The study of Severini’s wall paintings in Switzerland: how to manage heterogeneity of data and team members?

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Abstract. A data management system has been created for the 4-year research project to manage the results of the study of the wall paintings by Gino Severini in five Swiss churches (https://www.stluc.ch/). The project involves art historical and scientific research to investigate painting materials and techniques. The data produced by the multidisciplinary team is vast and varied and is archived in a database (Db) designed to act both as a file repository and as an exchange platform. The documentation is based on a 3D survey carried out with stereo photogrammetry and 3D laser scanning. The Db contains data sheets describing ‘entities’ which can be physical objects with cultural significance (e.g. a wall painting) or the structures containing them (e.g. the church). It is possible to establish hierarchical relationships between entities, e.g. the church, the apse, one of the paintings in the apse etc.. There are no limits to the number of sub-entities that can be created and nested one in the other recursively (as folders and sub-folders). In this way, the Db structure can register any type of activity involving the heritage by collecting all the documentation and data produced at all levels. Data includes vector drawings that are recorded as tables in the Db and can be visualized as maps. These allow the linking of any file and data sheet, providing immediate access to information starting from the map. Data entry is carried out by the professionals creating it, i.e. the project team members. The system has a client-server architecture based on PostgreSQL with the PostGIS extension server side and is currently accessed by the team through a front-end application based on Access and a cartographic application based on QuantumGIS. The challenge and the innovation of this system is to allow professionals from the different disciplines within the research groups to safely enter and access data working with sophisticated profiled privileges while the project is on-going. Once the project is completed, in an ‘Open science’ framework, data will be accessible to common users and to specialists. The Severini project is in its second year and currently two of the five churches have been studied. The paper will discuss the challenges encountered, the solutions developed, and the potentiality and flexibility of the data model designed.

1. Introduction: St. Luc

The information system described in this paper was developed for the project ‘Gino Severini in Switzerland: mural paintings and catholic art revival of the ‘groupe de Saint-Luc’ (http://p3.snf.ch/project-179364). The ‘St Luc’ project aims to study, through a multidisciplinary approach, the religious murals created by Gino Severini during his collaboration with the “Groupe de Saint-Luc” in French-
speaking Switzerland between 1920s and 1940s. The research, involves many different professionals, and includes the study of the executive technique and the materials used by Gino Severini to make the wall paintings decorating the churches of Saint Nicholas in Semsales, of Notre Dame de l’Assomption in La Roche, Saint Pierre in Friburg, Notre Dame du Valentin in Lausanne, and Couvent des Capucins in Sion. The project involves research and study of archive sources (newspaper articles, letters, invoices, notes and sketches of the author), close visual examination (photographs with diffused and raking light, portable microscope, survey and thematic mapping of materials, of execution techniques and signs of previous interventions), scientific investigations (technical imaging, p-XRF, p-FT-IR, analysis of samples, etc.). This multidisciplinary study requires data interpretation and integration of different types of information, in different format. The project team members have different background and the data management system was developed to enable data entry, exchange and collaboration within the team and is based on several year-long experiences in conservation and cataloguing cultural heritage preservation projects [1], [2] and [3].

1.1. Related works
In the past decades, the field of heritage study and assessment, has seen a revolution thanks to the advent of non-invasive investigations [4]. Many techniques have become portable and can be taken on site to investigate vast surfaces without the need for sampling. These techniques include technical photography, thermography, radar, X-ray, or ultrasound measurements. Some studies have combined the use of laser scanner and photogrammetry to connect heterogeneous data to the graphic representation of buildings. Other studies combines image-based-modelling techniques, reverse engineering modelling and a 3D layer-like annotation technique in a CAD environment, and other studies organize 2D hierarchical heritage data based on GIS (Geographic Information System) [3], [5], [6] and z[7]. These methods allow to display information and filter it according to the goal of the investigation. Thanks to the expansion of Information Technology (IT), new collaborative platforms have been developed to catalogue, archive, protect in case of emergency (risk management), and share and provide access to heterogeneous data collected on heritage buildings and sites [8]. Some features of these platforms have been adopted for the storage and analysis needs of the team members involved in the research project described in this paper. In particular, developing an inventory (through an identity data-sheet fiche) of all the objects (entities) and linking the data that is created as the research project develops.

1.2. Fundamental problems and goals
In an interdisciplinary research project, collecting and organizing its content in a systematic way is a complex activity and big responsibility. Generally, projects can focus on different aspects: the study of a building and its decorated surfaces, the conservation-restoration interventions, monitoring and maintenance, protection and much more. The St. Luc project focusses on the technical examination of the wall paintings by Severini in Switzerland and the information system was designed to:

- Identify the heritage both in its geometry (2D and 3D survey) and through its description;
- Record the activities conducted on the heritage (historical and on-going as part of the project);
- Organize, archive, and make accessible the documentation produced as part of the project.

Of these goals, data entering, data access to the different team members is a challenging one and important in the short term for different reasons. First of all, for study purposes the data must be available immediately to researchers for integration and comparison. In the long term, the information system is fundamental for those responsible for protection, management and valorization of cultural heritage. The system will keep the “medical record” with all the data collected to date and will be useful for future restoration activities. Finally, the common users or researchers interest in some aspect of the heritage studied can find clues and useful data in the system.

2. Type of data acquired as part of the project
The following chapter illustrates the phases involved and the type of data produced in each phase [9] and [10]. The first operation, while research starts on the different fronts, is the metrical survey which is
then utilized to support all the information collected in the following phases.

2.1. 3D metrical survey
To offer a metrical support to the various specialists of the project, a 3D measure campaign was conducted by two complementary recording methods: lasergrammetry and photogrammetry. 2D and 3D metric references were position *in-situ* and measured with an electronic tachometer in order to gather 3D data issued from photogrammetry and lasergrammetry in the same 3D reference coordinate system. Photogrammetry was carried out with a set of photographs, with an overlap of 75%, taken from different points of view. To guarantee color uniformity and chromaticity, lightning was provided by two or three electronic flashes. A test pattern was placed in each scene to allow a precise calibration of white balance. The data computer processing stands on several distinct phases. Firstly, the relative position for each snapshot is automatically found. Secondly, the algorithm recognizes 2D coded targets whose metric coordinates are measured with a precision of 0.1 mm. At this stage we obtain the absolute orientation in space. Finally, a 3D point cloud is generated in the 3D reference coordinate system. In the case of Severini’ research sites, the 3D point cloud has a mean square error of 0.5 mm.
Lasergrammetry is a range-based survey and consists in projecting a laser beam at high speed in all directions in space (obtaining one to two million 3D points per second depending on the instrument models). In order to acquire the entire morphology of the church, multiple scans have been obtained and combined in the same 3D reference system by means of 3D targets automatically detected by the processing algorithms of the software. A 3D point cloud is obtained with an overall accuracy of +/- 1 mm with an average density of 100 points per cm$^2$. The main advantage of this survey technique is that, for each point of impact, in addition to the X, Y and Z coordinates the scanner records the reflectivity of the surveyed surface (infrared at 1555nm) to give an intensity value. This information can provide clues on the nature of the material hit by the laser.
The 3D data is used to generate ortho-photos of each painting portion. These are then uploaded on to AutoCAD and serve as cartographic base onto which graphic recording is carried out and to link points and areas with files (written, photographic, and scientific data collected).

2.2. Historical data
The collection of historical and archive information is fundamental. There are administrative documents (letters, correspondence, and invoices for materials purchased by the artist), technical documents (sketches, preparatory drawings, reports of past restorations, scientific investigations, other studies) publications (newspaper articles, and exhibitions catalogues) and photographs (postcards, various photos taken during particular events). These documents are organized and studied generally by art historians and archivists and archived in the Db as file in .jpg and in .pdf formats.

2.3. Visual examination
Direct examination of the work of art carried out on site, typically from scaffolding, by the restorer produces notes, graphic documentation, photos which document signs of the painting technique by the artist. All this information is also reported graphically in AutoCAD to record the extension and distribution of the features documented (Figure 1). Typically, the observations are also described in a written report. The type of data produced in this phase includes file in several formats (.jpg, .doc, .dwg, and .pdf).

2.4. Scientific investigation
The on-site visual examination is fundamental to guide scientific investigations. Typically non-invasive investigations, imaging and point analysis are carried out first in collaboration between the scientist and the conservator. Selected areas were studied with multispectral imaging (MI) which highlights the different optical behavior of the decorated surfaces and can indicate the presence of different painting materials. Then selected points are analyzed with X-ray fluorescence spectroscopy (p-XRF) and portable infrared spectroscopy (p-FT-IR). These techniques provide information on elemental and molecular
composition of the surface suggesting the pigments and the binders used. All the data obtained, raw and elaborated, must be archived and must be accessible. For imaging raw and reworked images (.raw, .tiff and .jpg) and for scientific spectra and numerical data are collected by the scientific instruments as files in different format for XRF (.ndt, .xls) and FT-IR (.jpg, .xls) (Figure 2). The team uses the information from non-invasive investigation to develop a sampling strategy. The point of sample collection is linked to all the laboratory analysis (invasive investigations) performed on the material collected. The data and information produced is vast, varied, and heterogeneous and is compiled in summary forms (for each image, point analyses and sample) and is archived in the specific format and in an elaborated form.

3. Adopted System

Based on the knowledge of other large and complex platforms developed, the archiving and organization of the documentation collected and produced by the research team, is achieved through a relational database integrated with a GIS. The system collects information on the works, on the activities conducted over time (e.g. historical research, visual examination, scientific investigations, etc.) and manages a digital archive of the documents produced during these activities.

3.1. Architecture of the information system

The information system (from now on called “System”), has a client server architecture, based on the open source DBMS PostgreSQL1 (Figure 3). The Db manages the alphanumeric data and, through the PostGIS spatial extension, the geometric and geographical data produced during the project. The adoption of open source DBMS and OGC® (Open Geospatial Consortium) standard makes the system accessible and adaptable to potential future expansions in compliance with an ‘open science’ approach. The system is developed to have two Restricted Access client applications and Free Access client applications. Currently, as the project is on-going, only the restricted access is developed and used by the team. A front-end application, based on Microsoft Access, is used for uploading and editing alphanumeric data and a cartographic application based on the popular open source client Quantum GIS allows browsing geometries, data sheets and files. This paper focuses on the restricted part and its use by the team members which were trained to upload their data and query the Db. The technology adopted allows to make data accessible through several options such as web GIS applications, publishing of Web Map Services (WMS).

1 DBMS stands for Data Base Management System while PostgreSQL is one of the many software which can manage a database.
3.2. Data model: entities.
The Db has a cataloguing function through data sheets describing ‘entities’ which are physical objects (Figure 4). An entity can be an artifact (e.g. a wall painting) or can be the building containing it (e.g. a church or a museum). The entities represent the starting point of the Db as any information collected as part of the project, such as a scientific analysis, is linked to entities. It is possible to establish hierarchical relationships between entities, e.g. the church, the apse, one of the paintings in the apse etc.. There are no limits to the number of sub-entities that can be created and nested one in the other recursively (as folders and sub-folders). Entities typically have a geometry specified in the data sheet with an absolute position on the territory map. Sub-entities will inherit the respective parent’s position, unless they have their own geometry. This allows to manage the situation of the St. Luc project, where several individual wall paintings are studied. Child entities inherit all the links from the parent as ‘indirect’ links. These ‘indirect’ links have a specific level of relationship: e.g. level 1 from the ‘parent’ and level 2 from the ‘grand-parent’ etc…. Similarly, the opposite is also true, a parent entity will acquire the child’s links with a certain level of relationship. For example, if a document (such as an historical picture of a painting or the results of point analysis) concerns a specific wall painting in a chapel, then it will also be found when querying the Db about the church as a whole. When searching for a specific information, it is possible to filter the query by the relationship level. The Db is structured with these hierarchical relations in a flexible manner so that these can be modified at any time and all the links, including the position, are automatically updated. The inheritance of the position is particularly important for movable heritage which may be transported to a museum.

3.3. Data model: projects, activities, players.
A ‘project’, such as the St.Luc project, is the framework under which a number of activities are carried out on multiple entities in a specific time frame. The roles played by the different institutions participating in a project are recorded in the Db. Several types of activities can be carried out as part of a project; these may include study, examination, scientific investigations, conservation, monitoring and maintenance, etc. and may involve one or more entities. The Db is designed to manage any and all of the activities of a project through a series of records describing purposes, expectations, process and methodology followed, results, as well as any critical issue and useful notes for the long-term management. Different professionals, individuals or companies, may be involved in these activities in different roles and are defined ‘players’. Although, the team members were trained to be able to enter data in the Db, one person keeps the overall responsibility to manage the entire system.

3.4. Data model: files.
Any data collected and/or created as part of the project, such as a scientific analysis, historical photos etc., is acquired as a ‘file’ and is briefly describe in a data-sheet. Files are linked to one or more entities directly or through ‘spots’ or ‘samples’ and are produced in the context of a specific activity. When
"files" can be any data collected and/or created during an activity as part of a project.

"Entities" can be any kind of physical objects, e.g. the St. Nicolas church in Semsales.

"Entities" can be nested one in the other (as folders and sub-folders), e.g. the painting representing St Nicolas is a "child" entity of the "parent" entity church.

A spot always belongs to one and only one entity.

"Spots" are significant points or areas of an entity where in-depth analyses are carried out.

A Spot can reference one or more spots.

"Samples" are small portions removed for lab analyses briefly described in a data sheet with links to related files.

A Sample always belongs to one and only one entity; a Sample can belong to one and only one spot.

"Entities" are identified in a territorial cartography with points or polygon geometries.

Entities without their own geometry inherit the position from the parent entity.

Specific entity-related cartographies contain in-depth information, such as thematic maps, data sheet of spots, samples and linked files.

"Geometries" of any geometric type and with any reference system can be used to define thematic layers in a project.

Geometries can represent physical objects, such as entities and spots, or be used as placeholders in specific layers and related to files thus making it possible to browse files from the map.

"Players" are different professionals, individuals or companies, involved in activities.

A player can be involved in one activity with different roles.

An activity always belongs to one and only one project.

One or more players are involved in one activity with different roles.

"Institutions" can be private or public subjects such as universities, research centers, archives etc, involved in projects.

One or more institutions cooperate in one or more projects with different roles.

"Institutions" can be private or public subjects such as universities, research centers, archives etc, involved in projects.

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Figure 4. The structure of project St. Luc’s database.
querying the Db searching for a file, the system provides not only content but also who produced the content, in what context, and for which purpose. For example, if the file is a reproduction of an archive source, the institution, the place where the original is kept, and the specific location is provided. Moreover, for each file, both the copyright owner and any restrictions for its use, dissemination and reproduction are specified.

3.5. Data model: spots, cartography
There are two types of cartography linked to the database: a territorial cartography in which all the entities are identified (in our case the different churches), and a specific entity-related cartography linked to detailed and in-depth information. For example, in the church of Semsaes, on the specific wall painting of St. Nicholas, cartography contains a certain number of graphics and thematic mappings organized in layers. Any geometry belonging to these layers can be linked to files and other information (e.g. a web site, other data sheets). For example, the layer graphically indicating the position of photographs can act as the index to link to the actual photo available in the Db. Similarly a particularly worrisome condition, such a structural crack, may be linked to the file ‘engineering report’.
When several types of data and files are specific to a point or an area, ‘spots’ are created. The ‘spots’ are represented on the cartography, have a data sheet describing the information available for this spot, and allow linking to the files. Typical files are data from point analysis and sampling area. In the case of sampling, which in turn will be producing much more data from lab analysis, there is an additional specific ‘sample’ data sheet.

4. Practical aspects
The issue of users and privileges is a difficult one, often encountered in the filling up of Db and data entry. Who provides data is straightforward, but who inputs it in the system, how and when is often undefined. The filling of the Db is a huge job, often underestimated, typically left at the end, carried out by someone not familiar with the project, and used just for dissemination purposes. Instead, the Db should be an operative tool developed to be used by the team during the project. In our case, the desire was that each author of the data, i.e. the members of the multidisciplinary research team, would be able to upload his/her data autonomously in the Db. In addition, each member would be able to retrieve and look at data and files entered by others. This is fundamental for data integration and for the good progress of the project. The challenge is to keep the Db in order with so many users and avoid disasters….
Another consideration is that, although the system is developed for one project, it has the potential to house many other projects which may be run by other institutions and different players. It is therefore fundamental to control users, data entry and the access privileges.

4.1. Data security: users and privileges
The database has a sophisticated system to authenticate and authorize the operations requested by users. The DBMS verifies the identity of the user and checks whether he/she has a valid privilege to perform the requested operation. The assignment of privileges is flexible, is given by the users with administration privileges, and include insertion, modification, and cancellation. These normally are given for an entire table (for example table of activities, table of entities etc.). The novelty for this Db is that privileges can be granted independently for specific records of the same table. For example, a user who can enter data on conservation activities may not be allowed to change a record about a scientific analysis. Considering the relationship between tables, typical of relational Db (e.g. project and activities), the privileges are automatically inherited following the relational structure of the Db itself. This means that a user authorized to modify an activity will automatically be authorized to modify all the files that descend from that activity. In addition, privileges can be granted to groups of users, e.g. conservators or scientist, etc. In this way a single user, without a nominal privilege to perform a certain operation, can perform it if he/she is a member of a group that owns that privilege. Membership to a group can be granted or revoked at any time. Tables containing shared data, for example thesauri, records about authors, or bibliographic references which are by default accessible by all, are managed in a slightly different way.
If the shared data has not been referenced by others, then changes can be made. On the other hand, if it is referenced by other users an explicit privileged of “revision” is requested and changes can only be done once granted.

5. Conclusions

This paper discussed the challenges faced when dealing with large and multidisciplinary studies of cultural heritage. To manage the data, a flexible and extensible Db was created so that storage and access of files can be done, as the project develops and unfold, by the various kinds of experts composing the research team. The project is on-going and the Db is still in development while the team members acquire data and populate it. As the project is completed in its different phases, data contained in the Db will be used to develop a WEB GIS for the dissemination of the project results. The system developed is sufficiently flexible to deal simultaneously with several project and several activities related to cultural heritage preservation.

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