Abstract
The aim of this paper is to give a quick overview of rapid prototyping possibilities in the conservation of cultural heritage. This technology enables the manufacturing of complicated elements or objects using 3D printing in combination with laser cutting, etc. Previously, such devices were expensive and rather inaccessible but today specialised laboratories, such as FabLabs, described here, offer such equipment for rent at low cost. After introducing some possible uses for rapid prototyping and FabLab technologies applied to cultural heritage, this paper will present a special conservation tool that has been recently designed and fabricated in a FabLab – the PLECO.

The PLECO is an electrolytic pencil used for the localised cleaning of tarnished silver and gilded silver composite artefacts combined with inseparable elements (for example wood, enamels, or precious stones). It was developed by the University of Applied Science – Arc and its conservation division (HE-Arc CR) in partnership with one of the engineering divisions, the Edana Laboratory (EDANA). Developed as part of the “Saint-Maurice” research project, it enabled the cleaning of some of the composite masterpieces of the Treasury of Saint-Maurice Abbey in 2015 before their installation in a new exhibition hall for the Jubilee (1500 years) of the creation of the Abbey.

Rapid Prototyping & the Fablabs - State of the Art
At the beginning of the 21st century, rapid prototyping technology and more particularly 3D printing have undergone almost explosive development. Everyday new uses of these technologies can be seen in unexpected domains. Low-cost prostheses are being produced in the medical field, and in a near future it will be possible to print human tissue and organs. The European Space Agency is at work on a giant 3D printer to build a lunar base using only salt water and the sand available in the moon soil. Artists and designers are increasingly users of 3D printing, the reduction of manufacturing constraints allowing them freedom to create.

For most applications mentioned above, the use of expensive and large printers is required. Cost is a major issue in the dissemination of a new technology, particularly in the conservation field. Fortunately many new developments are occurring in this domain because of the presence of a large, active, and networked community of professionals. Low cost does not mean low level technology, and the use of such 3D devices enables the conservator to count on 0.1mm precision for a basic printer.

The FabLabs
As suggested by its name, a FabLab is a fabrication laboratory. More precisely it is a place with computer controlled equipment that can produce different types of objects in various materials and for different purposes. In a FabLab, we can make “almost anything.” Based on the “makers” movement and the “Do It Yourself” philosophy, the aim of these laboratories is to offer the possibility to anyone to make his or her own personal and everyday objects or technical systems. It is also a place of co-working and net-working.

There are more than 200 FabLabs all around the world (addresses available from the following site: www.fablab.io). All FabLabs are connected and share their knowledge about digital manufacturing. This network is also based on the “open source” and “open hardware” philosophy. With the exception of some FabLabs built around specific fields like biology, chemistry, or specific means of manufacturing, the most common instruments in a FabLab are 3D printers (fig.1), laser cutters, milling machines, and some electronic devices. They are often based on a low-cost technology concept and should be replicable in any FabLab.

With the typical machinery available in a local FabLab, someone can produce anywhere an object designed in another country. The FabLab network can be used as a new way to distribute products. FabLabs are also helpful during the design process of a product. The different machines of rapid prototyping can be used to test, modify, and validate the shape and the function on the basis of an iterative process.

In addition to being open to the public, FabLabs often organize workshops on specific themes or products: learning 3D modelling, electronic prototyping, programming, or manufacturing of objects of all kinds. The goal is to teach everybody the different techniques and possibilities of digital manufacturing.
When Rapid Prototyping meets Electrochemistry:
The PLECO, an electrolytic pencil for the localised cleaning of tarnished silver & gilded silver, continued

Table 1: Review of the different technologies and related materials of 3D printing.

<table>
<thead>
<tr>
<th>Technique</th>
<th>Materials</th>
<th>Specificities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fused layer Modelling (FLM)</td>
<td>ABS, PC, HD-PE, PLA, PPSF, and PCL</td>
<td>Functional pieces, various colour in one piece</td>
</tr>
<tr>
<td>Selective Laser Sintering (SLS)</td>
<td>PA, PC, PS, Acrylate, Methacrylate, PVC, PBT, Polyacetal, Elastomer, and Metal</td>
<td>Rapid manufacturing possible</td>
</tr>
<tr>
<td>Stereo Lithography (STL)</td>
<td>EP, Acrylate, Methacrylate, and Vinyl Ether Resin</td>
<td>Good surfaces, various colour in one piece</td>
</tr>
<tr>
<td>Layer Laminate Manufacturing (LLM)</td>
<td>Paper, PS, PVC, EP, Acrylate, Methacrylate, and PE</td>
<td>Plate-like construction</td>
</tr>
<tr>
<td>Three Dimensional Printing (3DP)</td>
<td>PMMA, PVA, PLA, and PCL</td>
<td>Rapidity</td>
</tr>
</tbody>
</table>

3D Printing in Conservation

Depending on the final use of the printed elements or objects, it is important to choose the proper techniques and materials. As indicated in Table 1, different techniques of 3D printing use specific materials according to the application foreseen.

The suitability of each printed plastic element needs to be considered such as transparency, cost, accuracy, texture, mechanical property, rapidity of fabrication, toxicity, handling, etc. For cultural heritage applications, the neutrality and the long term chemical stability are undoubtedly essential parameters to consider. As a fledgling technology, a lot of new polymers are developed with no background on their behaviour.

For example, the UV resins are not considered stable materials due to the polymerization process occurring during exposure to UV radiation. Accuracy and rapidity of polymerization are prioritised for a commercial use rather than the long term chemical stability of the final product. We need to be really careful and critical when using such material. Some research needs to be carried out to assess the compatibility of these materials with cultural heritage.

3D printing is that the joining operation can be carried out without any adhering material such as glue. This technology can be very powerful in addition to 3D scanning. It offers the possibility to create a copy of an object without any physical contact and to recreate its original appearance if needed.

As an example we can mention the copy of the Persian Horseman made at the Liebegshaus in Frankfurt. Printed in a PMMA materials the replica was painted (fig.2) according to the colours of the original.

An object or parts of an object can be produced as positives or negatives that allow building the product directly or indirectly. For example a mold can be printed from a scanned objet. A copy using loss wax molding is also possible using the proper printed polymer.

Still, there are a lot of potential application for using rapid prototyping technology (especially 3D printing and laser cutting) in the cultural heritage field. The laser cutter can be used to cut PE foam for housing quickly and with precision. For exhibition purposes the same techniques can be used on wood, PMMA, PE, or other plastics to cut aesthetically appropriate stands to display objects. It is also possible to consider laser cutting techniques to replace or refill missing parts of a wood marquetry.

In the same way 3D printing can be used to manufacture fill materials for an incomplete ceramic or to replace broken pieces of a furniture. The advantage of using this technique is that the joining operation can be carried out without any adhering material such as glue. This technology can be very powerful in addition to 3D scanning. It offers the possibility to create a copy of an object without any physical contact and to recreate its original appearance if needed.

Finally rapid prototyping techniques can be used in a different way to develop innovative tools. In the next section, we will give an example of such an application.

![Fig. 2: View of the Replica of the Persian Horseman presented at the Liebegshaus in Frankfurt ©Alphaform AG.](image-url)
Saint-Maurice Project – The PLECO

Electrolytic cleaning is a less invasive and safer way to clean silver tarnish compared to more traditional mechanical and chemical cleaning. The latter abrade the metal surface or might provoke new forms of tarnishing due to inappropriate rinsing processes. Electrolytic cleaning uses more neutral and less concentrated solutions to prevent any unwanted effects.

Until now, electrolytic cleaning on silver and gilded silver was conducted by immersion. Other applications of electrolytic processes have been developed such as the stabilisation of active corrosion on lead artefacts, the stabilisation of copper chloride, and the cleaning of marine iron based artefacts.

The electrolytic cleaning of composite artefacts made of inseparable tarnished silver/wood components cannot be carried out by full immersion. With localised cleaning being the only reasonable option, we had to develop a portable, easy to use, and safe electrolytic pencil.

Some metal conservators - including ourselves - had tested in the past rudimentary versions of an electrolytic pencil with limited success (re-tarnishing of the cleaned spot due to a high concentration of sulphur at the tip of the pencil). The PLECO was designed to solve these problems by providing a constant renewal of the electrolyte and enabling a thorough control of the potential applied. It is built using (fig.3 & 4)

3D printing elements: 1. tip 3. piston head 5. cover
and assembled laser cut pieces: 2. envelope 4. piston

The PLECO, How It Works

As noted, the PLECO is used for the localised electrolytic cleaning of silver/gilded silver tarnishing. It is equipped with a 3 electrode cell – a platinum counter electrode, a vitreous carbon rod used as a reference electrode (both situated inside the PLECO (fig.5), and the object to clean being the working electrode. The PLECO and the object are connected to a stabilised power supply, the object being plugged as a cathode and the platinum wire as the anode. A voltmeter is added to control the potential between the reference electrode and the object. Therefore the conservator can follow and control precisely the parameters of the electrolytic reduction.
Conclusion

Through the example of the fabrication of the PLECO we see that the FabLab technology is not limited to designers, engineers, and artists. The conservation field has many potential uses for 3D printing, laser cutting, etc. In addition to the PLECO itself we plan to manufacture the pumping system using similar tools. This should decrease tremendously the cost of the PLECO. Furthermore more research has to be carried out to investigate the compatibility of printed polymers with cultural artefacts.

The PLECO project shows that such a tool can be disseminated and modified by the professional conservation community, and we expect a self-appropriation of the tool by end-users to optimise it. As an example, an HE-Arc CR masters student has chosen to apply the PLECO for the stabilisation of active corrosion on lead artefacts.

References


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