Rapid Prototyping from Fast Contactless 3D Reconstruction (FC3DR) device

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Abstract

This document illustrates a method for manufacturing geometries acquired by contactless 3d reconstruction device FC3DR[2]. The reconstructed geometries are printed by Fused Deposition Modelling (FDM) Rapid Prototyping techniques. A sample model reconstructed by FC3DR device has been built and the pipeline of the whole FDM RP process is discussed.

1. Introduction

An important application field of FC3DR [5] is represented by the possibility of physically building models of the acquired samples by *Rapid Prototyping* techniques. This term (*RP* in the following) indicates a host of technologies used to fabricate physical objects directly from *CAD* or other digital data sources. See for details of the RP technology.
In this document we concentrate on describing the *FDM* technique of Stratasys device which has been used to produce a human hand resin model. Section 2 describes the mathematical model of the acquisition method. Section 3 provides a brief introduction about *RP* technique and *stereo lithography* file format, focusing on *FDM* technology. Section 4 describes how to use *RP* techniques to get physical models of the objects represented by the acquired datasets, describes and shows the sample realized and specifies the problems related to the material realization task.

This work, realized inside the activities of the LAPS project, presents first results of the scientific collaboration between the research group directed by Prof. Massimo Vanzi of the Dept. of Electronic Engineering of the University of Cagliari (DIEE) and the Geometric Modeling and Monte Carlo Simulations Area of CRS4. The printing process has been executed thank to the Proto21 service of PST Polaris in Pula (CA).

2. Rapid Prototyping

Rapid Prototyping is the name given to a host of related technologies that are used to fabricate physical objects directly from CAD data sources[1]. These methods are unique in that they add and bond materials in layers to form objects. Such systems are also known by the general names solid freeform fabrication and layered manufacturing and offer advantages in many applications compared to classical subtractive fabrication methods such as milling or turning [2]:

- Objects can be formed with any geometric complexity or intricacy without the need for elaborate machine setup or final assembly;

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[2] FC3DR device has been developed by the research group directed by Prof. Vanzi of the University of Cagliari.

- Objects can be made from multiple materials, or as composites, or materials can even be varied in a controlled fashion at any location in an object;
- Solid freeform fabrication systems reduce the construction of complex objects to a manageable, straightforward, and relatively fast process.

These properties have resulted in their wide use as a way to reduce time-to-market in manufacturing. Today's systems are heavily used by engineers to better understand and communicate their product designs as well as to make rapid tooling to manufacture those products [3]. Surgeons, architects, artists and individuals from many other disciplines also routinely use the technology. *RP* machines are also called *3D printers.*

The names of specific processes themselves are also often used as synonyms for the entire field of rapid prototyping. Among these are stereolithography (SLA for stereolithography apparatus), selective laser sintering (SLS), fused deposition modeling (FDM), laminated object manufacturing (LOM), inkjet-based systems and three dimensional printing (3DP). Each of these technologies - and the many other rapid prototyping processes - has its singular strengths and weaknesses.

The STL file format

STL or *STereoLithography* file format is an ASCII or binary file used in manufacturing to export data from CAD systems to the RP devices. It is the de-facto standard data format used in *RP* industry for furnishing input data to *3D printing* processes. It is constituted by a triangulated surface representation of the 3D CAD model, i.e. a triangular representation of a 3-dimensional surface geometry. The not approximated surface modelled by the CAD system (surface o solid geometric modeller system) is tessellated or broken down logically into a series of small triangles (facets). Each facet is described by a perpendicular direction and three points representing the vertices (corners) of the triangle. These data are used by a slicing algorithm to determine the cross sections of the 3-dimensional shape to be built by the fabber. An *STL* file consists of a list of facet data. Each facet is uniquely identified by a unit normal (a line perpendicular to the triangle and with a length of 1.0) and by three vertices (corners). The normal and each vertex are specified by three coordinates each, so there is a total of 12 numbers stored for each facet.

The FDM process

The *FDM* (*Fused Deposition Modelling*) process forms three-dimensional plastic models and objects from *CAD* generated 3D solid or 3D surface models, previously exported or saved as *STL* files. A temperature-controlled head extrudes *ABS* or Polycarbonate plastic material, layer by layer. The designed object emerges as a solid three-dimensional part without the need for tooling. The stages of the implemented pipeline are the following ones:

1) the solid model 3D design *(STL* file) is imported into a pre-processing software developed specifically for the *FDM* machines by Stratasys. In our case the software is Stratasys Quickslice v6.4;

2) the part design is orientated and software slices the 3D drawing into horizontal layers varying from .005" -.014" inch thickness. Support is automatically or custom generated based on the position and geometry of the part. Toolpaths are then created; Path data is reviewed, changed if necessary and then downloaded to the *FDM* machine. The system operates in a *x*, *y* and *z* axes. In effect, it draws the model one layer at a time, similar to how a hot glue gun extrudes melted beads of glue;

3) the *FDM* head directs the heated "hair thin strands" of plastic material into place with precision (approximately +/- .005" in X and Y, i. e. +/- 0.126 mm). The material solidifies, laminating to the preceding layer creating your plastic 3D model one strand at a time;

4) once the part is completed the support material is removed and the part is lightly sanded when needed, or primed and painted upon request.

3. Printing FC3DR reconstructed geometries

In order to prepare an input file for the FD machine, we produced three STL files, starting from three acquisitions at different resolutions: 100x75, 800x600 and 1704x2272. They led to STL files with number of facets 12.000, $>1.8\mathrm{x}10^6$, $>10^9$ respectively. The last one was definitely too heavy to be managed. The other two were suitable to be realized. Figures 1 and 2 show a particular of the slices of the 100x75 and 800x600 acquisitions.

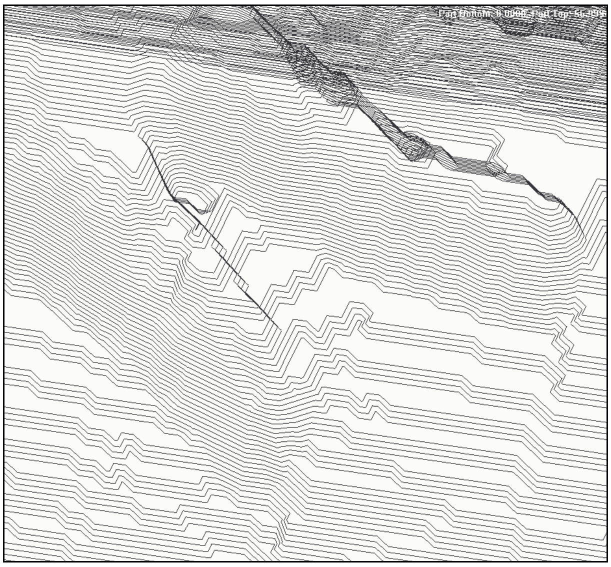

Fig.1 Particular of the level curves set of the 100x75 acquisition.

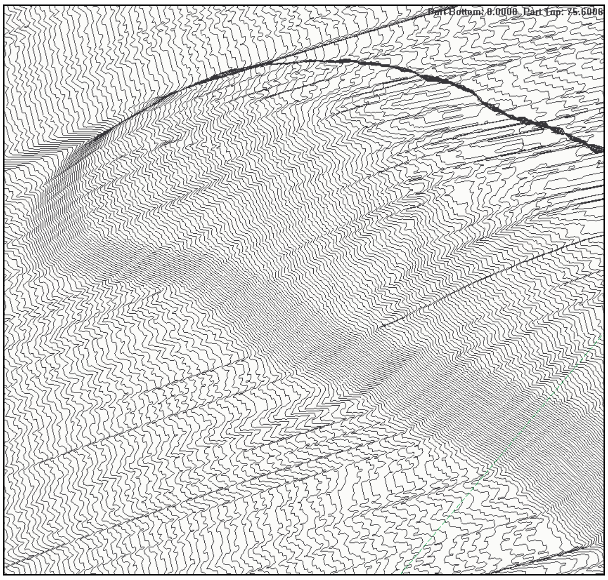

Fig.2 Particular of the level curves set of the 800x600 acquisition.

The 800x600 acquisition presented, after it has been sliced, some sections where the contours were too jagged and fragmented to be correctly realized by the FDM machine. The situation at the same section of the 75x100 acquisition was quite better, even if the definition was reduced (factor 10). Figure 3 shows the comparison between the two acquisitions.

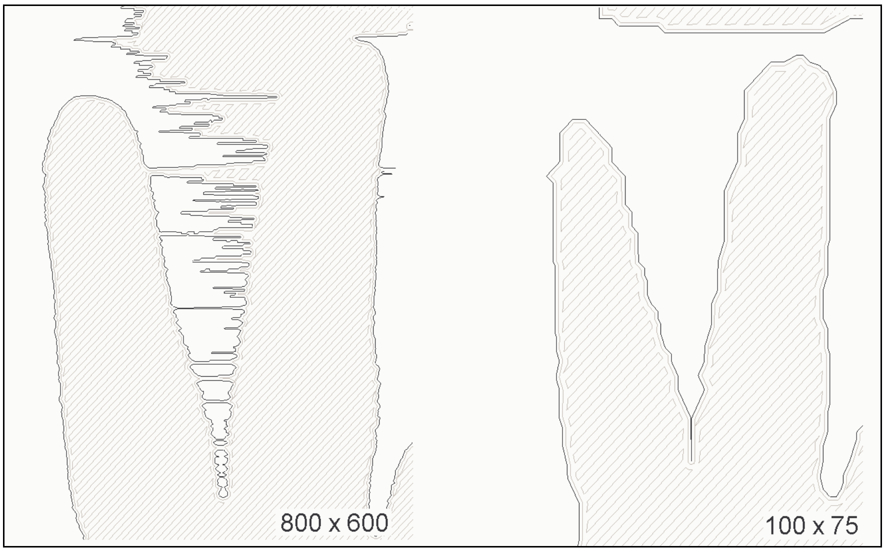

Fig.3. Comparison of two level sections from 800x600 and 100x75 images.

We have chosen to print the 100x75 acquisition because the appropriate quality of the physical model . Figure 4 below shows the *STL* representation of it, taken from a QuickSlice screen. In order to avoid waste of material and to shorten printing time, we made some holes at the bottom of the object before building it (figure 5).

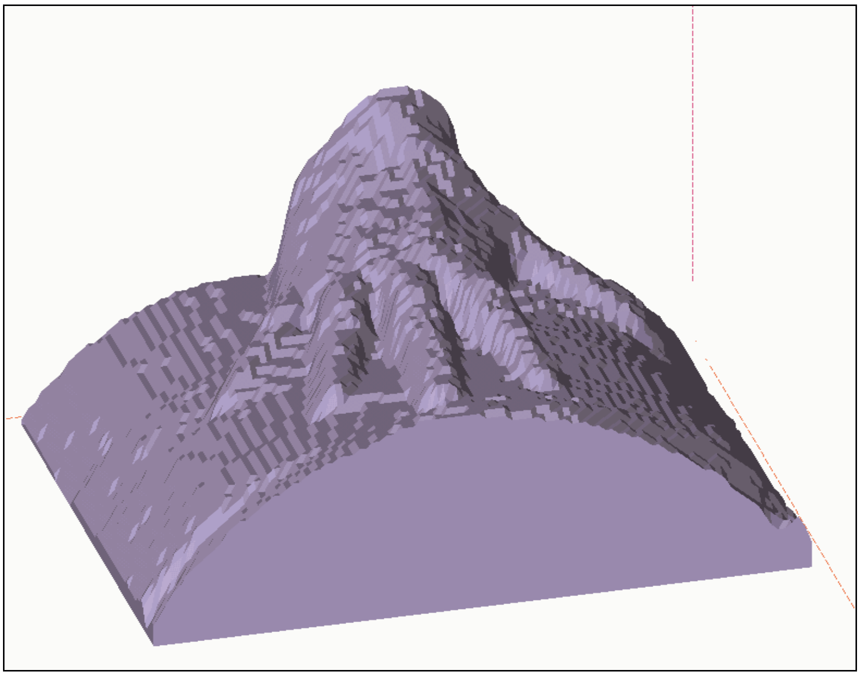

Fig.4. Rendering by QuickSlice software of the STL relative to 100x75 acquisition.

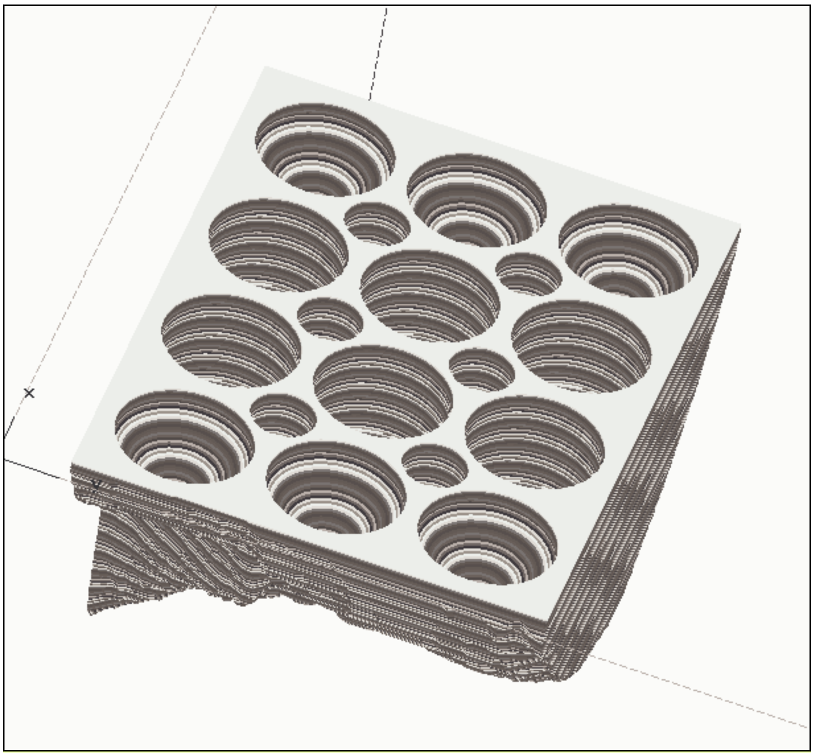

Fig.5. Bottom of the sample: the holes have been made to optimize material use and printing time.

Then we printed this reconstruction with the FDM 3D printer. The result is shown in the pictures below. The building job took about 14 h, the model weight is 110 g and its maximum dimension is 120 mm.

Fig.6. Prototype images.

Fig.7 Prototype images.

5. Conclusion

Main open problems for the physical realization ofg geometries reconstructed by FC3DR are:

- reducing the high printing cost (about 40 €/g for FDM technology);
- choosing the most suitable RP technique for this specific application fields;
- performing an automatic offset generation from extracted FC3DR surfaces (for example, by using Minkowsky operators [4]).

References

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