REVERSE ENGINEERING OF A PSEUDO-COMPOSITE CAPITAL

It seems fitting to define the meaning of the word Synagogue before starting to analyse the building:

Synagogue: from the Greek συν + αγω (syn + ago), "with" + "gathering" from which the term συναγωγη is derived, a place of gathering, hence synagogue.

HISTORICAL EVENTS

After they were thrown out of Spain in 1492, many Jews reached Modena where, in 1630 the Plague erupted. In those times of terrible crises and difficulties due to famine, wars and widespread misery, everyone, including the Duke, borrowed money from the Jewish pawnshops banks pawning their belongings. The plague did not spare the Jews and decimated their number but they still had a lot of items pawned that belonged to dead Christians. The Conservatives requested a law to require such items (without any money passing hands) and to have measures against Jews who possessed *"grandi quantità di oro e d'argento, e mobilie, che non vi sarà mai che ne riscuota"* (*"great quantities of gold and silver as well as furniture, with no one alive to claim them"*). Thus, in 1638 the Estensi, who had hemmed and hawed till then, ended up by giving in to what the people and the catholic church demanded and set up the Modena ghetto by the will of Duke Francis I. This was the beginning of a dark period which lasted for more than 200 years.

In 1859 all the persecuting laws were definitively abolished and the ghetto was opened. The Jews of Modena once again had rights equal to those of all the other townsfolk and it was subsequently decided to build a Synagogue where they could officiate freely without harassment or restrictions and which would be a "worthy and dignified building".

On 29th June 1869, Major Cesare Rovighi, a person of note in the Modena Jewish community, wrote to the Ornato Commission of the Modena Town-Hall: '*I have the honour of presenting…a drawing for the building of a new Israeli temple in Contrada Coltellini*', on behalf of the Commission for erecting the new Temple'.
With his request he enclosed the drawing signed by the designer, Ludovico Maglietta.
Several alterations were made to the original design up until the final one was drawn up and the temple built.
Erected with the co-operation of the entire Jewish community of Modena and, in particular, with the generous donations of the wealthy Mosè Isacco Sacerdoti, the Synagogue was opened on 19th December 1873.

After 1943, during the crucial race persecution period with the escape and arrest of Jews, the Synagogue doors were sealed by the local authorities but there was no plundering, devastation or vandalism and everything remained intact.
When the war ended the Synagogue was officially opened on the 4th May 1945 in the presence of many townsfolk and authorities.
This building, owned by the Israeli Community of Modena, was declared of particular interest from a historical, artistic and cultural point of view and as such considered part of the descriptive lists as established by art. 4 of law no. 1089 of 1st June 1939. This was communicated by the Emilia Romagna Superintendency for Environmental and Architectural Heritage on 27th August 1975.

THE SYNAGOGUE OF MODENA FROM ROMANTIC ECLECTICISM AND ORIENTAL REMINISCENCES

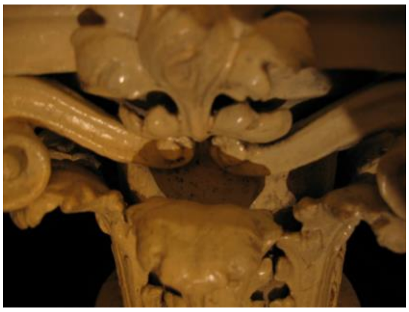
From a formal stand point, the Synagogue is an admirable mixture of refined references to classical architecture (huge semicolumns, capitals, the enormous pediment of the facades, etc.…), elegant elements typical of fifteenth century Venetian architecture as well as evocative and fascinating flashes from an absolutely romantic idea of the "Orientalism" concept.

The Synagogue is divided into two floors, the big room on the ground floor and the women's gallery "loggia" on the upper floor, enclosed by a balustrade.

Besides references to the antique we also find new materials: iron and cast iron taken directly from the new engineering technologies that were experimented in France and England (just think of Crystal Palace or Galérie des Machines or even the famous Eiffel Tower). But the metal substance is disguised, 'sincerely' concealed from the eyes of the faithful: the grooved metal columns are, in fact, in cast iron as well as the newels of the women's gallery; the balustrade and handrail by the Aron are also in cast iron. This metal is used outside this metal is also used outside for the trusses that form the pediment dentil. The imposing light fixture and twelve wall lamps are also in pressed cast iron.

TECHNICAL REPORT

The survey of the Israeli Temple of Modena was extremely hard and excruciatingly slow work due to numerous problems that had to be overcome; this monument is, in fact, situated in the former ghetto area, right in the historical centre of the town. In fact, taking photographs of the temple was an amazingly arduous and complicated task seeing as it is practically wedged between two blocks, one on the left and one on the right, that appear to be one with it! The only facade that we were able to document more thoroughly during this first analysis was, without doubt, the one facing Piazza Mazzini. We had many different tools to help us with this task and each one was of fundamental importance: a ruler, an ultrasound measuring instrument, a ladder, a camera and a 3D scanner to document the architectural detail we had chosen as completely and impeccably as possible.



1 – THE RULER

This tool was very important for measuring directly the building we had chosen: basically each architectural element that could "be reached" was measured in this simple but effective way.

2 – THE CAMERA

Undoubtedly one of the indirect tools that was the most useful in finishing this work; in a nineteenth-century building like this Synagogue of eclectic inspiration it was simply impossible to measure or geometrically reconstruct each frieze, each capital (which, among other things, are beyond one's reach except with scaffolding) etc., but we were able to snap each capital with a camera - straightening them out as necessary with Photoshop of course! – obtaining a jpeg image that was easy to trace with AutoCAD 2007; the precision we were able to reach, not excellent but acceptable (also because it was the maximum that could be reached), was quite satisfactory. The same applied to the complicated trabeation on top of the exterior semicolumns. We were unable to place the capitals into any architectural category, being palm-shaped and decorated with bunches of grapes (all fundamental symbols for the Hebraic culture): and it was for this that the camera allowed us to redesign them which would have been absolutely impossible otherwise.

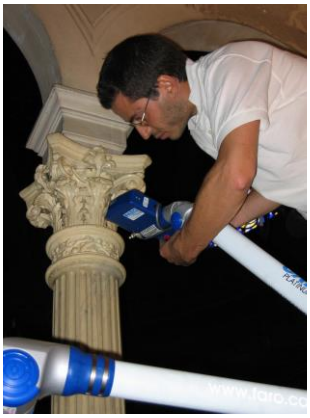
3 – THE 3D SCANNER (REVERSE ENGINEERING)

Reverse Engineering (RE) is a method that allows you to find its mathematical description starting from the physical model. So from the points cloud, obtained with the feeler process, with a contact o non-contact, it is possible to describe the object mathematically, create a shading or generate a suitable STL file for future prototyping if necessary.

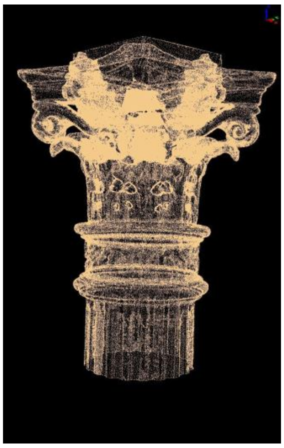
The Reverse Engineering cycle

In order to reconstruct three dimensional geometry of an object it's important to follow a three-phase cycle. If the reverse engineering target is a parametric CAD model one more step has to follow.

1. The first step is the optical scanning, to acquire **a point cloud**, that is points in space belonging to the surfaces of the solid.


2. The file coming from the scanning system has to be optimized using filters and tools inside the reverse engineering software. Different point clouds, coming from different measuring sessions, are aligned in the same reference system while the double points, that are captured during the sessions more than one time, are deleted.

3. The following step is to generate a STL model, showing the object surfaces with a triangular faced trheedimensional mesh. This file can be sent to rapid prototyping machines to manufacture copies of the original model, it can be exported in graphig formats for video presentation (3D rendering) or it even can be saved to generate the database of the parts digitized.

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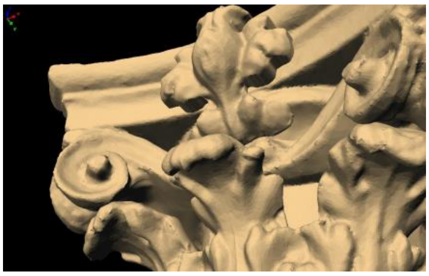
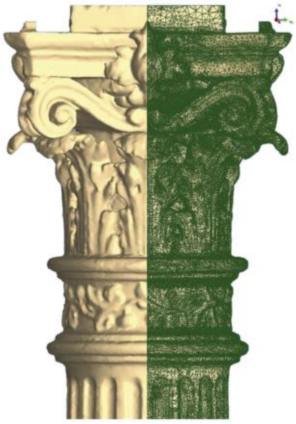
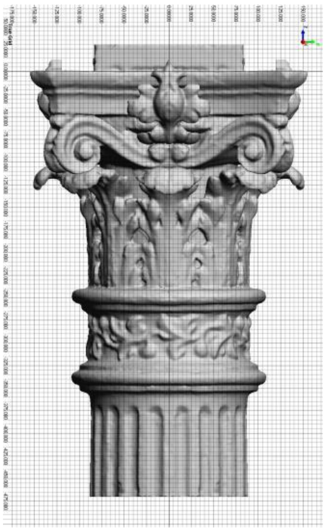
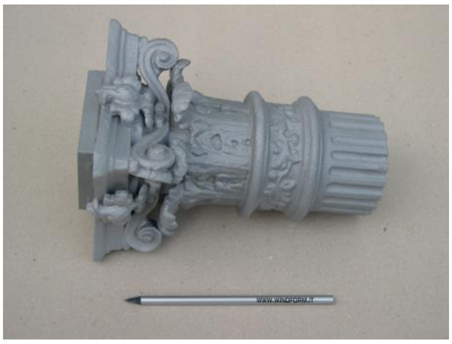




4. If the object shapes can to be “described” by a parametric CAD model, it is possible to use the point clouds or the STL file as a 3D reference for modelling. First it is necessary to extract a range of CAD primitives (plane, spheres, cylinders, axes) from the point cloud, automatically or semi automatically, approximating the solid; it is possible to fit NURBS surfaces on the STL file in order to model the most complex areas of the object. Finally all the information generated (STL, primitives, NURBS surfaces) are imported into the CAD software to create the final model. An experienced technician is needed for this step, to be able to correct any mistake and to integrate any missed dataduring the scanning process. The final CAD model can be exported into a neutral format (IGES, VDA, STEP, …) and used to manufacture the digitized object.





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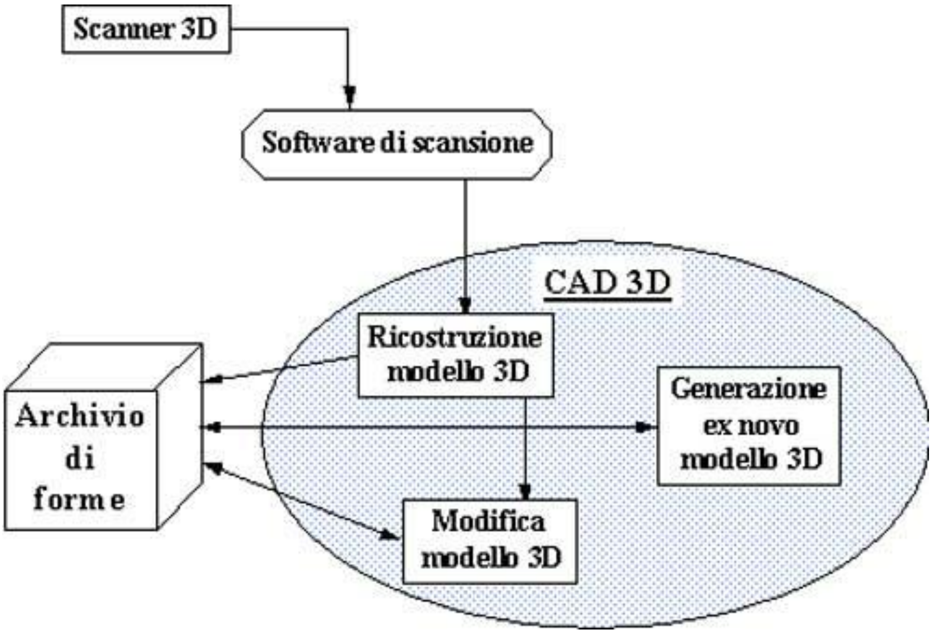

It's really surprising the level of detail and perfection that can be reached with this equipment. Here are some pictures CRP Department took during the measuring session:

Reverse Engineering completes the CAD/CAM and Rapid Prototyping technologies and closes the DESIGN LOOP**: concept development-design-engineering-production**

These same hardware and software tools used for Reverse Engineering allow us to digitize the surfaces of a part completely, to compare them with the original CAD model and therefore to generate a measurement report that highlight the dimensional discrepancies due to the production process.

The Equipment used

7 axis CMM Faro Platinum Arm + Faro Laser Line Probe optical system

Spherical measuring range: 3 m (10 ft.)

Scanning speed: 19.200 points/second

2σaccuracy in non-contact measurements: 0.05 mm

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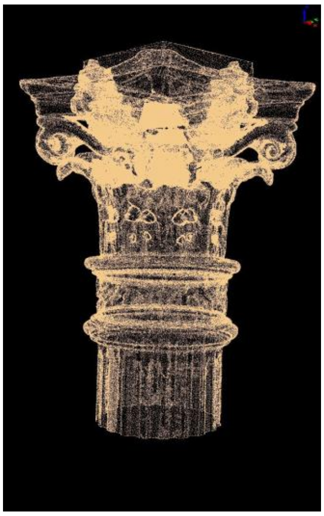
The system is completely portable and 3D scannings and measurements are possible on the customer site.
The combined use of the seven-axis arm and the laser scanning system allows contact measurements or optical scanning to be done simultaneously inside the same reference system. The lightness of the tool plus the high number of freedom degrees make measurements quick and reliable even of complex, hard to reach parts.

TARGETS TO REACH

The target of this work made by CRP Technology was the on-site measurement of a pseudo-composite capital using a reverse engineering technology. More specifically, we used our new optical scanning system Faro Laser Line Probe (non-contact measuring system) mounted on an anthropomorphic measuring arm, Faro Platinum Arm.
This portable scanning system can be mounted on different supports depending on the object that needs measuring so it can "see" the surfaces of objects that are normally difficult to reach. After assembling and calibrating, the instrument was "vacuum" flanged to the platform of scaffolding by the side of the capital.
Measuring the surfaces of the capital, which took about 1 hour, generated a three dimensional point clouds that reproduced the shape of the capital in CAD environment with a measuring error of about 0.1 mm. The resolution, that is the distance between the points captured by the scanner, chosen for this measurement was 1 mm to avoid having a file that is too "heavy", but the equipment makes it possible to have a resolution as low as 0.1 mm.

When measuring was finished, the three dimensional point cloud was transformed into a 3D mesh in .stl format.



From this type of file:

- it is possible to make a virtual analysis of the scanned object in terms of volume and dimensions , while views and cross sections can be created;

- comparisons can be made between the different files of the same object obtained by measurements taken at different moments to verify the state of preservation of an asset and to monitor damage caused by external agents;

- with rapid prototyping technologies copies of the model can be made, even on a reduced scale, to use for demonstration and educational purposes;

- virtual galleries can be created where sculptures or architectural details are shown in 3D (allowing rotations, zooming and panoramic views).

MEASURING: METHODS, STRONG AND WEAK POINTS

The measuring of the capital was part of a bigger project that entailed measuring the whole building where the capital is located. If traditional measuring methods can give sufficiently satisfactory results for the whole building although with considerable limits and imperfections), for an object of the shape and size as the one in question, such methods are ineffective as they are too approximate.

Concerning the limits of the previous measuring methods:

1) making traced copies is an invasive method that risks damaging the surface of the object to duplicate;

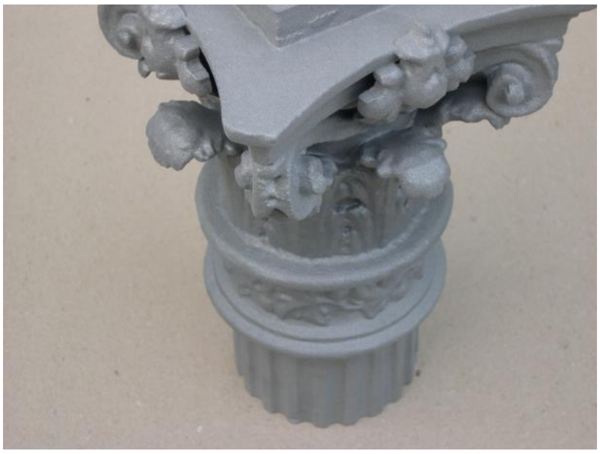
2) digital photogrammetry allows the measurement of only some of the significant points fixed on the object and does not allow an accurate measurement of the surface in all its detail;

3) The optical measuring systems dedicated to architecture allow great portions of the building to be measured quickly with resolutions that are lower than those of the laser

used in this application, e.g. wide range laser scanners measure a distance of up to 25 m with an average error of +- 3 mm.

The purpose of the whole operation would therefore would therefore have been useless because it would give us an object that is nothing like the real thing. It is easy to see how important this new method should be in measuring complicated, unique and culturally important objects. As all the operators in the sector and art lovers know, in fact, an enormous intrinsic value of artistic production of all times also lies in its preservation and in the possibility of being able to convey it into the future. If the memory of a painting can be entrusted to the photographic technique (seeing as its peculiar characteristics are colour and light) the same can’t really be said for a three-dimensional work where volume plays a part. We can easily understand how much value reverse engineering can have, together with photography, in collecting, filing and transmitting, as faithfully as possible, data related to a unique object of inestimable value.

The final aim of this operation was, in fact, to accurately measure an architectural detail of interest and to quickly create a 3D model faithful to the original physical model.



The following advantages were possible using this technology:

1) high resolution of the measurement and consequently of the 3D model created,
2) a perfect match between the physical model and the three-dimensional file,
3) using a non invasive scanning system

Whatever the case, the problems connected to using this technique cannot be ignored.
The system, that works according to the optical triangulation principle, is only able to measure the visible areas of the object meaning that the undercuts and tiny cavities are not measured.
A high resolution scanner is able to scan the surfaces only by staying very close to the objects it is measuring (about 100 mm): this can lead to serious logistic problems when the component you intend measuring is difficult to access, as in this case study.
So first of all there is the difficulty in transporting the equipment when the object to measure cannot be moved. In the case of the capital, in fact, the measuring device had to be fixed to some movable scaffolding close to the object and this in itself created quite a lot of problems due mostly to the instability of the supporting structure. Despite all this though, the operation was finished successfully, proof being the graphical model that was made. As for all innovative and experimental technologies, each small problem along the path is the cue for improvement.

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Another flaw in using this technique is the high cost, essentially due to the amortization cost of the equipment: this too will be improved as technology progresses. The only other thing to say about this is that the cost of the operation is economically infinitely less than the historical, artistic and cultural value of a work of art.