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Application of Reverse Engineering based on Computer in Product Design

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Abstract

This paper described the application of reverse engineering in product design and development; effectively solved the design and subsequent engineering design, manufacturing link disjoint problems; put forward a kind of using computer software Pro/Designer, Pro/ Engineer and SolidWorks seamless connection method in the process of product design; industrial product modeling design and the engineering and manufacturing of coherence have opened up a new way; the design process will provide effective measures for the product design system, so as to shorten the product design and development cycle and realize the product design system.

Keywords: *Reverse engineering; CAD technology; product design*

1. The content of reverse engineering and scope of application

With the development of computer technology, CAD technology has become a new technology and played a decisive role in today's global design, manufacturing and management and other related fields. It is widely used in aviation, marine, medical, automotive, high quality, high precision industry. CAD software meanly includes: Auto Desk, 3DM ax and AutoCAD, America Solid Works & Solid Works, CV & Pro/E software. Along with the development of CAD, now industrial enterprises also pay attention to the application of this technology in the design of industrial products. 3-dimensional modeling technology has been widely used in the manufacturing industry product and mold design, programmer evaluation, manufacture and management in all aspects of maintenance. In the actual development of the manufacturing process, design staff received technical information which may be a 3-dimensional model of the various types of data. But most of the time, they are physical model of product from the upstream manufacturers. Designers need to adopt a certain way putting this kind of information into the CAD model, which is applied to reverse engineering. The so-called reverse engineering, refers to the measurement means of measuring the physical model or certain process through CAD model and physical reconstruction of the 3D geometric modeling method based on measured data.

There is a great difference in reverse engineering technology and positive traditional design. Reverse engineering is starting from a prototype, then obtain three-dimensional digital model of products, so as to further use of CAD/CAE/CAM and CIMS and other advanced technology to carry on processing.

In general, reverse engineering includes the shape reverse, process reverse and material reverse. The practical application in the industrial field, mainly includes the following content:

(1) The new part design, mainly used for modification or imitation type of product design.

(2)The copy of the existing parts, to reproduce the original product design intent.

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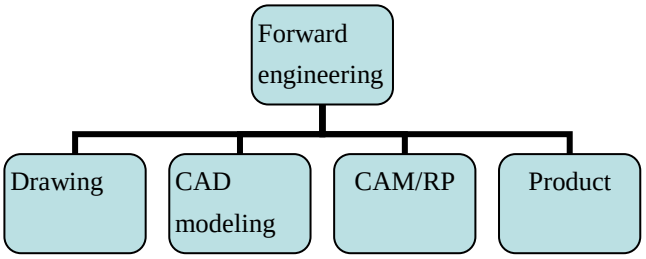
(3) To restore damaged or worn parts.

(4) Detection of digital model, such as the inspection of welding quality, and model comparison.

Reverse engineering technology provides a good technical support for the rapid design and manufacturing. It has become an important and simple way in manufacturing information transmission.

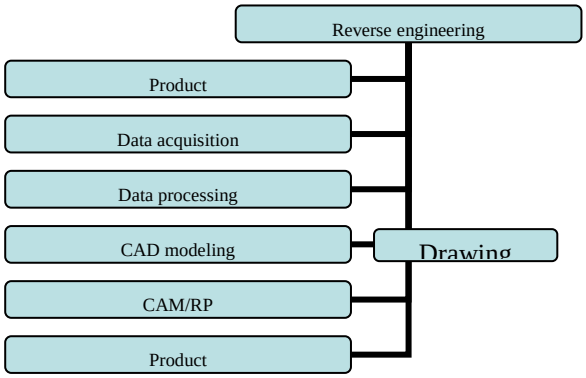
Traditional product design generally expand the sketch design at first, forming a slightly complete solutions, and start drawing three-dimensional diagram, after the market research and making the demand schedule, and then according to the drawing effect chart, three view or creating a simple model after finalizing the design. In the process of design, it needs the united strength to other staff and workers, engineering and technical personnel, to express the designer's idea with samples or physical model. But traditional product design makes samples of each scheme and pays a lot of labor with low precision. It is difficult to adjust and modify the problem in higher long design cycle and in higher cost. The traditional product design is usually drawn from conceptual design to design, and then manufacturing is product, which is called forward engineering (as shown in Table 1).

Table 1. Forward Engineering



Reverse engineering is to extract the data generation pattern, remanufactured products from the parts or raw mode. The following matters need to complete: the software structure, object-oriented development tools, data model, intelligent design, product data management, quality control and the application of multimedia technology to achieve new breakthroughs, which truly realize the concurrent product design and development to provide better and more efficient design, analysis, management control, manufacturing, and other aspects of the environment and tools from the whole product environment (The reverse engineering process is shown as in Table 2).

Table 2. The Reverse Engineering Process



2. Application of CAD in product design

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The development of computer technology brings the third technology revolution. Computer aided design (CAD) technology is most active with the application of computer in the industrial field. It sets the numerical calculation, simulation model, geometry processing, graphics, database management system and other aspects of the technology as a whole making the abstract, plane, separate design object specific, vivid, and it can reproduce process performance through the "virtual reality" technology to the product shape, material, color, even the most incisive, and can make the product design process data management, systematic, standardized, which is the foundation of industrial design and CAD technology must combine.

The current reverse engineering software commonly used includes Surfacer, Delcam, Cimatron and Strim. The application of reverse engineering system is mainly in the following aspects: Evans for the development of machinery parts recognition in reverse engineering; Dvorak development system; imitation of old parts of reverse engineering system; H.H.Danzde CNC CMM system. These systems meanly deal with the practical problems in reverse design, greatly facilitating the design personnel. In addition, some of the large CAD software also provides the reverse engineering module. For example, Pro/E ICEM Surf and Pro/SCANTOOLS module, can accept the order point (line), and can also accept the point cloud data. Other UG software, with the improved version, their reverse engineering module also gradually has been enriched. But in recent years, it has gained the fastest growing market share. Solid Works 3D design software made by American Solid Works has higher Technique with the fastest development, best market prospect and price. The development of the software provides the conditions for the implementation of software reverse engineering.

Then, what are the advantages of the Solid 3D design software Works in the industrial product design? How does the design of both the Pro/E and the Pro/D get a better combination, and better complete the conversion from design to process? This is the problem of product design we have to consider.

3. The application of reverse engineering CAD Technology in product design

3.1. The application of Solid Works

The software is easy to learn and use. The most powerful advantages are its side surface modeling function and parameter design.

Surface functions include following aspects: surface construction modeling, C2 fillet, fill the surface, flat surface, elongation, rotation, regular surface, bending, curve, dome, laminated stretch, and *etc*… Surface edit function includes: curved surfaces, thick noodles, remove surface trimming, moving surface, replacement, sewing, restoration of trimmed surface, surface extended surface, single side trim etc… These features in the design of industrial products are especially difficult to show with the basic geometric elements of complex curved surface: the most typical is streamlined car body design of automobile manufacturing industry. We need to know if the modeling is with other techniques, the speed and accuracy of design may not reach good requirements (shown as in Figure 1) .

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Figure 1. Streamlined Car Effect Designed bySolid Works Software

The parametric design of the software is the advanced modeling technology of Solid in Works software, and the model is driven by a variable parameter model. In the design of industrial products, if it is not for 3D model parameter driven, there is not much use to improve the design efficiency. For the requirements and using Visual Basic language standard in the industry we can do second development for Solid Works to complete the process driven model. In recent years, the Solid Works software is improved according to the market and the reflection of the designer. The product development cycle is shortened greatly, and the rapid development of various industries is also realized to make the system to be in line with today's industrial product design industry.

But the future design is towards "sustainable design" concept. With the global environment worsening situation, green design, green, low carbon has become the theme of industrial design. While the Solid Works Sustainability Solid module in Works software is designed for good product life cycle assessment, the environmental impact factor analysis, product Recyclable components etc… The design of industrial products began to predict the use of renewable resources from the design, improve the utilization of enterprise resources and improve design quality efficiency, reduce the cost, which build the foundation for domestic enterprises to go abroad, to lay the foundation and compete with the foreign design companies ("Sustainable design" concept shown as Figure 2).

Figure 2. Sketch of Sustainable Design Concept

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3.2. Using the Pro/E parametric design in Engineering

Parametric design (Parametric) (also called Dimension-Driven) is proposed by CAD technology in the practical application of the subject. It not only can make the CAD system with interactive graphics, also has the function of automatic drawing. At present, it is one of the most important study of CAD technology in the field. Product design system with parametric design tools development can make the designers from the heavy and trivial mapping out, can greatly improve the design speed, and reduce the volume of stored information. The key parameters of the design are the geometric constraint relation extraction and expression, constraint solving and parametric geometric model. In 1988, the Parametric Technology Corporation (Ptc) launched the first parametric design CAD system Pro/Engineer (Pro/E), which fully embodies the simple presence in parts design of general parts. Its main characteristic is: based on features, full size constraints, all data, design modification driven by dimension.

We can use PTC's industrial design software Pro/Designer (Pro/D) of surface design, because Pro/D and Pro/E use the same database, and it is the seamless connection between the them, modeling designer and structural engineer can better through collaboration in design.

3.3. Surface design ability of Pro/D

For industrial designers and those who want to construct the surface model of engineering staff, Pro/D is the tools they need. Free surface model Pro/D can build high quality, and can easily switch to other system based on CAD in manufacturing engineering. Pro/D can create a true and accurate aggregation, and it can be used to create the model more easily, shorten the design cycle. Pro/D can be used to make the visual aesthetic requirements and mold manufacturing process engineering requirements be well combined. This point in the process of creating freeform surface model is especially significant.

3.4. The data transmission between Pro/D and Pro/E and NURBS curve and surface

There are two ways between Pro/Designer and Pro/Engineer in the process of data exchange: one is to exchange data directly with Pro/Engineer, another is to exchange data with Pro/Engineer in document.

The NURBS curve is non uniform rational B spline curves. It is a very flexible curve. There must be one or more nodes. Such curve is often used in reverse engineering. The NURBs curve (non formrationalBSplineeurve) equations describing such as type.

$$C(u)=\frac{\sum_{i=0}^{n} N_{i,p}(u)w_i P_i}{\sum_{i=0}^{n} N_{i,p}(u)w_i}=\sum_{i=0}^{n} R_{i,p}(u)P_i \quad R_{i,p}(u)=\frac{N_{i,p}(u)w_i}{\sum_{j=0}^{n} N_{i,p}(u)w_i} \tag{1}$$

Type (1): Pi -- control point;

Ni, P -- P order B spline function;

Wi -- weighted value (weight)

U -- parameter value

Ri, P (U) are rational basis functions (rational basis function), in addition to having the same properties with and B spline basis function, it increases the effect of weighted value. Because weighted value is added, the control effects on the curve / surface control have different proportion. When weighted value modification makes the curve away from or close to the control polygon (control polygon), the curve control will have more space.

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The NURBS curve from the one-dimensional parameter space (U) is extended to two dimensional parameters (U, V). The equations describing the formula as (2).

$$S(u, v) = \frac{\sum_{i=0}^{m}\sum_{j=0}^{n} N_{i,j}(u)N_{i,q}(v)w_{ij}P_{ij}}{\sum_{r=0}^{m}\sum_{i=0}^{n} N_{r,p}(u)N_{r,q}(r)w_{ri}} = \sum_{i=0}^{m}\sum_{j=0}^{n} R_{i,p;i,q}(u,v)P_y$$

$$R_{i,p;\,i,q}(u,v) = \frac{N_{i,p}(u)N_{i,q}(v)w_{ij}}{\sum_{r=0}^{m}\sum_{t=0}^{n} N_{r,p}(u)N_{t,q}(v)w_{rt}} \tag{2}$$

Type (2): Pij -- surface control points;

Rt, p; t, q (U, V) -- basis function of NURBS surface

In the existing CAD/CAM software, B spline function and the Bezier function are more widely used model. However, from the above analysis, the Bezier function is a special case of the B spline function, and when the weighted value is 1, rational basis function will become B spline function.

B spline surface has the same properties with B spline curve, which is basically from one-dimensional parameter (U) extended to two-dimensional parameters (U, V). The equations describing the formula are shown as (3).

$$S(u, v) = \sum_{i=0}^{m}\sum_{j=0}^{n} N_{i,p}(u)N_{i,q}(v)P_{ij} \tag{3}$$

B spline curve has good regional control (loealconirol)

$$N_{i,k}(u) \begin{cases} > 0 & t_i < u < t_{i+k} \\ = 0 & u \le t_i \text{ or } u \ge t_{i+k} \end{cases} \tag{4}$$

Ni, K (U) in the interval (Ti, ti+k) is positive. In other parts it is zero, which makes the K order and B spline curve be modified only to be controlled by the adjacent K vertices, and has nothing to do with the other vertex. When moving a vertex, only one curve is affected, and the curve is not affected. It is the same when vertex changes.

3.5. The CAD application modeling of complicated 3D design

For the others needing special adornment, especially containing complex surface products, you can operate by combining Pro/D and Pro/E. Starting Pro/E, putting the data to the Pro/E structure design by the architect. The whole process of design and structure design are all done. According to the planning of the customer requirements or designer, all data needing change can be operated only in the Pro/D, conducted to Pro/E, and then the data in Pro/E would also be changed. But the structure needn't redoing (of course structure is modified to existing conditions, namely its present characteristics have no problems). In CAD software, if the point, line, surface information are put into the software of CAD, useful information will be extracted in accordance with the features of parts, fitting for solid modeling, then information will be extracted from entities. The drawing data will be finished.

3.6. The reconstructed surface model

Principle of surface modeling and NC machining is in the same way. In fact, the first machining is rough, semi finishing, and stepwise refinement. Surface modeling steps are as follows: firstly extracting feature line from point cloud data. Feature line is the appearance of the product line, or the boundary line and assembly line, which is the surface model /

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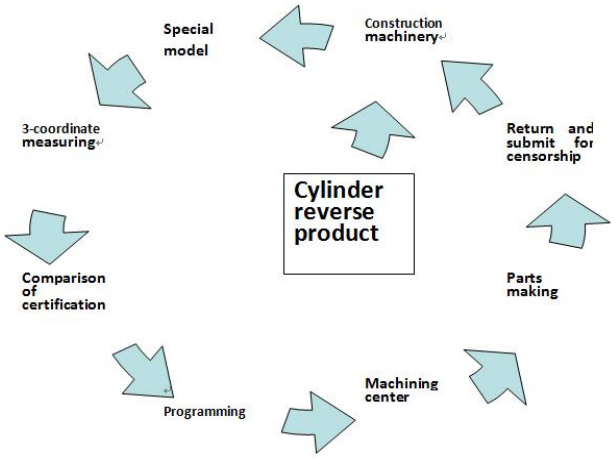
framework; then constructs basic surface deciding the appearance of the products, and the precision and smoothness degree are adjusted to the best state; transition surface then is added base surface. After rounding and cutting down, the surface model will be completed. Each of the steps above includes smoothing quality inspection of the surface. Then a general quality inspection and evaluation must be finished. The final stage is the product design stage while the surface is switched and thickened. In reverse engineering, there are mainly 3 kinds of method of surface structure: the first is the method based on with triangular Bezier curved surface. Because of its flexible structure, adaptability to boundary, triangular surface has been the subject of attention. The application study on the triangular surface focuses on how to extract the feature line, how to simplify triangle mesh and how to handle multi view. The inadequacy of the surface model structure is that it does not meet the product description standard, and has communication difficulties with the general CAD /CAM system. In addition, some research about the calculation of triangular Bezier surfaces are not very mature. The second is to describe the surface objects with polyhedral methods. The third is the method of curved surface based on NURBS surface. NURBS modeling method based on the theory of surface pretreatment on the measurement data are relatively complex, the scattered point cloud data processing is generally the result of approximation instead of interpolation, and the block boundary must be a quadrilateral. Because its theoretical foundation has the same principle with most common CAD /CAM system, therefore it is easy to integrate directly into the existing CAD /CAM system.

4. The Object Reverse Engineering Model with Modern Design System

Combining with the application requirements of reverse engineering and a new generation of the cylinder, the basic framework of modern design system for reverse engineering is put forward. In this model, the 3-coordinate measuring machine is used for the operation of matrix on the parts or model operation and data extraction, and the cylinder standard system is used to guide the three coordinate measuring machine. The measuring data are processed by the computer program, introduced into the processing center or NC parts manufacturing. Finally the processed parts were measured by three coordinate measuring machine, and the results are compared with the original parts and model. According to the thought of a new generation of cylinder standard system, the uncertainty factors must be considered to form a closed system of modern design (as shown in Table 3).

Table 3. The Reverse Engineering System Model



The cylinder engineering illustrates the application of 3-coordinate measuring machine in reverse engineering. While point cloud filtering, the uniform grid method can remove a large number of data points. The principle is: first of all the data points are uniform grid, and then extract the sample point from each grid, and the rest will be removed from the grid. Data reduction rate is determined by the mesh size. When mesh size is large, removal of data points is more, and then the reserved is less. Figure 3 is the link point cloud model after data reduction, which set up the grid length is 2mm. After data reduction the number of points reduced from 635818 to 31281. The reduced rate was 49.2%, but the number of point cloud remained sufficient to create curve and surface (as shown in Figure 3).

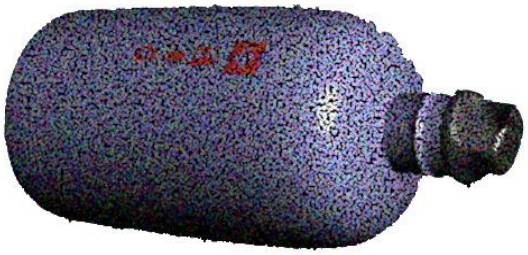


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Figure 3. Point Cloud after Filtering

The following is a case of reverse operation on a cylinder surface. The cylinder surface is scanned to extract data points with the coordinate measuring machine, laser scanning measuring head, as shown in figure 3. First, the benchmark calibration of the standard ball for calibration was done with CMM, then, the point cloud data was put into Imageware. The point cloud graphics was obtained after processing. Putting point cloud data into Pro/E, 3D modeling was reconstructed. This also can be used to probe and scanning multiple types of sensors on the measured surface to collect data point. It will be more conducive to guarantee 3-coordinate measuring machine data extracted from point cloud in reverse engineering precision, which will realize the real copy, reproduce the original design.

Grid processing of point cloud is done with grid tools. After processing the point cloud looks like entity. It is convenient for behind point cloud processing. And the grid can provide STL information for rapid prototyping machine. The point cloud smoothing will be done after grid (shown as Figure 4).

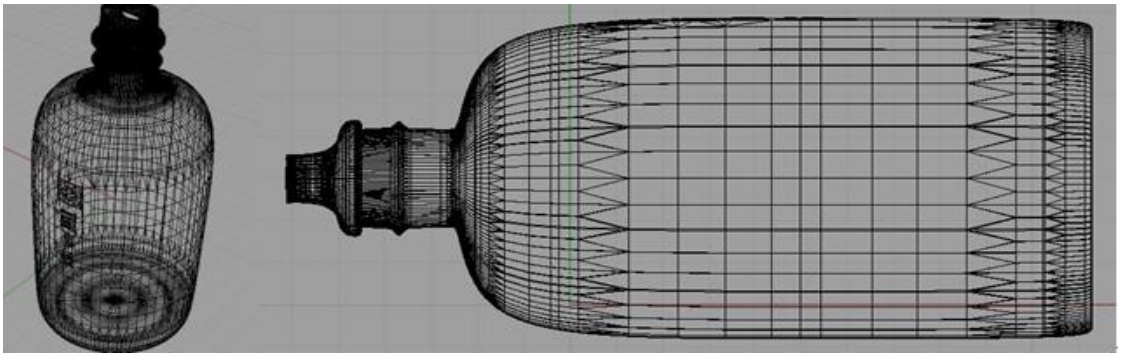

Figure 4. Grid Processing of Point Cloud

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For the better application of reverse engineering technology, the reverse engineering of modern design system model has been put forward, which forms a closed loop machining for feedback high quality information in order to further promote the modern design and implementation of quality control. Measurement is the key technology of reverse engineering. Data extraction directly influences the accuracy of reverse engineering precision. Traditional measurement methods and criteria cannot meet the requirements of reverse engineering. The 3-coordinate measuring machine based on a new generation of cylinder will provide a reliable tool for reverse engineering (shown as Figure 5).

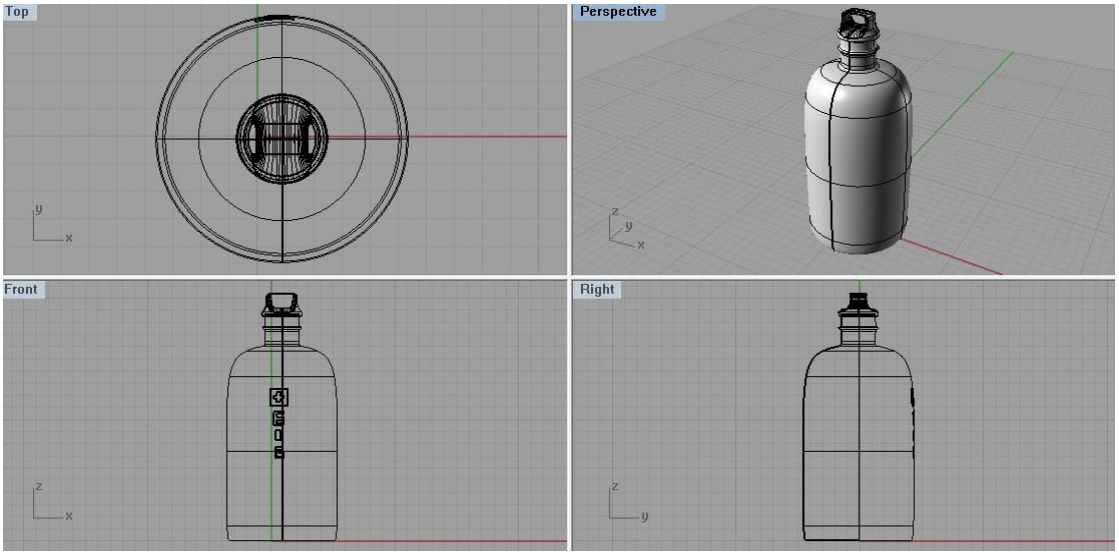

Figure 5. Cylinder Example Map

5. The Design Scheme of Integrated

As the digestion and absorption of product design and shortening manufacturing cycle, RE technology and RP technology are important supporting technology. Among them, RE focuses on the use of the experience, knowledge and new thinking of engineering design from various professional with physical model of anatomy, deepening and recreation of oneself, which is to design an existing design. RP is focused on the verification and evaluation of design. It will cause the discrete of arbitrarily complex 3D entity as a set of parallel section accumulation and eliminate the geometrical interference problems in manufacturing, without the restriction of forming complex degree of parts. Although RE and RP all use the 3D CAD model, and have made a lot of achievements, the comprehensive and systematic study of them on the direct integration mechanism and mode is still in the primary stage.

The following is the analysis of reverse engineering and rapid prototyping integrated model.

The 3D CAD model in RE is the use of 3D digital results physical structure, and in the RP 3D CAD model for prototype manufacturing is used. So RE and RP integrated data exchange interface mode has four kinds (as shown in Table 4).

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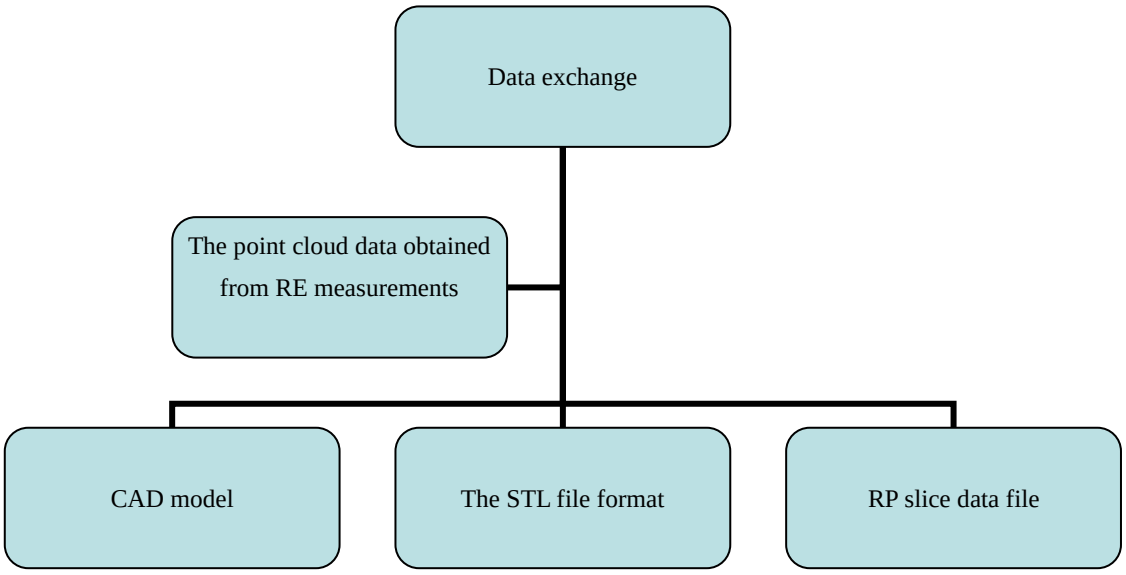
Table 4. Data Exchange Interface Mode



First, the measurement data-"processing point cloud" fits to generate curve, curved surface CAD model by the surface reconstruction software, CAD model, and then through the surface and plane intersection algorithm generating RP slice contour form, which is the most commonly used data exchange mode at present between RE and RP.

Second, making the measurement data -"point cloud" surface reconstruction and 3D feature modeling convert into STL file, processing the output RP layer file via special layered software. Commercial reverse engineering software is mainly used for surface reconstruction from measured data, and the results of reconstruction are output by using commercial CAD software packages (such as Pro/E) in acceptable format (IGES), then completing the curve editing and 3D solid modeling by using the commercial software CAD, and outputting in the STL file format.

Third, measuring "point cloud" by filtering, smoothing, splicing and resampling processing, then directly to the output STL file by using triangulation algorithm.

Fourth, measuring data "point cloud" by the data preprocessing, through the method of interpolation or approximation to generate the meridional line, through the space curve and the plane intersection algorithm to directly get the RP slice data.

These four kinds of data exchange model has its advantages and disadvantages: The mode of the first and second can package for surface reconstruction using the existing 3D reconstruction software or CAD software, but the complicated surface reconstruction of scattered data requirements of operation personnel have a strong professional knowledge and rich practical experience, and a large amount of calculation, time consuming work. The first model also involves complex curved surface intersection problem, and the surface intersection algorithm, the search efficiency and stability are the main factors influencing the actually used. The second kinds of modes needs to transform the common sense of the CAD model to output STL file. The more complex the CAD model, the higher accuracy are the parts, the more errors and defects while using commercial CAD software to transform STL file. The common problems are: causing data truncation error to grow the gap between the patches, method vector error, error surface intersection and degraded patches etc…This makes the researchers need to spend a lot of time and energy to correct or amend the error in the test of STL data format. The third and fourth modes will bypass the reverse engineering

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technology "bottleneck", the 3D scattered data surface reconstruction and CAD modeling, and the third modes application the triangulation to directly measure data triangulation. So compared with the second kinds of mode, there are less errors while outputting STL file. The third and fourth model should be the RE and RP direct integration ideal data exchange interface mode.

The concrete realization processes are as follows: point cloud data of the entity will be obtained through 3D measurement. If it is multiple point cloud ,splicing will be used. The point cloud will form the surface model of the product when it is treated with reverse engineering software (mainly point - line - surface treatment). The surface model of the product will be got. Then the surface model will be output to the CAD software to do further perfected in the format (IGES)CAD can accept, such as local modifications to the building surface, stitching between surfaces surface, empty patch, entity operation etc. The entity CAD model is obtained after the treatment. Further modifications on the model of innovative design can also be used in the CAD software.

6. Conclusion

Reverse engineering is a creative, practical and comprehensive technology. Reverse engineering technology has been widely applied to the detection of the development of new products, the reduction of the old parts and the inspection of products. It is not only the digestion and absorption of the prototype, and can design new products. The product design of CAD technology, not only means the changed design means, but the way of thinking in industrial design which can promote a series of profound, comprehensive, far-reaching changes from product design, manufacturing to technology management. It is a technical revolution in product design and product manufacturing and it can achieve systematic product design, shorten the product development cycle so as to create practical, economic, beautiful and pleasant products.

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