had an overall positive user experience with this application regarding the information, the interaction, and the experience provided by it.

### 7.2.3.3 Ad-hoc questions

This section of the post-interaction questionnaire for the Mastic gestures questionnaire included 3 questions, that aimed at measuring the visitors' impression of the ease of applying the gestures, ease of understanding when the gestures were performed correctly, and their overall satisfaction with the application. As all the ad-hoc questions were scored on a 5 item Likert scale, the data collected was treated as ordinal and thus the results are reported in the median, mode, and inter-quartile ranges and frequency (%). Respective data is shown in Table 22 and Table 23 while the data is shown in bar charts in Figure 88.

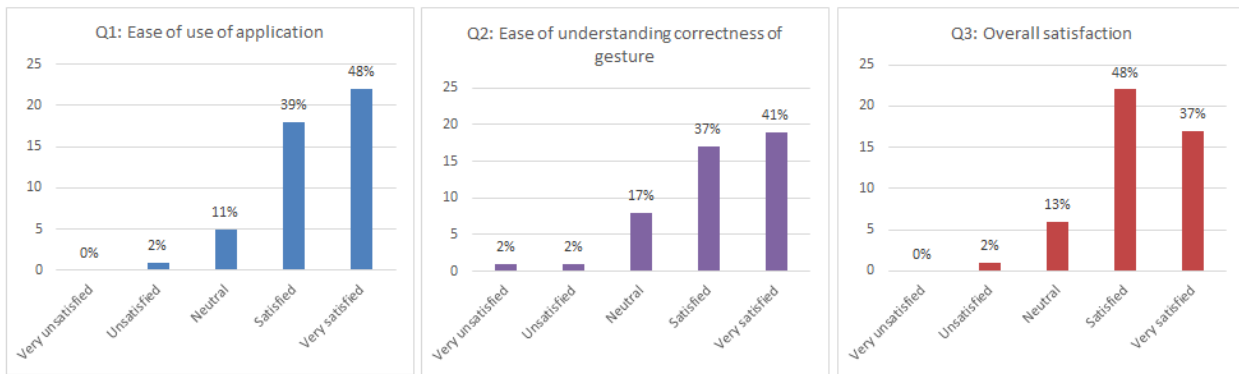
Part B: Questions 1-3	N	Median	Mode	IRQ (Q3-Q1)
Q1: Ease of applying the gestures as they were shown by the mastic grower in the video	30	4	5	1 (5-4)
Q2: Ease of understanding whether you performed the gesture correctly or incorrectly	30	4	5	1 (5-4)
Q3: Overall satisfaction with this interactive application	30	4	4	1 (5-4)

**Table 22: Median, mode, and inter-quartile ranges for ad-hoc questions – Mastic gestures application**

	Q1 Freq. (%)	Q2 Freq. (%)	Q3 Freq. (%)
Very unsatisfied	0%	2%	0%
Very little	2%	2%	2%
Neutral	11%	17%	13%
Somewhat	39%	37%	48%
Very much	48%	41%	37%

**Table 23: Frequency of answers for questions Q1-4 – Mastic landscapes**





**Figure 88: Frequency for ad-hoc questions Q1-3 – Mastic gestures application**

From the data presented in the tables, it is shown that the central tendency (*median*) was 4 in all the questions and the most frequent value (*mode*) of the respondents was 5 for Q1 and Q2 and 4 for Q3. This means that the majority of the respondents were satisfied with the ease of use of the application, the ease of understanding correctness of performed gestures, and the overall satisfaction with this interactive application.

Specifically, looking at the graphs, it can be seen that 87% of the respondents were satisfied with the ease of use of the application (Q1), 78% of the respondents were satisfied with the ease of use of the application, the ease of understanding correctness of performed gesture (Q2), and 85% with the overall satisfaction (Q3).

#### 7.2.3.4 Net Promoter Score (NPS)

The NPS for the Mastic gestures application was calculated at **45**, with 61% of the 46 respondents to this question answering 9 or 10 on the likeliness to recommend this application to their relatives and friends scales, and 16% answering 6 and below, while the remaining 23% of the respondents answered with an 8 or 7, falling in the “passives” category.

### 7.3 Glass pilot questionnaire results

The post-interaction questionnaire for the Glass installation consisted of the following three parts:

**Part B:** Included 3 ad-hoc questions answered on a 5-item Likert scale format: Not at all, a little, neutral, somewhat, very much.

These questions aimed at measuring the visitors' prior knowledge about the life of mastic growers, their impression on whether the application helped them learn about the life of mastic growers, and their impression of whether the application made them want to learn more about the mastic growers, their impression on whether the application enhanced their overall museum experience, and whether they considered the use of avatars as an appropriate medium to convey the mastic growers narrations, respectively. Specifically, the questions were phrased as follows:

1. How knowledgeable were you about the craft of glass blowing before visiting this exhibition?
2. How much do you think this exhibition helped you learn more about the craft of glass blowing?

3. How much do you think this exhibition made you want to learn more about the craft of glass blowing?

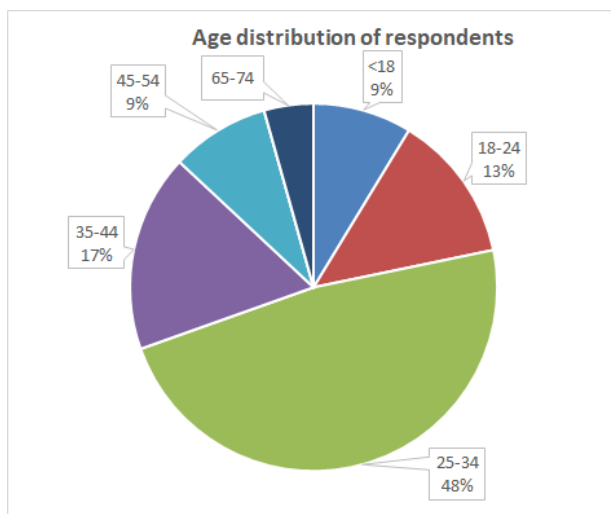
**Part C:** Included 5 more ad-hoc questions answered on a 5-item Likert scale format: Very unsatisfied, unsatisfied, neutral, satisfied, very satisfied.

In this part, the visitors were asked to indicate their level of satisfaction with various technical and design aspects of the application. Specifically, with the following:

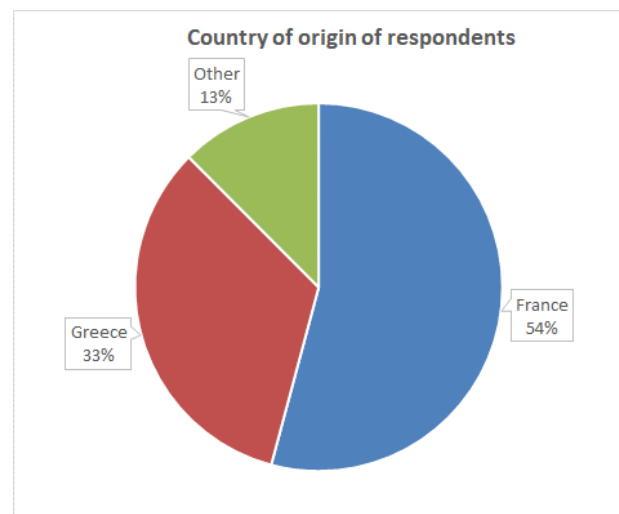
4. Graphics and animations used in the virtual glass workshop
5. Ease of applying the gestures shown by the virtual character
6. Quality of feedback from the application when I performed a gesture correctly or incorrectly
7. The authenticity of the virtual workshop representation
8. The educational value of the exhibition

**NPS question:** On a scale from 0 (Not at all likely) to 10 (Extremely likely), how likely are you to recommend this interactive application to a friend or a family member visiting the museum? Circle the number that corresponds to your score.

A total of 23 visitors to the CNAM museum answered this post-interaction questionnaire after interacting with the glass installation application. The age and country distribution are depicted in Figure 85 and Figure 86 respectively.



**Figure 89: Age distribution of post-interaction questionnaire respondents – Glass interactive application**



**Figure 90: Country of origin distribution of post-interaction questionnaire respondents – Glass interactive application**

## 7.2.4 UEQ results

The results of the aggregated means and variance for these four scales are depicted in Figure 91, whereas the results per each of the semantic differential items are presented in Table 24.

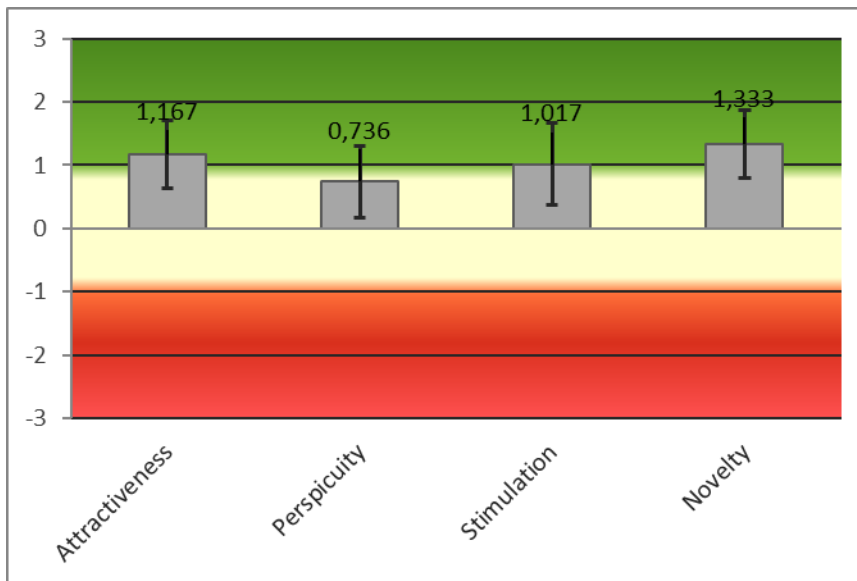


Figure 91: Aggregate means and variance per UEQ scale-Glass interactive application

Item	Mean	Variance	Std. Dev.	No.	Left	Right	Scale
1	1,0	2,1	1,5	24	annoying	enjoyable	Attractiveness
2	1,2	2,6	1,6	24	not understandable	understandable	Perspicuity
3	1,3	2,7	1,6	24	creative	dull	Novelty
4	0,7	3,1	1,8	23	easy to learn	difficult to learn	Perspicuity
5	1,0	3,8	1,9	23	valuable	inferior	Stimulation
6	0,8	3,2	1,8	24	boring	exciting	Stimulation
7	1,4	2,3	1,5	24	not interesting	interesting	Stimulation
8	1,5	3,0	1,7	24	inventive	conventional	Novelty
9	1,3	2,8	1,7	24	good	bad	Attractiveness
10	0,3	3,2	1,8	24	complicated	easy	Perspicuity
11	1,5	1,9	1,4	24	unlikable	pleasing	Attractiveness
12	1,3	2,0	1,4	24	usual	leading edge	Novelty
13	1,1	1,6	1,3	24	unpleasant	pleasant	Attractiveness
14	0,8	3,8	2,0	24	motivating	demotivating	Stimulation
15	0,8	2,0	1,4	24	clear	confusing	Perspicuity
16	0,9	2,9	1,7	24	attractive	unattractive	Attractiveness
17	1,2	2,0	1,4	24	friendly	unfriendly	Attractiveness
18	1,3	2,0	1,4	24	conservative	innovative	Novelty

Table 24: UEQ results per item (Mean, variance, std. dev) – Glass interactive application

From the results of the UEQ scales and individual item scores of the Glass interactive application depicted on the above figure and table respectively, it can be concluded that the visitors that responded to the post-interaction questionnaire, rated positively this Mingei installation on the three scales of novelty, attractiveness and stimulation, and rated slightly lower, but still in the neutral zone the installation on the perspicuity scale. The novelty scale received the highest marks from the respondents who seemed to find the whole concept of trying-out the master glass blower's gestures innovative and impressive, as it is reflected in the written comments of the open-ended

section. However, some visitors found it a little difficult to follow the gestures displayed on the screen and would have liked more contextual information in order to understand better how to execute them. This might have been a factor that affected the rating of these respondents in the perspicuity scale.

### 7.2.5 Open-ended questions

In this post-interaction questionnaire, two open-ended were provided:

1. List what you liked the most about this interactive application
2. List what you liked the least about this interactive application

The Glass installation received comments from 19 of the 24 respondents in the “List what you liked the most about this interactive application” section and from 18 of the 24 respondents in the “List what you liked the least about this application” section.

The answers to these questions were aggregated and then categorised manually. Table 25 and Table 26 present the categories and their representative comments (*left column*) and the number of comments per category received (*right column*).

List what you liked the most about this interactive application	
Categories	Number of individual comments
<b>Interaction:</b> the reproduction of the gestures of the glass master, applying the observed gestures and being able to correct them, imitating gestures as an apprentice would do, holding a blower’s pipe and following the same gestures as a glassblower	7
<b>Experience:</b> Following the gestures of a craftsman is a brilliant and attractive experience, immersing in the skin of the glass craftsman, the sound when a movement was well executed was very immersive, beautiful location and nice set-up, great to have the real workshop bench and tube	6
<b>Information:</b> learning the history of glassmaking, the process of glass blowing was impressive and instructive, and the video of the glassmaker handling the glass allows visitor to see in detail each stage of realization	3

**Table 25: Categories of comments and number of comments per category for question “List what you liked the most” – Glass interactive application**

From the positive comment analysis, the installation element that seemed to have made the strongest impression on the visitors was the interactive gestures. This element received the vast majority of the comments in the “List what you liked the most about this application” question. This sentiment was summarized perfectly by three visitors, who wrote: “Being able to immerse yourself in the skin of the glass craftsman in such an immersive way is captivating”, “The idea of offering visitors the opportunity to understand this know-how by imitating gestures, as an apprentice would do”, “Being in the shoes of the glassmaker and realizing that it is not easy”.

The question “List what you liked the least about the application” received 26 comments. From these comments, some of them were suggestions of what would have enhanced the experience. These are listed as a separate category.

List what you liked the least about this interactive application	
Categories	Number of individual comments
<b>Interaction:</b> sensor malfunctioning, lack of a way to go to the gestures mode right away	12
<b>Experience:</b> trying to follow the content on three screens at the same time was a bit confusing, absence of sound or music in the 3D workshop, the 3D scene was a bit slow, exhibition is small (little info, objects, not very interactive)	6
<b>Information:</b> lack of context regarding the gestures performed, instructions had too much text, projection on the canvas was blurred (cannot see the finesse of the glassmaker's gestures)	3
<b>Suggestions:</b> more user-controlled actions were needed (to start the presentation, how to learn more about the craft, etc.), add guidance/introduction to the 3D objects on the screen, additional physical tools, i.e. pliers would add to the experience, more sound, more filmed images of the workshop and the glass blowing to be able to compare with the 3D reconstruction, image of the glassmaker at work chaining these gestures	5

**Table 26: Categories of comments and number of comments per category for question “List what you liked the least” – Glass interactive application**

The characteristics of the installation that received the most mentions in the list of things visitors liked the least, were the lack of sound or music in the 3D representation scene and the way the instructions were provided about the implementation of the gestures, which some visitors found them too textual while others found them not detailed enough. Regarding the lack of sound or music in the 3D screen, the environment and the set-up of the installation in the CNAM museum did not allow for such addition. Another comment that stood out was that visitors would have liked to have more footage of the glassmaker doing the demonstrated gestures to have a better context of their purpose.

### 7.2.6 Ad-hoc questions

This section of the post-interaction questionnaire for the Glass installation questionnaire included 8 questions.

The first 3 questions (Q1-Q3) aimed at measuring the visitors' prior knowledge of the subject, whether they think the application helped them learn more about it, and whether they think it intrigued them in learning more. These 3 questions were measured on a 5 item Likert-scale with the following options: Not at all, a little, neutral, somewhat, and very much.

The other 5 questions (Q4-Q8) aimed at measuring the visitors' impression of the graphics and animations used for the 3D representation of the workshop, the ease of applying the gestures of the glassmaker, the quality of the information received when they performed the gesture correctly or incorrectly, the authenticity of the 3D representation of the workshop, and the overall educational value of the installation. The 5-item Likert scale used for these questions had the following options: Very unsatisfied, unsatisfied, neutral, satisfied, and very satisfied.



As all the ad-hoc questions were scored on a 5 item Likert scale, the data collected was treated as ordinal and thus the results are reported in the median, mode, and inter-quartile ranges and frequency (%). Respective data is shown in Table 27, Table 28, and Table 29 while the data is shown in bar charts in Figure 92, Figure 93, and Figure 94.

<b>Part B: Questions 1-3</b>	<b>N</b>	<b>Median</b>	<b>Mode</b>	<b>IRQ (Q3-Q1)</b>
Q1: How knowledgeable were you about the craft of glass blowing before visiting this exhibition?	24	2	2	2 (4-2)
Q2: How much do you think this exhibition helped you learn more about the craft of glass blowing?	24	4	4	0 (4-4)
Q3: How much do you think this exhibition made you want to learn more about the craft of glass blowing?	24	4	4	1,5 (5-3,5)
<b>Part C: Questions 4-8 - level of satisfaction with the following</b>	<b>N</b>	<b>Median</b>	<b>Mode</b>	<b>IRQ (Q3-Q1)</b>
Q4: Design and animation of virtual characters (avatars)	24	4	4	2,5 (4,5-2)
Q5: Ease of applying the gestures shown by the virtual character	24	4	4	1 (4-3)
Q6: Quality of feedback from the application when I performed a gesture correctly or incorrectly	24	4	5,4	2 (5-3)
Q7: Authenticity of the virtual workshop representation	24	4	5	3 (5-2)
Q8: Educational value of the exhibition	24	4	4	1 (4,5-3,5)

**Table 27: Median, mode, and inter-quartile ranges for ad-hoc questions – Glass application**

	<b>Q1 Freq. (%)</b>	<b>Q2 Freq. (%)</b>	<b>Q3 Freq. (%)</b>
None at all	17%	4%	13%
Very little	38%	13%	8%
Neutral	0%	4%	4%
Somewhat	29%	58%	42%
Very much	17%	21%	33%

**Table 28: Frequency of answers for questions Q1-3 – Glass application**

	<b>Q4 Freq. (%)</b>	<b>Q5 Freq. (%)</b>	<b>Q6 Freq. (%)</b>	<b>Q7 Freq. (%)</b>	<b>Q8 Freq. (%)</b>
Very unsatisfied	4%	0%	0%	4%	0%
Unsatisfied	25%	21%	21%	25%	13%
Neutral	8%	13%	21%	17%	50%
Satisfied	38%	46%	29%	17%	50%
Very satisfied	25%	21%	29%	38%	25%

**Table 29: Frequency of answers for questions Q4-8 – Glass application**

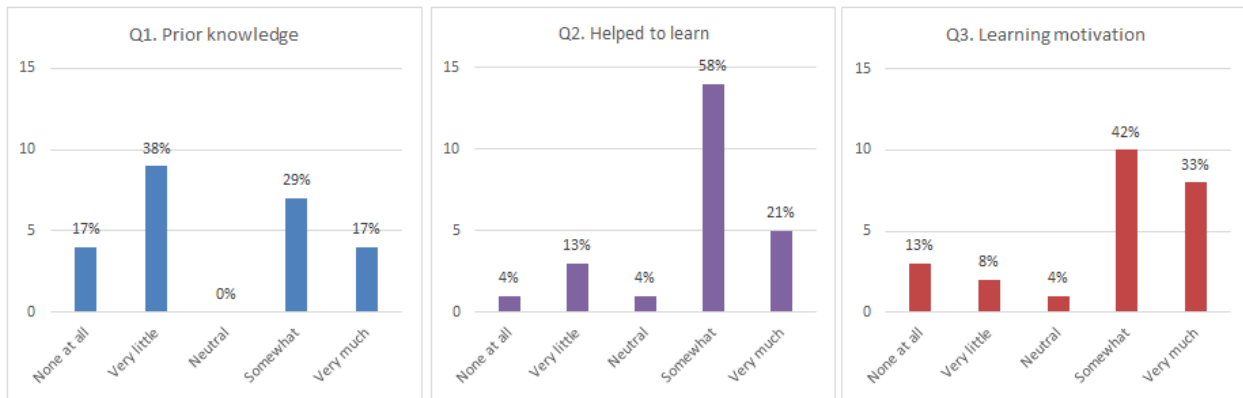


Figure 92: Frequency for ad-hoc questions Q1-3 – Glass application

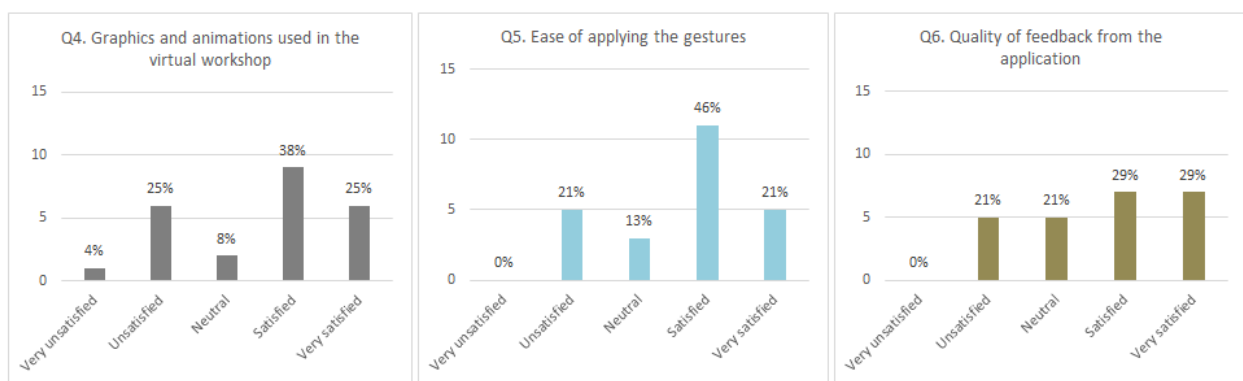


Figure 93: Frequency for ad-hoc questions Q4-6 – Glass application

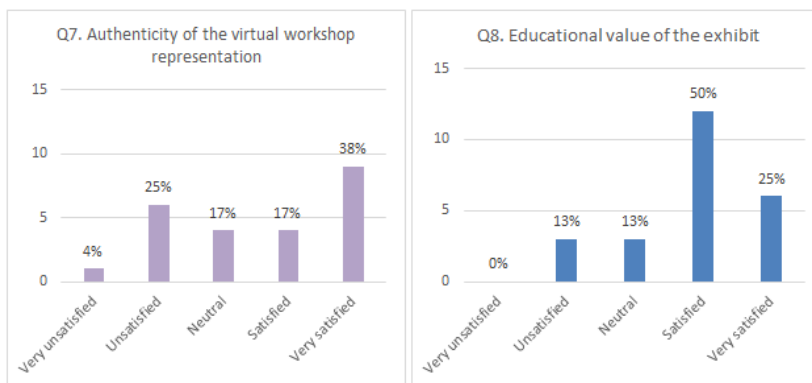


Figure 94: Frequency for ad-hoc questions Q7-8 – Glass application

From the data presented in the tables above, from this sample of visitors, 46% of them stated that they had some prior knowledge of the craft of glass blowing (Q1), while 55% stated that they had little to no prior knowledge. The majority of the respondents said that they thought that the application helped them learn more about it (Q2) and made them want to learn more about it (Q3), with both questions receiving a *median* and a *mode* of 4. This result coincides with the sentiment of the majority of the respondents, 75%, who rated their level of satisfaction with the educational value of the application positively (Q8).

Looking at the results for questions, Q4-Q8, where the respondents were asked to indicate their level of satisfaction with various parameters of the application, the calculated *median* and *mode* were 4. For Q7 (authenticity of the virtual workshop) the *mode* was 5. Overall, these results show that the majority of the respondents have rated positively all aspects of the application.

Respectively, looking at the graphs, it can be seen that the majority of respondents rated positively their level of satisfaction with the measured parameters, as follows: 55% - graphics and animations (Q4), 67% - ease of applying the gestures (Q5), 58% - the quality of feedback received regarding the correctness of gesture applied (Q6), and 56% - authenticity of the virtual workshop (Q7). Looking at the individual comments of those respondents who rated negatively on the above parameters, to examine what could have caused their negative reaction, the lack of sound in the virtual workshop, the way the instructions on how to do the gestures were presented, and missing more context on how the gestures are tied in the whole process of glass blowing seemed to be the factors that affected their scores.

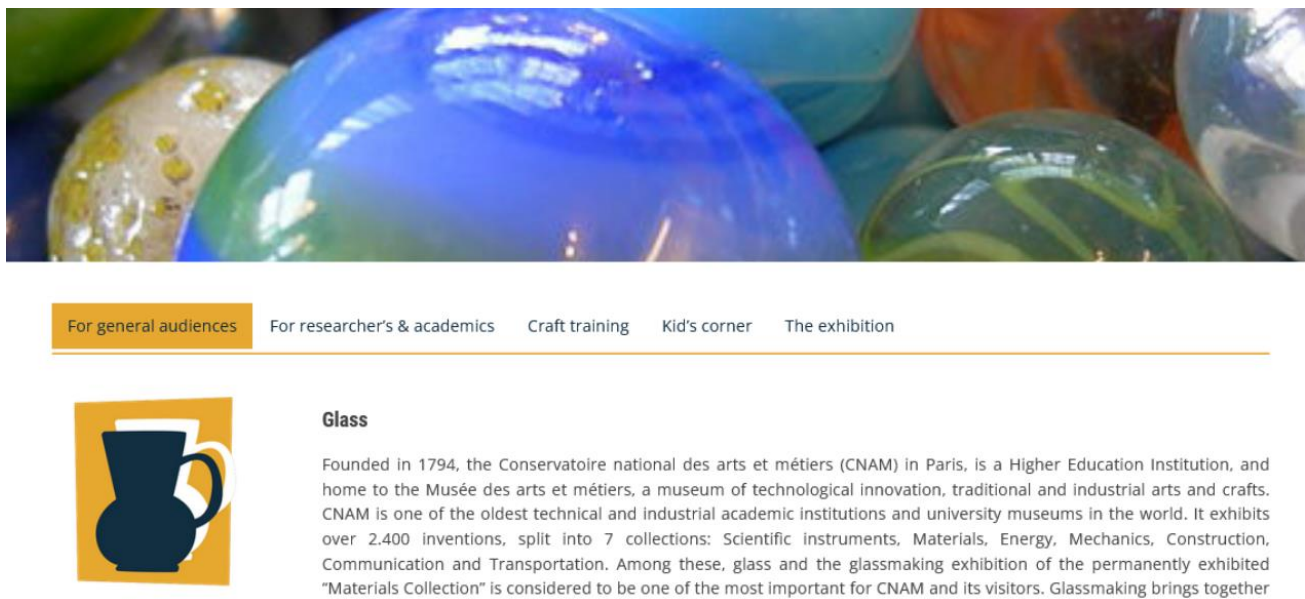
### 7.3 Discussion of evaluation results

The user-based evaluation of the installations and applications at the three pilot sites aimed at investigating their overall usability and user-experience. To this end, post-interaction questionnaires were constructed for each individual application, which included both quantitative and qualitative metrics. To ensure the validity and reliability of the quantitative results, the UEQ a well-established standardized questionnaire was used, which measures both usability and user experience aspects of a system. For the qualitative data, ad-hoc questions in Likert format and open-ended questions were utilized. The questionnaires were handed out by cultural partners to visitors of the museum that were willing to fill them out after spending some time interacting with the applications. The analysis of the results of both the quantitative and qualitative metrics showed that the applications were received positively and with enthusiasm by the visitors who answered the questionnaires. All five installations received positive UEQ scores, while the feedback received from the ad-hoc and open-ended questions supported the calculated user experience scores. At the same time, problems that were observed and noted by the respondents of the questionnaires or museum staff were addressed and improvements were made in the latest versions of the applications.

## 8. Web-based communication of the pilots

All of the Mingei pilots have physical installations and an online counterpart. The online components are part of the Mingei website [126]. The online pilots were used as a means of communicating both the project details and also part of the experiences. Each pilot site page was structured accordingly, in a way that users may access information and content based on their interests. The horizontal design and analysis of the online pilots are provided in D6.5. In the following, we only discuss the parts of the online pilots, relevant to education and training.

### 8.1 Glass



**Figure 95. A segment of the glass pilot landing page.**

From the glass pilot landing page [129], visitors can access rich audiovisual information and contextualisation narratives suitable for general audiences.

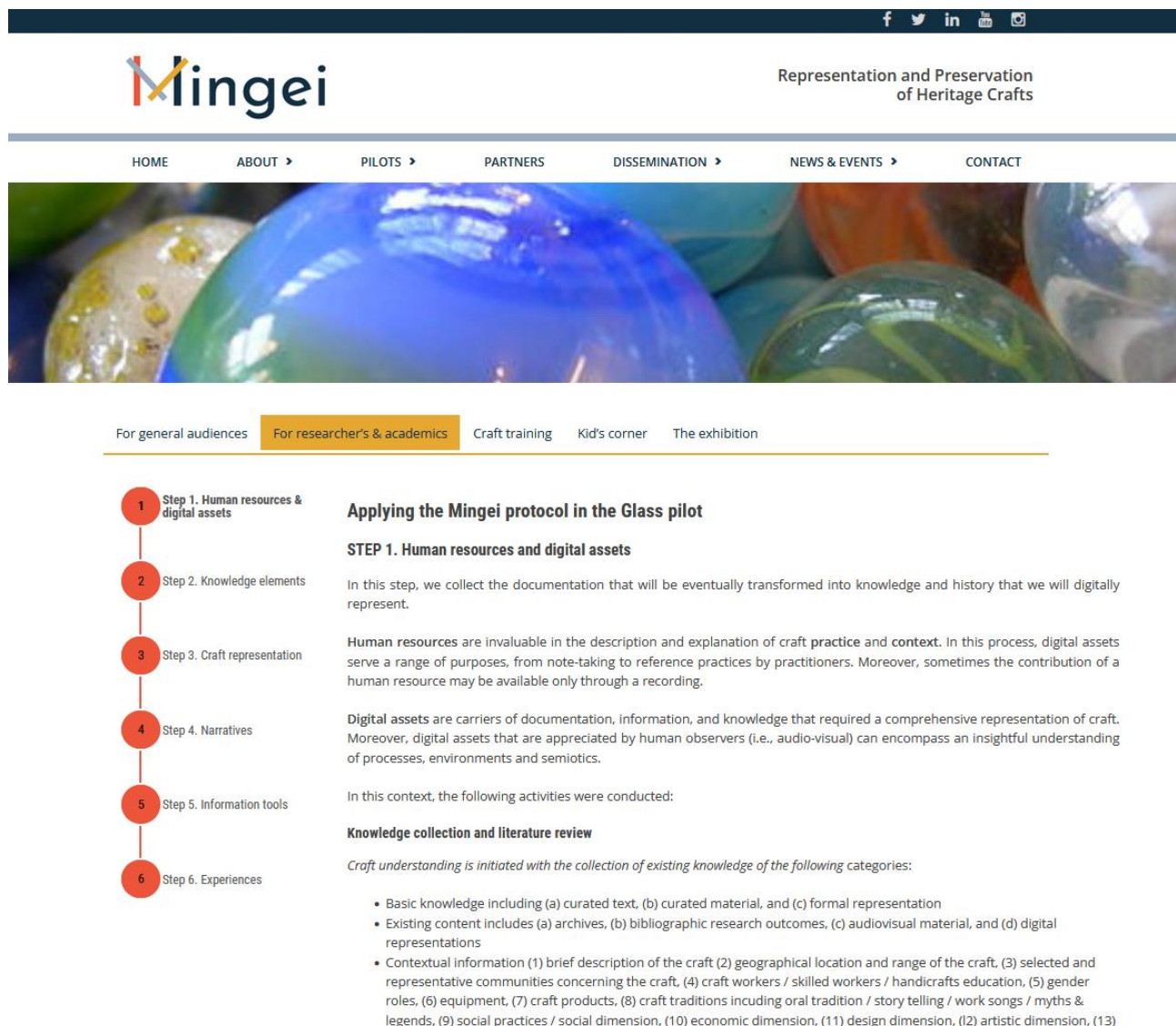
More specifically from the landing page visitors may access:

- information on the socio-historic context of glassblowing through narratives.
- Introductions to the main tools and machines used in a glass workshop.
- Presentation of the glassblowing workshop
- Abstracted craft action representations
- Illustrated demonstrations of the carafe making process

While this info appears on the main page, other pages go deeper into information following the interests of each visitor.

#### 8.1.1 Researchers and Academics

For researchers and academics, there is a page where Mingei presents how it applied the Mingei protocol to the glassblowing instance presenting step by step the scientific and technical work done and linking to the project's publications. As shown in Figure 95 on the left side of the page there is a navigation bar presenting the steps of the protocol. The selection of an item from the navigation bar results in the presentation of all the activities conducted by the project in the specific step of the protocol.



The screenshot shows the Mingei website interface. At the top, there is a dark blue header with the Mingei logo and the text 'Representation and Preservation of Heritage Crafts'. Below this is a navigation bar with links: HOME, ABOUT, PILOTS, PARTNERS, DISSEMINATION, NEWS & EVENTS, and CONTACT. A large banner image shows colorful glassblowing. Below the banner, there is a sub-navigation bar with options: 'For general audiences', 'For researcher's & academics' (selected), 'Craft training', 'Kid's corner', and 'The exhibition'. The main content area is titled 'Applying the Mingei protocol in the Glass pilot'. On the left, there is a vertical navigation bar with six steps, each in a red circle: 1. Step 1. Human resources & digital assets, 2. Step 2. Knowledge elements, 3. Step 3. Craft representation, 4. Step 4. Narratives, 5. Step 5. Information tools, and 6. Step 6. Experiences. The main content area for Step 1 is titled 'STEP 1. Human resources and digital assets'. It contains a paragraph: 'In this step, we collect the documentation that will be eventually transformed into knowledge and history that we will digitally represent.' followed by a paragraph: 'Human resources are invaluable in the description and explanation of craft practice and context. In this process, digital assets serve a range of purposes, from note-taking to reference practices by practitioners. Moreover, sometimes the contribution of a human resource may be available only through a recording.' and another paragraph: 'Digital assets are carriers of documentation, information, and knowledge that required a comprehensive representation of craft. Moreover, digital assets that are appreciated by human observers (i.e., audio-visual) can encompass an insightful understanding of processes, environments and semiotics.' Below this, it says 'In this context, the following activities were conducted:' followed by a sub-header 'Knowledge collection and literature review' and a paragraph: 'Craft understanding is initiated with the collection of existing knowledge of the following categories:' and a list of activities:

- Basic knowledge including (a) curated text, (b) curated material, and (c) formal representation
- Existing content includes (a) archives, (b) bibliographic research outcomes, (c) audiovisual material, and (d) digital representations
- Contextual information (1) brief description of the craft (2) geographical location and range of the craft, (3) selected and representative communities concerning the craft, (4) craft workers / skilled workers / handicrafts education, (5) gender roles, (6) equipment, (7) craft products, (8) craft traditions including oral tradition / story telling / work songs / myths & legends, (9) social practices / social dimension, (10) economic dimension, (11) design dimension, (12) artistic dimension, (13)

Figure 96. Glass pilot – for researchers and academics.

### 8.1.2 craft education and training

For craft education, the specific page presents the representation of glassblowing schemas and processes and their implementation in the context of immersive craft presentations. Visitors are introduced to the tools and machines used in the craft and abstracted craft visualisation of specific craft actions. Direct links are provided to the MOP to browse and see the vocabularies of tools and



actions. In the kid's corner, visitors can browse educational material such as the Mingei comic book presenting the process of creating a glass carafe.

A selection of indicative segments from this page is presented in the following figure:

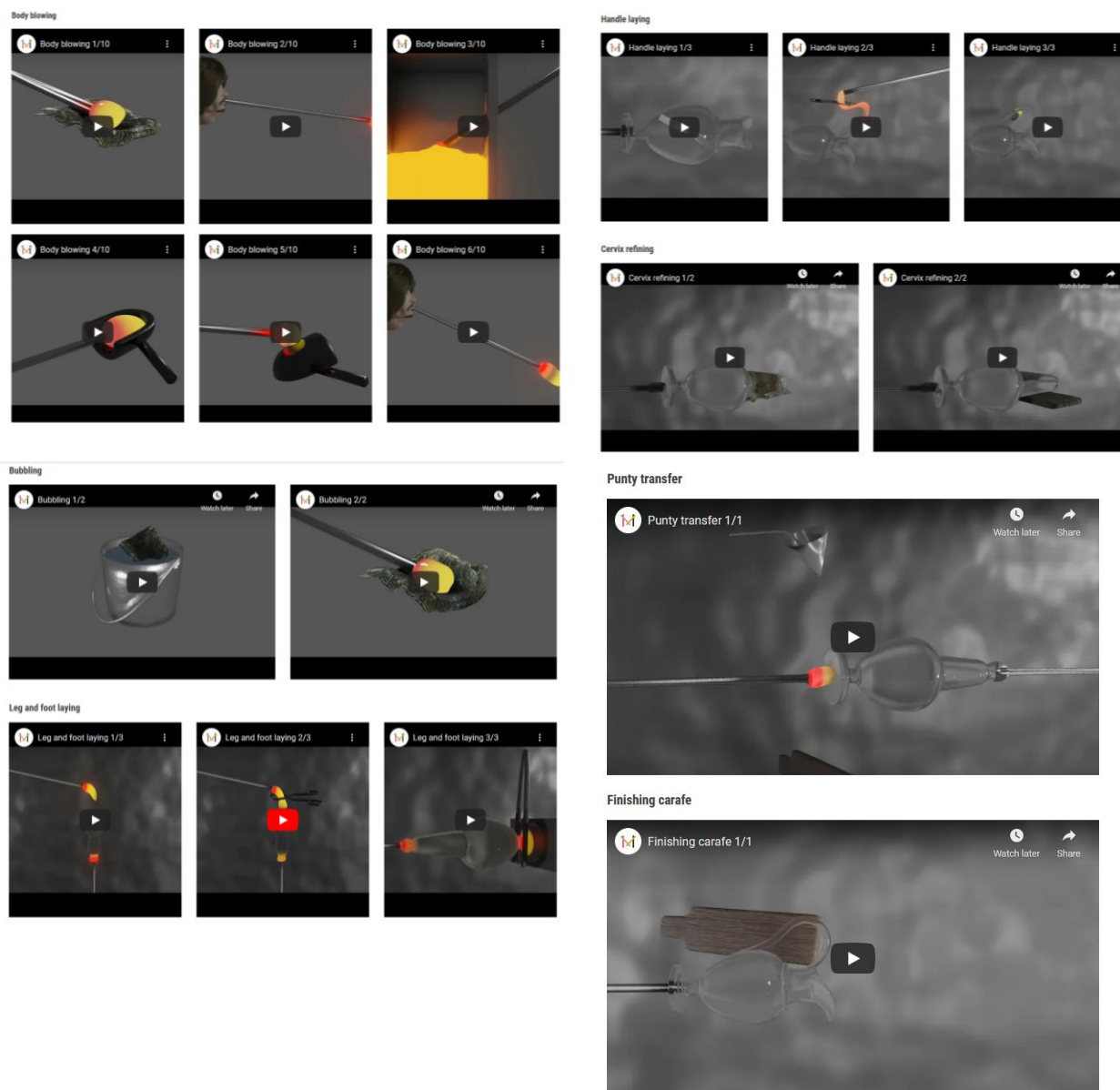
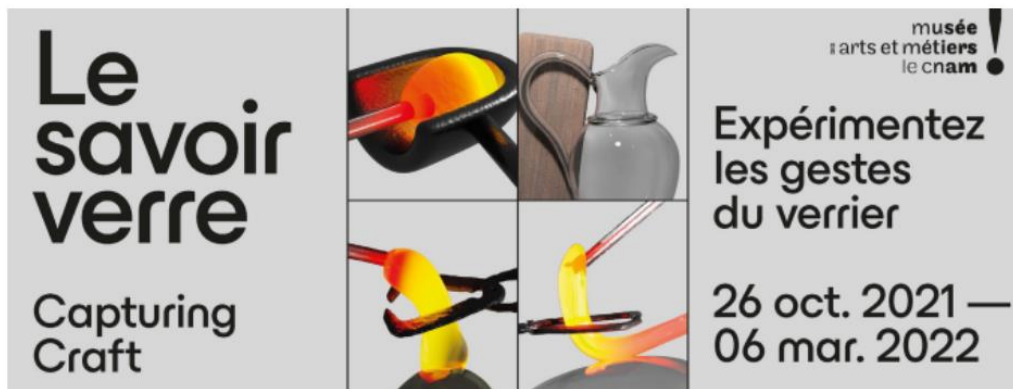


Figure 97. Glass pilot – education and training material.

### 8.1.3 Exhibition

The exhibition page presents information on the exhibition for the period of its operation and sums up the outcomes through audio-visual demonstrations that will be available for communication of the pilot outcomes after its end.

## Location



Visit our installation at the museum of CNAM where the worlds of academics and professional activity come together. It is the only higher education establishment dedicated to life-long professional training. A dedicated space at the cathedral which is part of the museum invites you to experience the craft of glassblowing and use actual glassblowing tools.

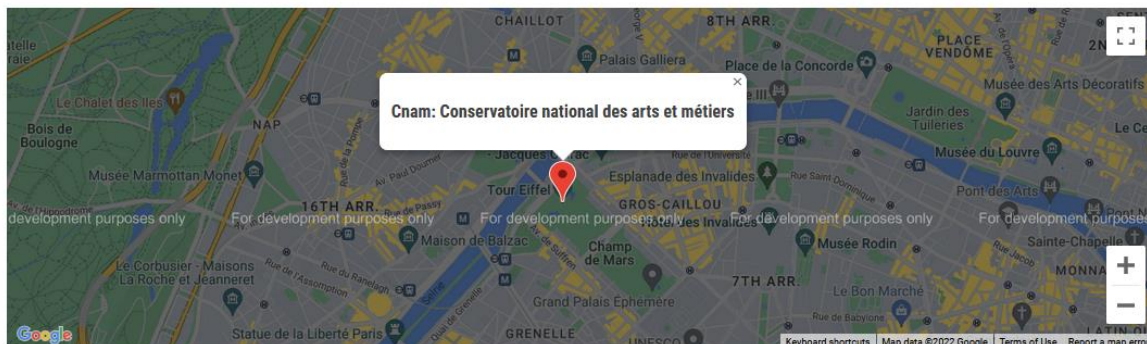


Figure 98. A segment of the CNAM exhibition page.

Furthermore, from this page, the visitors may experience part of the installation concerning the presentation of the glass workshop and tools and the virtual demonstration of the glassblowing process for the creation of the Glass Carafe as shown in the following figure.

### Experience it online!



Figure 99. Online presentation of the virtual glassblowing workshop.

## 8.1.4 Kid's corner

In the kid's corner, little friends of Mingei may learn about the glassblowing craft through an online comic book available to download and share! An example of its presentation on the pilot page is presented in Figure 100.

For general audiences

For researcher's &amp; academics

Craft training

Kid's corner

The exhibition

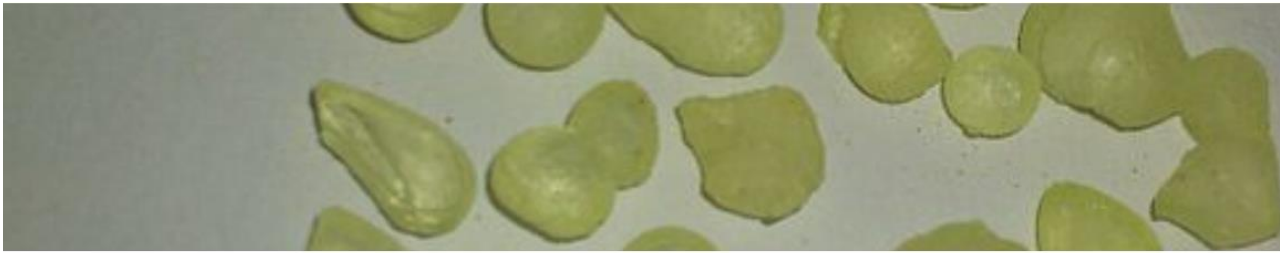


Figure 100. Glassblowing comic book.

## 8.2 Mastic

The mastic pilot landing page [128] is structured as follows. It provides information on the socio-historic context of mastic cultivation through narratives, it introduces part of the Chios Cultural Heritage relevant to the cultivation of mastic such as villages, tools, traditional costumes, etc and introduces aspects of the pilot site relevant to the industrial production of mastic chicle.



[For general audiences](#)[For researcher's & academics](#)[Craft training](#)[Kid's corner](#)[The exhibition](#)[Thematic tourism](#)[History and society](#)

### Mastic

Mastiha, or mastic, is a product from the mastic tree, which exclusively grows in the south-west of Chios Island in Greece. This HC is therefore highly localised (indigenous craft) and part of the fabric of local life. The 24 villages from where mastiha is harvested are known as Mastihochoria, or Mastic Villages, their name being an indication of the importance of mastiha for the region. It is an outdoor craft, which relies on cottage industry while it is also centralised and organised through the Chios Mastic Growers Association. The production of mastiha, an ancestral practice, unaltered over time, is a family occupation that requires laborious care throughout the year, and in which men and women of all ages participate on equal terms. Tasks are divided across genders and ages. The culture of mastiha represents a comprehensive social event, around which networks of alliances and mutual help have been established in society. Traditions and legends survive in the vernacular language, some of religious nature. The knowledge for growing mastiha follows certain rules and traditional characteristics, which ensure its authenticity, while also promoting improvisation and individuality. The craft and local life still witness age-old traditions related to the production of mastiha, even if the cultivation and application of mastiha are constantly subject to innovation.

**Figure 101. A segment of the mastic pilot landing page.**

## 8.2.1 Researchers and Academics

For researchers and academics, there is a page where Mingei presents how it applied the Mingei protocol to the mastic craft instance presenting step by step the scientific and technical work done and linking to the project's publications. An example of this page for step 5 of the Mingei protocol for the Mastic cultivation instance is presented in Figure 102.

- 1 Step 1. Human resources & digital assets
- 2 Step 2. Knowledge elements
- 3 Step 3. Craft representation
- 4 Step 4. Narratives
- 5 Step 5. Information tools
- 6 Step 6. Experiences

## Applying the Mingei protocol in the Mastic pilot

### Step 5. Information tools

#### Historical narratives

- [The mastic cultivation process](#)
- [A Year in a Mastic Village](#)
- [Mastic Trade & Organization](#)
- [Mastic Industry & the Chios Gum Mastic Growers Association](#)

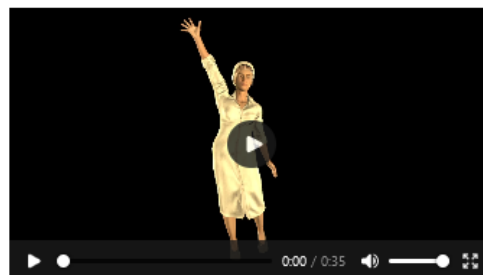
#### Virtual Humans

For the needs of the demonstrations 3D virtual humans, with their corresponding garments and accessories, have been carried out based on cultural and historical information and sources. VHS were created using references from the ethnographic research. For the definition of the 3D meshes and the design of the skin surfaces a customized toolchain was employed that combines automatic generation methods, with manual editing and refining. The approach utilizes VH creation software and 3D modeling software for clothes and accessories. The final model inherits and encapsulates the required structural components, such as bone and skin attachment data. This allows the VH to be dynamically animated and to exhibit real-time animation capabilities.

Another important aspect for attaining a high level of realism is the motion, behavior, and natural interaction of the VH with users, to avoid the "uncanny valley" effect. The VH must have the ability for verbal as well as nonverbal communication skills, be intelligent, have natural communication with the users, perceive information from the user, and physically react with them. The deformation of the skinned characters during their movements must be realistic, smooth, and not contain any discontinuities.

Garment design was also considered during the implementation of avatars. To ensure appropriate rigging, since the generated models are automatically rigged an additional checking was performed to ensure that the rig is applied correctly, and the bones are well adjusted to the 3D body.

An example of a Virtual Human for the mastic pilot can be seen in the following video:



Hello! My name is Anna. Welcome to the chewing gum factory of the Chios Gum Mastic Growers Association.

I am coming from the village of Tholopotami, just a 25 minutes ride by car from the factory. I grew up and still live in the village. Both my parents come from the village and they are cultivators of mastic, olive, and almond trees. We always had an immediate income from the almond production because it does not need any processing, in contrast to mastic that needs year-long processing before we deliver it to the Association. I also have two siblings and when we were all children, we used to accompany our parents in the fields. Nevertheless, I only finished primary school because I was mostly cultivating with my parents.

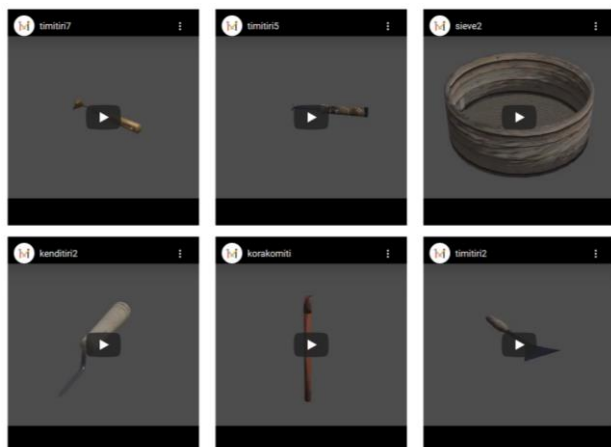
Figure 102. A segment from step 5 on the researchers and academics page.

## 8.2.2 craft education and training

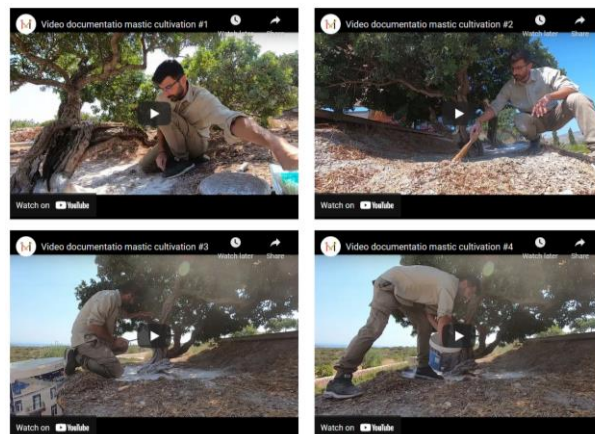
For craft education, the specific page presents the representation of mastic cultivation schemas and processes and their implementation in the context of immersive craft presentations. Visitors are introduced to the tools of cultivation and machines of industrial production. Furthermore, the ethnography conducted on craft understanding is presented together with a visualisation of craft



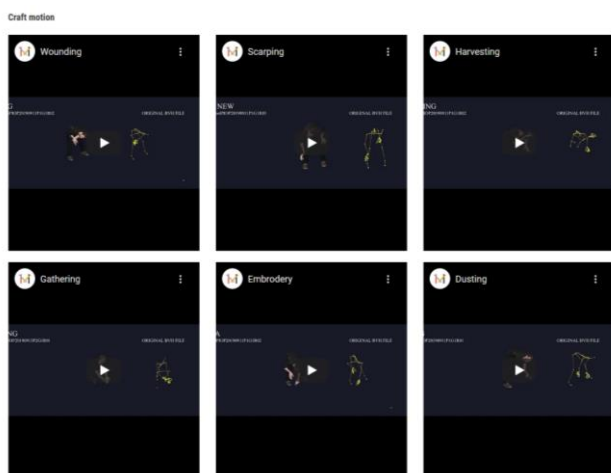
activities both isolated and in a virtual mastic field. Some indicative segments of the page are presented in Figure 107.



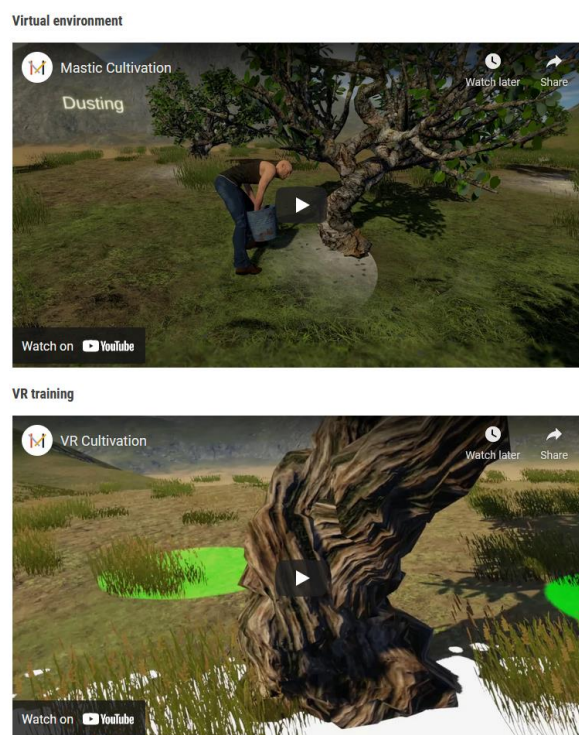
Mastic cultivation tools



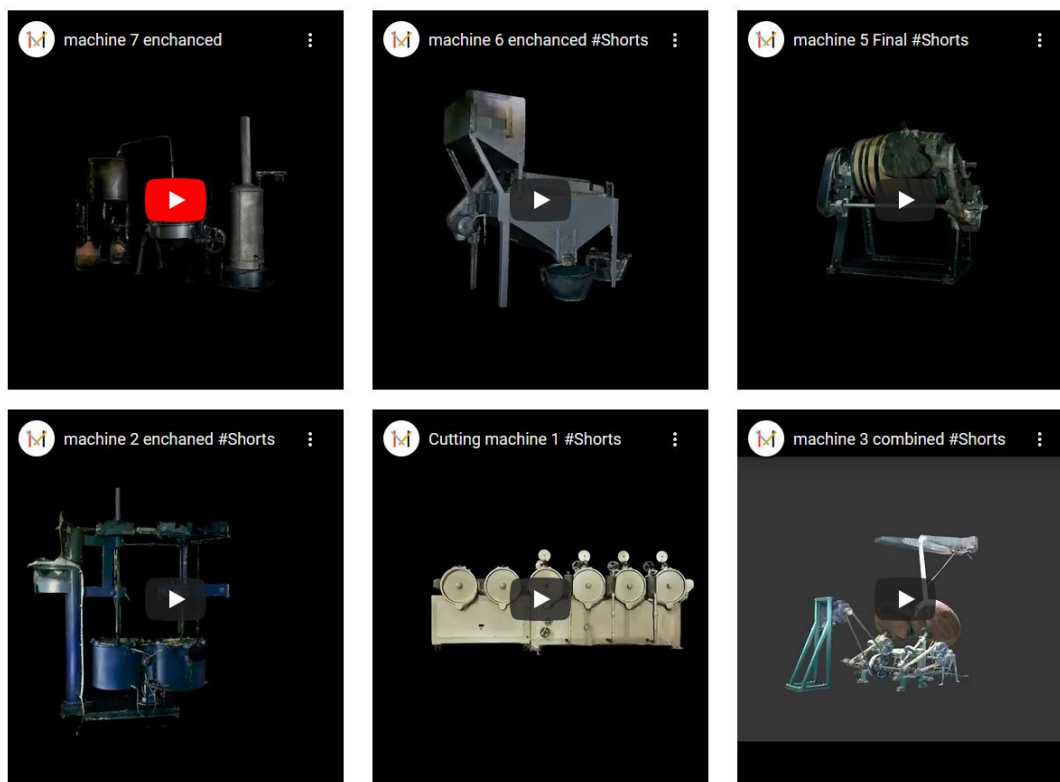
Video documentation



Craft motion visualisation



Virtual craft demonstrations



Industrial production of mastic chicle - machines

**Figure 103. Online craft education for the Mastic cultivation.**

To further enhance the educational dimension, in the mastic pilot, two extra thematic topics were added due to the nature of the craft and its rich socio-historic context. The first section regards information on the thematic tourism activities provided on the island related to the cultivation of mastic (see Figure 104) and the second regards the historical and societal aspects that make the craft of mastic cultivation so unique to the European landscape.

[For general audiences](#)[For researcher's & academics](#)[Craft training](#)[Kid's corner](#)[The exhibition](#)[Thematic tourism](#)[History and society](#)

## Thematic tourism

### An Island Full of surprises

#### About mastic

Mastiha, or mastic, is a product from the mastic tree, which exclusively grows in the south-west of Chios Island in Greece. This HC is therefore highly localised (indigenous craft) and part of the fabric of local life. The 24 villages from where mastiha is harvested are known as Mastihochoria, or Mastic Villages, their name being an indication of the importance of mastiha for the region. It is an outdoor craft, which relies on cottage industry while it is also centralised and organised through the Chios Mastic Growers Association.



The production of mastiha, an ancestral practice, unaltered over time, is a family occupation that requires laborious care throughout the year, and in which men and women of all ages participate on equal terms. Tasks are divided across genders and ages. The culture of mastiha represents a comprehensive social event, around which networks of alliances and mutual help have been established in society. Traditions and legends survive in the vernacular language, some of religious nature. The knowledge for growing mastiha follows certain rules and traditional characteristics, which ensure its authenticity, while also promoting improvisation and individuality. The craft and local life still witness age-old traditions related to the production of mastiha, even if the cultivation and application of mastiha are constantly subject to innovation.

#### Mastic cultivation

##### Processes performed by the producers

Cultivation of new trees: The cultivation of new trees takes place during the winter, from beginning of January until mid-February. The producers cut branches from a male tree of good quality and plant them in depth of 40 to 60 centimetres. It is rather easy for a plant to be successful and it does not need special care in the beginning.

**Figure 104. A segment of the thematic tourism page of the Mastic pilot.**

## 8.2.3 Exhibition

The exhibition page presents information on the permanent exhibition at the Mastic Museum of Chios. The page starts with useful information on how to reach the installation and the museum in general as shown in Figure 105.



### Location



The Chios Mastic Museum has a strong geographical link to the HC it represents. It is built at the south of the Greek island of Chios, whilst the craft is unique to that particular location. Part of the Piraeus Bank Group Cultural Foundation (PIOP), the Chios Mastic Museum is one of a series of craft-related museums across Greece. Mastiha, or mastic, is a product from the mastic tree which exclusively grows in the south-west of Chios.

This HC related to mastic is therefore highly localised (indigenous craft) and part of the fabric of local life. The 24 villages from where mastiha is harvested are known as Mastihochoria, or Mastic Villages, their name being an indication of the importance of mastiha for the region. It is expected that the pilot at the Chios Mastic Museum will explore the impact of hyper-locality, as well as the challenges related to capturing a craft that is highly interwoven with the everyday life of a region. In addition, this pilot offers the possibility of exploring unique traits related to an outdoors craft that relies on cottage industry, but is also centralised and organised through the Association of Mastic Producers of Chios.



*Image courtesy of Piraeus Bank Group Cultural Foundation*



The production of mastiha, an ancestral practice, unaltered over time, is a family occupation that requires laborious care throughout the year, and in which men and women of all ages participate on equal terms. Tasks are divided across genders and ages. Men take care of plant fertilisation, pruning, as well as soil and plant preparation. Women (and, in the past, children too) harvest and prepare the raw product, while older members of the community are responsible for transmitting know-how down the generations. The culture of mastiha represents a comprehensive social event, around which networks of alliances and mutual help have been established in society. Traditions and legends survive in the vernacular language, some of religious nature, such as the one about the tree that shed tears when seeing the death of Saint Isidore. Those from this culture see Mastic as part of their identity, which drives their feeling of belonging to the community. The know-how for growing mastiha follows certain rules and traditional characteristics, which ensure its authenticity, while also promoting improvisation and individuality. The craft and local life still witness age-old traditions related to the production of mastiha, even if the cultivation and application of mastiha are constantly subject to innovation.

**Figure 105. A segment of the Mastic museum exhibition page.**

Furthermore, from this page visitors can get a summary of the main attractions available in the museum as part of the Mingei interventions as shown in Figure 106.

<p><b>Narrations in the Mastic Factory</b></p> <p>The installation at the mastic factory exhibition room is comprised of four tablet devices mounted on floor mounter bases that are located in four main spots of the museum. From each tablet, a specific area of the museum is covered and augmented through the camera of the tablet with hot spots. In each hot spot, one or more stories to be told exist. By selecting the hotspot, a VH appears that is the visual twin of a persona used to work in the factory and operating one of the machines in visual approximation to its location. When the hot spot is selected the VH appears in the factory through the camera of the table to narrate his life story and his daily life and work at the factory.</p> 	<p><b>Craft presentations in the mastic field</b></p> <p>One of the requirements of presenting the craft was to display its seasonality. Very often visitors do not understand the complete process of mastic cultivation. Another necessity for the museum was the exploitation of the external spaces and the beautiful mastic tree field which is often overlooked by the visitors. It became also evident that this "guided" tour (it is a simple and straight path through the phases of mastic cultivation, harvesting, and cleaning) is a perfect example of the yearlong process. Visitors of the rural space outside the museum can experience mastic cultivation in the field through their mobile devices. The application facilitates an AR-capable device to recognize metallic sculptures that exist in the rural space of the museum. Through the camera, these sculptures become alive to present typical cultivation activities. The following figure presents an example of app screens with an emphasis in the middle on the AR augmentation of the sculps that are part of the mastic field with animations of the cultivation process.</p> 
<p><b>Virtual Narrations</b></p>	<p><b>Mobile experiences in the mastic field</b></p>
<p><b>Craft Training</b></p> <p>Craft training is intended for demonstrating the cultivation activities to the visitors of the museum thus providing a more immersive experience. This application was installed on the ground floor of the museum in the multimedia space. The installation is comprised of a personal computer and a monitor together with a depth sensor for tracking the user's actions. The user stands in front of the installation and follows the instructions provided on the screen to mimic craft actions. An example of this process is presented in the following figure.</p> 	<p><b>Presentation of geographic context</b></p> <p>Information on geographical location and context shows environmental aspects affecting craft practice and development. We developed Airborne an Immersive flight simulator allowing users to fly over various mastic villages of Chios. During the flyover, users can stop at each village and retrieve multimedia and text information related to those villages. Airborne is installed in the multimedia room of the museum. The setup was very simple and straightforward as it involved a desktop computer set. There are two options available (a) automated tour and (b) flight simulator. The automated tour targets users that wish to explore the mastic villages in a movie-like way while the flight simulator is more gamplay-oriented since users have control of the virtual drone flying on Chios sky and are free to explore information in any way they like. In the future, the setup will be updated with a large touch-enabled screen to enhance the gameplay of the installation.</p> 
<p><b>Craft training</b></p>	<p><b>Presentation of geographical context</b></p>

Figure 106. Presentation of experiences available on site.

## 8.3 Silk

The silk pilot landing page [127] is structured as follows. It starts with a rich collection of socio-historic narratives that reveal the deep roots of textile tradition in the history and society of the European continent and continues with a demonstration of the outcomes of the project through audiovisual and interactive presentations. Then, the presentation continues with the hidden dimension of textile manufacturing and the processes for preparing a jacquard loom for weaving.




[For general audiences](#)
[For researcher's & academics](#)
[Craft training](#)
[Kid's corner](#)
[The exhibition](#)

### Silk pilot

Pure silk, one of the oldest known natural fibres, is still highly fashionable even after thousands of years. This beautiful and elegant fabric fascinates mankind with its precious radiance, gossamer touch and strength. As long ago as antiquity, the incomparable haptic inspired the powerful in this world to such a degree that they even weighed the fibres in gold. Kings, emperors and the clergy wore splendid silken garments, the wealthy ladies and gentlemen of society did not want to forego silk clothes. The history of city of Krefeld, also referred to as the 'Town Like Silk and Velvet', is closely linked to this magical material.

### Key silk pilot results



#### Historical narratives

Explore our collection of curated historical narratives relevant to the silk industry history of Krefeld from the Mingei Online Platform.



#### Interactive timeline

Explore our interactive streaming gallery of Silk fabulae presenting historical and social events related to the craft of Silk in Krefeld in a timeline format.



#### 3D Reconstructions

View videos of our 3D reconstruction results and explore our interactive ecclesiastical vestment application.



#### Digitisation of textiles, fabrics, and paper

How does fabric look like up close? View a video of how this is possible with the use of our overhead micrometer surface scanner solution.



#### Archives

Learn more about historic patterns of the period.



#### Craft understanding

How does a pattern become a final product? Learn about the Jacquard weaving process and the hidden arts involved.

### Historical narratives – Explore Silk narratives from the Mingei Online Platform

Explore our historical narratives to learn more about Krefeld and its evolution to a major player in the European textile industry. The historic narratives have been produced by curated historic data provided by the museum of Haus der Seidenkultur and authored in the Mingei Online Platform.

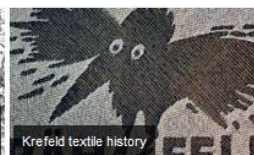
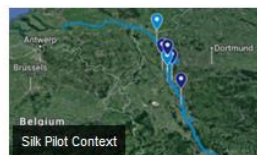


Figure 107. A segment of the Silk pilot landing page.

## 8.3.1 Researchers and Academics

For researchers and academics, there is a page where Mingei presents how it applied the Mingei protocol to the textile manufacturing craft instance presenting step by step the scientific and technical work done and linking to the project's publications. An example of this page for step 3 of the Mingei protocol for the Textile production craft instance is presented in Figure 108.



### Applying the Mingei protocol in the Silk pilot

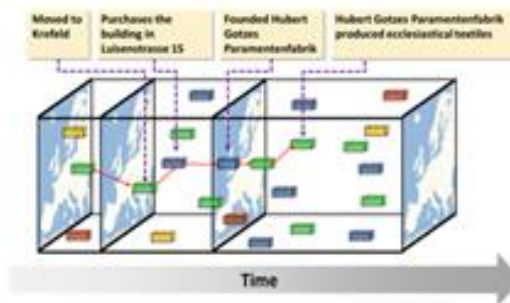
#### STEP 3. Craft Representation

In this step, the individual entities represented in the previous steps are linked to each other into an organic representation of the craft instance. This linkage implements the semantic representation of the craft.

The scope of this representation covers the following craft dimensions:

- Tangible elements, such as materials, tools, and products
- Craft actions and processes
- Contextual knowledge that provides an understanding of
  - Artefact usage
  - The CH of a region and its people embedded in the artefact
  - The historic, geographical, economic, and social dimensions of the associated craft instance.

#### Social and Historic context



#### Representation of Fabulae

Regards the structuring of 'Events' in MOP to 'Fabulae' presenting the sequence of 'Events' that are the backbone of a 'Narrative'. Connection between 'Events' is established by two kinds of relations:

1. Mereological relating events to other events that include them as parts, e.g., the invention of the flying shuttle is part of the life of the Industrial Revolution.
2. Causal dependencies, relating 'Events' that in are predicated to have a cause-effect relationship, e.g., 'The Industrial Revolution resulted in a reduction of the number of weavers'.

Through MOP 'Event' entries are transformed into 'Fabulae'.

Figure 108. A segment from step 3 on the researchers and academics page.

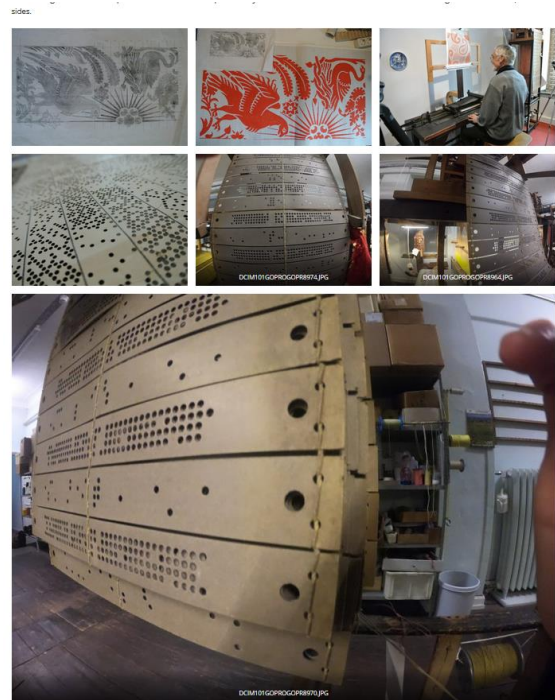
## 8.3.2 craft education and training

For craft training, the specific page introduces the processes and tools used in textile manufacturing including aspects of creative design such as drawing and point paper designing. Examples of information presented from this page are shown in Figure 109.

Examples of looms with a Jacquard attachment is presented below:



Textile manufacturing machinery



Point paper design and punch cards manufacturing

Figure 109. Segments from the education and training page.

### 8.3.3 Kid's corner

In the kid's section, the same aspects are introduced through educational gaming experiences, available online to educate on pattern design and punch card generation. The first of the available games allows kids to create their own punch cards using a real-time Tetris style game and then use the patterns to dress-up manikins.

The second gaming experience allows kids to see scanned vestments from the museum in 3D and learn more information on their history and included patterns.

A segment of the kid's corner page is presented in Figure 110.

## Silk Games!



## Interactive Ecclesiastical Vestments application

Explore ecclesiastical vestments.

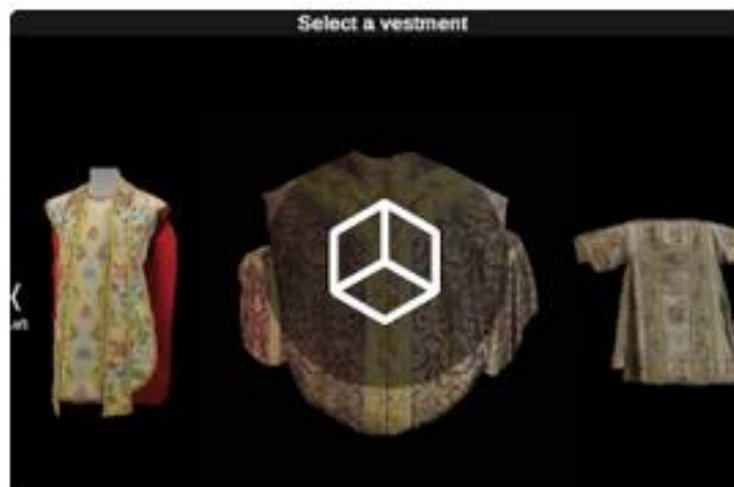


Figure 110. A segment of the kids' corner page.

### 8.3.4 Exhibition

The exhibition page provides practical information on reaching the museum (see and present information on the technology installed as part of the permanent exhibition at the Haus der Seidenkultur at Krefeld, Germany. Furthermore, it sums up the outcomes through audio-visual demonstrations.



For general audiences

For researcher's &amp; academics

Craft training

Kid's corner

The exhibition

### Location



The Haus der Seidenkultur (HdS) is a museum about Krefeld's silk industry, located in a former silk factory that specialised in producing liturgical vestments. The museum has a rich archive and collection of objects related to silk and jacquard weaving, some of its looms are still in operation thanks to a group of volunteers, who had careers in the city's silk weaving industry. HdS provides the case of a craft at risk of becoming extinct. During this pilot, partners will explore the challenges and requirements related to an industrialised craft that takes place in a (small) factory setting. Some of the expected points of attention will be the challenge of dealing with a wide variety of information, from written archival sources to fragile textiles and large looms; the use of machinery; capturing the locality of a craft strongly associated with Krefeld, yet also practiced elsewhere in slightly different ways; recording the activity and noise associated with the craft; the role of gender in silk weaving.



Image courtesy of Haus der Seidenkultur

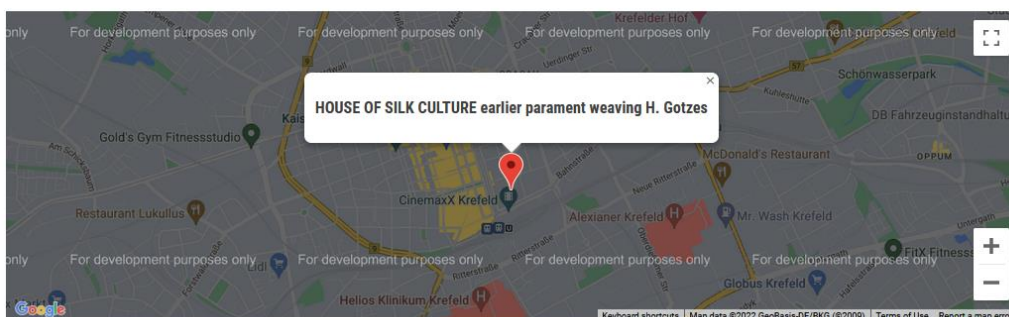


Figure 111. A segment of the exhibition page.



## 9. Discussion and lessons learned

The processes presented in this deliverable are the results of applying the methodology discussed over three years to represent and present the TCs of mastic cultivation, silk weaving and glassblowing. In this period, lessons learned, apply to a wider scientific context based on the collaboration of multiple researchers and scientific disciplines.

### 9.1 Methodology structure

As presented in Section 3 in this work a systematic methodology for the representation and presentation of a TC instance is applied. This methodology, summarized in a series of steps, was adapted to address the needs of each specific TC. Of course, the linear execution of these steps meant that the entirety of digital assets would have been acquired a priori. However, knowledge acquired in the second step in some cases referred to non-digitized items, which were only then identified, and needed to be digitized as new digital assets in the context of the first step. Moreover, more sophisticated digitizations of assets were acquired later on in the timeline of this work, judged so by CH professionals. Thus, the main lesson learned was that the linearity in these steps can be disrupted by refining iterations when needed. However, the methodology was found to be very adaptive to such iterations taking into account that new needs resulted in the application of the previous steps only for the acquired assets and their context.

### 9.2 Collaboration

One of the main challenges faced by the application of this methodology was the need for several scientific disciplines to work together under a unique methodological framework. This was indeed challenging since different scientific approaches, technical tools, and research methods were applied. In this challenge, we learned that the MOP as a single point of representation of research data greatly enhanced the collaboration of the team as it allowed different scientific disciplines to report and document results under a uniform semantic representation. Of course, several adaptations in terminology had to be made for the entire team to have a common understanding of the represented data.

### 9.3 Replicability

Replicability can be judged even from the application in these three use cases by referring to the genericity of the approach. In these use cases, we were able to apply several scientific approaches for each step and combine the results in a single representation. This became evident both in the craft understanding phase where several approaches to studying social and historic contexts were applied and in the data collection step where several scientific methods were used for data acquisitions. Regardless of the heterogeneity of the results MOP has been proven sufficient as a representation and no surprises were encountered in the representation of processes and narratives. Another supportive finding for the replicability of this methodology was that detaching the representation from presentation in this work multiple presentation instances were created from different technologies. This was achieved by applying the exporting functionality of MOP in the representation and leaving it to the developers of the presentation layers to judge the most appropriate way of facilitating the representation in their presentation context. Finally included

web-based presentation modalities in MOP allowed the direct preview and dissemination of the represented knowledge through the Web.

#### **9.4 Potential improvements**

Regarding future improvements of the presented methodology, several directions can be followed. Initially, we acknowledge that the process presented is time and resources demanding considering that the objective is a valid representation that could lead to multiple presentations of a craft. As such, optimizations in the process can significantly improve the uptake of the proposed methodology. To that respect, optimizations could regard the data curatorial platform by simplifying and automating parts of the process to minimize the time spent in data curation in conjunction with the time spent for the scientific exploitation of data. Additionally, simplification could also regard additional actions required for the post-processing of input data by integrating more automated tools and data processing wizards. Furthermore, another direction regards the further validation of the methodology through new craft instances. The study of new instances and the creation of new presentations and visualizations will enhance the value of the representation. Finally, further research could concert computer-aided facilities for the semi-automated creation of craft representations.

## References

1. European Commission, Report on Digitisation, Online Accessibility and Digital Preservation of Cultural Material 2011/711/EU 2011-2013 and 2013-2015
2. Boston Consulting Group, “Digitizing Europe”, Survey Commissioned by Google, May 2016
3. Europeana, Survey Report on Digitisation in European Cultural Heritage Institutions, ENUMERATE EU project, Deliverable 1.2, 2015
4. European Commission, Cultural heritage research. Survey and outcomes of projects within the Environment Theme From 5th to 7th FP 2012.
5. ETH-Bibliothek, Best Practices Digitization (Version 1.1, 2016)
6. UNESCO, Text of the Convention for the Safeguarding of the Intangible Cultural Heritage, 2003.
7. Metcalf, Contemporary Craft: A Brief Overview, in Exploring Contemporary Craft: History, Theory and Critical Writing, 1998
8. L. Donkin, Crafts and Conservation: Synthesis Report for ICCROM 2001
9. Cruz-Neira, C., Sandin, D. J., & DeFanti, T. A. (1993, September). Surround-screen projection-based virtual reality: the design and implementation of the CAVE. In Proceedings of the 20th annual conference on Computer graphics and interactive techniques (pp. 135-142).
10. Roussou, M. (2004). Learning by doing and learning through play: an exploration of interactivity in virtual environments for children. Computers in Entertainment (CIE), 2(1), 10-10.
11. Liarokapis, F., & White, M. (2005). Augmented reality techniques for museum environments. Mediterranean Journal of Computers and Networks, 1(2), 95-102.
12. ARCO (Augmented Representation of Cultural Objects) consortium. Available online: <http://www.arco-web.org> (accessed on May 2021)
13. White, M., Mourkoussis, N., Darcy, J., Petridis, P., Liarokapis, F., Lister, P., ... & Gaspard, F. (2004, June). ARCO-an architecture for digitization, management and presentation of virtual exhibitions. In Proceedings Computer Graphics International, 2004. (pp. 622-625). IEEE.
14. Karuzaki, E., Partarakis, N., Patsiouras, N., Zidianakis, E., Katzourakis, A., Pattakos, A., ... & Zabulis, X. (2021). Realistic Virtual Humans for Cultural Heritage Applications. Heritage, 4(4), 4148-4171.
15. Milgram, P., & Kishino, F. (1994). A taxonomy of mixed reality visual displays. IEICE TRANSACTIONS on Information and Systems, 77(12), 1321-1329.
16. Hughes, C. E., Stapleton, C. B., Hughes, D. E., & Smith, E. M. (2005). Mixed reality in education, entertainment, and training. IEEE computer graphics and applications, 25(6), 24-30.
17. Hall, T., Ciolfi, L., Bannon, L., Fraser, M., Benford, S., Bowers, J., ... & Flintham, M. (2001, November). The visitor as virtual archaeologist: explorations in mixed reality technology to enhance educational and social interaction in the museum. In Proceedings of the 2001 conference on Virtual reality, archeology, and cultural heritage (pp. 91-96).
18. Fast-Berglund, Å., Gong, L., & Li, D. (2018). Testing and validating Extended Reality (xR) technologies in manufacturing. Procedia Manufacturing, 25, 31-38.
19. Margetis, G., Papagiannakis, G., & Stephanidis, C. (2019). Realistic natural interaction with virtual statues in x-reality environments. International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences.
20. Fairweather, P., Culture Vultures or the Boorish Masses – Who are Cultural Visitors in Australia? Canberra: Tourism Research Australia, Cultural Tourism Conference, February 2008.
21. UNWTO, Study on Tourism and Intangible Cultural Heritage, 2012, ISBN 978-92-844-1479-6
22. O. Acker, F. Gröne, L. Kropiunigg, T. Lefort, The digital future of creative Europe: The impact of digitization and the Internet on the creative industries in Europe, Strategy&, 2015.

23. European Council, “Framework Convention on the Value of Cultural Heritage for Society”, CETS No.199, Faro, 27/10/2005.
24. Blender 3D. Available online: <https://www.blender.org/>, accessed on 10-11-2021
25. Unity 3D. Available online: <https://unity.com/>, accessed on 10-11-2021
26. High Definition Render Pipeline. Available online: <https://docs.unity3d.com/Packages/com.unity.render-pipelines.high-definition@10.8/manual/index.html>, accessed on 10-11-2021
27. Fuse. Available online: <https://store.steampowered.com/app/257400/Fuse/>, accessed on 10-11-2021
28. Character creator 4. Available online: <https://www.reallusion.com/>, accessed on 10-11-2021
29. 3ds-max. Available online: <https://www.autodesk.com/products/3ds-max>, accessed on 10-11-2021
30. Mixamo. Available online: <https://www.mixamo.com/>, accessed on 10-11-2021
31. MacDorman, K. F.; Chattopadhyay, D. (2016). "Reducing consistency in human realism increases the uncanny valley effect, increasing category uncertainty does not". *Cognition*. 146: 190–205. doi:10.1016/j.cognition.2015.09.019. PMID 26435049.
32. MacDorman, K. F.; Ishiguro, H. (2006). "The uncanny advantage of using androids in social and cognitive science research" (PDF). *Interaction Studies*. 7 (3): 297–337. doi:10.1075/is.7.3.03mac. S2CID 17092251. Archived from the original (PDF) on 2019-02-18.
33. E. Ceseracciu, Z. Sawacha, and C. Cobelli. 2014. Comparison of Markerless and Marker-Based Motion Capture Technologies through Simultaneous Data Collection during Gait: Proof of Concept. *PLOS ONE* 9, 3 (03 2014), 1–7. <https://doi.org/10.1371/journal.pone.0087640>
34. N. Sarafianos, B. Boteanu, B. Ionescu, and I. Kakadiaris. 2016. 3D Human pose estimation: A review of the literature and analysis of covariates. *Computer Vision and Image Understanding* 152 (2016), 1 – 20. <https://doi.org/10.1016/j.cviu.2016.09.002>
35. N. Partarakis, P. Doulgeraki, E. Karuzaki, I. Adami, S. Ntoa, D. Metilli, V. Bartalesi, C. Meghini, Y. Marketakis, M. Theodoridou, D. Kaplanidi, X. Zabulis, "Representation of socio-historical context to support the authoring and presentation of multimodal narratives: The Mingei Online Platform", *Journal on Computing and Cultural Heritage*, (to appear, JOCCH-20-0216).
36. Mingei Online Platform. Available online: <http://mop.mingei-project.eu>, accessed on 10-11-2021
37. Object Management Group. 2007. OMG Unified Modelling Language (OMG UML), Superstructure Version 2.1.1
38. Available online: <https://www.openstreetmap.org>, accessed on 10-11-2021
39. Zabulis, X., Meghini, C., Partarakis, N., Kaplanidi, D., Doulgeraki, P., Karuzaki, E., ... & Beisswenger, C. (2019). What is needed to digitise knowledge on Heritage Crafts?. *Memoriamedia Review*.
40. Zabulis, X., Meghini, C., Partarakis, N., Beisswenger, C., Dubois, A., Fasoula, M., ... & Galanakis, G. (2020). Representation and preservation of Heritage Crafts. *Sustainability*, 12(4), 1461.
41. Partarakis N., Zabulis X., Antona M., Stephanidis C. (2020) [ In: F., Voulodimos A., Doulamis N., Doulamis A. (eds) *Visual Computing for Cultural Heritage*. Springer Series on Cultural Computing. Springer, Cham. [https://doi.org/10.1007/978-3-030-37191-3\\_13](https://doi.org/10.1007/978-3-030-37191-3_13)
42. Anni Albers, *On Weaving*, Dover Publications Inc., 1965.
43. Zabulis, X.; Koutlemanis, P.; Stivaktakis, N.; Partarakis, N. A Low-Cost Contactless Overhead Micrometer Surface Scanner. *Appl. Sci.* 2021, **11**, 6274. <https://doi.org/10.3390/app11146274>
44. UNESCO, Text of the Convention for the Safeguarding of the Intangible Cultural Heritage, 2003

45. A. Qammar and A.A. Argyros, "MocapNET: Ensemble of SNN Encoders for 3D Human Pose Estimation in RGB Images", In British Machine Vision Conference (BMVC 2019), BMVA, Cardiff, UK, September 2019
46. P. Panteleris, I. Oikonomidis and A.A. Argyros. Using a single RGB frame for real time 3D hand pose estimation in the wild. In IEEE Winter Conference on Applications of Computer Vision (WACV 2018), pp. 436-445, lake Tahoe, NV, USA, March 2018.
47. F. Goudis, P. Panteleris, I. Oikonomidis and A.A. Argyros. Accurate Hand Keypoint Localization on Mobile Devices, In Machine Vision Applications (MVA 19), Tokyo, Japan, May 2019
48. <https://www.autodesk.com/products/motionbuilder>
49. Fowler, M. (2004). UML distilled: a brief guide to the standard object modeling language. Addison-Wesley Professional.
50. Getty Arts and Architecture thesaurus. Available online: <https://www.getty.edu/research/tools/vocabularies/aat/>, accessed on 10-11-2021
51. UNESCO Thesaurus. Available online: <http://vocabularies.unesco.org/browser/thesaurus/en/>, accessed on 10-11-2021
52. Doerr, M., Gradmann, S., Hennicke, S., Isaac, A., Meghini, C., & Van de Sompel, H. (2010, August). The europeana data model (edm). In World Library and Information Congress: 76th IFLA general conference and assembly (Vol. 10, p. 15).
53. Hartig, O., Bizer, C., & Freytag, J. C. (2009, October). Executing SPARQL queries over the web of linked data. In International semantic web conference (pp. 293-309). Springer, Berlin, Heidelberg
54. Open pose. Available online: <https://github.com/CMU-Perceptual-Computing-Lab/openpose> , accessed on 10-11-2021
55. Tscheu, F., & Buhalis, D. (2016). Augmented reality at cultural heritage sites. In Information and communication technologies in tourism 2016 (pp. 607-619). Springer, Cham
56. Partarakis, N., Grammenos, D., Margetis, G., Zidianakis, E., Drossis, G., Leonidis, A., ... & Stephanidis, C. (2017). Digital cultural heritage experience in Ambient Intelligence. In Mixed reality and gamification for cultural heritage (pp. 473-505). Springer, Cham.
57. Magnenat-Thalmann, Nadia; Thalmann, Daniel (2005-11-24). "Virtual humans: thirty years of research, what next?". The Visual Computer. 21 (12): 997–1015. doi:10.1007/s00371-005-0363-6. ISSN 0178-2789.
58. Jung T, Tom Dieck MC, Lee H, Chung N (2016) Effects of virtual reality and augmented reality on visitor experiences in the museum. [https://doi.org/10.1007/978-3-319-28231-2\\_45](https://doi.org/10.1007/978-3-319-28231-2_45)
59. Billinghurst M., Kato H., Myojin S. (2009) Advanced Interaction Techniques for Augmented Reality Applications. In: Shumaker R. (eds) Virtual and Mixed Reality. VMR 2009. Lecture Notes in Computer Science, vol 5622. Springer, Berlin, Heidelberg. [https://doi.org/10.1007/978-3-642-02771-0\\_2](https://doi.org/10.1007/978-3-642-02771-0_2)
60. L. Merino, M. Schwarzl, M. Kraus, M. Sedlmair, D. Schmalstieg and D. Weiskopf, "Evaluating Mixed and Augmented Reality: A Systematic Literature Review (2009-2019)," 2020 IEEE International Symposium on Mixed and Augmented Reality (ISMAR), 2020, pp. 438-451, doi: 10.1109/ISMAR50242.2020.00069
61. Eleonora Bottani & Giuseppe Vignali (2019) Augmented reality technology in the manufacturing industry: A review of the last decade, IISE Transactions, 51:3, 284-310, DOI: 10.1080/24725854.2018.1493244
62. Rankohi, S., Waugh, L. Review and analysis of augmented reality literature for the construction industry. Vis. in Eng. 1, 9 (2013). <https://doi.org/10.1186/2213-7459-1-9>



63. Bang, J., Lee, D., Kim, Y., & Lee, H. (2017, February). Camera pose estimation using optical flow and ORB descriptor in SLAM-based mobile AR game. In 2017 International Conference on Platform Technology and Service (PlatCon) (pp. 1-4). IEEE.
64. Aldoma, A., Tombari, F., Rusu, R. B., & Vincze, M. (2012, August). OUR-CVFH-oriented, unique and repeatable clustered viewpoint feature histogram for object recognition and 6DOF pose estimation. In Joint DAGM (German Association for Pattern Recognition) and OAGM Symposium (pp. 113-122). Springer, Berlin, Heidelberg
65. Sandor C, Fuchs M, Cassinelli A, Li H, Newcombe R, Yamamoto G, Feiner S (2015) Breaking the barriers to true augmented reality.
66. Geronikolakis, E., Zikas, P., Kateros, S., Lydatakis, N., Georgiou, S., Kentros, M., & Papagiannakis, G. (2020). A True AR Authoring Tool for Interactive Virtual Museums.
67. Magnenat-Thalmann, N., Foni, A., Papagiannakis, G., and Cadi-Yazli, N. 2007. Real-Time Animation and Illumination in Ancient Roman Sites. The International Journal of Virtual Reality, IPI Press, 6 (1), pp. 11 – 24.
68. Pilet, J., Lepetit, V. and Fua, P. 2008. Fast Non-Rigid Surface Detection, Registration and Realistic Augmentation, International Journal of Computer Vision, February, volume 76, number 2.
69. Nowrouzezahrai, D., Geiger, S., Mitchell, K. and Sumner, R., Jarosz, W. and Gross, M. 2011. Light Factorization for Mixed-Frequency Shadows in Augmented Reality. IEEE International Symposium on Mixed and Augmented Reality.
70. <https://www.autodesk.com/products/motionbuilder/overview>
71. Papaefthymiou, M., Feng, A., Shapiro, A., Papagiannakis, G., “A fast and robust pipeline for populating mobile AR scenes with gamified virtual characters”. ACM SIGGRAPH-ASIA 2015, Symposium On Mobile Graphics and Interactive Applications, Kobe, ACM Press, November 2015.
72. Egges, A., Papagiannakis, G., Magnenat-Thalmann, N. Presence and interaction in mixed reality environments. The Visual Computer 23(5): pp. 317-333, 2007.
73. Zhou, F., Duh, H. B.-L. and Billinghamurst, M. 2008. Trends in augmented reality tracking, interaction and display: A review of ten years of ISMAR, in Proc. of IEEE and ACM International Symposium on Mixed and Augmented Reality.
74. Feng, Y. (2008, May). Estimation of light source environment for illumination consistency of augmented reality. In 2008 Congress on Image and Signal Processing (Vol. 3, pp. 771-775). IEEE.
75. Liarokapis F, Sylaiou S, Basu A, Mourkoussis N, White M, Lister PF (2004) An interactive visualisation interface for virtual museums. In: Proceedings of the 5th international symposium on virtual reality, archaeology and cultural heritage, Eurographics Association, Brussels, Belgium, 6–10 Dec, pp 47–56
76. Pedersen, I., Gale, N., Mirza-Babaei, P., & Reid, S. (2017). More than meets the eye: The benefits of augmented reality and holographic displays for digital cultural heritage. Journal on Computing and Cultural Heritage (JOCCH), 10(2), 1-15.
77. Papaefthymiou M, Kanakis EM, Geronikolakis E, Nochos A, Zikas P, Papagiannakis G (2018) Rapid reconstruction and simulation of real characters in mixed reality environments. Digital cultural heritage. Lecture notes in computer science, vol 10605, pp 267–276.
78. Papagiannakis G, Geronikolakis E, Pateraki M, Bendicho VM, Tsioumas M, Sylaiou S, Liarokapis F, Grammatikopoulou A, Dimitropoulos K, Grammalidis N, Partarakis N, Margetis G, Drossis G, Vassiliadi M, Chalmers A, Stephanidis C, Thalmann N (2018) .
79. Ioannides M, Magnenat-Thalmann N, Papagiannakis G (eds) (2017) Mixed reality and gamification for cultural heritage. Springer-Nature. <https://doi.org/10.1007/978-3-319-49607-8>

80. Ioannides M et al (eds) (2018) Digital heritage. Progress in cultural heritage: documentation, preservation, and protection. In: Proceedings of 7th international conference, EuroMed 2018, Nicosia, Cyprus, 29 Oct–3 Nov 2018, vol 11196. Springer.
81. Zikas P, Bachlitzanakis V, Papaefthymiou M, Kateros S, Georgiou S, Lydatakis N, Papagiannakis G (2016) Mixed reality serious games for smart education. In: European conference on games-based learning 2016, ECGBL'16.
82. Jung, Y., Kuijper, A., Fellner, D., et al. 2011. Believable virtual characters in human-computer dialogs. Eurographics 2011 - State of The Art Report, pp. 75–100.
83. Kasap, Z. and Magnenat-Thalmann, N. 2007. Intelligent virtual humans with autonomy and personality: State-of-the-art. Intelligent Decision Technologies, IOS Press.
84. Shapiro, A. 2011. Building a character animation system.
85. Egges, A., Papagiannakis, G., Magnenat-Thalmann, N. Presence and interaction in mixed reality environments. The Visual Computer 23(5): pp. 317-333, 2007.
86. Papanikolaou, P. and Papagiannakis, G. 2013. Real-time separable subsurface scattering for animated virtual characters. Lecture Notes in Computer Science, Springer-Verlag, 2013, in-print, also presented in 2013 Symposium on GPU Computing and Applications by NTU and NVIDIA, Singapore, 2013, pp. 1–16.
87. Stefanidi, E.; Partarakis, N.; Zabulis, X.; Zikas, P.; Papagiannakis, G.; Thalmann, N.M. TooltY: An approach for the combination of motion capture and 3D reconstruction to present tool usage in 3D environments. In Intelligent Scene Modelling and Human Computer Interaction; Thalmann, N.M., Zheng, J., Eds.; Springer: Basel, Switzerland, 2020
88. Zhang, J.; Wu, Q.; Zhang, J.; Shen, C.; Lu, J.; Wu, Q. Heritage image annotation via collective knowledge. Pattern Recognit. 2019, 93, 204–214.
89. Su, X.; Sperli, G.; Moscato, V.; Picariello, A.; Esposito, C.; Choi, C. An edge intelligence empowered recommender system enabling cultural heritage applications. IEEE Trans. Ind. Inform. 2019, 15, 4266–4275
90. Tscheu, F., & Buhalis, D. (2016). Augmented reality at cultural heritage sites. In Information and communication technologies in tourism 2016 (pp. 607-619). Springer, Cham.
91. Carre, A. L., Dubois, A., Partarakis, N., Zabulis, X., Patsiouras, N., Mantinaki, E., ... & Manitsaris, S. (2022). Mixed-Reality Demonstration and Training of Glassblowing. Heritage, 5(1), 103-128 Dimensions of Traditional Crafts
92. Partarakis, N., Antona, M., Zidianakis, E., & Stephanidis, C. (2016). Adaptation and Content Personalization in the Context of Multi-User Museum Exhibits. In AVI\* CH (pp. 5-10).
93. Partarakis, N., Antona, M., & Stephanidis, C. (2016). Adaptable, personalizable and multi-user museum exhibits. In Curating the Digital (pp. 167-179). Springer, Cham.
94. Partarakis, N., Zidianakis, E., Antona, M., & Stephanidis, C. (2015, August). Art and Coffee in the Museum. In International Conference on Distributed, Ambient, and Pervasive Interactions (pp. 370-381). Springer, Cham.
95. Vayanou, M., Ioannidis, Y., Loumos, G., & Kargas, A. (2019). How to play storytelling games with masterpieces: From art galleries to hybrid board games. Journal of Computers in Education, 6(1), 79-116.
96. Partarakis, N., Patsiouras, N., Evdemon, T., Doulgeraki, P., Karuzaki, E., Stefanidi, E., ... & Zabulis, X. (2020, December). Enhancing the Educational Value of Tangible and Intangible Dimensions of Traditional Crafts Through Role-Play Gaming. In International Conference on ArtsIT, Interactivity and Game Creation (pp. 243-254). Springer, Cham.

97. Partarakis, N., Kartakis, S., Antona, M., Paparoulis, G., & Stephanidis, C. (2011, July). Classic art for modern people. In *International Conference on Human-Computer Interaction* (pp. 529-533). Springer, Berlin, Heidelberg.
98. Redström, J., Skog, T., & Hallnäs, L. (2000, April). Informative art: using amplified artworks as information displays. In *Proceedings of DARE 2000 on Designing augmented reality environments* (pp. 103-114).
99. Holmquist, L. E., & Skog, T. (2003, February). Informative art: information visualization in everyday environments. In *Proceedings of the 1st international conference on Computer graphics and interactive techniques in Australasia and South East Asia* (pp. 229-235).
100. Ferscha, A. (2007, July). Informative art display metaphors. In *International Conference on Universal Access in Human-Computer Interaction* (pp. 82-92). Springer, Berlin, Heidelberg.
101. Zidianakis, E., Chatziantoniou, A., Dimopoulos, A., Galanakis, G., Michelakis, A., Neroutsou, V., Ntoa, S., Paparoulis, S., Antona, M. & Stephanidis, C. (2021, forthcoming). A technological framework for rapid prototyping of X-reality applications for interactive 3D spaces. In *4th International Conference on Human Interaction & Emerging Technologies: Future Applications*.
102. UNESCO. Traditional Craftsmanship. Available online: <https://ich.unesco.org/en/traditional-craftsmanship-00057> (accessed on 16 January 2020).
103. G. Shi, Wang Y., and Li S. 2014. Human Motion Capture System and its Sensor Analysis. *Sensors and Transducers* 172 (2014), 206–212. Issue 6.
104. M. Field, D. Stirling, F. Naghdy, and Z. Pan. 2009. Motion capture in robotics review. In *IEEE International Conference on Control and Automation*. Institute of Electrical and Electronics Engineers, Christchurch, New Zealand, 1697–1702. <https://doi.org/10.1109/ICCA.2009.5410185>
105. 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 Digitisation of traditional craft processes, (in press, JOCCH-21-0060), *ACM Journal on Computing and Cultural Heritage*, DOI:10.1145/3494675.
106. Stefanidi, E., Partarakis, N., Zabulis, X., Zikas, P., Papagiannakis, G., & Thalmann, N. M. (2021). TooltY: An approach for the combination of motion capture and 3D reconstruction to present tool usage in 3D environments. In *Intelligent Scene Modeling and Human-Computer Interaction* (pp. 165-180). Springer, Cham.
107. Stefanidi, E., Partarakis, N., Zabulis, X., & Papagiannakis, G. (2020, November). An approach for the visualization of crafts and machine usage in virtual environments. In *Proceedings of the 13th International Conference on Advances in Computer-Human Interactions*, Valencia, Spain (pp. 21-25).
108. UNESCO. Traditional Craftsmanship. Available online: <https://ich.unesco.org/en/traditional-craftsmanship-00057> (accessed on 16 January 2020).
109. Eugène Peligot. Douze leçons sur l’art de la verrerie. Le verre, son histoire, sa fabrication.
110. Ginzarly, M., & Srour, F. J. (2021). Cultural heritage through the lens of COVID-19. *Poetics*, 101622.
111. Hamilton, R. W., & Thompson, D. V. (2007). Is there a substitute for direct experience? Comparing consumers' preferences after direct and indirect product experiences. *Journal of Consumer Research*, 34(4), 546-555.
112. Millar, M. G., & Millar, K. U. (1996). The effects of direct and indirect experience on affective and cognitive responses and the attitude–behavior relation. *Journal of experimental social psychology*, 32(6), 561-579

113. Gino, F., Argote, L., Miron-Spektor, E., & Todorova, G. (2010). First, get your feet wet: The effects of learning from direct and indirect experience on team creativity. *Organizational behavior and human decision processes*, 111(2), 102-115.
114. Duerden, M. D., & Witt, P. A. (2010). The impact of direct and indirect experiences on the development of environmental knowledge, attitudes, and behavior. *Journal of environmental psychology*, 30(4), 379-392.
115. Daugherty, T., Li, H., & Biocca, F. (2008). Consumer learning and the effects of virtual experience relative to indirect and direct product experience. *Psychology & Marketing*, 25(7), 568-586
116. Keng, C. J., Liao, T. H., & Yang, Y. I. (2012). The effects of sequential combinations of virtual experience, direct experience, and indirect experience: the moderating roles of need for touch and product involvement. *Electronic Commerce Research*, 12(2), 177-199
117. MINERVA, Ministerial Network for Valorising activities in digitisation, "D6.2. Good Practice Handbook", November 2003.
118. 3D-ICONS, "Guidelines & Case Studies", 2014. 3D-ICONS is a project funded under the European Commission's ICT Policy Support Programme, project no. 297194
119. Papagiannakis, G., Partarakis, N., Stephanidis, C., Vassiliadi, M., Huebner, N., Grammalidis, N., ... & Margetis, G. (2018). Mixed reality gamified presence and storytelling for virtual museums (No. IKEEBOOKCH-2019-233). Springer
120. UNSECO, "Know-how of cultivating mastic on the island of Chios", Inscription: 9.COM 10.18, 2014.
121. Partarakis, N., Zabulis, X., Chatziantoniou, A., Patsiouras, N., & Adami, I. (2020). An approach to the creation and presentation of reference gesture datasets, for the preservation of traditional crafts. *Applied Sciences*, 10(20), 7325.
122. Hinderks, A.; Schrepp, M.; Domínguez Mayo, F.J.; Escalona, M.J. & Thomaschewski, J. (2019). Developing a UX KPI based on the user experience questionnaire.
123. Schrepp, Martin. Data analysis tool. Retrieved on March 01, 2022 from: <https://www.ueg-online.org/>
124. Reichheld, Frederick F. (December 2003). "One Number You Need to Grow". *Harvard Business Review*. 81 (12): 46–54, 124. PMID 14712543.
125. Lewis, J. R. (2018). The system usability scale: past, present, and future. *International Journal of Human–Computer Interaction*, 34(7), 577-590.
126. Mingei web site: [www.mingei-project.eu](http://www.mingei-project.eu)
127. Silk pilot landing page: [https://www.mingei-project.eu/silk\\_pilot/](https://www.mingei-project.eu/silk_pilot/)
128. Mastic pilot landing page [https://www.mingei-project.eu/mastic\\_pilot/](https://www.mingei-project.eu/mastic_pilot/)
129. Glass pilot landing page [https://www.mingei-project.eu/glass\\_pilot/](https://www.mingei-project.eu/glass_pilot/)