

Review of Computer Aided Design (CAD) Data Transformation in Rapid Prototyping Technology

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Abstract

Manufacturing of any product involves not only in design and material selection but also selection of appropriate manufacturing process required to obtain the desire shape and properties of the product. Prototyping is a process of structure pre-production models of a product to test various aspects of its design. Rapid Prototyping (RP) techniques are methods that allow to quickly producing physical prototypes with the important benefit to reduce the Time to Market. In these RP processes the part is produced from CAD model which is transferred to machine computer in STL format. Prototyping or model making is one of the important steps to finalize a product design. It helps in conceptualization of a design, before the start of full production a prototype is usually fabricated and tested. This paper provides a review on data transfer between the CAD and the RP system.

Keywords: Rapid prototyping technology, Computer Aided Design.

Introduction

Now days due to competition in global market, the manufacturers require getting a new and improved product to the market as fast as possible to compete with other. So the pasture of product development, mainly product modeling, has become quite

critical in industrial performance improvement [1]. The major obstacle for this task has been a long product development cycle, i.e., design, prototype manufacturing and testing. Manufacturing can be divided into three different types of processes i.e. subtractive, formative and additive manufacturing processes [2]. In subtractive type of processes material is generally removed from the work piece e.g turning, milling, drilling, grinding and boring etc. In forming processes the desired shape of model is obtained by applying stress on work piece e.g rolling, extrusion, drawing, forging and stamping etc. In additive manufacturing the final model is obtained by joining the powder particles. All Rapid prototyping processes comes under additive manufacturing in which low volume, high value, custom-designed parts can be produced easily. There are wide ranges of materials such as nylons, polymers and metal powders which are used to produced different parts with the use of different RP processes. From 1988 RP has grown as integral part of the new product development process. The products having high quality, with low production cost can be produced by the use of different RP processes. In these RP technologies manufacturing professionals have a tool to rapidly verify and fine-tune designs before committing these to costly tooling and fabrication because it passes the number of steps as shown in Fig 1. RP also has some challenges that must be improved upon before it becomes rapid manufacturing (RM) for producing parts in small batches or customized parts.

Mechanism of rapid prototyping

Description of the virtual model is a crucial part of RP technology. The preparation of data can represent 2/3 of the total cost. In all RP methods the starting point is a computer-aided design, computer-aided manufacturing (CAD/CAM) system for modeling [3]. The originate model which represents the physical part to be built must be represented as closed surfaces which definitely define an enclosed volume, i.e. the data must specify the inside, outside and boundary of the model. This is not necessary if the modeling technique used is solid modeling because, by virtue of the technique used, a solid model will be automatically an enclosed volume. This requirement ensures that all horizontal cross-sections are closed curves to create the solid model. The CAD model (sometimes in neutral format) is normally converted into an STL model that is a faceted version of the surface of the model. Such a model is then sliced at distances equal to the layer thickness. Additional information is supplied with regard to the design of supports (when necessary), the machine orientation of the work piece and the scan path for each layer. The physical object is then created using one of the many currently available RP systems. In all these rapid prototyping systems the accuracy and quality of products very much depends on a CAD model transferred to machine for production of parts in STL format. In below section description of different procedures of CAD model transformation has been discussed.

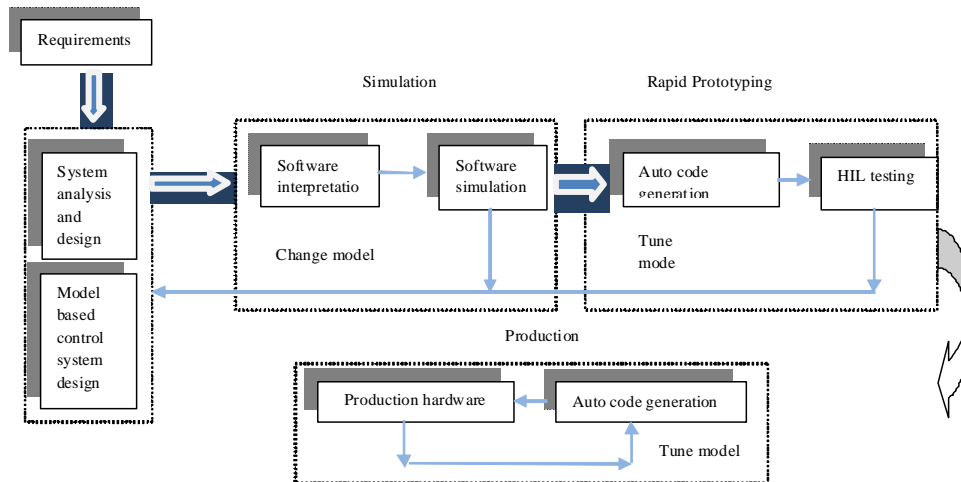


Figure 1: Typical work flow in rapid prototyping technology.

Different methods of CAD data transfer in RP System

In rapid product development, rapid prototyping (RP) is a significant technology, which connects the physical world and the digital world bidirectional. The physical model is converted into copies or scale models in some application areas, e.g., in mold manufacturing, aiming to decrease product development time [4]. A key problem in the RP is to transform a dense point set to a suitable layer-based model that can be used in the RP process. Different slicing procedures of CAD models have been projected and compared. Although perfect layer models may be achieved by used slicing procedures, but the reformation of the CAD model is not an easy task. The reconstruction process contains data smoothing, segmentation, fitting, etc., which is laborious and far from automation. This approach of transformation can be mainly classified into three categories:

- Triangular mesh-based methods
- Segment-and-fit based methods
- Direct prototyping methods

Triangular mesh-based methods

In this triangular mesh-based method, the facet model is directly generated from the point cloud. After this it is further used in RP system for slicing and part deposition. The accuracy of the layer model depends on the mesh, which needs to have high fidelity. But in this triangular mesh-based method carry defects like gaps, overlaps, degenerate facets, etc in the facet models. To generation and repair of the facet model consumes much time. Exported STL file contains list of triangular facet data, which is generally larger than the original point cloud file, since each triangle is individually recorded and shared ordinates are duplicated. A problem for high resolution is caused by these large files, when computation and storage done. Recently, some novel approaches take into account a direct slicing of the point cloud to create layer-based model.

Segment-and-fit based methods

In segment-and-fit methods, a computer-aided design (CAD) model created by fitting the appropriate surfaces and dividing the point cloud into a suitable patchwork of regions. Reconstructed CAD model is converted into facet model (STL file) and sliced into layers. There are number of slicing procedures which are used or purposed for different CAD models. Kulkarni and Dutta [5] developed a procedure to determine the variable thickness slicing for an object, represented in parametric form, to be manufactured by LM processes by considering two important issues related to the accuracy of a part. The staircase effect was analyzed and solved in a unique manner. The containment problem was analyzed and it was shown that it is simple to solve it in certain situations. This procedure algorithmically ensured that none of the tangential points on the surface were missed while slicing the object. This is important since it is difficult to determine tangency points for an arbitrary parametric surface. The algorithm was implemented and tested on two sample parts fabricated by the Stratasys 3D modeller. A comparison between the uniform and adaptive slicing procedures clearly showed the advantages of adaptive slicing over uniform slicing in layered manufacturing. Sun et al. [6] studied, an adaptive direct slicing method complete with the algorithm for calculating the thickness of each layer is proposed. As an illustration of the method, the algorithm was programmed within the commercial CAD software package, PowerSHAPE. It is further found that the method seems to be fast and accurate in comparison with STL file slicing and direct slicing, which both used a constant layer thickness.

Ma et al. [7] presents slicing algorithms for efficient model prototyping. The algorithms directly operate upon a non-uniform rational B-spline surface model. An adaptive slicing algorithm is developed to obtain an accurate and smooth part surface. A selective hatching strategy is employed to further reduce the build time by solidifying the kernel regions of a part with the maximum allowable thick layers while solidifying the skin areas with adaptive thin layers to obtain the required surface accuracy. In addition, it provides a generalization to the containment problem with mixed tolerances for slicing a part. They also developed a direct method for computing skin contours for all tolerance requirements. Case studies are presented to illustrate the developed algorithms and the selective hatching and adaptive slicing strategy. The developed algorithms have been implemented and tested on a fused deposition modeling rapid prototyping machine.

Jun C S et al [8] presented an algorithm to compute the intersections of a parametric regular surface with a set of parallel planes. Rather than using an ordinary surface plane intersection algorithm repeatedly, pre process a surface to identify points called topology transition point (TTP's), on the surface where the topology of interaction curves change. It is further found that these points can be computed efficiently. Exactly and robustly employing a normal surface, and are categorized into seven district groups. Analyzing the properties of such characteristic point on the surface, the starting points to trace intersection curves can be found rather efficiently and robustly.

Zhou MY et al [9] presented an approach toward adaptive direct slicing with non-uniform cusp heights independent of CAD systems for rapid prototyping. First the geometry model is imported into the adaptive direct slicing system from CAD systems using the standard STEP format. Using OpenGL graphics libraries, the solid model is then displayed and the user is prompted to specify the allowable cusp height for each highlighted surface. Lastly, the CAD model is sliced adaptively with different cusp heights (tolerance requirements) for different surfaces. With non-uniform cusp heights, adaptive slicing has a higher efficiency. Jamieson and Hacker [10] first implemented direct slicing of CAD models using parasolid CAD software, and user-defined routines in C.

Direct prototyping methods

In direct prototyping methods, the scope of error is very less because some in-between processes such as surface reformation or triangulation are avoided, also results in low computation time. Park and Chung [11] presented a procedure to directly generate 3-axis NC tool path from measured data. The rough machining is performed by machining volumes of material in a slice by slice manner. Extraction of machining regions from each slice is necessary to generate the roughing tool path. Further in this study assumed that the input points were organized following a series of sequence curves. Wu et al. [12] extracted 2D contours from perpendicularly projected points to the slicing plane. Wide-band problem which brought projection errors into 2D contours construction has been seen. Saravana et al.[13] used the growing self-organizing map neural network algorithm for piecewise linear reconstruction of curves and surfaces from unorganized thick point data. Liu et al. [14] constructed an intermediate point-based curve model (IPCM) to generate direct layer file from point data. Kumhbar et al. [15] improves of the IPCM method including adaptive slicing based on surface roughness model and ability of handling complicated input models. Yang and Qian [16] provided a direct slicing method based on the moving-least square (MLS) surface. The projection errors were avoided by employing an intersection method instead of the projection method. Meanwhile, adaptive slicing was realized through curvature computation on the MLS surface. In direct prototyping methods, the input point cloud is the lack of connection structure. Most of the above direct approaches generate slicing points by local surface fitting without considering the global topological structure.

Summary

All three above methods used to transfer CAD models have been discussed and have vital role in rapid prototyping technologies. Number of researchers have been worked and generate procedures to overcome shortcomings of these method. In end it is seen that direct prototyping methods is widely used, because the scope of error in this method is very less. Further in this method with the extracted topological information, the contour numbers and the start points for tracing each contour can be determined as prior, so the slicing process can efficiently and correctly handle complex shapes with multi-contoured slices.

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