This document is an adaptation of chapter 9 of the doctoral thesis: VISUALIZATION OF THE CONTENT OF SPACE-TEMPORARY DATA GRAPHS OF THE HERITAGE AREA CULTURAL

EXAMPLE OF INSTANTATION OF THE STEVO ONTOLOGY FOR THE REPRESENTATION OF THE SPACE TIME VISUALIZATION SYSTEM OF THE SILKNOW PROJECT.

SILKNOW project

The SILKNOW project (Silk heritage in the Knowledge Society: from punched cards to bigdata, deep learning and visual/tangible simulations) (Portalés, Sebastián et al. 2018), funded by the European Union, within the research and innovation program , with the code 769504.

The objective is to develop a computerized system designed to improve the current understanding of the European cultural heritage related to silk fabrics. This system starts from a basic task, consisting of the design and implementation of a knowledge graph based on the CIDOC-CRM model. This graph must integrate the information related to these tissues that is currently digitized.

The knowledge graph is a result of the project, which, like all those of the project, is open and publicly accessible. In addition to this, the rest of the project's results are divided into two large groups, one aimed at introducing data into the knowledge graph, and another set of tools that will allow searching for and visualizing its information.

The group aimed at introducing information into the knowledge graph is made up of the following tools:

- A system of semantic analysis of text. This system uses as a base the rules of the knowledge graph, its information, and other sources, such as WikiData, and the use of morphological, syntactic, and disambiguation analysis tools. Its function is to analyze the content of a text from digitized data sources to update and introduce new data into the knowledge graph.

- An intelligent image analysis system based on neural networks. This system allows analyzing the digitized images of the fabrics and using the information obtained to update the grade with data on the motifs, colors, weaving techniques, sometimes even obtaining data on the time and place where it was made, with a high probability.

- A mapping tool, which allows connecting a digitized data source with the previous tools and update the knowledge graph.

- The development of a multilingual thesaurus on silk weaving techniques used in Europe (León, Gaitán et al. 2020). The thesaurus extends to the hierarchical level the Getty AAT thesaurus (Getty 1997a). The thesaurus has a high development complexity, since it applies the translation of terms used in very specific contexts and several centuries old.

Among the results that have the purpose of showing the information of the graph to the user and allow interaction with it, the following tools have been developed:

- A web browser that allows users with different profiles, both knowledge and interests, to obtain information on these fabrics that are part of the cultural heritage. In this web portal, the following tools have to be developed and integrated:

- A virtual loom, which allows the interactive visualization in three dimensions of the application of various weaving techniques that represent how it has been produced. This tool allows to see, starting from an image, and from the information how these techniques are executed, the different threads that have been used and how they are intertwined with each other.

- An interactive spatio-temporal map that shows the geographic and temporal distribution of the objects resulting from a search using the web browser. This map should allow additional filtering, spatial navigation, visualization of the relationships between the different objects and analysis of the fluctuation over time of this information.

Figure 1 shows a diagram with the different modules and results of the SILKNOW project, structured around three main objectives: OB1: Obtain information, OB2: Introduce the information in a knowledge graph, OB3: Visualize and interact with the information.

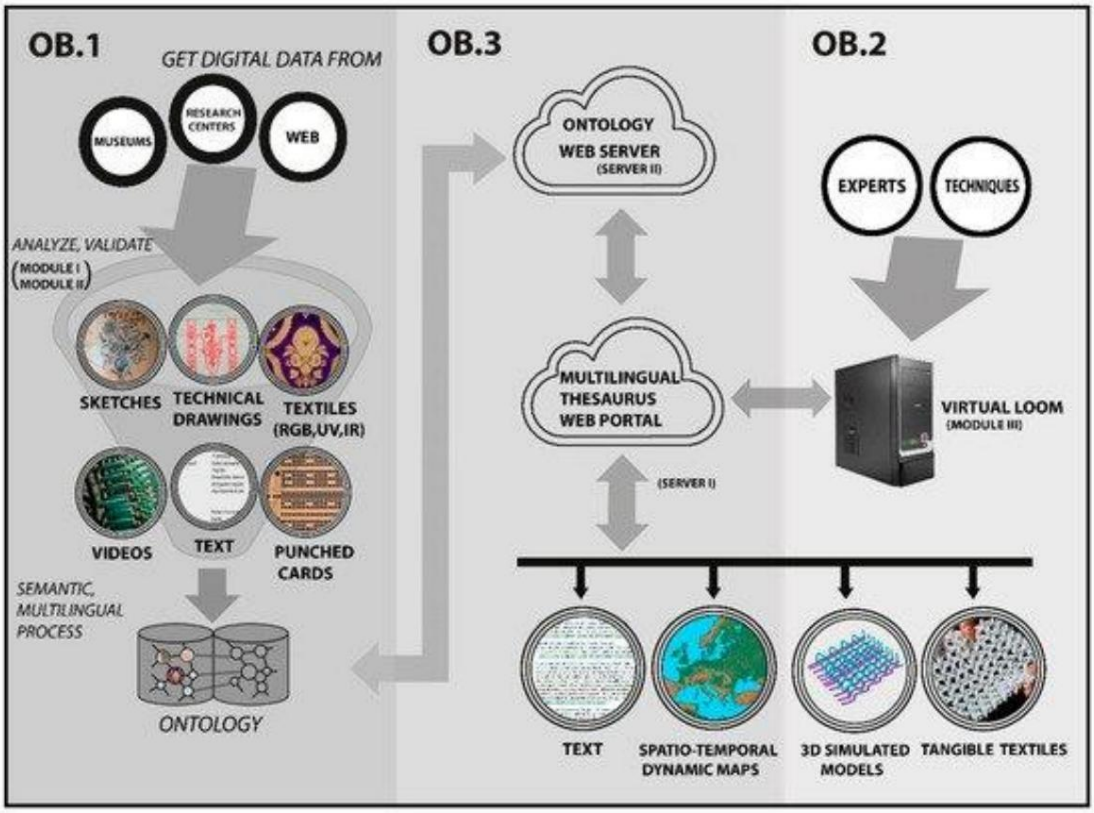

Figure 1. Diagram with the results of the SILKNOW project. Source: (Portalés, Sebastián et al. 2018)

In the SILKNOW project there are two data visualization tools, which take the content of a knowledge graph with cultural heritage data as a data source: the virtual loom and the interactive spatiotemporal map.

In the virtual loom, the objective is to visualize the application of a weaving technique on the image of an object. In this case, it does not make much sense to apply the STEVO ontology, since cultural heritage data will not be visualized where its position in the scene depends on the knowledge graph data. In this tool, the knowledge graph is used to extract the image of the object, as well as the data associated with it: colors, motifs, etc., and the technique used to weave it. With this information, the system displays a tissue in three dimensions. Figure 21 shows in the upper part the image of a fabric that would be one of the inputs of the virtual loom, after correcting aspects such as inclination, or

damaged fragments, a fragment is selected and the tool shows the distribution of threads in a three-dimensional environment at the bottom.

The other SILKNOW visualization tool, the spatio-temporal map, has as its objective the visualization of various objects of cultural heritage in a spatial scene, represented by a map, where its fluctuation in space must also be visualized.
This tool fits perfectly with the objective of the data visualization framework, through a web application, designed and developed in this work.

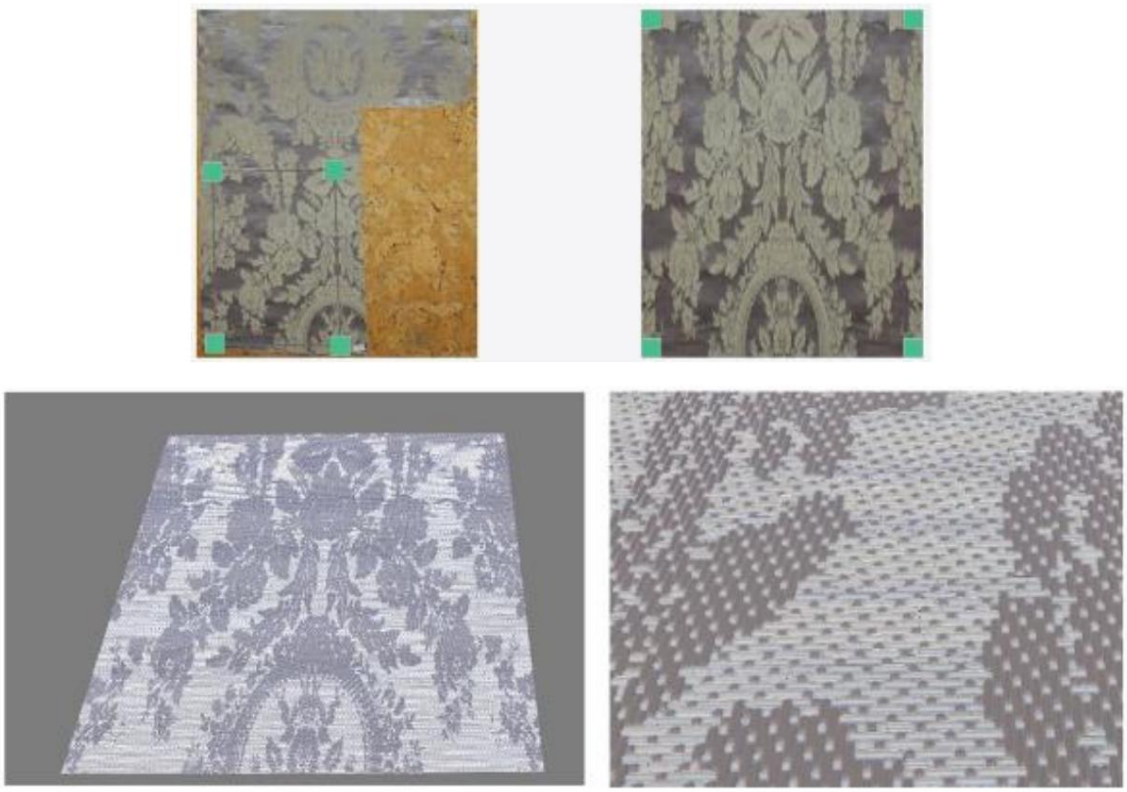

Figure 21 Screenshot of the results of the virtual loom of the SILKNOW project: Source: (Portalés, Pérez et al. 2021)

In the SILKNOW space-time map, the data to be represented are fabrics made of silk, which also belong to different types, depending on the use made of these fabrics, for example: clothing, home decoration, furniture decoration, religious , etc. All the objects have a geographical location that indicates their production, as well as a temporal reference, taking the century as the reference unit. As usual, there are data where there is uncertainty, both geographically and temporally, in addition to a significant presence of uncertainty due to granularity, mainly spatial, but also temporal.

The total number of objects in the SILKNOW knowledge graph was 37832 in January 2022.
Given this number of data, it is necessary to carry out groupings for its visualization.
In this case, a grouping by clusters was preferred, in which a graphic object represents a set of elements, and as the user interacts with the map, these groups are separated, until reaching a level that allows the visualization of objects of individually.

Another of the project's requirements on the tool is the creation of dynamic filters on the map. Although the content of the map is the result of an initial search, once displayed, the possibility of making new filters on the map data must be offered.
For example, the visualization of objects that use gold in their threads may be required, and once visualized, from the space-time map, see only those that have been produced in Italy in the 16th century.

It is also a required functionality that it can be filtered at any time and in a simple way, by the century in which the objects were produced. In this way, it should be possible to see on the same screen the change of data from one century to another. The objective of this requirement is to be able to see the spatial variation of the data, almost as if it were a movie in order to be able to infer reasons, or behaviors that cause this variation.

In order to reinforce this last objective even more, the spatiotemporal map must be able to simultaneously display data from different time periods in a spatial region. This requirement allows to see this spatial variation directly. Finally, it must be possible to show on the spatiotemporal map, at each moment, the map objects that have the same value for a given property. This association or relationship will be marked graphically, linking the objects in a specific way, through arcs or lines.

In addition, the spatio-temporal map should allow to show what percentage of objects that are being displayed have the same value in their different properties. With this functionality you can easily see objects that follow anomalous behaviors.
For example, if on the map, all the objects have a similar percentage of objects in their properties (used material, technique, etc.), but there is one that has a much lower percentage, or a much higher percentage, it does not follow the pattern usual, and it may be interesting to see why this behavior occurs.

All these visualization requirements are representable through the STEVO ontology, and therefore could be visualized with the framework developed in this work. Figure 3 shows a snapshot of the SILKNOW spatiotemporal map, developed with the results of this work, where the main parts of the user interface of the visualization system are described.

Figure 3 Diagram on screenshot of the spatiotemporal map to indicate the different areas of the component. Source:Adapted from ADASILK (SILKNOW Consortium 2022)

Next, the considerations that have been followed to introduce instances in the STEVO ontology that allow this visualization to be represented will be presented. For this, the type of scene, grouping, the different visual concepts, as well as their properties, and finally the behavior will be determined.

The knowledge graph of the SILKNOW project is public and there is a web portal with several access points to its content, from a SPARQL point to a facet search engine. It can be consulted at the address http://data.silknow.org.

9.2.2. STEVO instantiation

To define how to instantiate the STEVO ontology in order to represent a system of visualization, the following aspects must be determined:

- How to access the content of the knowledge graph.
- Define the scene to represent.
- Define the visual concepts to be represented.
- Define the visual properties of the selected concepts and their characteristics, that is, which ones determine the spatial and temporal positions, and how, in addition to which ones can be viewed by the user, as well as by which ones can be filtered and related to other objects.
- Define the graphic representation of the concepts.
- Specify if a grouping of the data and its graphical representation have to be used.
- Define whether to instantiate the rest of the behaviors defined by STEVO (relationship, temporary display, etc.)

Access to the knowledge graph.

The knowledge graph in SILKNOW is supported by the Virtuoso platform. Therefore, at the internal level of the project, there is direct access to a direct SPARQL access point against the server that contains the knowledge graph. In addition, to allow access to external applications, publicly, there is access to a series of web services generated using the GRLC tool (Meroño-Peñuela, Hoekstra 2016). This tool transforms SPARQL queries into RESTFul web services in an automated way. In the performance of the system it was observed that the performance of these web services is not as good as the direct one over the SPARQL point of Virtuoso.

In any case, access to the content of the SILKNOW knowledge graph will be done through special web services, or through the execution of SPARQL queries.

Definition of the scene.

The SILKNOW spatiotemporal map scene must be based on a map. On this map, the data must be represented at the appropriate point. In addition, as the user approaches an area, this can be interpreted as zooming in, or descending, the map content should update and show textures with higher resolution and where more details can be seen, such as roads, rivers, etc. .

Therefore, it will be necessary to instantiate the Scene concept, with the instance that will be called *“sceneSilknow”*

For this scene, you will have to use the following representations:

-Map . This relationship is obvious, since it is a scene where the special base is a map.

-Link *Diagram.* The objects are going to be linked to each other, since they have to display the relationships graphically.

- *TimeLine,* to be able to filter the data through a time line.

- *Time Layer,* to be able to visualize the data in the same space, but showing several layers of the same space, where each layer will be related to a different time interval.

As the map has to start from a world vision and go down to a vision that shows the main streets of the cities, without the need to reach a higher detail, it is estimated initially to define 12 zoom levels to ensure an acceptable change for the user. user, but that does not clutter the system too much. Of which, the last 3 levels would not be accessible in navigation, since it is not necessary to reach a maximum level of detail. These values can be adjusted later. Because of this, the values of the maximum and minimum zoom level properties will be 12 and 3 respectively.

Figure 4 represents a diagram with the relationships and basic properties of the "sceneSILKNOW" instance that will represent the scene of the space-time map in the SILKNOW project. More properties and relationships will be added later, as more concepts are instantiated in the STEVO ontology related to the SILKNOW spatiotemporal map.

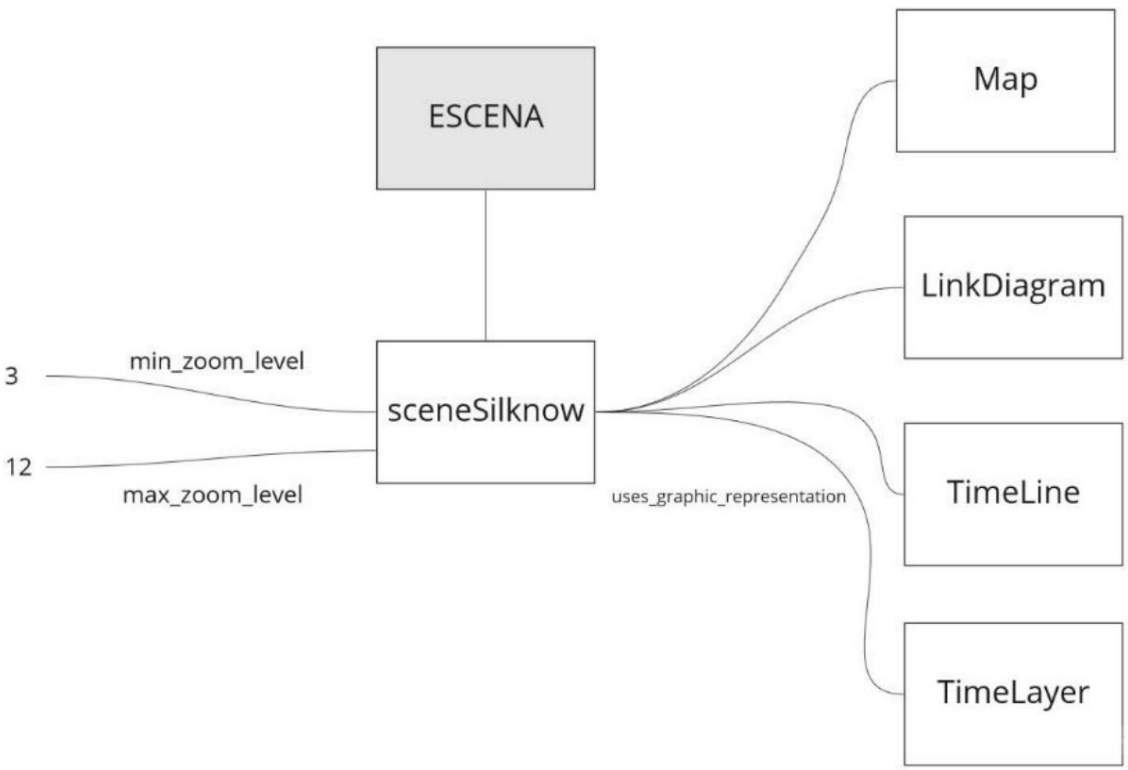

Figure 4 Diagram with relationships and properties of the Scene instance in STEVO of the SILKNOW scene

Definition of visual concepts.

In the spatio-temporal map of the SILKNOW project, fabrics have to be represented.

The fabrics in the SILKNOW knowledge graph, being based on the CIDOC-CRM model, could be instances, or extensions of the *E22_Man-made_Object concept,* of the model. In the case of the SILKNOW project, it was decided to instantiate the concept directly.

Then, the *Visual_Concept* concept of the STEVO ontology will be instantiated , with the *visualTextile* instance , which will have the value in the *"represents_domain_concept"* property :

"http://erlangen-crm.org/current/E22_Human-Made_Object"^^xsd:anyURI

This value corresponds to the concept E22_Man-made_Object in the implementation of the CIDOC-CRM model with the ontology of the University of Erlangen.

To represent this visual concept, the concept Visual_Concept must be instantiated . The will be represented by the instance will have the tag *visualTextile.* , scene instance *(Scene) sceneSilknow.*

Definition of visual properties.

The properties of the fabrics that have to be visualized are the materials from which the object is made, the weaving technique with which it was made and the type or category of the object.
In addition, due to the uncertainty of the data, the time and place of production can also be displayed. This is because in SILKNOW it was decided to represent the uncertainty with a special marker and to represent a single object. In this way, if you want to know the different data of the object, there is no other option than to be able to visualize the value of these properties.

Figure 5 shows a screenshot of the spatiotemporal map of the SILKNOW project website. This map has been generated with the framework implemented in this research. When there are properties that can be filtered by, the system displays a filter button on the interface (see bottom of the figure). When activating this button, a window is displayed with the different properties that are filterable ("is_filterable" property of the Visual_Property concept) and their possible values of the data set that are displayed.

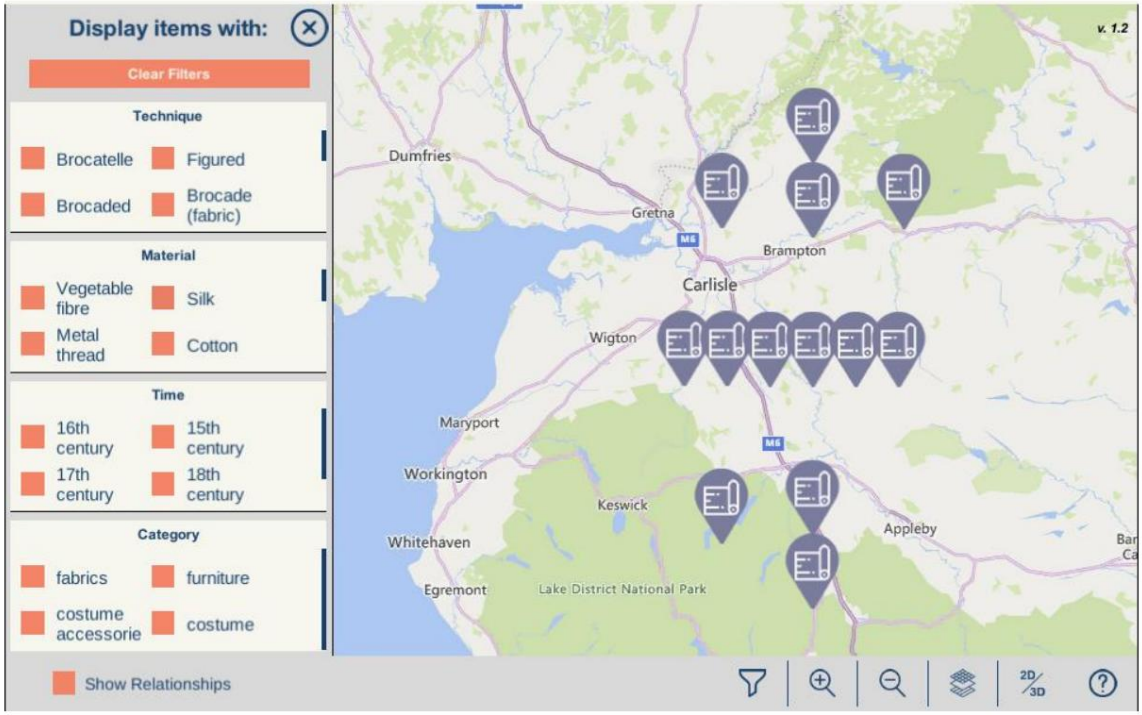

Figure 5 Spatiotemporal map user interface showing the properties that can be filtered by and their possible values. Source: ADASILK (SILKNOW Consortium 2022)

Figure 6 shows a screenshot of the SILKNOW spatio-temporal map, in which, after selecting an object, information is shown on its different visual properties that are visible ("is_visible" property of the Visual_Property concept). In this window, a check type control is also shown, over those properties that are relatable (Property “is_relatable” of the concept Propiedad_Visual) .

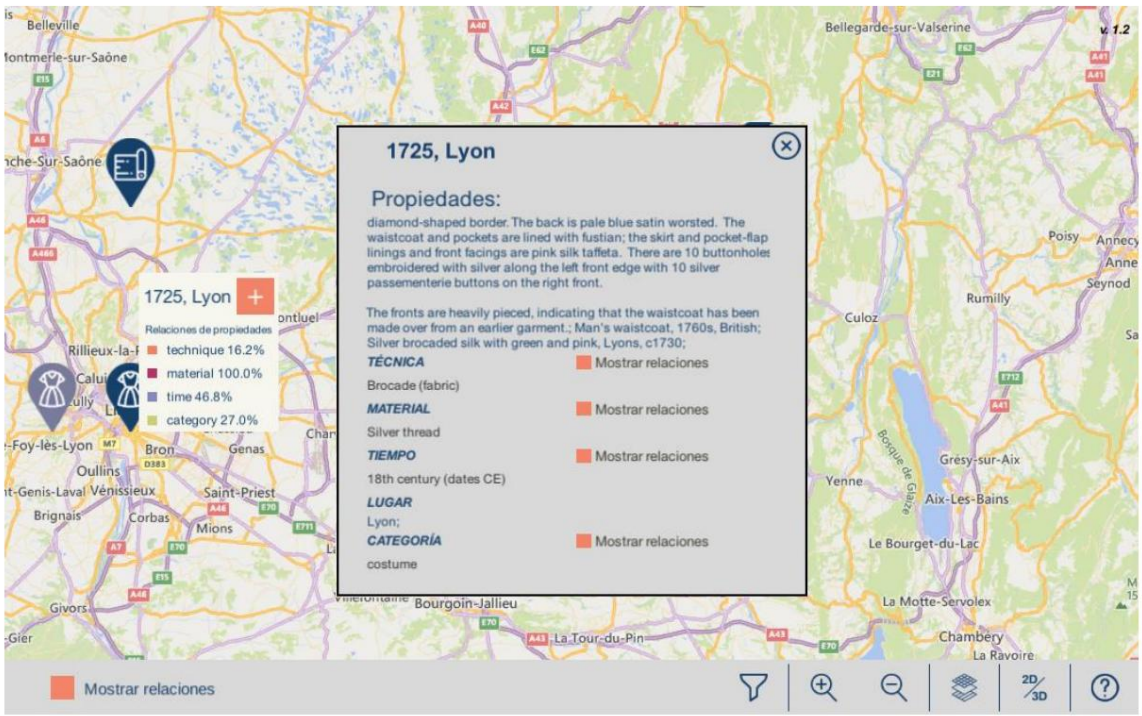

Figure 6 Screenshot with a pop-up window with information about the object represented in the SILKNOW spatiotemporal map. Source: ADASILK (SILKNOW Consortium 2022)

Material of the object

In the SILKNOW data domain, to know the material of which the fabric is made, the CIDOC-CRM model is applied. Therefore, it is necessary to instantiate the concept E12_Production related to the fabric (E22_Man-made_Object), through the relationship P128_has_produced. In this instance, the value of the material used can be obtained through the relationship P126_employed, which links to one or several instances of the concept E57_Material. The instance of E57_Material has the information about the material, or materials used to make the fabric.

In the STEVO ontology, to represent this property, the *Visual_Property* concept must be instantiated with the visualTextileMaterial instance . The project requirements indicated that information on the material of the object will be displayed on the space-time map, as well as being able to filter by this property and show relationships with other objects that have the same value in this property. The properties and relationships of this instance are shown in Table 1.

The instance of the Query concept of the STEVO ontology, queryForTextileMatyTec, referenced by visualTextileMaterial and by visualTextileTechnique, which is detailed in the next section, has in its expression a Query in SPARQL, which allows obtaining the values of the object's material and technique. The properties of the queryForTextileMatyTec instance are shown in Table 2.

Table 1 Properties and relationships of the visualTextileMaterial visual property

Guy	**Name**	**Worth**
is_relatable property		True
Is_filtered property		True
Has_name property		“material”
Uses_query_variable_name property		“materialLabel”
Relationship	represented_by_color	blueColor (Color)
Value_per_query relationship		queryForTextileMatyTec (Query)
Relationship	is_domain_property	visualTextile (VisualConcept)

Table 2 Query instance properties, queryForTextileMatyTec

	Worth
Has_expression **property**	SELECT distinct ?technicalLabel ?materialLabel WHERE { ? s rdf:type <http://erlangen-crm.org/current/E12_Production> . ?s <http:// erlangen-crm.org/current/P108_has_produced> this . ?s <http://erlangen-crm.org/current/P32_used_general_technique> ?p . ?p <http:// www.w3.org/2004/02/skos/core#prefLabel>

	?techniqueLabel ? s <http://erlangen-crm.org/current/P126_employed> ?q . ? q <http://www.w3.org/2004/02/skos/core#prefLabel> ? materialLabel }

Figure 7 represents a diagram with the concepts of the STEVO ontology involved in the representation of visual concepts and their visual properties required by the SILKNOW project.

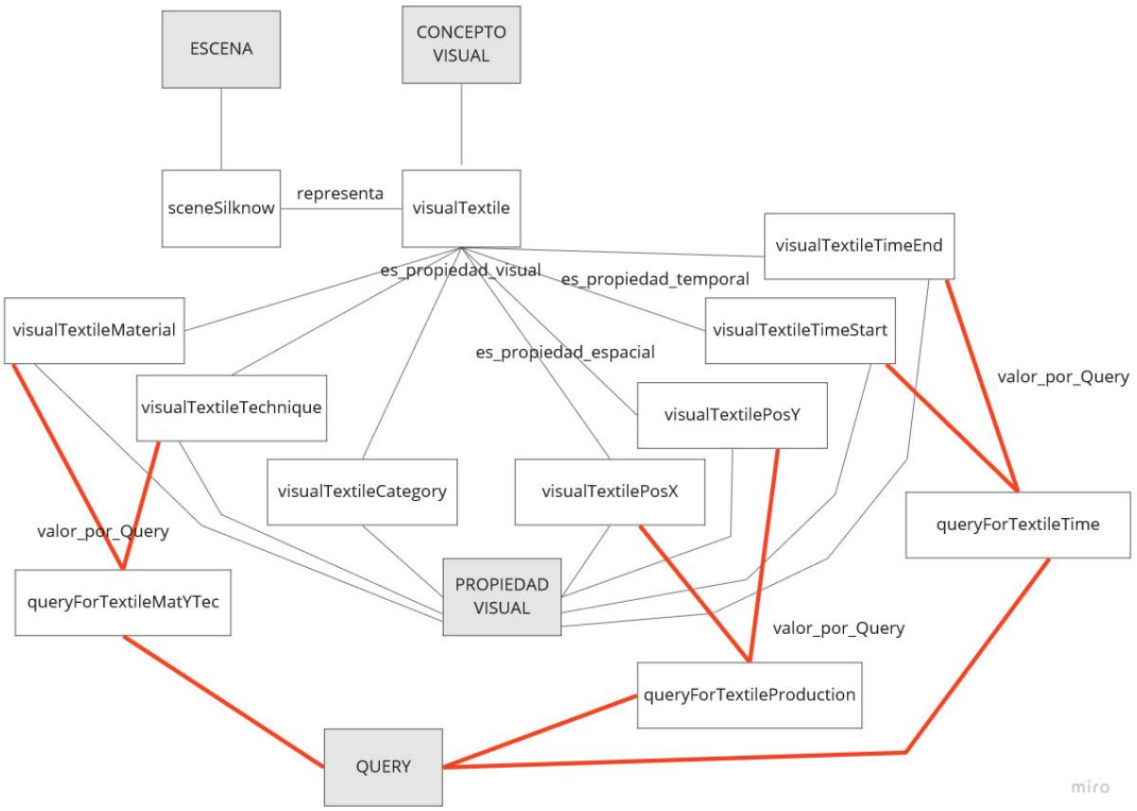

Figure 7 Diagram with concepts (grey background) and instances of the STEVO ontology to represent the visual concepts and their visual properties to represent the SILKNOW project data

object technique.

With the technique, like the material, in SILKNOW the CIDOC-CRM model is applied. As in the material, it is necessary to instantiate the E12_Production concept, and in this instance, through the P32_used_general_technique relation, one or more instances of the E55_Type concept are accessed. The E55_Type instance is used in CIDOC-CRM to link to thesaurus terms. In this case, it is linked to the SILKNOW thesaurus that classifies the different silk weaving techniques.

In the STEVO ontology, to represent this property, the *Visual_Property* concept must be instantiated with the visualTextileTechnique instance . The value of this property must be able to be displayed on the space-time map, in addition to being able to filter data by this value, and

display related objects with the same value of this property. The properties and relationships of this instance are shown in Table 1.

Table 1 Properties and relationships of the visualTextileTechnique visual property

Guy	Name	Worth
is_relatable property		True
Is_filtered property		True
Has_name property		“technique”
Uses_query_variable_name property		“techniqueLabel”
Relationship	represented_by_color	greenColor (Color)
Value_per_query relationship		queryForTextileMatyTec (Query)
Relationship	is_domain_property	visualTextile (VisualConcept)

Object category.

The type, or category of the object, is resolved in the SILKNOW project by the relationship *P41_classified_of,* which relates the instance of the concept *E22_Man-made_Object* to instances of *Object_type_assignment,* which refers to a controlled language of terms with the different types of SILKNOW textiles.

This property will require the *Visual_Property to be instantiated,* which will be named *visualTextileCategory.* In this case, since it is a property accessible through a direct relation of the data domain concept, it is not necessary to use a query to access its value.
To do this, the property_URI property will be given a value . The value of this visual property of the object will not be observable, nor will it give the option to filter, or relate. This is so because the user will be able to see the value directly on the object, since the object will have one image or another, depending on the value of this property. Figure 4 shows the properties and relationships of the *visualTextileCategory instance (Visual Property).*

Table 4 VisualTextileCategory visual property instance properties and relationships

Guy	Name	Worth
is_relatable property		false
Is_filtered property		false
Has_name property		“category”
Property_URI property		http://erlangen-crm.org/current/P41_classified
Relationship	is_domain_property	visualTextile (VisualConcept)

Object position.

The object's position is a special property, as it is linked to the visual concept via the position_domain_property.

Otherwise, it follows a definition similar to that of the other properties.

In the SILKNOW model, following the philosophy of the CIDOC_CRM model, as it happened with material and technique, the production location of an object is done through the relationship with E12_Production, and within this entity, it is related, through of the property *P8 took*

place on or within with an instance of the *Feature1* entity from the Geonames.org knowledge graph. The following properties of this entity will be referenced in STEVO:

- geonames:name ÿ Principal name of the place, with the language prefix.

- geo:lat ÿ latitude of the place.

- geo:long ÿ longitude of the place.

This implies the instantiation of three visual properties in STEVO:

- *visualTextilePositionName,* with the name/names of the location of the place of production.

- *visualTextilePosX,* with the length of the object.

- *visualTextilePosY,* with the latitude of the object.

The *visualTextilePositionName property,* due to the uncertainty of the production of the objects, must be able to be displayed, in addition to filtering and displaying the related objects with the same value in said property. Table 5 lists the properties and relationships of this visual property.

The *visualTextilePosX* and *visualextilePosY* properties will be used only to represent the object, its content cannot be displayed, filtered, or related.

The properties and relationships of *visualTextilePosX* detailed in Table *visualTextilePosY* are , those of analogous, but changing X to Y in the name.

Table 5 Relationships and properties of the visualTextileProductionName visual property instance

Guy	Name	Worth
is_relatable property		True
Is_filtered property		True
Has_name property		“production”
Uses_query_variable_name property		“production”
Relationship	represented_by_color	greenColor (Color)
Value_per_query relationship		queryForTextileProduction (Query)
Relationship	is_domain_property	visualTextile (VisualConcept)

Table 6 Relationships and properties of the visualTextilePosX visual property instance

Guy	Name	Worth
is_relatable property		false
Is_filtered property		false
Has_name property		"length"
Uses_query_variable_name property		"length"
Value_per_query relationship		queryForTextileProduction (Query)
Relationship	Is_Position_x_domain_property	visualTextile (VisualConcept)

It is also necessary to instantiate the concept of *Query,* in order to be able to consult the data of the object's production. The instance is called *queryForTextileProduction* and it describes

[1] URI of the Feature concept of the Geonames.,org knowledge graph. <http://www.geonames.org/ontology#Feature>

its relationships and properties. Table 7 lists the relationships and properties of this instance.

Production time of the object.

To deal with time in SILKNOW, an instance of the E12_Production concept is used, such as to represent technique and material. From that instance, with the P4-has_time span property, one or several instances of the E52_Time-Span concept of the CIDOC-CRM model are accessed.
This instance has the hasBeginning and hasEnd properties, which allow you to get the start and end values of the interval.

In SILKNOW, although alternative labels are used, the preferred label applies an annual time unit to express the interval.

Table 7 Relationships and properties of the Query instance, queryForTextileProduction

Property	Value
Has_variable for_instance	this
Has_expression	SELECT distinct ?latitude ?longitude WHERE { ?s rdf:type <http://erlangen-crm.org/current/E12_Production> . ?s <http://erlangen-crm.org/current/P108_has_produced> this . ? s <http://erlangen-crm.org/current/P8_took_place_on_or_within> ?p . ? p rdf:type <http://www.geonames.org/ontology#Feature> . ?p <http://www.w3.org/2003/01/geo/wgs84_pos#lat> ? latitude . ? p <http://www.w3.org/2003/01/geo/wgs84_pos#long> ? length ?p <http://www.geonames.org/ontology#name> ? production. }

Production time of the object.

To deal with time in SILKNOW, an instance of the E12_Production concept is used, such as to represent technique and material. From that instance, with the P4-has_time span property, one or several instances of the E52_Time-Span concept of the CIDOC-CRM model are accessed.
This instance has the hasBeginning and hasEnd properties, which allow you to get the start and end values of the interval.

In SILKNOW, although alternative labels are used, the preferred label applies an annual time unit to express the interval.

In the STEVO ontology, to represent these properties, the *Visual_Property* concept must be instantiated with the visualTextileTimeStart and visualTextileTimeEnd instances . The values of these properties must be able to be visualized in the space-time map, mainly due to the uncertainty, which is very high in this property. In SILKNOW it was determined that the visualization of related objects was not very efficient, also due to the uncertainty of the data, and because they are intervals. It was unlikely in the project's data domain to find related objects that had the same time interval value. It could make sense if the relationship was effective at the moment when there was a percentage of overlap in the time interval, but it is a fact that would have to be investigated. The properties and relationships of the *visualTextileTimeStart* instance are listed in Table 8, those of *visualTextileTimeEnd* are fully analogous.

Table 8 Relationships and data properties of the visualTextileTimeStart instance

Guy	**Name**	**value**
is_relatable property		false
Is_filtered property		true
Has_name property		“from”
Uses_query_variable_name property		“start”
Value_per_query relationship		queryForTextileTime (Query)
Relationship	Is_time_start_domain_property	visualTextile (VisualConcept)

Table 9 lists the property value and relationships of the *Query concept instance, queryForTextileTime,* used to get the values of the *visualTextileTimeStart* and *visualTextileTimeEnd* visual property instances , which get the production time values associated with an object.

Table 9 Data properties and relationships of the queryForTextileTime instance

Has_variable	**Worth**
property for_instance	Este
Has_expression	SELECT distinct ?this, ?start, ?end WHERE { ?s rdf:type <http://erlangen-crm.org/current/E12_Production> . ?s <http:// erlangen-crm.org/current/P108_has_produced> ?this . ?s <http://erlangen-crm.org/current/P4_has_time-span> ?p . ?p <http://www.w3.org/2006/time#hasBeginning> ?st . ?p <http://www.w3.org/2006/time#hasEnd>

	? ed . ?st <http://www.w3.org/2006/ time#inXSDDate> ?start . ?ed <http://www.w3.org/2006/time#inXSDDate> ? end . FILTER (?uriInstance in (this.value)) }

Definition of the graphic representation of the concepts.

In the SILKNOW spatiotemporal map only the objects and their groupings are represented.

The groups are represented with a circle, so their representation is very simple, since they only need the definition of a Marker whose graphic representation is a circle.

In this case, it will be necessary to create a Marker instance, which will be called *silknowClusterMarker,* associated with the grouping behaviour, which will be a *Circle_Marker type marker,* represented by a circular geometric figure.

However, the concept represented by the *visualTextile* instance is similar, but has some complexity associated with it. The marker of the object that represents the concept, depending on the type of category of the object, has an associated texture that defines it. To do this, an instance of the Marker concept is created, which is associated with as many modifiers as there are different categories of the object. In addition, the marker will be associated with the primitive graphic representation instance (Primary Graphic Representation, from VISO ontology) circleTextile, to define different properties of the figure. Table 10 lists the properties and relationships of that instance.

Table 10 Relationships and properties of the circleTextile Instance

Guy	Name	value
has_image property		defaultTextileTexture (instance of Picture with texture value with default in has_URL property) circle
Has_graphic_representation property		(Shapes, VISO ontology)
color_rgb property		LightBlueColor (Color, VISO ontology)

The Marker instance is named *silknowTextileMarker.* Table 11 lists the properties and relationships of this instance of the Marker concept. This marker has as many relationships to modifier instances as there are different tissue types to be represented.
The table represents the woven modifiers of the Clothing, Religious, Unknown, Home, and Accessories types.

Table 11 SilknowTextileMarker Marker instance properties and relationships

Guy	Name	value
has_graphic_representation relation		circleTextile (Marker)
Use_modifier relationship		correspondingTextileTypeClothesPicture (Modifier)

Use_modifier	relation	correspondingTextileTypeReligiousPicture (Modifier)
Use_modifier	relationship	correspondingTextileTypeUnkownPicture (Modifier)
Use_modifier	relationship	correspondingTextileTypeHomePicture (Modifier)
Use_modifier	relationship	correspondingTextileTypeCompPicture (Modifier)

As an example, the properties and relationships of the modifier instance used to represent the Clothes type objects are detailed in Table 12 .

Table 12 Relationships and properties of the correspondingTextileTypeClothes instance of the Modifier concept.

Guy	Name	value
Relationship	modify_over_value	visualTextileType
Property	Has_graphical_representation	PictureTextileTypeClothes (Picture instance with texture value of type Clothes property has_URL) http://
Property	Property_Value	data.silknow.org/category/40

Figure 8 2 shows the graphical representation of various objects of the SILKNOW spatiotemporal map. As can be seen in the image, each object has a type of texture that identifies it based on the type to which the object belongs.

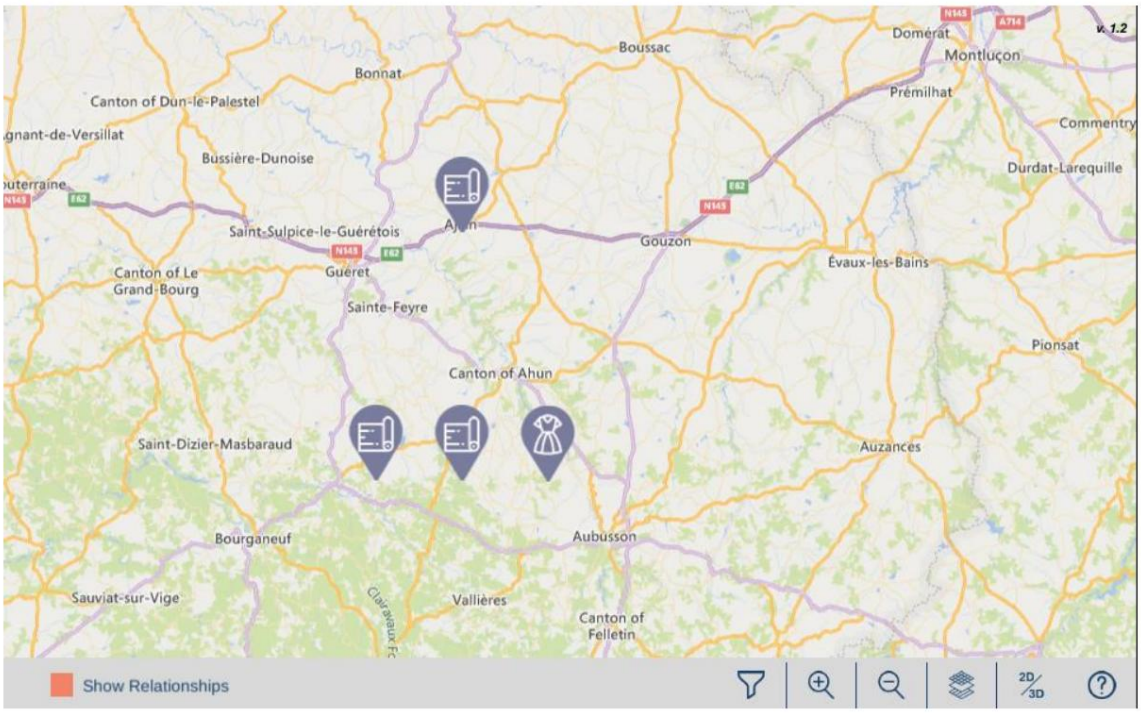

Figure 8 2 Graphic representation of the concepts represented in the space-time map. Source: ADASILK (SILKNOW Consortium 2022)

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Definition of behaviors.

Given the complexity of the space-time map requirements of the SILKNOW project, it will be necessary to instantiate several STEVO behavior concepts so that the interaction can be adequately represented.

Next, the instances made in STEVO are detailed, and their relationships, to represent the behaviors of grouping, time control, and visualization of relationships between objects.

Groupings.

Since the data will be grouped in groups, and not in heat maps, the *Clusters_Group_Behaviour* concept will be used , which extends Group_Behaviour, *creating the silknowGroupBehaviour instance. This instance will use the silknowClusterMarker* marker instance commented out previously.

Table 13 lists the relationships and properties of the *silknowGroupBehaviour instance.*

Table 13 Properties and relationships of the silknowGroupBehaviour (Clusters_Group_Behaviour) instance to represent how to display clusters.

Guy	Name	Worth
Relationship	representative_marker	silknowClusterMarker (Marker)
Relationship	Is_behavior_of_group_of	sceneSilknow (Scene)

Figure 9 shows several screenshots of the SILKNOW spatiotemporal map.
The screenshots show the result of a browsing process in which the user gets closer and closer to the city of Paris. Initially, clusters are seen throughout Europe, but as you zoom in, in addition to seeing the map with more information, different clusters are shown, the result of higher level clusters.

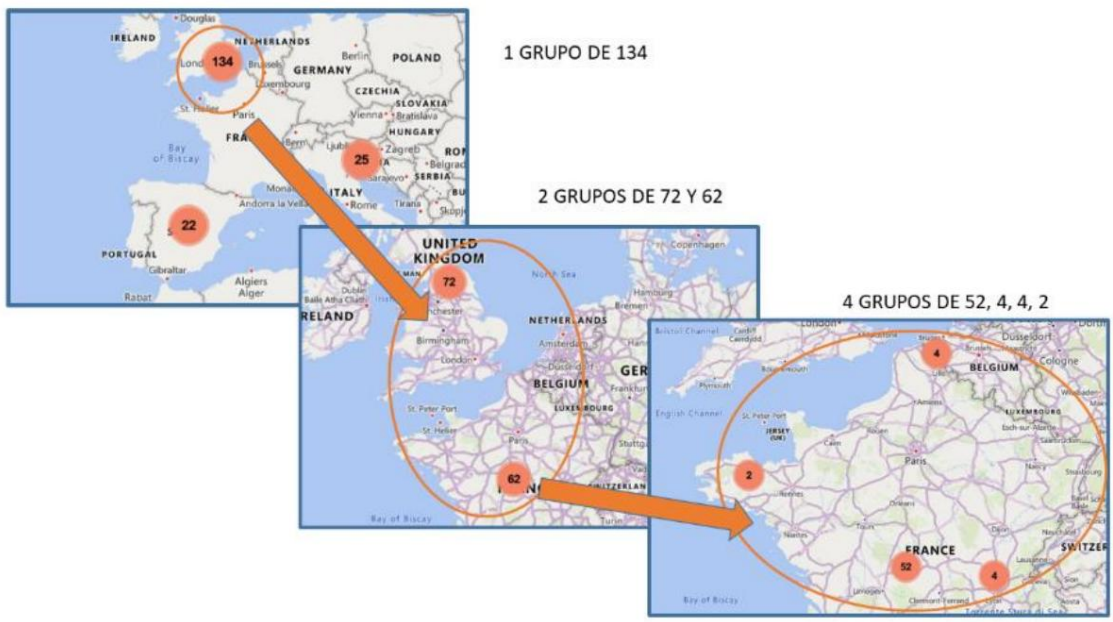

Figure 9 Zoom with clusters on ADASILK spatiotemporal map. Composition with ADASILK screenshots. Source: Adapted from ADASILK (SILKNOW Consortium 2022)

Time control.

Time control in the SILKNOW spatiotemporal map has to be done in two ways. First, with a time line control (TimeLine), so that taking the century as the unit of time, you can see which of the objects have been produced in a specific century, and in a simple way, see those that have been produced in the next, or previous. Using the control with a certain speed, a film effect can be observed, since in each interaction the data of each century would be seen in a correlative way.

On the other hand, it is also desired to be able to observe the data of each century, or an interval of centuries, simultaneously with those of another century, or interval. With this function you can simultaneously observe the data of each time interval.

To define the time control it will be necessary to instantiate two STEVO concepts, the first will be *Control_Individual,* to represent the TimeLine, and the second *Control_Simultaneous.*

The instance of *Control_Individual* will be *silknowTimeLineControl,* whose relationships and properties are exposed in Table 14 2.

Figure 103 shows a screenshot of the SILKNOW spatiotemporal map with the detail of the user interface to activate the different time controls, which in this case are two: Individual (TimeLine) and Simultaneous.

Table 14 2 Properties and relationships of the silknowTimeLIneControl instance (Control_Individual)

Guy	**Name**	
Relationship	frequency_control_time	UnityCentury **Value** (Time Unit) Predefined instance in STEVO.
Relation Is_time_behavior_of sceneSilknow(Scene)		

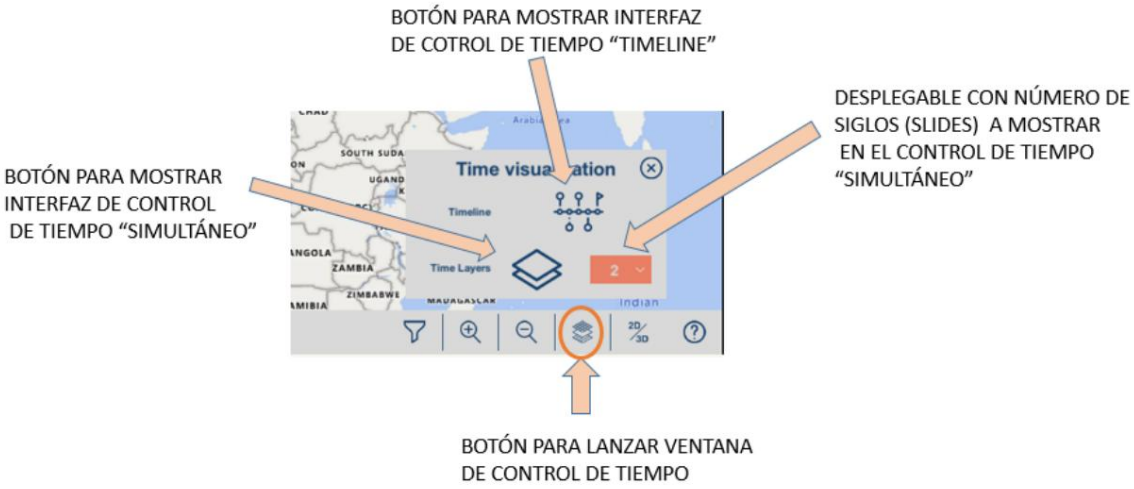

Figure 103 ADASILK screenshot showing the interface to select the different time control modes and their parameters. Source: Adapted from ADASILK (SILKNOW Consortium 2022).

Figure 11 shows different screenshots of the SILKNOW spatiotemporal map with the Individual time control interface, or TimeLine. This interface consists of a slider type control, which allows you to activate one century or another in a simple way. Thus

From left to right, data produced in the 15th, 16th and 17th centuries, respectively, are shown.

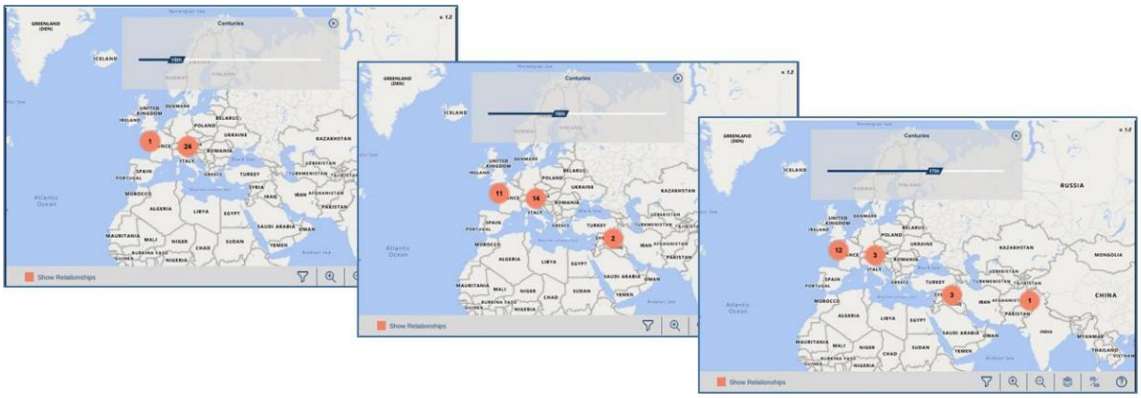

Figure 11 Different screenshots with the "TimeLine" time control active at the top on the same data set. Each capture corresponds to a different century. Source: Adapted from ADASILK (SILKNOW Consortium 2022)

The *Simultaneous_Control* instance will be *silknowSimultenaousTimeControl* and its relationships and properties are listed in Table 15.

Table 15 Relations and Properties of the silknowSimultaneousTimeControl instance (Control_Simultaneo)

Guy	**Name**	
Relationship	frequency_control_time	UnityCentury **Value** (Time Unit) Predefined instance in STEVO.
Relation Is_time_behavior_of sceneSilknow(Scene)		
Use_steps property		True
Property Maximum_number_of_steps		4
Display_spatial_zone property		True

Figure 12 shows two captures with the simultaneous time control mode of the SILKNOW space-time map. The same data set is displayed in both captures, showing three data layers for the same spatial area. In the upper figure, the active layer is the lower one that includes the interval from the 17th to the 18th century, although the data for the interval defined by the 16th to 17th centuries are also observed. In the lower figure, after activating the active layer, the one between the 16th and 17th centuries, the layers are scrolled down, perfectly showing the distribution of data between the 16th and 17th centuries, and revealing the data between the 15th and 16th centuries, as well as showing a large part of the layer defined by the centuries 16 and 17.

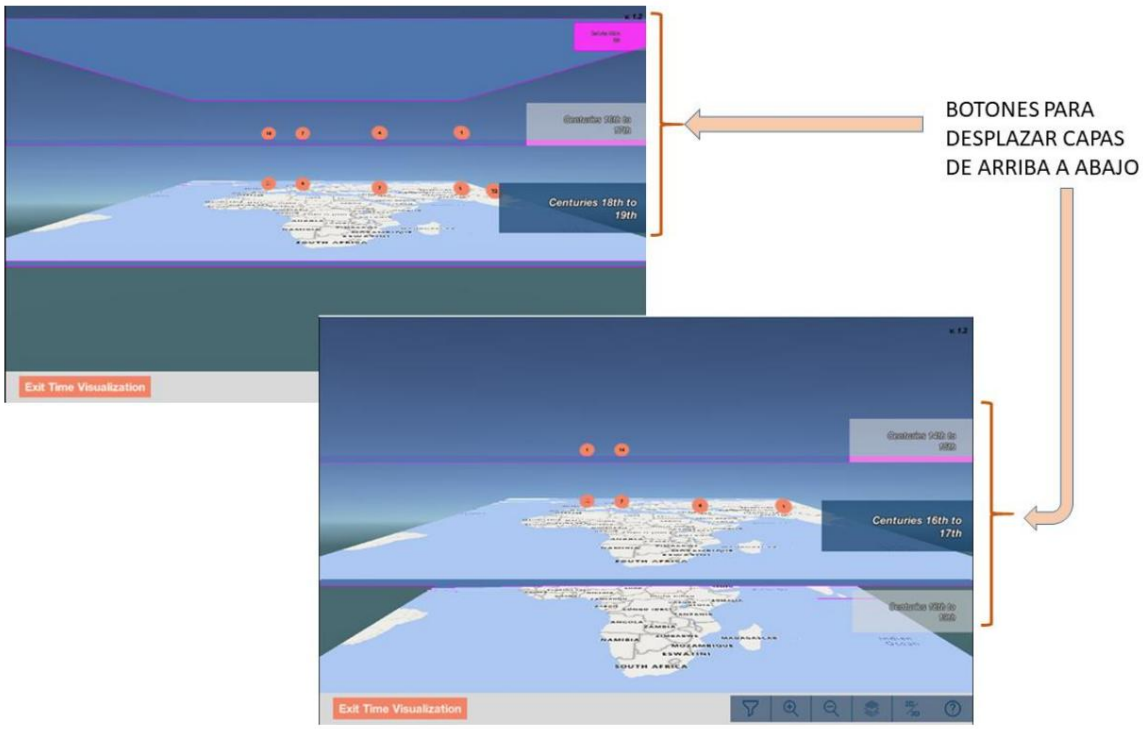

Figure 12 Simultaneous time visualization screen shots on SILKNOW map. Each layer represents a time interval (in centuries). The buttons on the right allow you to move the layers from top to bottom for a better visualization. Source: Adapted from ADASILK (SILKNOW Consortium 2022)

Relations.

In the SILKNOW spatiotemporal map, represented through the STEVO ontology, two types of relationships between objects are visualized, using the properties that are relatable ("relatable" property of the Visual_Property concept).

The first type draws lines between objects that have the same value of the checked properties to see their relationships. The second type represents the ring control, which allows you to see the percentage of objects that have the same value for each of their relatable properties.

For the first type of relations, the concept *Relación_Enlaces* will have to be instantiated through the silknowLinkedRelationBehaviour instance . Table 16 defines the properties and relationships of this instance.

Table 16 Relations and properties of the silknowLInkedRelationBehaviour instance (Relation_Links)

Guy	Name	value
Relationship	Is_behavior_of_Relationship	sceneSilknow (Scene)
Property Applies_Line_Technique		True
Maximum_Number_of_Links property		2000
Applies_Color_Technique Property		false

Figure 13 shows two screenshots of the silknow spatiotemporal map, after activating the display of related objects through the material property. In this case, all the objects being displayed have the same material as the selected object, so it is related to all of them. At the top, the zoom level is high, and you see the relationship to nearby objects. At the bottom, the user's view is further removed, having

a lower zoom level, and relationships are seen, but through groupings, since the activated object and others are not displayed.

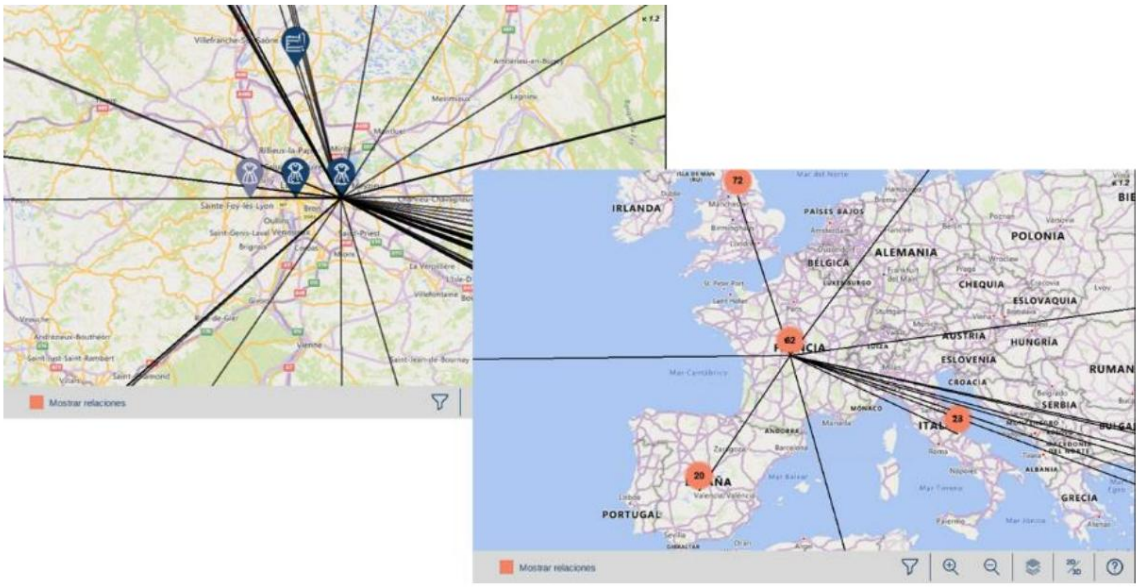

Figure 13 Figure composed of two screenshots showing the relationships of one object with the rest. The top image is at a high zoom level, and the bottom image is at a lower zoom level, the relationships are shown between the clusters. Source: Adapted from ADASILK (SILKNOW Consortium 2022)

To represent the second type of relationships with rings, or circular crown, which allows knowing the percentage of objects that have the same value in the properties of all objects, for each object that is displayed, it is necessary to instantiate the concept Ring_Relationship . The *silknowMarkerRelationBehaviour* instance is created and is related to the *sceneSilknow instance,* of Scene, through the relationship *"Has_Relation_Behavior"* and its inverse *"Is_Relation_Behavior".*

Figure 14 shows a screenshot of the SILKNOW spatiotemporal map, after activating the display of ring relationships of the objects being displayed.

The spatial zone is the same as that represented in Figure 14, and the objects are the same.
It can be seen that the object is actually related to all objects (100%) through the "material" property, as seen in the other figure with the lines. This percentage is seen visually, which also happens with the object next to it, but in the other two, although it is high, it is no longer 100%.

uncertainty

Having cultural heritage data in the SILKNOW project, it is not surprising that they also have uncertainty. In this case, the data present uncertainty mainly in space and time. As they are fabrics, sometimes almost a millennium old, and as they often lack purchase and sale documents, as well as signatures or authoritative labels, it is difficult to know who, when and where they were produced. These data have to be obtained from the materials, technique, the reasons for the fabric and the different places of origin, which entails uncertainty.

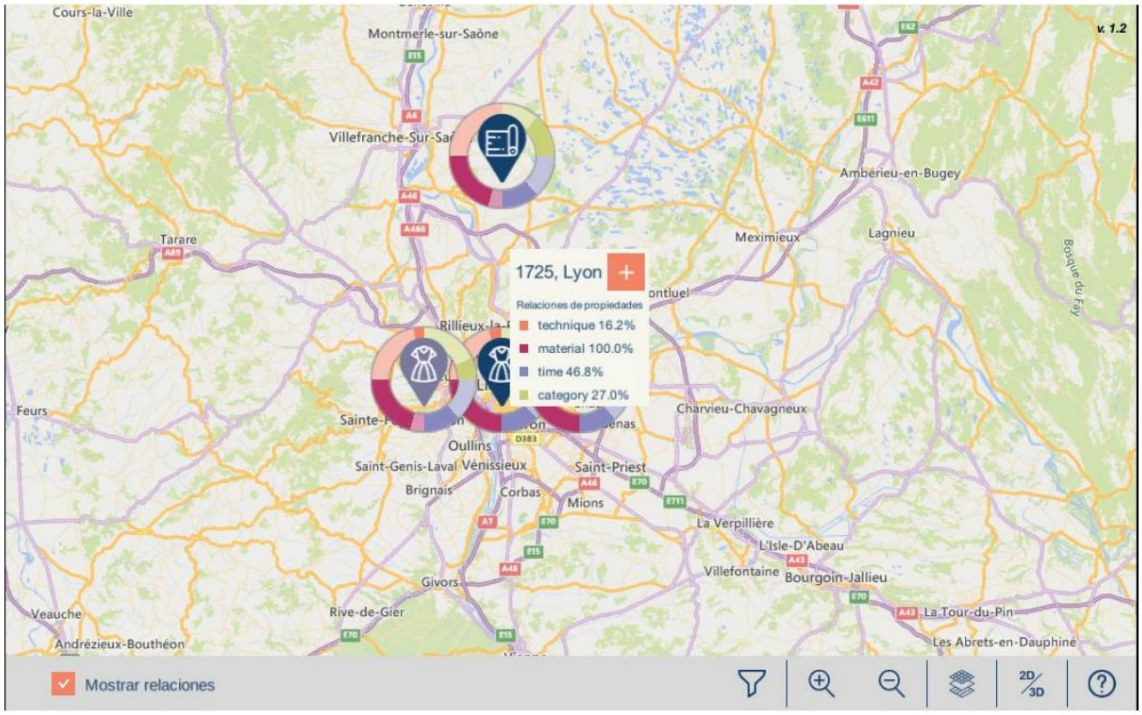

Figure 14 Screenshot of the SILKNOW spatiotemporal map. In this image you can see the ring with the total relationships of the objects. The property legend shows that 100% have the same material. Source: Adapted from ADASILK (SILKNOW Consortium 2022)

As discussed in the definition of the model for this research (see chapter 6), there are several ways to manage this problem. In the SILKNOW project it was decided to do this by spatial replication and marker bleaching. That is, if an object can come from two or more different places, its spatial location in the data representation will be one for each possible place. This can lead to confusion, since a result can generate X number of data that satisfies a query, but X + N data can exist in the representation, where N is an increment generated by the doubling of uncertainty. This situation can easily happen on relatively small data sets and is confusing because the number of data is represented by the groupings. In a visualization with a low zoom level, with few groupings, it is easy to detect, through the sum of the groupings, that the number of data is greater than expected and this can confuse the user.

To represent the uncertainty of the SILKNOW space-time map, the STEVO concept *Treatment_Uncertainty_With_Replication is instantiated,* silknowUncertaintyBehaviour instance . Table 17 details the properties and relationships through of this instance.

Table 17 Relationships and properties of the silknowUncertaintyBehaviour instance (Treatment_Uncertainty_With_Replication)

Guy	Name	Worth
Relationship	Is_treatment_of_uncertainty	sceneSilknow (Scene)
Property Applies_Discoloration		True
Applies_Displacement property		false

The application of this technique in the SILKNOW spatiotemporal map can be seen in the Figure and Figure 1, where a piece of data that has a lighter color than

the rest, even if of the same type, this data presents uncertainty. If you want to know the type of uncertainty, which can be due to space, time, or both data, you have to view the object information, as shown in Figure , to see the properties "Place" and "Time" on the interface. ", which in the event that they have several data, would be the cause of the uncertainty.

Figure 6 shows that there are objects where the icon has a light color, this is because they present uncertainty of some kind.

Units of time, space and reference systems.

The units of time, space, as well as the reference spaces used in the SILKNOW space-time map, can be represented with predefined instances in the STEVO ontology.

To define the temporal environment, an instance called *silknowTime* has been created , from the Temporal_Environment concept , indicating that the SILKNOW work time interval (from the year 0 of our era to the 20th century) and the unit of time, which is the century . Table 18 lists the properties and relationships of this instance.

Table 18 Relationships and properties of the silknowTime instance (Time_Environment)

Guy	**Name**	**Worth**
Time_Unit Relationship		unitCentury (Time_Unit)
Beginning_of_Time Relationship		startSilknowTime (Instant)
Relationship	End_of_Time	endSilknowTime (Instant)

To reference the spatial environment of the map, the predefined instance in STEVO of the *Spatial_Environment concept is used: "Unity3D"*