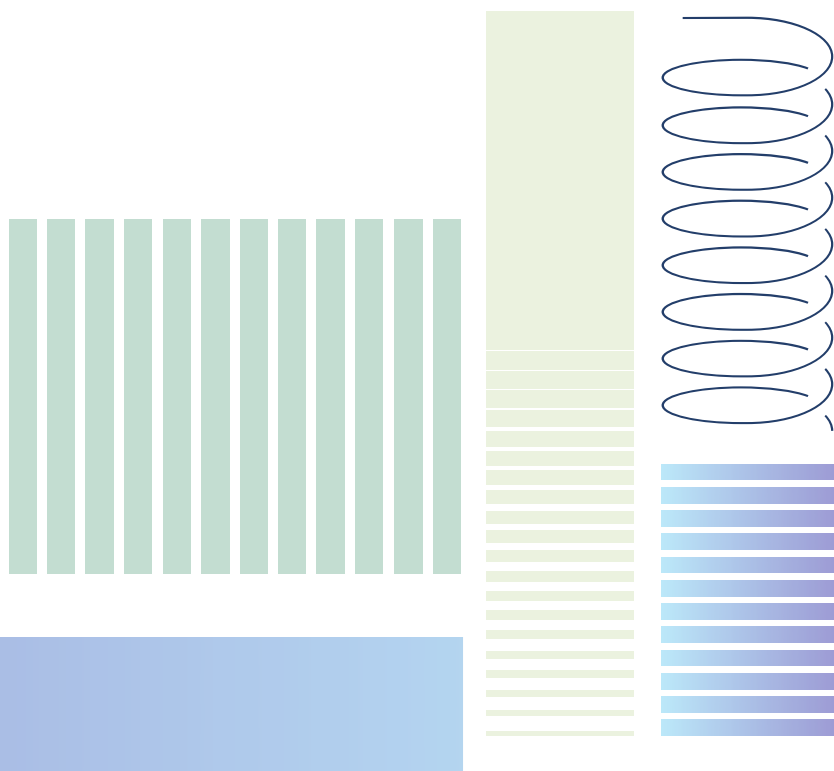


## D8.7. SCIENTIFIC RESULTS AND INTERDISCIPLINARY SYNERGIES



|                              |                                                                                                                                                                                                                                |
|------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
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| <b>List of acronyms</b> |                                                           |
|-------------------------|-----------------------------------------------------------|
| <b>AAT</b>              | Art and Architecture Thesaurus, from the Getty Foundation |
| <b>CH</b>               | Cultural Heritage                                         |
| <b>ICT</b>              | Information and Communication Technologies                |
| <b>KG</b>               | Knowledge Graph                                           |
| <b>SSH</b>              | Social Sciences and Humanities                            |

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The tools resulting from the SILKNOW project are the outcome of a highly interdisciplinary effort. In this report, we illustrate the results of the project with a particular focus on how the interaction among the partners and the knowledge of the experts in ICT and SSH has enabled the final outcomes of SILKNOW. We then show how the partners interacted and which decisions were crucial.

## 1. INTRODUCTION

The SILKNOW project aims to promote silk and the universe that surrounds it, a universe of ancient and modern knowledge. Indeed, this natural textile fibre has accompanied the technological and cultural evolution of humanity and permeated the different social classes.

The universe that surrounds silk touches on different spheres of human knowledge and also influences and promotes the socio-economic development of society. Technical knowledge allowed the production of increasingly refined fabrics, thanks to technological development represented by emblematic instruments such as the Jacquard loom and punch cards. The social motivations that kept the use of silk alive can be explained thanks to historical and artistic knowledge that shows how the adornment of certain fabrics had much deeper meanings, beyond the human physiological need to cover oneself with clothing. Behind each fabric can be found both a technological knowledge that made its realization possible and a historical and cultural motivation that determined its appearance and gave it meanings that reveal its belonging to a particular historical period or segment of human history.

At the same time, making this knowledge accessible to both professionals and the general public through electronic databases and the Internet requires technical know-how from the Information and Communication Technologies (ICT) sector. This is also true if recent developments in Artificial Intelligence are to be used to complete knowledge of existing artifacts that would otherwise be inaccessible, or to enable alternative methods of searching for information, such as using images to search a database of artifacts. Therefore, it was necessary to include different types of knowledge, from humanities to computer and technological disciplines, in order to enhance and preserve from oblivion the history, techniques and know-how associated with silk.

Consequently, the members of a multidisciplinary team working on the project had to combine their expertise and knowledge and put them at the service of preserving and disseminating the culture of the silk world. The combination between the knowledge and expertise of the

partners has allowed the realization of the SILKNOW tools: a variety of interactive tools and computer technologies designed and developed in close collaboration between experts in ICT and SSH (Social Sciences and Humanities).

This document reports the results of the SILKNOW project, focusing on its interdisciplinary aspects. It shows how each tool developed required constant collaboration among project partners with backgrounds in different scientific disciplines. It is organized as follows: in Section 2, we describe the relationships between this deliverable and all the others; in Section 3, we discuss the characteristics of software systems supporting the cultural heritage field to better show how interdisciplinary work is absolutely necessary in this context; in Section 4, we describe how interdisciplinarity was realized throughout the SILKNOW project; in Sections 5, 6, and 7, we illustrate the project outcomes (from tools to dissemination) and focus on how they were carried out in an interdisciplinary way; and finally, in Section 8, we draw some conclusions.

## **2. RELATIONSHIP WITH OTHER DELIVERABLES**

This deliverable has no real dependence on other deliverables of the project, since it is more focused on methodological issues. However, in preparing this report, the following deliverables were primarily reviewed and considered:

- Deliverable D3.2 (Design of the SILKNOW Ontology and the Ontology), which describes the design of the ontology, provides an overview of the CIDOC-CRM reference ontology [1][2], and illustrates the mapping between the data provided by the cultural heritage partners and the data model provided by the ontology.
- Deliverable D3.1 (Historical silk multilingual thesaurus) illustrating the first version of the multilingual thesaurus.
- Deliverable D5.3 (Design and adaptation of 3D printers for textiles), illustrating the main problems in the definition and analysis of 3D printing on textiles.
- Deliverable D4.4 (Design and implementation of a deep-learning-based image classification system), which contains the design of the classification software and the guidelines for its use.
- Deliverable D5.4 (Design and implementation of Virtual Loom), which shows how the Virtual Loom has been implemented and how it will be used.
- Deliverable D5.5 (Visualization and deployable components), which shows how STMaps and 3D printing components were designed and implemented.
- Deliverable D3.3 (Design and Implementation of text analytic module), which reports on how the text analytic module was created.
- Deliverable D6.4 (Design and implementation of the multilingual web-based thesaurus), which shows the design of the SILKNOW thesaurus and the web application that allows the end user to explore the Knowledge Graph.

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- Deliverable D6.5 (Integrated System), which describes the exploratory search engine whose interface is accessible through a web application called ADASilk.
- Deliverable D4.5 (Design and implementation of image retrieval method based on Siamese CNN), illustrates the system module for image retrieval.
- Deliverable D4.6 (Test report of image processing and deep learning module), illustrates the final versions of the image analysis tools from D4.4 and D4.5 along with their evaluation and provides recommendations for the integration of these tools into ADASilk.
- Deliverable D7.1 illustrates the validation process performed by the SSH experts to train the network underneath the text analytics module, evaluate the image retrieval module, and validate the information entries contained in the records within SILKNOW Knowledge Graph.
- Deliverable D7.3 (Usability evaluation by online users of the system), presented feedback from volunteers after using the SILKNOW tools.

All these deliverables helped to explore how the work of the project partners was carried out, to highlight the interdisciplinary processes that were followed and therefore the outcomes.

### **3. FEATURES OF CULTURAL HERITAGE SUPPORT TOOLS**

SILKNOW aims to preserve the heritage of silk and make it productive. This is one of the main objectives of what is commonly referred to as Cultural Heritage. On the other hand, the integration with ICT leads to very efficient software systems and tools to create and manage large material archives, to support scientific research, to promote the care and preservation of artifacts of any cultural sector; it is no coincidence that one of the first applications of photogrammetry that brought the image analysis module to the project was the documentation of cultural heritage [3]. SILKNOW is all of this, as it aims to create a set of tools for the use, study and conservation of the cultural heritage of silk, and to do this it has used a partnership with members with experience in various areas of SSH and ICT.

This section lists some of the main requirements for the types of software produced and used in the field by Cultural Heritage experts. One of them is a functionality that allows them to examine an object in detail using a digital support. To this end, the representation of the artifact must become increasingly dynamic and interactive. The user chooses the level of detail and the vantage point for viewing or studying an artifact. The way the user does this is closely related to his background and the goal of his study or observation. An ordinary tourist will look at an artwork from a completely different perspective than, for example, a scientist studying art history. In this case, a cultural heritage support tool must take into account and support the user according to his needs and specificities, and therefore also dynamically adapt to the user's background.

Another requirement relates to the sharing and dissemination of knowledge, information and awareness about cultural heritage. This can be done through the creation of digital tools that

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offer different views and perspectives, detailed and general, with images and with 3D visualizations. The user is the main actor in the interaction with the tool and defines the access criteria with his own interaction.

Yet another aspect to consider is the possibility to access or avail oneself of any resource, archaeological, artistic, etc., distant in time and space. Moreover, it allows to see an artifact in its original environment or a reconstructed version of it, in later or current contexts, or even to experience it through virtual reality.

An ICT system for the field of cultural heritage preservation/restoration/use is something that contains so much information that by its nature it can be discovered rather than learned. This leads to the development of software that supports the personalization of what we can call personal itineraries and learning approaches based on personal experiences.

Furthermore, the use of mobile technologies opens up new and interesting possibilities. Users can be enabled to perform a variety of activities with a mobile device. For example, capturing data or commenting on information or details that can then be edited later. The ability to communicate and collaborate remotely, using both mobile and desktop devices, is also a very important feature to consider.

Due to the range of requirements outlined above, the tools of Cultural Heritage belong to the so-called "complex systems". The term "complex" is a very specific term in the ICT field, originating mainly from biology [4]. In simple terms, a complex system is a system that cannot be explained as the sum of its parts. A complex system "lives" as a result of the interactions between its parts and between its parts with the external world. The behaviour of the system, it is claimed, arises from the context in which it operates, and it also arises through and as a result of interactions with the environment.

In software engineering, the discipline that deals with structured software development [5], one of the first and most important activities is requirement analysis. Continuous interaction with domain experts is of paramount importance to fully determine the requirements of the software being developed. Interviews with experts are used to analyse how they work in their domain, but also to highlight any hidden aspects that are often implicit to the expert and must be made explicit by the software designer with care and acumen to produce good software.

Normally, the work of domain and ICT experts in requirements analysis consists mainly of interaction and communication. Once the initial requirements analysis phase is over, the domain experts disappear from the software development process, only to reappear, if necessary, in the testing phase of the software product. As a rule, the software is developed by the designers and developers alone.

The development of Cultural Heritage support tools, which, as mentioned above, have very specific requirements and fall into the category of complex systems, follows the classical phases of software development. However, the specificity of these tools does not allow

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domain experts to withdraw from the development process after the first phase; their contribution is necessary throughout the process, from the conception of the tool to its development and installation. In the SILKNOW project, we have experienced that the SSH domain experts need not only to communicate with the ICT development teams, but also to integrate with the teams and be a "cultural complement" so that the two different groups of disciplines converge on common approaches and theories. The domain experts are needed to give semantics to the data, processes and outputs to ensure that what is developed by the ICT teams is meaningful support for the end users' goals. They must interact with its entire background in an interdisciplinary effort that is critical to the success of the end product. In short, in this case, the SSH experts are not only the expert end users, but also the reservoir of knowledge that ICT techniques must draw upon to produce an efficient, usable, and useful end product for the general user.

## **4. INTERDISCIPLINARITY IN SILKNOW**

In SILKNOW, experts from the fields of SSH and ICT have been working together since the first project idea, long before the project was submitted to European Commission. After the project was approved, they continued their collaboration in the way we will explain in more detail in the following sections. During the project we were able to understand and test some of the interactions between SSH and ICT, which enabled the development of a very interdisciplinary product. SILKNOW required close collaboration between partners with expertise in areas as diverse as text analysis, image processing, semantics, Big Data, 3D printing, visualization, art history, terminology, textile production, data modeling and conservation. This fostered the development of unified knowledge, a link between traditional sciences and the latest technological ones, which was actually realized and is available at the end of the project in the form of the project results.

To give a very simple example: the creation of the virtual loom needed the knowledge and experience of the textile experts to implement the knowledge of specific concepts such as warp and weft in a way that could be ported to software. In this way, the ICT experts were able to develop computational models to create 3D models that resembled fabrics created using real weaving techniques.

The partners who participated in SILKNOW and their main areas of expertise as well as their contributions to the project are listed in Table 1.



| <b>Partner</b>                                                          | <b>Area</b>                                              | <b>Role in the project</b>                                                         |
|-------------------------------------------------------------------------|----------------------------------------------------------|------------------------------------------------------------------------------------|
| <b>Universitat de València (UVEG)</b>                                   | SSH - Art History<br>ICT – Interactive Computer Graphics | Coordination, thesaurus and dissemination<br>Coordination, interactive tools       |
| <b>Gottfried Wilhelm Leibniz Universität Hannover (LUH)</b>             | ICT- Photogrammetry, Computer Vision                     | Image analysis                                                                     |
| <b>Institut Jozef Stefan (JSI)</b>                                      | ICT – Computer Science                                   | Text analytics and thesaurus                                                       |
| <b>Università degli Studi di Palermo</b>                                | SSH - Art History<br>ICT - Computer Science              | Data provider<br>End-user evaluation and usability tests                           |
| <b>Instituto Cervantes</b>                                              | SSH - Education                                          | Educational materials and communication                                            |
| <b>Garín 1820 S.A.</b>                                                  | SSH - Production of silk fabrics                         | Data provider and expert in silk fabrics                                           |
| <b>EURECOM</b>                                                          | ICT – Computer Science                                   | Knowledge Graph, data integration, exploratory search engine and thesaurus browser |
| <b>Centre National de la Recherche Scientifique – Université Lyon 2</b> | SSH - Digital and Textile history.                       | Data provider and ontology engineering                                             |
| <b>MonkeyFab S.C.</b>                                                   | ICT - 3D printing                                        | 3D printing                                                                        |

*Table 1. Partners with their main area of expertise and their role in the SILKNOW project.*

Work done in SILKNOW can be divided into two major phases. The first one involved the collection and processing of data, and the second involved the design and implementation of software modules for their intelligent presentation.

The aim is to realise an intelligent system to support the preservation, dissemination and exploitation of the European cultural heritage of silk. A large amount of existing information from major museum collections has been collected and adapted to the data model defined in the project. It is also made available in various forms, mainly through an exploratory search

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engine, a multilingual thesaurus, a virtual loom and a spatio-temporal map. End users can access and explore information about the silk heritage through visual or tangible simulations.

The main steps in creating the final product were the automatic extraction of records supplied by content providers or by harvesting data from online digital collections of various museums; the creation of a silk fabric thesaurus and a silk textile ontology; and the implementation of an analysis system to query large amounts of data, including advanced search. The system had to allow the linking of high-level concepts and the analysis and automatic processing of data of varying quality from different European museums and SILKNOW partners. In the process of creating this system, data collected from the internet and different museum collections had to be mapped to the ontology, resulting in the SILKNOW Knowledge Graph, which allows for a systematic search of records. The extracted and considered data were very heterogeneous, classified in different languages and with different modalities and standards. Therefore, the created ontology gave a common basis and structure to all the catalogued information. In order to extract semantic information from the collected datasets, which could not be easily extracted from images and textual data, data processing methods based on Artificial Intelligence had to be implemented, in particular Deep Learning techniques. Deep Learning was also used to enable record searching in the Knowledge Graph with images as input.

Another SILKNOW tool is a virtual loom that can be used to generate 3D models of fabrics that simulate ancient weaving techniques. The models created with the virtual loom can be made tangible through the use of advanced 3D printing techniques. Finally, a tool for spatio-temporal visualisation of the results of a search has been implemented to support a geographical and chronological analysis of the information about the textile objects under consideration.

As can be seen from the description above, for the implementation of the two aforementioned phases, the coordination and continuous feedback between the ICT and SSH disciplines, which form the basis of the expertise of the project partners, was fundamental. In detail, the results of the first phase of the project are:

- **Multilingual thesaurus:** a multilingual controlled vocabulary for silk heritage, mainly describing production techniques and materials.
- **Ontology:** the ontology describes how terms and concepts related to silk textiles and their evolution are combined in a data structure containing all entities and their relationships. It is based on the CIDOC CRM model as a general framework and extends the Getty Foundation AAT [12] with specialized silk terms in four languages: English, French, Spanish and Italian.
- **Digital catalogue:** a collection of documents about museums that contain collections relevant to the SILKNOW project and the artifacts present in these collections.

The results of the second phase are:

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- **SILKNOW Knowledge Graph:** This knowledge graph uses the SILKNOW ontology to instantiate numerous descriptions of silk fabrics, drawn from numerous museum sources. It contains nearly 40,000 entries about fabrics with images and other relevant information describing them, in particular semantic information in a standardized format according to the ontology and using the Thesaurus. This information is enriched by the combination of two additional software modules:
  - **Text analytic module:** This module analyzes free-form texts associated with records in the Knowledge Graph to extract the semantic information that could not be automatically mapped from the harvested data. This information is used to augment the content of the knowledge graph.
  - **Image classification module:** This module serves the same purpose as the text analytic module, using instead images of silk fabrics to extract semantic information that is used to complement the knowledge graph.
- **ADASilk (Advanced Data Analysis for Silk Heritage):** An exploratory search engine built on top of SILKNOW Knowledge Graph. It is enriched by an additional software module:
  - **Image retrieval module:** this module allows searching for records in the SILKNOW knowledge graph using an image as input to retrieve records similar to the query image.
- **Virtual Loom:** An application dealing with the virtual 3D representation of historical silk fabrics at yarn level. It is offered as a standalone application and is integrated with ADASilk. Its results can be exported so that they can be 3D printed.
- **STMaps (spatio-temporal maps):** An interactive tool for visualizing silk-related objects at temporal and spatial scales, also showing the relationship between their properties. It is integrated with ADASilk.

All these results are based on interdisciplinary work of the partners. Towards the end of the project, SSH and ICT experts worked closely together to validate the results. Training sessions of the models were conducted, where the skills of the SSH experts were fundamental, and real validation sessions were conducted by several volunteers who acted as end users.

Validation was performed in two ways. For most modules, it consisted of a standard validation session with the end users, divided into several groups. For the image analysis and text analysis modules, a technical evaluation using standard ICT industry practices was combined with a usability evaluation by SSH experts. In the case of the text analytic module, they were also involved in providing training data. In this part of the validation, the knowledge of experts in both fields was literally interwoven to bring in the knowledge of SSH experts in the field of intelligent algorithms, with the aim of supporting their training to be used in the final product.

Section 5 details the interdisciplinarity aspect of each project deliverable, while Section 6 focuses on the validation phase of the project.

## 5. INTERDISCIPLINARY ISSUES WITHIN PROJECT RESULTS

### 5.1. Multilingual Thesaurus

The multilingual thesaurus is a vocabulary of unique terms devoted to silk heritage. The thesaurus contains mainly concepts and terms related to techniques, materials, depiction and equipment. The thesaurus has a hierarchical structure consisting of concepts that have both preferred names and alternative names or synonyms in each language. In addition, the concepts are organized in a hierarchy with narrower and broader relationships. The creation of the thesaurus involved experts in textile terminology and art historians, historians of applied art in general, and ICT partners who provided the SKOS framework as a formalism for modeling. It was implemented by experts in text mining, multilingualism and semantic extraction. The thesaurus is the result of a true interdisciplinary team effort.

The development of the thesaurus required knowledge of the Getty AAT and ISO 25964 thesaurus specification [12], in addition to a thorough knowledge of historical weaving techniques. For term formation, museum catalogs were consulted and examined, among other bibliography, to extract the most frequently occurring terms. In addition, general and silk-specialized dictionaries, historical sources to review the evolution of terms over time, other thesauri and journal articles were examined. The work was mainly carried out by UVEG ICT and SSH experts, and Garín researchers who are experts in historical weaving techniques.

Originally, the Thesaurus was created as a Google Docs spreadsheet, first in Spanish and then in Italian, English and French. Since the beginning of the work on the thesaurus, several meetings took place between the partners involved to review terms and align translations. After the publication of the first version of the thesaurus, it was transformed into a web-based application. In this case, it was necessary to make some decisions about the format of the table cells in order to make them compatible with the SKOS standard for a correct conversion into an RDF vocabulary.

At the time of writing this deliverable, the thesaurus continues to be revised and corrected, mainly regarding the visualisation of the concept hierarchy, for instance of the exact position of a concept within the hierarchy, or on meaningfully grouping concepts with few instances

As can be seen in Table 2, the development of the SILKNOW thesaurus was highly interdisciplinary. Professionals as diverse as weavers (coming from Garín, that treasures 200 years of experience in the field), art historians (UNIPA, UVEG, Garín, CNRS-LAHRA), philologists (UVEG), historians (CNRS-LAHRA), digital humanities researchers (UVEG, CNRS-LAHRA) and computer scientists (EURECOM, JSI) were involved. There were more than 5 meetings between SSH and ICT, that helped to include some terms that are not normally included in a thesaurus, such as plurals, but they had to be included to improve the performance of the KG.

| Partner                                  | Area                            | Work done in the Multilingual Thesaurus                                                                                                                               |
|------------------------------------------|---------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Garín 1820</b>                        | SSH<br><br>Creative industry    | Coordination, defining the Spanish vocabulary, defining associated terms, defining groups and hierarchies.                                                            |
| <b>UEVG SSH</b>                          | Art history, textile knowledge. | Coordination, defining the Spanish vocabulary, defining associated terms, defining groups and hierarchies.<br><br>Defining the English vocabulary.                    |
| <b>Università degli Studi di Palermo</b> | SSH                             | Contributed in determining and defining the Italian vocabulary                                                                                                        |
| <b>CNRS - LARHRA Lyon 2</b>              | SSH                             | Contributed in determining and defining the French vocabulary and hierarchies.                                                                                        |
| <b>JSI</b>                               | ICT                             | Coverage of multilingual terms, mapping to Wikidata                                                                                                                   |
| <b>EURECOM</b>                           | ICT                             | Conversion in SKOS/RDF, formal validation, versioning                                                                                                                 |
| <b>UEVG ICT</b>                          | ICT                             | Creation of a shared Google spreadsheet with imported ranges in order to facilitate the thesaurus concepts' introduction and their translations in a shared document. |

*Table 2. A summary of the partners involved in the creation of the Thesaurus, their main area of expertise and the work done.*

## 5.2. Ontology

The SILKNOW ontology was created to structure and analyze the information coming from the content providers. The ontology is based on the CIDOC Conceptual Reference Model and its purpose is to form a basic structure related to silk textiles, their historical evolution and their relationship with society. CIDOC-CRM, as the international standard, provides a basic structure and definitions to describe the semantics associated with the documentation of cultural heritage.

The integration of the ontology in SILKNOW allows a user to find similar content to texts or images of textiles. To this end, certain mechanisms have been explored to extend and

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integrate the elements already present in CIDOC and adapt them to the context of silk textiles. The ontology is the basis for queries to the ADASilk web application to navigate the extensive silk heritage curated in SILKNOW.

Building the ontology required a deep understanding of the structure of CIDOC CRM. This included understanding which concepts inherent to the world of silk textiles and their spatio-temporal evolution correspond to the representation and structure of documentation from the various museum collections, which were then catalogued as explained in the next subsection. The CIDOC CRM ontology, for example, has a very precise structure that required close interaction between SSH and ICT to determine how the main classes should be extended.

Thus, the temporal entity is at the center of the ontological model and the integration between the different backgrounds of the project partners has made it possible to define the line of specializations (is-A) of the temporal entity, in order to first define the essential elements for the development of the project and then to be able to include them in the ontology. Elements such as space, time, event, involvement of people, period, etc. were considered, as shown in Deliverable D3.2.

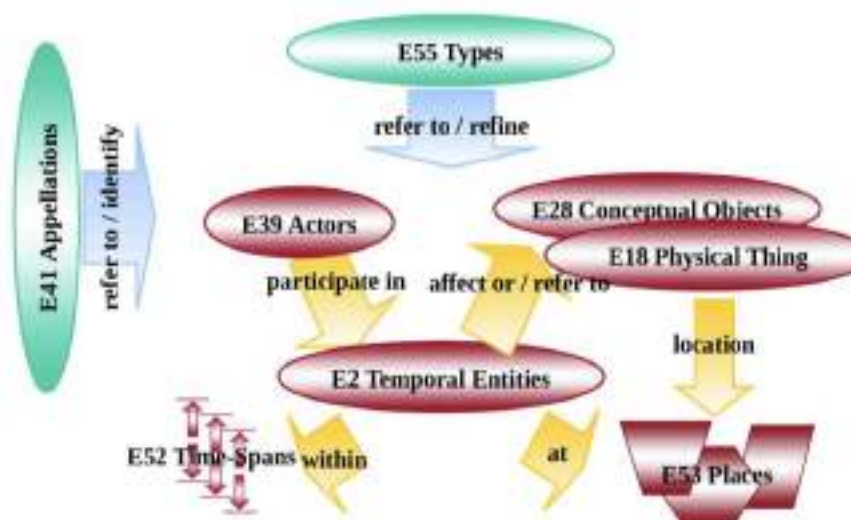


Figure 1. Top level classes from CIDOC CRM.

To the instances that allowed the ontology to be extended, the experts added some mapping rules. The mapping rules allow to bring back to the digital space all the concepts and words present in the documentation from the different textile collections. The continuous alignment between SSH and ICT, which is still ongoing as the integration phase of the modules is coming to an end, has allowed this very important implementation of concepts that has enabled the representation of silk-related data through a digital medium.

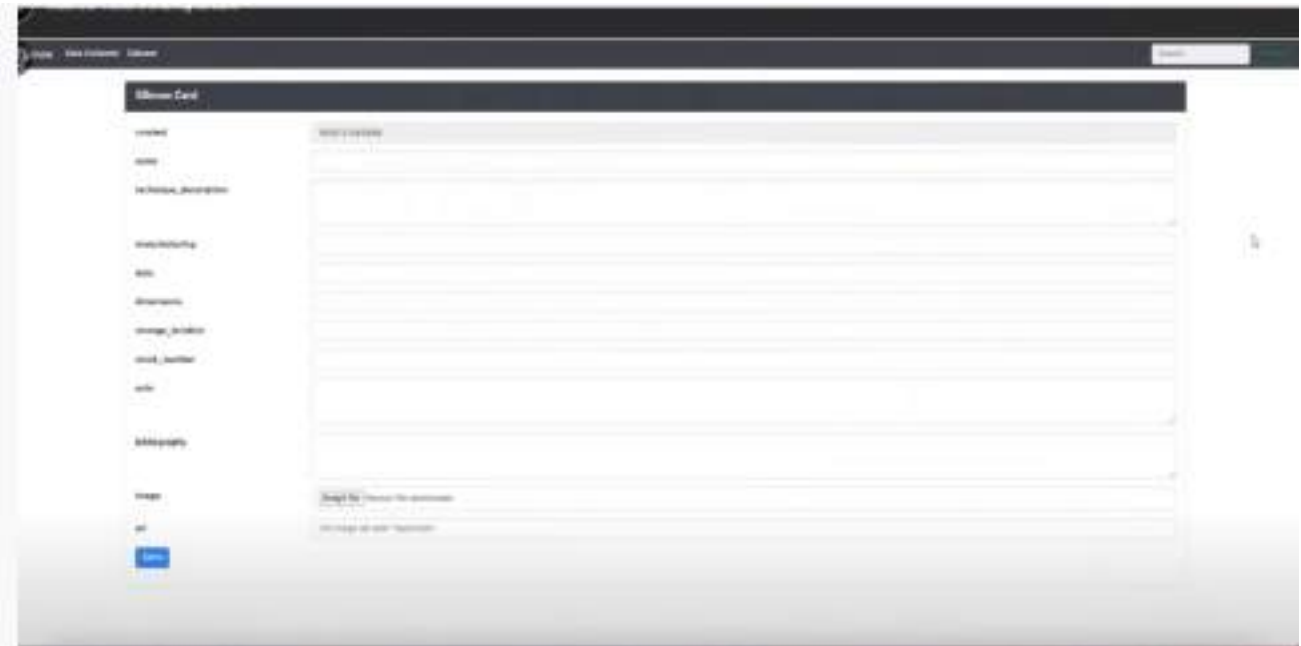
| Partner                     | Area                                                     | Work done for developing the Ontology                                                                                                                                       |
|-----------------------------|----------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>CNRS - LARHRA Lyon 2</b> | Digital and Textile History                              | Defining the Data Model, creating new classes and properties. Mapping of the datasets to the SILKNOW model.                                                                 |
| <b>EURECOM</b>              | ICT, Ontology Engineering, Semantic Web, Knowledge Graph | Help define the data model, focus on modelling the provenance of the information for the integration of the image and text analysis modules, validation of the OWL document |
| <b>UVEG SSH</b>             | Art history. Textile knowledge                           | Working with CNRS in order to better define the mapping of the datasets to the SILKNOW model.                                                                               |
| <b>Garin 1820</b>           | Textile specialists, creative industry                   | Working with CNRS in order to better define the mapping of the datasets to the SILKNOW model.                                                                               |

*Table 3. A summary of the partners involved in the creation of the ontology, their main area of expertise and the work done.*

### 5.3. Digital catalogue

The creation of the digital catalog is the central outcome of what we have called the data collection and preparation phase. SSH partners oversaw the retrieval of databases from various museums that provided records of their textile artifacts for the project. In the case of the artifacts housed in Italy, ad hoc cataloging was necessary for the project. Thanks to the collaboration between art historians and computer scientists, the UNIPA team created an application that provides a digital interface to facilitate the work of experts in the field. The qualitative needs of the historian-cataloguer were combined with the functional requirements for computerized use, using the CIETA cataloging framework [6] as a reference.

The interface created for use by catalogers allows the paper record to be translated into a digital record ready to be inserted into the knowledge graph and semantically mapped. The application allows to create a dataset that is streamlined in content but contains the basic information needed to identify a textile artifact and link it to other similar artifacts. The record consists of an identification number, a formal description of the artifact, weave type, manufacture, chronological location, dimensions, storage location at the time of cataloging, and inventory number, and finally stylistic notes that include decorative modules to better identify the uniqueness of the artifact and historical notes if known. The notes are accompanied by a bibliography if the artifact is not unpublished and photographs taken on site. In order to create this application, it was necessary to educate the ICT experts on the types of documentation of the artifacts and on the essential elements to be cataloged, which would then be combined with the elements of the ontology and with the attribution rules.



*Figure 2. The visual interface for producing records in the digital catalogue.*

This activity was carried out iteratively and incrementally, in parallel with the creation of the ontology and mapping rules. SSH experts acted as a bridge for communication between museums and ICT to retrieve data in a format that was aligned with the creation of the ontology. In the case of the Victorian and Albert Museum, for example, SSH contributed significantly to the skimming of the collections; guided by the ICT experts to build the ontology, they explored the VAM's vast collection, containing a myriad of objects of all kinds, extracting what was relevant to the project and documenting it in the most appropriate way.

EURECOM then implemented a separate crawler for each museum source to collect the metadata for all objects selected by the domain experts. The SSH experts then reviewed the crawled data to prepare the mappings to the target ontology model. In the various working sessions conducted in different ways, from meetings on meeting platforms to email and instant messaging exchanges, important decisions were made such as:

- Clarifying the concept of place of production: from the information on textile artifacts in museum catalogs, it is not always possible to determine whether what is indicated in the documents as a place of origin is really the place where the artifact was produced or rather the place where it was found.
- The inclusion or non-inclusion of some details, e.g. Pattern Unit, lining, gallon, which are present in some records and not in others. This decision was necessary because partners producing the data and compiling the records of artifacts from different collections were initially working with different templates. Only after several iterations was the artifact description finalized and aligned with the rest of the project.



| Partner                                  | Area                                | Work done for developing the data catalogue                                                                                                                                                                                                                              |
|------------------------------------------|-------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Università degli Studi di Palermo</b> | SSH<br>ICT                          | Contributed in the preparation of catalogues for some Italian museums.<br><br>Validated the correct instantiation of two concepts: production and place of origin.<br><br>Developed a small interface to shorten and homogenize the work of cataloguing.                 |
| <b>EURECOM</b>                           | ICT, data integration, data crawler | Development of open-source crawlers for each museum source. Definition of a common JSON-based interchange format for all museums.                                                                                                                                        |
| <b>UVEG ICT</b>                          | ICT                                 | Managed the processes of image files maintenance and making them accessible from a secure server. It included the file renaming tasks.                                                                                                                                   |
| <b>UVEG SSH</b>                          | Art history, textile knowledge      | Skimming the collections of the museums integrated into SILKNOW to understand how they catalogue and name their objects. Extracting relevant information from the collections to include in the SILKNOW ontology.<br>Defining searches to harvest data from the museums. |

Table 4. A summary of the partners involved in the creation of the Digital Catalogue, their main area of expertise and the work done.

## 5.4. SILKNOW Knowledge Graph

While the numerous digital catalogues all focus on silk fabrics and information about their production and trade, they use different data models and provide information at different levels of granularity. The goal of SILKNOW Knowledge Graph is to provide a single data model that consistently presents all this information. After all data catalogues were defined and crawled, SSH domain experts developed mapping rules from the original data source to the target ontology based on CIDOC CRM. This often requires an interpretation of the original data that only domain experts are capable of.

EURECOM implemented converters for each source. After the data was converted, the domain experts performed validation again to ensure that no data was lost or misinterpreted during the conversion.

| Partner         | Area                                       | Work done in the context of the Knowledge Graph                                                                                                                                          |
|-----------------|--------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>EURECOM</b>  | ICT, Semantic Web, data integration        | Lead participant, knowledge graph architect, converter software implementation, development of RESTful APIs to provide access to the knowledge graph and enable third-party integration. |
| <b>LUH</b>      | Photogrammetry, Computer Vision            | Image classification module, integration of this module to enrich the knowledge graph with automatic predictions; contribution to joint text and image classification.                   |
| <b>JSI</b>      | ICT, semantic technologies, text analytics | Text classification module, integration of this module to enrich the knowledge graph with automatic predictions; contribution to joint text and image classification.                    |
| <b>UVEG ICT</b> | ICT, Data integration.                     | Contribution to the discussions related to the definition of the integration of the Knowledge graph with the STMaps tool.                                                                |

Table 5. A summary of the partners involved in the creation of the SILKNOW Knowledge Graph, their main area of expertise and the work done.

## 5.4.1. Text analytic module

The purpose of the text analytic module is to automatically fill in relevant information that is missing from the SILKNOW knowledge graph. We refer to this missing information as "gaps" or "slots". We use automatic text analysis methods to infer this information from free form text descriptions associated with the records of silk fabrics by the museums, and present in the knowledge graph as "unstructured information" captured as text "notes". We used and evaluated several different techniques, ultimately settling on a Text Convolutional Neural Network (TextCNN) to predict a series of primary semantic properties and a transformer-based approach using XML-R. These methods were implemented in software by JSI, a partner with a long experience in text analytics. The entire process, which is more than just writing a software module, directly or indirectly involved almost every other partner in the project in an interdisciplinary effort:

- The creation of the text analytic module involved discussions with LUH, who created an image classification module to accomplish some of the same goals, but by deriving information from images rather than text descriptions. Finally, we created a joint multimodal image and text classifier that showed improved results and was reported in Deliverable D3.4.
- CNRS had defined the ontology, and the UVEG SSH team, bringing the perspective of heritage domain experts, was instrumental in defining the semantic variables to be predicted and the class structure, including grouping labels in a way that made sense for

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the heritage domain. This process was a continuous collaboration throughout the project between CNRS, the SSH team of UVEG, EURECOM, LUH and JSI. It helped to ensure that all stakeholders had a common goal and expectation consistent with these labels and structure, which was a prerequisite for the machine learning algorithms of the text and image modules. In addition, the text analysis module (and image classifier) was linked to the SILKNOW Thesaurus, another important deliverable of the project. This follows directly on from deliverables D3.1 and D3.2. Much of the early work on defining the semantic variables and class structure was reported in Deliverable D4.1 and refined in Deliverables D3.3 and D3.4

- CNRS and EURECOM developed and populated the Knowledge Graph, EURECOM provided the necessary support for JSI and LUH to access the data by developing SPARQL queries that ultimately automated the data exports from the Knowledge Graph that generated the datasets used for text and image classification throughout the project and included the label grouping of the SSH team. The centralized automated generation of these datasets helped ensure that JSI and LUH remained in sync and ultimately enabled the common multimodal classifier by ensuring that both text and image classifiers used the same dataset.
- The predictions of the different classifiers were again imported into Knowledge Graph by EURECOM using an ontology defined by CNRS, this collaboration also ensured that they could be appropriately represented by ADASilk. EURECOM, JSI and LUH agreed on a common interface format so that the predictions, an estimated probabilistic confidence value and a description of how the prediction was generated could be displayed to users. The GUI to display the results was developed by EURECOM. This work was finally reported in Deliverable D6.7.
- For the semantic variables "production location" and "Production Time", EURECOM, at the request of JSI and LUH, with advice from CNRS and the SSH team of UVEG and UNIPA, automated the process of displaying and discretizing time spans and linking location strings to defined geographical areas that could be automatically grouped hierarchically. This allowed JSI and LUH to use centuries and countries, respectively, as labels, which helped to ensure that for these two variables the class labels were not overlapping, which can be better handled by machine learning algorithms.

| <b>Partner</b> | <b>Area</b>                                | <b>Work done in the context of the text analytic module</b>                                                                                                                                                                                                                                                                                                 |
|----------------|--------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>JSI</b>     | ICT, text analytics, semantic technologies | Lead participant, development of multilingual text annotation, development of the SILKNOW thesaurus, development of machine learning methods for metadata extraction from text and text classification, implementation and evaluation of the developed software components, coordination with other partners, preparation of the integration of the result. |

|                  |                                        |                                                                                                                                                                                                                                                                                                                                                                          |
|------------------|----------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>EURECOM</b>   | ICT, Knowledge Graph, Data Integration | Providing the interface between the knowledge graph and the text classification module.<br>Contributing to the discussions about the class structure and adapting the knowledge graph to the simplified class structure.<br>Integrating the results of the text classification module into the knowledge graph, including presenting the results to the user in ADASilk. |
| <b>UVEG SSH</b>  | Art history, textile knowledge.        | Evaluation of the text analytic module.                                                                                                                                                                                                                                                                                                                                  |
| <b>LUH</b>       | ICT, Photogrammetry, Computer Vision   | Collaborate to define the class structure and a coherent interface between SILKNOW Knowledge Graph and both the text analytic and image classification modules; support the integration of the image and text analytic modules based on a common class structure and a common interface to the knowledge graph.                                                          |
| <b>UNIPA SSH</b> | Art history, textile knowledge.        | Collaborating in evaluating and training the text analytic module.                                                                                                                                                                                                                                                                                                       |

Table 6. A summary of the partners involved in the creation of the Text analytic Module, their main area of expertise and the work done.

## 5.4.2. Image classification module

The goal of the image classification module is to complete the SILKNOW knowledge graph annotations based on images. That is, for datasets in the knowledge graph for which some semantic properties could not be inferred directly from the information downloaded from the websites from which the content was harvested, but which were associated with images, the missing information should be automatically predicted from the image using convolutional neural networks (CNN). The method was implemented by LUH, a representative of the IT sector with expertise in automatic image analysis but implementing the method and integrating the results into the SILKNOW knowledge graph required LUH to collaborate extensively with other partners from different fields, making the development an interdisciplinary endeavor. The contributions of the other partners were needed for the following phases:

- **Definition of the variables to be predicted:** This step was necessary at the beginning of the implementation and required the consultation of the CNRS, who defined the ontology, and the SSH team of the UVEG, who represented the view of the cultural heritage experts. The combination of this expertise with LUH's expectation of the feasibility of the task led to the selection of five semantic variables to be predicted from images, as first documented in Deliverable D4.1.

- **Definition of the class structures:** For each variable that is to be predicted, a corresponding class structure must be designed that defines all the possible values that this variable can take. On the one hand, the classes must be related to the terms in the Thesaurus, and from the SSH perspective, the class structures should be as fine-grained as possible. On the other hand, there are practical constraints imposed by the requirements of machine learning methods, e.g., in terms of a non-overlapping definition of classes and the availability of a sufficient set of training samples. The class structures were defined by the SSH team of UVEG based on a statistical analysis performed by LUH on the basis of data provided by EURECOM. JSI was also involved in this process, as the class structures of the text analytic and the image classification modules had to match in order to allow a later integration of the two modules. The class structure defined by UVEG was a compromise between the requirements of the different disciplines. Each class grouped together several related classes from the Thesaurus so that a sufficiently large number of training samples were available for each class to allow the CNN to learn the appearance of related objects from the training data. This process was performed twice. First, it was performed by the UVEG SSH team in the early stages of the implementation, based on raw annotations from the data harvested from IMATEX, the online repository of the Centre de Documentació i Museu Tèxtil de Terrassa (cf. Deliverable D4.1), to kick-start the developments; at this point, the knowledge graph was not mature enough to be used in this context. Once the knowledge graph reached a certain level of maturity, a new class structure was defined by UVEG, which was now based on a set of collections that had already been integrated into the knowledge graph. This class structure was used for the rest of the project. It is documented in Deliverables D4.5 and D4.6, and also forms the basis for the image classification module integrated into ADASilk. Once the class structures were defined, EURECOM supported an automated extraction of the information from the knowledge graph by enriching the knowledge graph datasets with group fields containing the semantic information corresponding to the simplified class structures; from the SSH side, this process was supported by the CNRS and the UVEG SSH team. This mechanism did not apply to the production location and production time span variables, since for these variables country codes and specific definitions of epochs were considered that could be used directly by the image classification module; it was only necessary to define the granularity of the corresponding class structures (country for production location, centuries for production time span).
- **Generation of the training samples:** The first set of training samples was based on IMATEX data, which had to be mapped to the class structure just defined by LUH, described in Deliverable D4.1; Deliverable D4.2 describes their integration into the SILKNOW knowledge graph, which was performed by the ICT team of UVEG with support from EURECOM. Then, the strategic decision was made to automatically extract the training samples from the SILKNOW knowledge graph; the required SPARQL queries were formulated and executed by EURECOM. Until the delivery of Deliverable D4.4, the resulting raw data had to be mapped to the class structure defined by UVEG using software from LUH. As the knowledge graph matured and EURECOM implemented the

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simplified class structures in the group fields, it was possible to implement a simplified and highly automated workflow based on EURECOM's SPARQL queries, which was used by both the image classification and text analytic modules to prepare the training data (see deliverable D4.6).

- **Strategies for improving the classification results:** After the preliminary evaluation of the image classification module in deliverable D4.6, strategies to improve the module and its results were discussed and implemented. One of the identified problems was the lack of training examples for some classes, which was addressed by integrating more and more data into the SILKNOW knowledge graph, mainly done by EURECOM in consultation with CNRS and UVEG. On the other hand, some algorithmic improvements were also implemented and tested by LUH, with advice from the SSH team of UVEG on the relevance of the changes for cultural heritage experts. The changes that led to the final version of the image classification model and the testing results are documented in Deliverable D4.6.
- **Integration of the results in the SILKNOW Knowledge Graph:** It was decided to use the image classification module to predict the information related to the five relevant variables for all datasets of the knowledge graph for which this information was missing. The prediction was based on the CNN model identified as optimal in Deliverable D4.6 and was performed by LUH. EURECOM, JSI and LUH agreed on a common interface format so that the predictions, together with information on the expected quality of the prediction (expressed by the probabilistic class score) and how the prediction was generated (in the form of a text briefly describing the method and parameter settings used to obtain these results), could be easily integrated into the Knowledge Graph in group fields. The graphical user interface for presenting the results was developed by EURECOM in consultation with CNRS and the SSH team, who ensured that the information about how the predictions were obtained was presented in a transparent way to each user. The integration of the image classification module is reported in Deliverable D6.7.

The image classification module was originally described in [7] and [8]. The way it is embedded in the SILKNOW project was published in [9], while some modifications regarding the training procedure are presented in [10].

| Partner | Area                                   | Work done in the context of the image classification module                                                                                                                          |
|---------|----------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| LUH     | ICT, Photogrammetry, Computer Vision   | Lead participant, implementation and technical evaluation of the software.<br>Coordination with other partners<br>Preparing the integration of the results into the knowledge graph. |
| EURECOM | ICT, Knowledge Graph, Data Integration | Providing the interface between the knowledge graph and the image classification module.<br>Participation in the discussions about the class                                         |

|                 |                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|-----------------|----------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                 |                                                    | structure and adaptation of the knowledge graph to accommodate the simplified class structure<br>Integration of the results of the image classification module into the knowledge graph, including the presentation of the results to the user in ADASilk.                                                                                                                                                                                                                   |
| <b>UVEG SSH</b> | Art history, digital humanities, textile analysis. | Supporting the definition of the variables to be predicted and the decision-making processes in the context of defining reasonable adjustments to the methodology in the course of improving it.<br>Definition of the simplified class structure at different stages of the method development<br>Discussions on the optimal and transparent integration of the results into the knowledge graph.<br>Guidelines for transparent presentation of results to users in ADASilk. |
| <b>UVEG ICT</b> | ICT                                                | Integration of the earliest version of the training dataset into an early version of SILKNOW Knowledge Graph.                                                                                                                                                                                                                                                                                                                                                                |
| <b>JSI</b>      | ICT text analytics, semantic technologies          | Contribute to the definition of the class structure and a coherent interface between the SILKNOW Knowledge Graph and the two modules for text analytic and image classification.<br>Support in the integration of the results into the knowledge graph.                                                                                                                                                                                                                      |
| <b>CNRS</b>     | Digital and Textile History                        | Support in the definition of the variables to be predicted<br>Support in defining the simplified class structures and integrating them into SILKNOW Knowledge Graph.<br>Proposal for modelling the prediction results for integration into the KG.                                                                                                                                                                                                                           |

*Table 7. A summary of the partners involved in the creation of the Image Classification Module, their main area of expertise and the work done.*

## 5.5. ADASilk (Advanced Data Analysis for Silk Heritage)

ADASilk is an exploratory search engine built on the SILKNOW knowledge graph, which contains information on more than 40,000 textile objects with relevant historical and technical information as well as temporal and geographical location details. The ADASilk platform makes it possible to navigate through thousands of textiles held in the collections of various European museums and beyond. Thanks to this platform, boundaries that hinder research, such as geographical distances, are overcome and the study of fragile, unwieldy artifacts becomes possible.

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Interdisciplinary work in the creation of the SILKNOW project's exploratory search engine has been fundamental. Indeed, it is a tool that appeals to users from different fields, from the simple passionate museum visitor to the textile expert, from the designer to the tourist guide, from the university researcher to the high school student. Thanks to the interaction between historical and cultural information and computer technology, it has been possible to make the world of silk accessible to all.

An important tool that increases the functionality of ADASilk is the STMap, which makes it possible to locate artifacts spatially and temporally and relate them to each other based on their historical and technical characteristics.

The SILKNOW project is also steeped in practical knowledge, from weaving in the Jacquard looms of the Garín factory to 3D printing by Monkeyfab. This knowledge represents the past, present and future of silk and has been used extensively in the creation of all parts of ADASilk. In particular, Garín's extensive experience was invaluable as his researchers provided and shared all the technical features related to silk weaving that went into the SILKNOW tools. The Virtual Loom benefited from the technical knowledge of silk processing to identify fabrics and the many variations of processing that can be simulated thanks to the loom itself.

The development of ADASilk also required in-depth knowledge of how an expert would search and find fabric. Knowledge of tissues and how weaving techniques are interconnected over time formed the basis for building the search engine. The analysis of the search path and the logic that a searcher would use in the SSH domain led to the resolution of important issues such as the mutual positioning of search terms and the nature of the description of the artifacts resulting from the search. This last aspect is closely related to what was described earlier for the catalog, thesaurus and ontology. Evidence of this is provided by the dependency relationships between the various deliverables presented in the concluding section.

| <b>Partner</b>  | <b>Area</b>                                                       | <b>Work done in ADASILK</b>                                                                                                                                                             |
|-----------------|-------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>EURECOM</b>  | ICT, Knowledge Graph, data integration, exploratory search engine | Lead participant, designer and developer of the ADASilk application, developer of the SILKNOW API to access the Knowledge Graph.                                                        |
| <b>LUH</b>      | ICT, Photogrammetry & Computer Vision                             | Developed the Image Retrieval module and helped integrate this module into the ADASilk platform.                                                                                        |
| <b>UVEG ICT</b> | Interactive Computer Graphics                                     | Design and development of STMaps and Virtual Loom. Preparation of tools for their integration into ADASilk. Functionality and load testing of ADASilk. Usability evaluation of ADASilk. |



|                           |                                                    |                                                               |
|---------------------------|----------------------------------------------------|---------------------------------------------------------------|
| <b>UVEG</b><br><b>SSH</b> | Art history, digital humanities, textile analysis. | Internal testing of ADASilk. Usability evaluation of ADASilk. |
|---------------------------|----------------------------------------------------|---------------------------------------------------------------|

Table 8. A summary of the partners involved in the creation of the ADASilk, their main area of expertise and the work done.

## 5.5.1. Image retrieval module

The goal of the Image Retrieval module is to allow the user to use images as an index for searching the database of ADASilk. Thus, when an image query is performed, the  $k$  most similar images available in the SILKNOW knowledge graph should be identified and presented to the user along with links to the corresponding datasets to provide an initial guide for further text-based queries. The module is also based on a CNN. Here, the CNN converts any input image into a feature vector (called a descriptor) that encodes the image content. The CNN is trained so that the feature vectors of similar image pairs should be close to each other in terms of their Euclidean distance, while the feature vectors of dissimilar images should be far apart. After the CNN is trained, the knowledge graph images are processed by the CNN to generate the corresponding descriptors, which are then stored in a spatial index. When a query image is provided as input to the image search, the corresponding descriptor is computed by the CNN, the  $k$  nearest neighbors are searched among all descriptors in the spatial index, and the results are presented to the user.

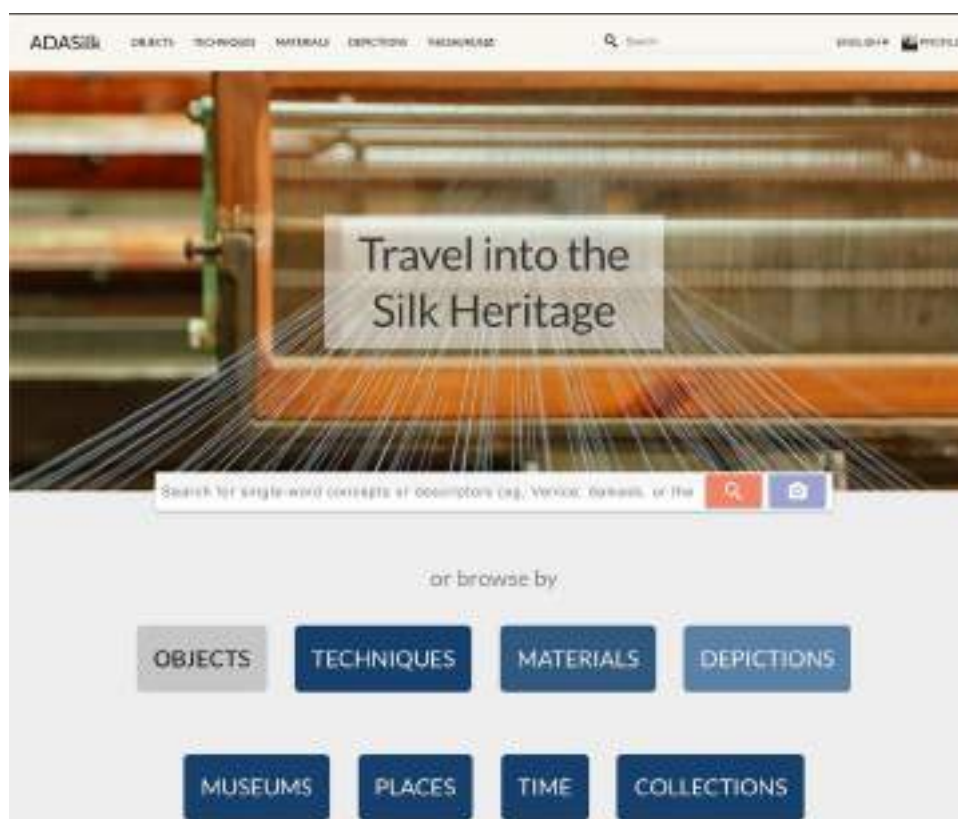


Figure 3. ADASilk main page, the elements conducting to search.

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The main problem in this context is the training process of the CNN. It requires pairs of images together with the information whether the pair is similar or not. Unfortunately, judging whether an image pair is considered similar or not is very subjective, as there is no clear and unambiguous definition of what constitutes "similarity". This problem would have made manual annotation of large sets of image pairs very difficult, regardless of the fact that such a process would have required an enormous amount of effort. In a series of technical meetings involving CNRS, the SSH team of UVEG and UNIPA, EURECOM and LUH, it was decided to start with an objective criterion based on semantic annotations, which, besides its objectivity, has the advantage that in this way the training data can be automatically derived from SILKNOW Knowledge Graph. This criterion is based on the assumption that the degree to which two images are considered similar depends on the number of semantic properties shared by the corresponding datasets in the knowledge graph. In this decision-making process, UVEG, UNIPA and CNRS discussed LUH's technical proposals from a cultural heritage perspective and made recommendations regarding the properties they considered most relevant. EURECOM was mainly responsible for matching the proposals with the possibilities of the Knowledge Graph.

Once this decision was made, LUH developed the first version of the Knowledge Graph with the support of EURECOM. At this point, the knowledge graph was already in a relatively mature state, so the automatic workflow for the extraction of training patterns with annotations in the group fields, already described in the context of the image classification module (cf. Section 5.4.2), was implemented. This means that the generation of training samples for the image classification module is based on the same interface to the knowledge graph as that for the image retrieval module, so that all the interdisciplinary work already described in Section 5.4.2 on the definition of the relevant variables, the class structures and the training samples was also essential for the development of the image retrieval module.

The first version of the image retrieval module was described in deliverable D4.4 and was also presented in [11]. The technical evaluation in D4.4 was based on the assumption that for a query image, a majority vote among the retrieved neighbors could be used for image classification, which allowed quantitative analysis based on reference data. An evaluation by UNIPA's SSH team during WP7, focusing on a mix of different visual criteria, found that the results were not entirely satisfactory from the point of view of cultural heritage experts; this evaluation is presented in Deliverable D7.1.

Consequently, a series of technical meetings to improve the module followed, again involving CNRS, the UVEG SSH team, EURECOM and LUH. CNRS and UVEG contributed different ideas on which criteria could be considered relevant for the definition of similarity, while LUH considered whether they could be implemented and EURECOM contributed its generic knowledge of search engines and its support for the use of data available in the knowledge graph in this context. It was soon decided that color should take a major role in defining visual similarity, together with the assumption that images of the same object should also be considered similar ("self-similarity"). Based on some preliminary experiments with these

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additional cues for similarity by LUH, the SSH team at UVEG defined "similarity rules" that define pairs of similar images based on the content of the knowledge graph, EURECOM provided the relevant SPARQL queries to extract these patterns, and LUH implemented the corresponding loss function to be used in training. The extended image retrieval module can be trained using four different aspects of similarity (semantic similarity, self-similarity, color similarity, and the rules defined by UVEG), which can be combined arbitrarily. This led to the definition and evaluation of five different scenarios in deliverable D4.6, where the technical evaluation was again based on the semantic aspects and was performed by LUH, while UNIPA evaluated the quality from the end-user perspective in a similar way as described in D7.1. The results were discussed with UVEG experts and consequently two scenarios for integration were recommended: One scenario combines all aspects of similarity, while the other focuses on the visual aspects.

The integration was carried out by EURECOM in collaboration with LUH, who adapted the software to speed up processing time by allowing preloading of data before actual retrieval. The integration was supported by the UVEG SSH team, who oversaw the way the options for the integration were to be presented to the user. The integration of the module into ADASilk is described in Deliverable D6.7.

| <b>Partner</b>  | <b>Area</b>                                                 | <b>Work done in the context of the image retrieval module</b>                                                                                                                                                                                                                                                                  |
|-----------------|-------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>LUH</b>      | ICT, Photogrammetry, Computer Vision                        | Lead participant<br>Implementation and technical evaluation of the software<br>Coordination with other partners<br>Preparation of the integration into ADASilk.                                                                                                                                                                |
| <b>EURECOM</b>  | ICT, Knowledge Graph, data integration, recommender systems | Providing the interface between the Knowledge Graph and the Image Retrieval module.<br>Support in discussions to define different concepts of similarity.<br>SPARQL queries to extract samples according to the UVEG similarity rules from the knowledge graph.<br>Integration of this module into ADASilk, including the GUI. |
| <b>UVEG SSH</b> | Art history, digital humanities, textile analysis.          | Contributions to the definition of the relevant variables, class structures and training samples as described in the context of the image classification module.<br>Support for the definition of similarity scenarios                                                                                                         |

|                               |              |                                                                                                                                                                                                                                                                                                                                                         |
|-------------------------------|--------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                               |              | <p>Definition of rules to identify "similar" samples in the data contained in the knowledge graph.</p> <p>Supervision of the integration in ADASilk from the point of view of a user from the field of cultural heritage.</p>                                                                                                                           |
| <b>CNRS - LARHRA / Lyon 2</b> | SSH, History | <p>Contribution to the definition of relevant variables, class structures and training samples as described in the context of the image classification module.</p> <p>Contributing to the definition of scenarios of "similarity".</p>                                                                                                                  |
| <b>UNIPA SSH</b>              | Art History  | <p>Definition of the evaluation criteria for image retrieval in the context of deliverable D7.1.</p> <p>Evaluation of the initial version of the module from the user's point of view within the scope of deliverable D7.1</p> <p>Evaluation of the final version of the module from the user's point of view within the scope of deliverable D4.6.</p> |

Table 9. A summary of the partners involved in the creation of the Image Classification Module, their main area of expertise and the work done.

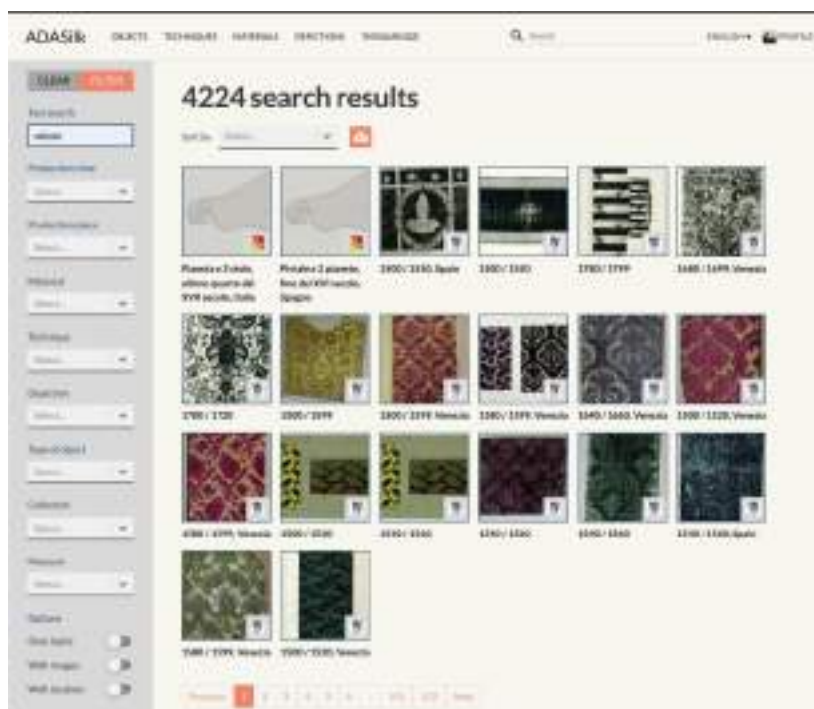


Figure 4. ADASilk results page with the filters for conducting searches following the ontology concept.

## 5.6. Virtual Loom

Virtual Loom is an interactive tool that provides the user with a 3D representation of historical silks. It is available both as a stand-alone application and integrated with ADASilk. Representation is possible at the weaving thread level. Virtual Loom goes beyond a simple documentation of the fabric surface with a visual representation in the form of images. The internal structure of a tissue is very complex and is composed of a large number of interwoven threads. Virtual Loom maps a tissue from a simple image down to the level of the weaving threads. Its development therefore required, in particular, interaction and integration between SSH and ICT. In particular, it was necessary to provide ICT experts with the geometry of the weaves and, in detail, the following factors:

- The weaving, studied to understand how a real loom works and how an artisan works with it.
- The weaving techniques, to understand how the number of threads and the way they are woven give an indication of how a fabric is structured, and how they have changed over time.
- The threads, i.e. to learn what threads, strengths, colors, etc. have characterized particular weaving techniques throughout history.

Therefore, the development of Virtual Loom was based on a computational model that took into account historical weaving techniques. This was only possible through a very close collaboration between SSH and ICT, mainly between the ICT of UVEG and the SSH of Garín. The UVEG researchers made several visits to Garín's factory to meet the artisans and ask them ad-hoc questions about silk textile production. On the other hand, Garín produced several textiles using different techniques and the ICT experts were able to define the main characteristics of the threads and the production of their 3D models.

Figure 5 shows a screenshot of the first version of Virtual Loom, whose functionalities were explained to the project partners. The feedback from the partners and the subsequent interactions made it possible to fix some bugs and obtain the current final version. Thanks to Monkeyfab's knowledge, the 3D pattern created can be printed, creating a macroscopic copy of the fabric, a 3D model that can be used in various ways. For example, for educational purposes or for the blind, so that they can "touch" the fabric represented in an image.

Preliminary work describing the workflow of Virtual Loom to subtract the design of a textile was presented in [13]. In [14] we also showed some basic 3D models of a weaving technique, and in [15] we explained how to apply the similarity functionality in VL to recover the design of traditional silk fabrics while also obtaining 3D representations. In [16], we showed the complete workflow and graphical user interface of VL and introduced them in detail, from design subtraction to yarn modeling to description of weaving techniques, etc. Finally, in [17] we bring some results using 3D printing technology.

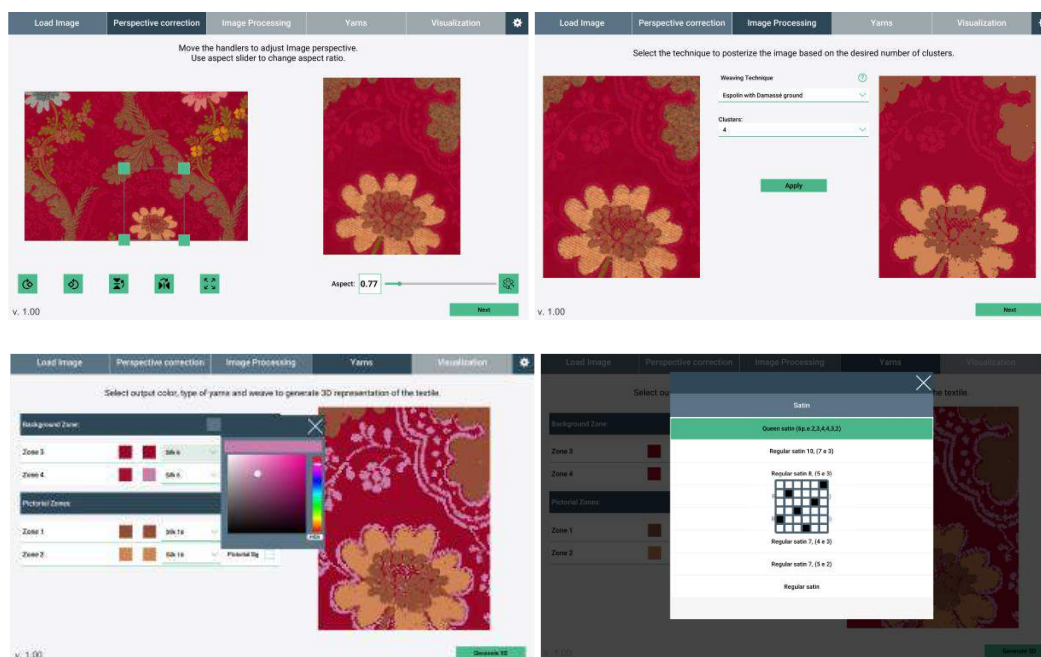


Figure 5. Version 1.0 of Virtual Loom. Part of the process to produce a 3D model.

| Partner   | Area                                               | Work done in VL                                                                                                                                                                                                |
|-----------|----------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| UVEG ICT  | Interactive computer graphics.                     | Designed and implemented Virtual Loom. Internal testing of the tool. Iterative improvements and bug solving. Optimization of the tool. Functionality and stress testing.                                       |
| UVEG SSH  | Art history, digital humanities, textile analysis. | SSH team contributed to naming and defining the techniques used in the virtual loom, as well as the weaves used. They were among the first terms included in the thesaurus.                                    |
| Garín     | SSH<br>Creative industry                           | Help in establishing weaving techniques, their weaves, and limitations. They had several meetings with the UVEG ICT team to help them understand the decisions weavers make when executing certain techniques. |
| MonkeyFab | 3D printing                                        | Implementation of the methodology to produce STL files. Produced 3D printouts of 3D models reproduced by Virtual Loom.                                                                                         |
| LUH       | ICT, Photogrammetry, Computer Vision               | Testing of the module                                                                                                                                                                                          |
| EURECOM   | ICT, software integration                          | Integration of the Virtual Loom in ADASilk                                                                                                                                                                     |

Table 10. A summary of the partners involved in the creation of Virtual Loom, their main area of expertise and the work done.

## 5.7. STMaps (Spatio-Temporal Map)

STMaps is an interactive tool for visualizing objects from both spatial and temporal perspectives. For this tool, too, the collaboration between ICT and SSH started at the very beginning of the project. In the development phase of the tool, UVEG members collaborated mainly as experts in geography. Later, when the tool was integrated with ADASilk, it was necessary to collaborate with ICT experts from EURECOM during the development to ensure that the data displayed by STMaps were correctly retrieved from the Knowledge Graph. This phase took into account that the KG is based on one ontology, which in turn is based on another ontology, to define how the data should be displayed, so the interaction between EURECOM and UVEG was crucial and continuous. Some of the problems that were discussed and solved were related to how to display objects that have multiple locations or multiple time periods. Also, the issues were how to represent the relationships between object properties and what were the most representative object properties and categories.

Figure 6 shows the first part of the exploration results in STMaps, a general view of all objects that meet a specific search criterion, and the type of view obtained when zooming in on a specific object. Finally, Figure 7 shows a multi-layered view. From the figures, the complexity of the tool becomes apparent, and thus also that this would not have been possible without the interdisciplinary work. Some preliminary work describing the workflow of STMaps was presented in [18]. In [19], a detailed description of the tool was presented, describing the implementation of the spatio-temporal relations and addressing specific case studies.

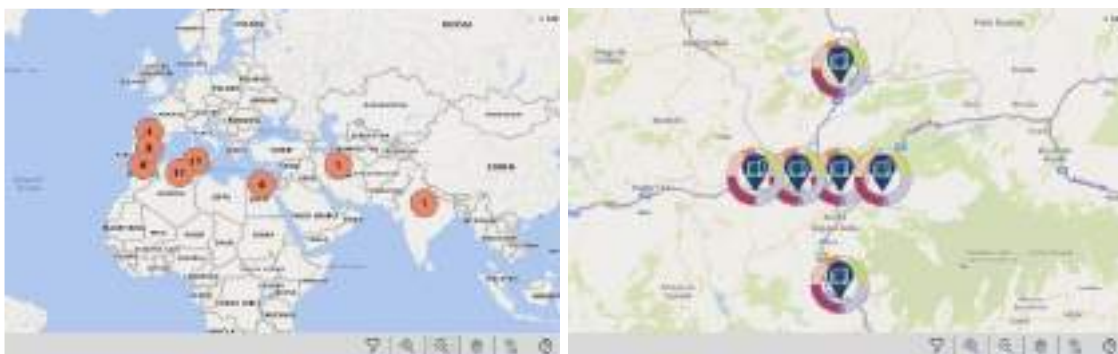


Figure 6. The STMaps and the spatial positioning of retrieved objects.



Figure 7. STMaps and the time positioning of retrieved objects.

| Partner         | Area                           | Work done in STMaps                                                                                                                                                |
|-----------------|--------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UVEG ICT</b> | Interactive computer graphics. | Designed and implemented STMaps. Internal testing of the tool. Iterative improvements and bug solving. Optimization of the tool. Functionality and stress testing. |
| <b>UVEG SSH</b> | Digital humanities, geography. | SSH team contributed to decide in certain aspects on how to display the objects on the interactive map.                                                            |
| <b>EURECOM</b>  | ICT, software integration      | Integration of the Spatio Temporal Map module in ADASilk                                                                                                           |

*Table 11. A summary of the partners involved in the creation of the STMaps, their main area of expertise and the work done.*

## 6. VALIDATION AND EVALUATION

Validation of the project results was carried out by all partners both during the development phase and at the end of the prototypes. A validation performed by ICT partners was done using cross-validation techniques to evaluate classification software.

For the Text Analysis and Image Retrieval modules, a training phase with SSH and a validation phase were carried out. The first phase concerned the semantic annotation of the text analysis module and the second the verification of the correct mapping between the datasets extracted from the museum collections and the ontology. Finally, a particular phase of validation concerned the image retrieval module. In this case, several meetings between SSH and ICT (particularly, LUH) were necessary to establish and define the concept of similarity. Subsequently, SSH experts analysed hundreds of images to determine the similarity as it resulted from the image retrieval module and to provide feedback to train the module.

All interactive tools (ADASilk, Multilingual Thesaurus, Virtual Loom, STMaps and Educational Materials) were also tested by SSH and ICT. Internal testing was conducted by the development partners in collaboration with all other partners. All SILKNOW tools were also evaluated by volunteer evaluators in the role of end users. These evaluators belonged to different user profiles, e.g., tourism staff, fashion journalists, art historians, etc., identified as Target Audiences, as presented in D.2.3. Thus, the external evaluators covered different knowledge areas.

## 7. DISSEMINATION

The project benefited from the partnership with Instituto Cervantes. It contributed its global presence and extensive connections in many countries. Their main achievement has been the transformation of silk heritage into an educational tool. The educational material "La Ruta de la Seda (The Silk Road)" was specifically designed for learning Spanish through different aspects related to silk in Europe. At the same time, it highlighted the cultural exchanges that



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silk production and trade brought and still bring, as well as the immense human heritage associated with it. Additionally, two fundamental events saw the Instituto Cervantes as a link between the two worlds of ICT and SSH experts: *Mayo de Seda* and the workshop titled: "From the documentation of museum collections to the management of digital data. Challenges and opportunities in the future".

## 7.1. Mayo de Seda

In order to spread knowledge about the heritage of silk, the collaboration between the UNIPA team and Instituto Cervantes also resulted in a cycle of cultural events called *Mayo de Seda*. From 4 to 27 May, 2021, seminars were held on various topics related to the world of silk and the link between Sicily and Spain: from production to commissioning, from collecting to musealization. The exhibition "Trame di seta fra Spagna e Palermo" (Silk threads between Spain and Palermo) was also shown in the church Santa Eulalia dei Catalani, the seat of Instituto Cervantes in the city of Palermo. The exhibition offers a selected photographic review of textile artifacts preserved in the treasure of Palermo Cathedral and Diocesan Museum of Monreale. Each exhibited panel is tagged with a QR code that, once captured by the smartphone camera, leads the user to the SILKNOW Thesaurus website, where the weaving technique related to the artifact can be found. The corresponding concept in the thesaurus is linked to others, making explicit the relationships between concepts in the domain of interest to SILKNOW. The terminological relationships are used to help the user navigate the thesaurus.

## 7.2. Workshop 'Dalla documentazione delle collezioni museali alla gestione dei dati digitali. Sfide e opportunità dei dati aperti'

Another example of the integration of interdisciplinary knowledge was the organization of the workshop 'From Museum Collections Documentation to Digital Data Management. Challenges and opportunities of Open Data' (as reported in D8.9).

The workshop was held on three different dates in Spanish, English and Italian. We created new synergies with other projects and institutions outside our consortium, with the aim that the results spill over to other disciplines. Seventy-three institutions that have textile artifacts in their collections participated.

By holding a roundtable and directly involving museums that are custodians of textile artifacts, attention was drawn to the preservation of textile artifacts and their enhancement. There has also been a recognition of the need for different cultural communities to network and share knowledge in order to achieve this. This is only possible thanks to recent information technologies that have modernized cataloging and conservation and made it more efficient and faster, as well as the new frontiers of communication thanks to social media and increased dissemination possibilities on web platforms.

## 7.3. Summary of the dissemination outcomes

In Table 12, we summarize all the dissemination events produced during the project, that benefited from the interdisciplinary work of the partners.

| EVENT                                                                                         | ORGANIZED BY                   | SSH              | ICT              | OUTCOMES                                                                                                                                                                                                                                |
|-----------------------------------------------------------------------------------------------|--------------------------------|------------------|------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Madrid, Museo del Traje: Conectando historias: de los tejidos al big data. 27/06/2019         | UVEG                           | UVEG SSH         | UVEG ICT         | This meeting served as a forum for dialogue with various stakeholders (museums, tourism agencies, creative industries, innovation centres, universities...) designed to create meeting points between cultural heritage and technology. |
| 2019 General Assembly of the Silk Road Universities Network. From 18/09/2019 until 21/09/2019 | Silk Road Universities Network | UVEG SSH         | UVEG ICT         | Conference on "The Role of Universities for Transforming Silk Roads into Peace Roads with Prominent Human Heritages"                                                                                                                    |
| Sharper Night 23/11/2020                                                                      | UNIPA                          | UNIPA SSH        | UNIPA ICT        | During this event, the SILKNOW team demonstrated the importance of silk heritage and the usefulness of the virtual loom. The importance of collaboration between historical and technological knowledge was demonstrated.               |
| Weaving Europe. Online International Conference on Silk heritage                              | UVEG                           | All SSH partners | All ICT partners | Experts, researchers, students and creatives gathered virtually for a meeting dedicated to silk heritage, its conservation                                                                                                              |

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|                                                                                         |                                       |                                    |            |                                                                                                                                                                                                                                                                                                                                                                       |
|-----------------------------------------------------------------------------------------|---------------------------------------|------------------------------------|------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| and Digital Technologies (from 30/11/2020 to 04/12/2020)                                |                                       |                                    |            | and restoration, its digitalization, tourism, creative industries, social innovation and communication of textile heritage.                                                                                                                                                                                                                                           |
| Warsaw: Fashion and technology: a tribute to silk (27/02/2021)                          | Instituto Cervantes Warsaw, MonkeyFab | Instituto Cervantes and Garín 1820 | Monkey Fab | Fashion catwalk with 12 3D printed designs: Highlighted the relation between silk heritage, weaving techniques and 3D printing                                                                                                                                                                                                                                        |
| SILKNOW lectures via Zurbaran Centre, Durham University (from 07/05/2021 to 17/05/2021) | Instituto Cervantes Manchester, UVEG  | UVEG SSH<br>Instituto Cervantes    | UVEG ICT   | 3 lectures.<br>* <i>Staging Medieval Silk in Iberia: Treasure, Ritual, and Ornament.</i> + ADASilk presentations<br>* <i>Revisiting Sericulture and Silk Production in the Kingdoms of Spain, circa 1300-1700: local and global networks</i> + Thesaurus presentation<br>* <i>Silk in contemporary society, beyond its ornamental use</i> + Virtual Loom presentation |
| Collaboration with EASD Valencia, during the 2019-2020 and 2020-2021 academic years     | UVEG                                  | UVEG SSH                           | UVEG ICT   | Collaboration with EASD Valencia, exchange of ideas between design students and ICT staff of the SILKNOW group for the optimal use of tools such as Thesaurus, Virtual Loom and ADASilk.                                                                                                                                                                              |
| Maggio di seta / Mayo de Seda - Exhibition                                              | UNIPA, Instituto Cervantes            | UNIPA SSH / Instituto Cervantes    | UNIPA ICT  | Conference series ' Maggio di Seta' every Tuesday and Thursday from 04/05/2021 to 27/05/2021 - The event                                                                                                                                                                                                                                                              |

|                                                                                                                |                            |                                |          |                                                                                                                               |
|----------------------------------------------------------------------------------------------------------------|----------------------------|--------------------------------|----------|-------------------------------------------------------------------------------------------------------------------------------|
| "Trame di seta tra la Spagna e Palermo" from 28/05/2021 until 30/06/2021                                       |                            |                                |          | was dedicated to the Silk Road and relations between Spain and Sicily.                                                        |
| Lyon, Exhibition: Le projet SILKNOW: avec notre passé, tissons notre avenir (from 07/06/2021 until 30/09/2021) | CNRS, Instituto Cervantes  | CNRS SSH Instituto Cervantes   | CNRS ICT | History and technology of silk production in Lyon in the 18th century.                                                        |
| Brussels: Conference series: Ensedados / Europe is woven in silk (from 15/06/2021 until 07/07/2021)            | UVEG / Instituto Cervantes | UVEG SSH / Instituto Cervantes | UVEG ICT | A two-part cycle of conferences exploring the fields of European Silk Road from different angles: from history to technology. |

Table 12. Events, meetings and conferences resulting from SILKNOW.

## 8. SCIENTIFIC RESULTS

The three years of work on the SILKNOW project resulted in several publications presenting and discussing the scientific results. Table 13 lists the papers published so far and assigns them to either ICT, SSH or ICT&SSH, according to both the expertise of the authors of the papers and the scope of the conference and/or journal. As can be seen, at least a third of the papers reflect the interdisciplinary nature of both fields, both in terms of authorship and scope.

| Scientific contributions | Authors |     |         | Scope |     |         |
|--------------------------|---------|-----|---------|-------|-----|---------|
|                          | ICT     | SSH | ICT&SSH | ICT   | SSH | ICT&SSH |
|                          |         |     |         |       |     |         |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |   |   |   |   |   |   |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|---|---|---|---|---|
| Portalés, C., Sebastián, J., Sevilla, J., Alba, E., Fernández, M., Gaitán, M., ... & Gimeno, J. (2021, July). Interactive Tools for the Visualization of Tangible and Intangible Silk Heritage Emerging from an Interdisciplinary Work. In International Conference on Human-Computer Interaction (pp. 100-118). Springer, Cham.                                                                                                                                |   |   | * |   |   | * |
| Portalés, C., Pérez, M., Casanova-Salas, P. et al. Virtual Loom: a tool for the interactive 3D representation of historical fabrics. <i>Multimed Tools Appl</i> (2021). <a href="https://doi.org/10.1007/s11042-020-10294-w">https://doi.org/10.1007/s11042-020-10294-w</a>                                                                                                                                                                                     | * |   |   | * |   |   |
| Pagán, E., Gaitán, M., León, A., Sebastián, J. (2021). El hilo de la historia: del patrimonio mueble al intangible. Rescatando el patrimonio textil sedero. In A. Lerma, V. López-Menchero, A. Maldonado, <i>Actas del I Simposio anual de Patrimonio Natural y Cultural ICOMOS España, València</i> , Editorial Universitat Politècnica de València, <a href="https://doi.org/10.4995/icomos2019.2020.12513">https://doi.org/10.4995/icomos2019.2020.12513</a> |   | * |   |   | * |   |
| Sevilla, J., Casanova-Salas, P., Casas-Yrurzum, S., & Portalés, C. (2021). Multi-Purpose Ontology-Based Visualization of Spatio-Temporal Data: A Case Study on Silk Heritage. <i>Applied Sciences</i> , 11(4), 1636. doi:10.3390/app11041636                                                                                                                                                                                                                    | * |   |   | * |   |   |
| Alba, E.; Gaitán, M.; Pitarch, M.D.; León, A.; Moya, M.; Marín, J.; Vitella, M.; Lo Cicero, G.; Rottensteiner, F.; Clermont, D.; Dorozynski, M.; Wittich, D.; Vernus, P.; Puren, M. From Silk to Digital Technologies: A Gateway to New Opportunities for Creative Industries, Traditional Crafts and Designers. <i>The SILKNOW Case. Sustainability</i> 2020, 12, 8279.                                                                                        |   |   | * |   |   | * |
| Pérez, M.; Casanova-Salas, P.; Twardo, P.; Twardo, P.; León, A.; Mladenic, D.; Massri, B.M.; Troncy, R.; Ehrhart, T.; Cicero, G.L.; Vitella, M.; Gaitán, M.; Gimeno, J.; Ribes, E.; Fernández, M.; Portalés, C. From Historical Silk Fabrics to Their Interactive                                                                                                                                                                                               |   |   | * |   |   | * |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |   |   |   |   |   |   |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|---|---|---|---|---|
| Virtual Representation and 3D Printing. Sustainability 2020, 12, 7539.                                                                                                                                                                                                                                                                                                                                                                                                                           |   |   |   |   |   |   |
| Clermont, D.; Dorozynski, M.; Wittich, D.; Rottensteiner, F. (2020): Assessing the semantic similarity of images of silk fabrics using convolutional neural networks. In: ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences V-2, pp. 641–648.                                                                                                                                                                                                                  | * |   |   | * |   |   |
| Pérez, M.; Casanova, P.; Portalés, C.; Gimeno, J. Virtual Loom, from Historical Fabrics to Interactive 3D Models. In: Montagud, Mario; Cesar, Pablo; Fernández, Sergi; Garcia-Pineda, Miguel; Gutiérrez, Jesús; Cernigliaro, Gianluca; et al. (2020): Adjunct Proceedings of the ACM International Conference on Interactive Media Experiences (IMX) 2020. figshare. Collection. <a href="https://doi.org/10.6084/m9.figshare.c.5020919.v1">https://doi.org/10.6084/m9.figshare.c.5020919.v1</a> | * |   |   |   |   | * |
| Poster: Pérez, M.; Casanova, P.; Portalés, C.; Gimeno, J. Virtual Loom, from Historical Fabrics to Interactive 3D Models. In: ACM International Conference on Interactive Media Experiences (IMX) 2020.                                                                                                                                                                                                                                                                                          | * |   |   |   |   | * |
| Gaitán, M.; Portalés, C.; Sevilla, J.; Alba, E. Applying Axial Symmetries to Historical Silk Fabrics: SILKNOW's Virtual Loom. Symmetry 2020, 12, 742.                                                                                                                                                                                                                                                                                                                                            |   |   | * | * |   |   |
| Sebastián, J.; Alba, E.; Portalés, C.; Gaitán, M.; León, A. (2020). Los catálogos de museo, una gran oportunidad para el conocimiento abierto... si se abren. PH: Boletín del Instituto Andaluz del Patrimonio Histórico, 29 (100), 2-4.                                                                                                                                                                                                                                                         |   |   | * |   | * |   |
| Alba, E.; Gaitán, M.; Sebastián, S; León, A. (2020). SILKNOW, tejiendo el pasado hacia el futuro. Datatèxtil (40)                                                                                                                                                                                                                                                                                                                                                                                |   | * |   |   | * |   |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |   |  |   |   |   |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|--|---|---|---|
| Puren, M., Vernus, P. Understanding and preserving the European Silk Heritage: producing accessible, interoperable and reusable Cultural Heritage data with the SILKNOW ontology. Darial Annual Event 2019, May 2019, Varsovie, Poland. (hal-02443486)                                                                                                                                                                                                                                                                                        | * |  |   | * |   |
| Léon, A., Gaitán, M., Sebastián, J., Pagán, E. A., & Insa, I. (2019, November). SILKNOW. Designing a thesaurus about historical silk for small and medium-sized textile museums. In Science and Digital Technology for Cultural Heritage-Interdisciplinary Approach to Diagnosis, Vulnerability, Risk Assessment and Graphic Information Models: Proceedings of the 4th International Congress Science and Technology for the Conservation of Cultural Heritage (TechnoHeritage 2019), March 26-30, 2019, Sevilla, Spain (p. 187). CRC Press. | * |  |   |   | * |
| Alba, E., Gaitán, M., León, A., & Sebastián, J. (2020). Spanish Religious Textiles from the 18th and the 19th centuries: the Garín case. European Journal of Science and Theology, 16(1), 187-197.                                                                                                                                                                                                                                                                                                                                            | * |  |   |   | * |
| Puren, M., Vernus, P. Improving the understanding and preservation of European Silk Heritage Producing accessible and reusable Cultural Heritage data with the SILKNOW ontology in CIDOC-CRM. Digital Humanities 2019, Jul 2019, Utrecht, Netherlands. (hal-02443403)                                                                                                                                                                                                                                                                         | * |  |   | * |   |
| Puren, M., Vernus, P. Understanding and preserving the European Silk Heritage: producing accessible, interoperable and reusable Cultural Heritage data with the SILKNOW ontology. Darial Annual Event 2019, May 2019, Varsovie, Poland. (hal-02443486)                                                                                                                                                                                                                                                                                        | * |  |   | * |   |
| Alba Pagán, E., Fernández, M., Gaitán, M., León, A., Portalés, C., Sebastián, J., & Sevilla, J. (2019). Technological tools for the conservation of silk Heritage: Improving the conservation of European religious textile cultural Heritage. ESRARC 2019 11th European on Religious Art, Restoration and Conservation, 2019, p. 150-156.                                                                                                                                                                                                    |   |  | * | * |   |

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|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|--|---|---|---|--|
| Dorozynski, M., Clermont, D., and Rottensteiner, F.: Multi-Task Deep Learning With Incomplete Training Samples For The Image-Based Prediction Of Variables Describing Silk Fabrics, ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci., IV-2/W6, 47–54, <a href="https://doi.org/10.5194/isprs-annals-IV-2-W6-47-2019">https://doi.org/10.5194/isprs-annals-IV-2-W6-47-2019</a> , 2019. | * |  |   | * |   |  |
| Gaitán, M.; Alba, E.; León, A.; Pérez, M.; Sevilla, J.; Portalés, C. Towards the Preservation and Dissemination of Historical Silk Weaving Techniques in the Digital Era. <i>Heritage</i> 2019, 2, 1892-1911.                                                                                                                                                                              |   |  | * |   | * |  |
| Mladenic, D.; Gaitán, M.; Troncy, R. (2019). SILKNOW – Multilingual Text Analysis for Silk Heritage. In Proceedings of the 25th ACM SIGKDD International Conference on Knowledge Discovery & Data Mining (KDD '19). Association for Computing Machinery, New York, NY, USA, 1–2.                                                                                                           |   |  | * | * |   |  |
| Portalés, C.; Sevilla, J.; Pérez, M.; León, A. A Proposal to Model Ancient Silk Weaving Techniques and Extracting Information from Digital Imagery – Ongoing Results of the SILKNOW Project.; Faro (Portugal), 2019.                                                                                                                                                                       |   |  | * | * |   |  |
| Sevilla, J.; Portalés, C.; Gimeno, J.; Sebastián, J. SILKNOWViz: Spatio-temporal data ontology viewer.; Faro (Portugal), 2019.                                                                                                                                                                                                                                                             |   |  | * | * |   |  |
| Dorozynski, M.; Wittich, D.; Rottensteiner, F. (2019): Deep Learning zur Analyse von Bildern von Seidenstoffen für Anwendungen im Kontext der Bewahrung des kulturellen Erbes. 39. Wissenschaftlich-Technische Jahrestagung der DGPF und Dreiländertagung der OVG, DGPF und SGPF in Wien, Publikationen der DGPF Band 28, 387-399.                                                         | * |  |   | * |   |  |



|                                                                                                                                                                                                                                                                                                                                                                                   |          |          |           |          |          |          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|----------|-----------|----------|----------|----------|
| Alba, E.; Pitarch, M.D; Sebastian, J.; Arnandis, R.; Portalés, C.; Gaitán, M. (2019). Innovación social en patrimonio cultural y museos de la seda en Europa: una mirada conectada con las industrias creativas. In. Boix, R. International Conference on Regional Science. Hacia un modelo económico más social y sostenible. Asociación Española de Ciencia Regional, Valencia. |          |          | *         |          |          | *        |
| Portalés, C.; Sebastián, J.; Alba, E.; Sevilla, J.; Gaitán, M.; Ruiz, P.; Fernández, M. Interactive Tools for the Preservation, Dissemination and Study of Silk Heritage—An Introduction to the SILKNOW Project. Multimodal Technologies Interact. 2018, 2, 28.                                                                                                                   |          |          | *         |          |          | *        |
| López Terrada, M.J; Alba, E. (2018). Pintores y ornatos para los Tejidos de seda en la Ilustración y la Academia valenciana de Bellas Artes, Quaderns de Filologia: Estudis Literaris XXIII                                                                                                                                                                                       |          | *        |           |          | *        |          |
| <b>TOTAL (number of collaborations)</b>                                                                                                                                                                                                                                                                                                                                           | <b>7</b> | <b>8</b> | <b>12</b> | <b>9</b> | <b>9</b> | <b>9</b> |

Table 13. The list of conferences and journal papers produced by the SILKNOW partnership.

## 9. DISCUSSION AND CONCLUSIONS

In this report we have shown how and why the outcomes of the SILKNOW project are the result of interdisciplinary activities between the SSH and ICT experts involved in the project. We have listed all the outcomes of the project and shown what this interdisciplinarity consisted of. We have also shown how the specific characteristics of the Cultural Heritage support tools required the presence of experts from different fields as different and complementary sides of the same coin.

From the analysis of the results obtained so far and the process carried out during the development of the project, it is clear that a deep understanding by the ICT team of a number of elements closely related to the world of textiles was necessary. For example, the most important ones include weaving techniques, how textiles are characterized according to weaving techniques, how information about textiles from different museum collections should be presented to highlight the elements relevant to SILKNOW and in accordance with the ontology created and derived from CIDOC-CRM.

The continuous interaction between the partners and the close connection between the different cultural domains involved in the project is illustrated by Table 14. In the table we have shown which deliverables related to the technical, development and dissemination aspects

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of the project have dependencies/relationships with other deliverables, and which were the main authors. As you can see, relationships between deliverables are abundant, implying a high degree of interdisciplinarity between project tasks.

| <b>Deliverable</b> | <b>in relation with</b>                                                                              | <b>Authorship</b> |
|--------------------|------------------------------------------------------------------------------------------------------|-------------------|
| <b>D2.4</b>        | D8.3, D8.4, D8.5                                                                                     | UNIPA, UVEG       |
| <b>D3.3</b>        | D2.2, D2.5, D6.1                                                                                     | CNRS, UNIPA, UVEG |
| <b>D3.4</b>        | D3.1, D3.2, D3.3, D6.1                                                                               | JSI, UVEG, LUH    |
| <b>D4.1</b>        | D2.2, D6.1                                                                                           | CNRS              |
| <b>D4.2</b>        | D4.1, D6.1                                                                                           | UVEG              |
| <b>D4.4</b>        | D2.1, D2.2, D2.5, D6.1, D6.3, D6.5, D3.1, D4.1, D4.2, D4.3, D3.3, D7.1, D7.2, D3.3, D4.5, D4.6       | LUH               |
| <b>D4.5</b>        | D2.1, D2.2, D2.5, D6.1, D6.3, D6.5, D3.1, D4.1, D4.2, D4.3, D3.3, D7.1, D7.2, D4.4, D3.3, D4.5, D4.6 | LUH               |
| <b>D4.6</b>        | D2.1, D2.2, D2.5, D6.1, D6.3, D3.1, D4.1, D4.2, D4.4, D4.5, D4.3, D7.1, D3.4, D6.7                   | LUH, UNIPA        |
| <b>D5.2</b>        | D5.1                                                                                                 | UVEG              |
| <b>D5.4</b>        | D5.2, D5.3, D5.4, D4.3, D5.6, D6.4, D6.5, D5.7, D7.3, D7.4                                           | UVEG              |
| <b>D5.5</b>        | D3.2, D3.3, D6.3                                                                                     | UVEG              |
| <b>D5.6</b>        | D5.3, D5.4, D5.5, D5.6, D7.4                                                                         | MONKEYFAB         |
| <b>D5.7</b>        | D2.4, D5.4, D5.5, D7.3                                                                               | UVEG              |
| <b>D6.1</b>        | D2.1, D2.2, D2.3, D2.4, D3.3, D4.1,                                                                  | EURECOM           |
| <b>D6.2</b>        | D2.1, D2.2, D2.3, D2.4, D4.1, D6.1                                                                   | EURECOM           |
| <b>D6.3</b>        | D2.1, D2.2, D2.3, D2.4, D3.1, D3.2, D3.3                                                             | EURECOM           |
| <b>D6.4</b>        | D3.1, D5.2, D6.3, D6.5, D7.3                                                                         | UVEG              |
| <b>D6.5</b>        | D6.3, D3.1, D5.4, D2.3, D2.4, D6.7                                                                   | EURECOM           |
| <b>D7.1</b>        | D2.3, D2.4, D3.3, D6.5, D4.5, D3.2, D4.4                                                             | JSI               |
| <b>D7.2</b>        | D2.4, D6.5                                                                                           | UNIPA             |

|              |                                     |       |
|--------------|-------------------------------------|-------|
| <b>D7.3</b>  | D2.4                                | UNIPA |
| <b>D7.4</b>  | D7.3, D8.3, D8.4, D8.5, D8.8        | IC    |
| <b>D7.5</b>  | D5.3, D5.4, D5.6, D5.7, D6.5        | GARIN |
| <b>D8.6</b>  | D6.1                                | CNRS  |
| <b>D8.9</b>  | D8.4, D8.6, D8.10, D1.3, D8.4, D8.6 | UVEG  |
| <b>D8.11</b> | D8.4, D5.3, D5.7, D6.4, D6.5, D8.7  | UVEG  |

Table 14. Relationship among deliverable and authorship.

Specifically, the deliverables listed in the table are approximately 62% of the deliverables released to date. Thus, about 62% of the work in the project required close collaboration between partners and knowledge sharing, and each deliverable has, on average, relationships with 5.5 other deliverables. This is of course a conservative estimate, as it is based only on the evaluation deliverables and does not take into account the number of internal meetings between teams and email, message or communication exchanges in general.

Figure 8 suggests a different view of the table above to highlight the number of deliverables each deliverable in the list is associated with.



Figure 8. The number of deliverables dependencies.

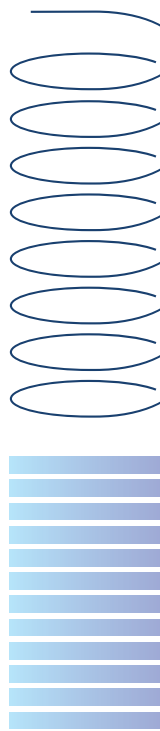
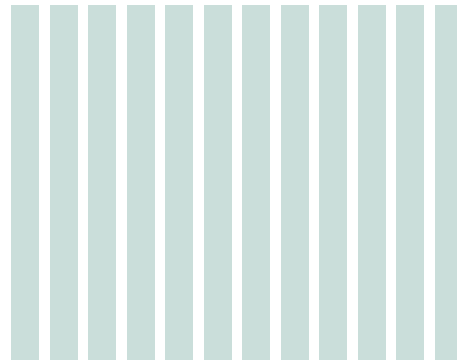
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As a conclusion, it should be emphasized that the collaboration between the different partners has allowed a continuous improvement of the final outcomes. In particular, the collaboration and interaction between ICT and SSH during the validation and testing phases has allowed, through the feedback received, to improve the interfaces, fix some bugs and make all tools more efficient from the point of view of the end users, who can be very diverse and have different needs, from the art history expert to the simple tourist. We can say that thanks to the high interdisciplinarity of the project, SILKNOW presents solutions that are completely usable in any context and by any user.

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