Applying Reverse Engineering to Manufacture the Molds for the Interior Decorations Industry

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Abstract:

Reverse engineering is a way of replicating complex shapes and designs with the use of specialized hardware and software. This paper presents the methodology needed for obtaining the 3D virtual model starting from existing models made by hand, and then editing this virtual model to manufacture molds. These are then machined using three axis CNC manufacturing equipment. The paper approaches some of the key challenges for reverse engineering: repairing damaged sections in the model, recreating an ordered pattern and balancing the number of points and processing time. An analysis is made to try and optimize both the scanning, processing and machining processes in order to decrease the time and costs associated.

Keywords: *scanning, reverse engineering, mould, CNC equipment*

1. Introduction

Interior decorations industry is a dynamic industry which, through the variety and multitude of products they offer, tries to keep up with customer needs. The increasing number of new constructions and the need for renovations or interior redesign requires that the decorations' industry designs new appealing products with low cost and manufacturing time.

In order to create such products that meet the requirements of the customers, the work starts in most cases with the artistic design. Through skill and imagination the artist creates a model that meets his reasoning in terms of aesthetic. But in the process of creating the model, the artist crafts by hand the geometry of the surface and the surface texture. In order to get a high quality product suitable for the demands of the mass market it is important to create products that appeal to the general consumer and current architectural trends. This will form the basis of the design process that will later be converted into high quality casting molds in the subsequent manufacturing of the final product.

Conception is for the artist and the execution is for engineer's "Scientists generalize, artist individualize" (Jules Renard). The science behind reverse engineering creates from the primary model envisaged by the artist, a reliable model of good quality that is used for mass production of products or for creating one of a kind prototypes.

Reverse engineering techniques allow for the selection of the optimal strategy for manufacturing the molds by first digitizing and artists concept and then processing the data to obtain the CAD model. The techniques and concepts used by the artists, lead to designs that feature complex and freeform surfaces. Reverse engineering methods enables the conversion of aesthetic design to virtual form design.

The artistic model is created on an aesthetic basis but processed CAD model must be able to both reproduce the artistic concept and allow for the manufacturing of the part. Reverse engineering provides the link between art and the manufacturing industry by bridging the gap between the design and manufacturing process. Reverse engineering technique allows the use of different forms and materials to express the artistic design (clay, wood, and fiberglass), however, obtaining a virtual model, based on the artistic creation poses several challenges.

Reverse engineering methods and techniques are being applied in several key areas of the industry in order to accomplish the following [1]:

- Design of new components;
- Reproduction of an existing component;
- Recovery of a damaged or broken component;
- Development of model precision;
- Observation of a numerical data.

The authors of this paper propose an algorithm and experimental case studies to obtain the desired molds for the interior decorations industry, starting from handmade models and using reverse engineering techniques. Through the strategy of reverse engineering allows the transition from the artistic concept to the parameterized one no matter how asymmetrical, abstract or free form the shapes are. Reverse engineering technology involves

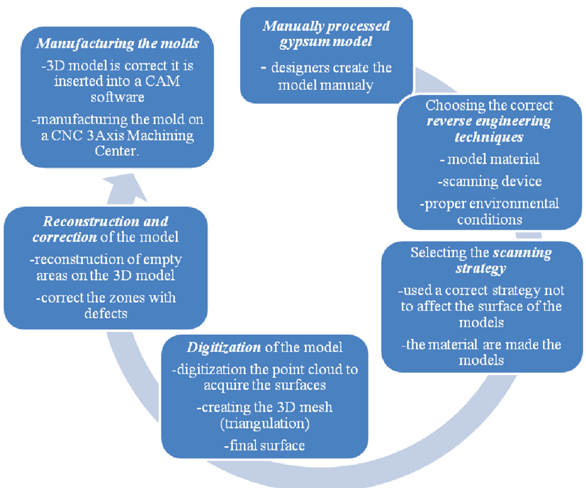


Figure 1. The steps required to achieve molds from hand shaped pieces

a complex activity theoretical foundation to go from the primary model to the virtual model – CAD. It will be created based on an algorithm controlled by reasoning based on experience and theory to identify the most effective model.

2. Methodology and case studies

This chapter of the paper presents a proposed methodology (Figure 1) for manufacturing molds starting from hand modeled designs that are digitized with revere engineering techniques. The case studies are based on three gypsum handmade models, two of them used for wall decorations and one for ceiling, each with different characteristics made by designers.

A. Handmade gypsum model

In the first phase designers manually craft the shapes from gypsum. These models are designed for the interior decorative industry. These three models have been chosen due the complex shape (Figure 2) of the surface making it difficult to design these freeform shapes with CAD software.

a b c

Figure 2. Gypsum model made by hand

B. Evaluation of the models and surface finish

The material used for making the parts is very fragile namely gypsum. Even so, using a contact scanner (Renishaw Cyclone Series II, Renishaw Ltd.) won't damage the surface of the part because the surface is coated with a thin layer of lacquer. This was considered to be the optimum scanning technique making it possible to capture the fine details crafted by the artist.

C. Scanning strategy

Because the material from which the pieces are made is gypsum, and the small details on each of the models a different scanning strategy was applied for each individual model.

For the first model (Figure 2a) the authors used a contact scanning technique with the following parameters:

- Stylus – ball type – Ø2 mm
- Distance between two scanned points – 0.1 mm
- Distance between two scanning lines – 0.2 mm
- Scanning speed – 600 mm

In the second case study (Figure 2b), for the ceiling tiles model, the parameters are:

- Stylus – ball type – Ø2 mm
- Distance between two scanned points – 0.2 mm
- Distance between two scanning lines – 0.2 mm
- Speed – 750 mm

The characteristics of the scanning process for the last case study (Figure 2c) which is the wall decorative model are:

- Stylus – ball type – Ø2 mm
- Distance between two points – 0.1 mm
- Distance between two scanning lines – 0.3 mm
- Speed – 650 mm

D. Digitization

In the digitization phase a contact scanning equipment, Renishaw Cyclone Series 2 CMM scanner was used. In this way the information resulted after scanning is and ordered point cloud of the scanned part (Figure 3). The digitized surface is processed using a dedicated software CopyCAD (Delcam Ltd.) [2] to compute the triangulation and then the 3D surface of the model. This process also eliminates any unwanted points resulted from the scanning process.

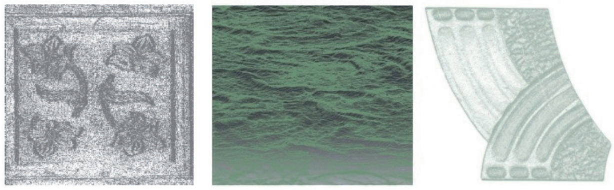
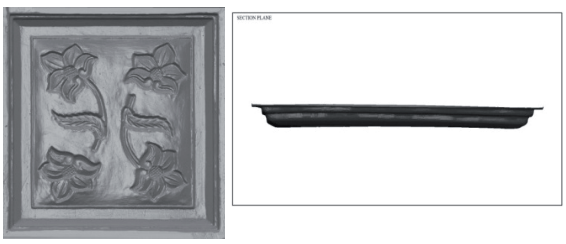


Figure 3. Point cloud of each part model

E. Reconstruction and correction

The imperfections that have to be inspected and corrected because the pieces are shaped by hand can be: form deviation of the margins for parts that are meant to join together, flatness of planar surfaces or consistent repetition of regular patterns that may be lost during the artists creation. These details can be repaired [3] or corrected once the CAD model has been generated using software that allows for editing of the surfaces.

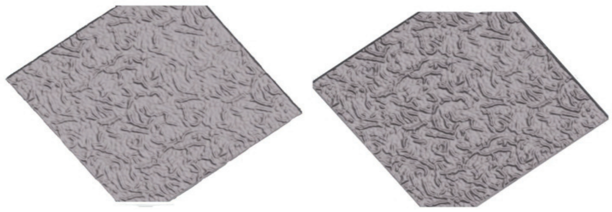
Planar surfaces (Figure 4 b) in certain areas of gypsum models are very difficult to create by hand. Furthermore the joining inner edges of the molds (Figure 4 a) that are essential in the manufacturing of molds for mass production of parts are difficult craft manually. As mentioned before applying scanning strategies to produce 3D model then allows for the editing of these joining edges to straighten them.



a b

Figure 4. Model with extraction edges a) and flatness b) issue

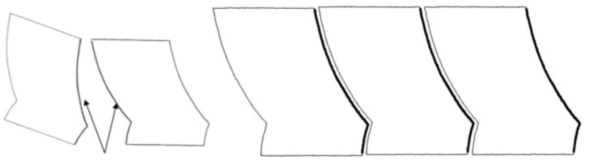
In case of degradation and damage of a used mold for making polystyrene ceiling covers, the initial model was remodeled manually using gypsum. After several attempts to obtain the correct mold depth and increase the existing depth of the figures on the model (Figure 5 a) by hand, a dedicated CAD software enabled the scaling of the 3D model in one direction, Z axis (Figure 5 b). The values used for the scaling process highlighted certain features on the model. In this way the 3D model was created at an appropriate depth for the texture on polystyrene to be produced correctly.



a b

Figure 5. Difference between the a) original and b) scaled model

Another example of presents a way of overcoming the problem of nonuniform joining edges[4] (Figure 6 a) of a certain part(Figure 6 b). The radius of curvature which in the case of manual crafting cannot be created perfectly. There is the possibility of joining problems between parts due to non uniform shapes. These problems can be corrected when the CAD model is edited using a dedicated CAD software CATIA V5, Imagine and Shape Module [5] where parameterized joining edges are created reconstructed that are later used in the CAM software generating the manufacturing code.



a b

Figure 6. Boundary edges a) of the boards and the way of joining b) them tougher

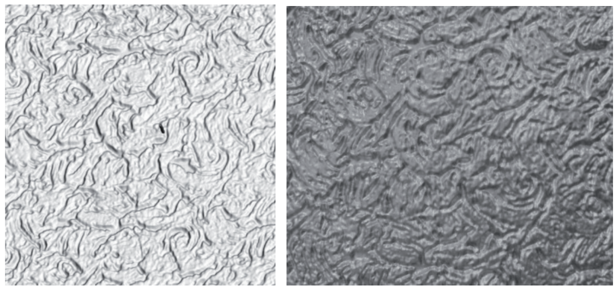
F. Manufacturing the molds

The manufacturing process was achieved using PowerMill (Delcam Ltd.) CAM software [6], and a Vertical 3-axis Milling Center. The manufacturing process was simulated in the CAM software in order to avoid any problems in the machining processes such as: collisions between the tool and the work piece, proper selection of the tools used during the manufacturing phase to ensure that the resulted 3D model is as accurate as possible. After finishing the manufacturing process, in each case study the resulted mold (Figure 7 b) was analyzed to compare the finished product to the initial 3D model (Figure 7 a).

a b

Figure 7. Resulted mould a) 3D and b) the machined

In the second case study the shapes on the initial mould were damaged and not so visible due to wear. The resulted virtual 3D mold (Figure 8 a) after scaling the model at the necessary depth, was compared to the manufactured mold (Figure 8 b) and the results obtained proved that it



a b

Figure 8. The reconstructed mould a) 3D and b) the machined version for the second case study

is feasible to use the scaling method to recreate certain worn out areas.

The analysis was performed in the case of the third where the resulted mold (Figure 9 b) was correct machined in accordance with the 3D model (Figure 9 a)

a b

Figure 9. The third case study a) 3D mold and b) the machined version

3. Conclusion

Modern scanning and manufacturing methods are the main driving forces behind the design of new complex and freeform surfaced parts. Manufacturers want to create mass produced parts with few losses and lower manufacturing costs. In the case of the interior decoration industry there are a vast number of models that need to be produced each requiring specialized injection or casting molds that are expensive to design and manufacture.

Imagination of the designers and requirements from clients have no limits when achieving models with complex forms, which due to time, resources or cost cannot be designed within CAD software. The creation process starts with designers that craft by hand the majority of the models. Thus reverse engineering techniques in this area is very important in terms of correcting or reconstruction of certain parts of the models and transform them into a 3D model.

The models created manually by designers will always have slight imperfections in details, form or surface deviations. Appling reverse engineering techniques these imperfections can be very easily repaired.

A major benefit of applying reverse engineering techniques in the interior decorations industry is that after the 3D scanning process the parts can be reconstructed or corrected. In order to obtain a larger sized model with the same features of the original a scaling process in one or more axes is required.

There is also the possibility of combining different details such as flowers, geometric shapes or other freeform surfaces from a 3D model to another in order to obtain a new design. Obtaining the 3D model of a handmade modeled part is the first step towards achieving the desired model by modifying and editing the virtual model with the help of dedicated CAD software.

In the case of mass produced parts the 3D model is imported into a CAM software in order to generate the NC file needed to manufacture the molds on CNC Machining Centers.

As further area of research for reverse engineering techniques the authors are investigating the reconstruction and restoration of missing parts from different monuments or important decorations from old historic buildings that have been damaged or are missing.

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