Feature Recognition and Reverse Engineering: Supplemental Techniques for Product Development

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Abstract: **In this era of highly customized product demand, a CAD-CAM related technology is capable to automate the downstream computer based activities like CAD-CAE-CAPP-CAM if a feature based product description is available. Reverse Engineering technology has its own significance in different fields including engineering, entertainment, medical and many more. The campaign, "manufacture-digitally" forces producers to switch to advance technology which is peeping out in this continuous developing trend. The recent article focuses on integrition of Feature Recognition with Reverse Engineering technology in order to manufacture digitally.**

Keywords: **Feature Recognition, Reverse Engineering, Product Design, Product Development, CAD-CAM**

I. Introduction

Features of any product are the attributes that deliver value to end-users and differentiate a product in the market. Electronic products are generally characterized by their features like reliability, repeatability, low power consumption, materials, space, human efforts etc. while features is for mechanical products can be characterized as physical constitutions like holes, slots, bored surfaces or any other developed shapes on any solid geometries. These features are used for any design development and any geometric modeling using any Computer Aided Design (CAD) modeling software.

Feature Recognition (FR) technique for mechanical component is basically a technique where the features of any solid geometries are read. The purpose of reorganization of features is to relate CAD with Computer Aided Manufacturing (CAM). FR is a processing of a geometric model of a CAD system to find portions of a model matching the characteristics of interest for a given application [1].

Even now days, a Computer Aided Process Planning are adopted for mass or chain production. These production processes are updated with Automated Feature Recognition (AFR) functions where the process of FR is governed by inbuilt computerized functions employed with the manufacturing system. They read and plan the manufacturing of any solid part with algorithmic model provided with the system.

Major Application of FR or AFR is to generate efficient translation of entities of any solid models such as (1) Low level entities – vertices, ages, etc and (2) High level entities – holes, slots, sprockets, chamfering, threading, etc to generate feasible definition of machining planning employed by system of CAM such as selection of manufacturing processes, work piece size, different auxiliary tools, set-up planning, selection, determination and grouping of elementary machining operations, selection of machining systems, operation sequencing and optimization of operation sequences, selection of cutting tools, determination of cutting parameters and conditions, tool path, selection of quality inspection methods, cost analysis, optimization of process plan elements, Computerized Numerically Control (CNC) code generation and verification [2].

II. Reverse Engineering Technology

Reverse Engineering (RE) is basically the technology working as per the words 'Reverse' & 'Engineering'. It is a process in which the part is recreated or cloned [3]. The RE technology is basically a practice, that how a product is actually made by the manufacturers as well as how it works with its functions. With the help of RE Technology, the manufacturers are able to replicate the existing model or a manufacturer can manufacture the similar object [4], so RE can be describe as a systematic process which helps to extract design information from any existing model. General steps to perform RE are as per figure 1.

Applications of RE in different industries is categorized as:-

- Design of new products: In major cases the design for products, specifically product designed from model testing (streamlined design, turbine blade design, injection mould design, etc) or product with aesthetic lines or design often starts from physical prototype without CAD information.
- Modification of existing products: Designs are often iteratively modified in order to get higher functionality of performances. However, it may possible CAD models for the product after modification will not available and need to be reverse engineered to store digital design data.
- Loss of product design data: In some instance existing parts to be manufactured, but either CAD models for the product may not available or the problem of corruption of data files.
- Verification of product: The RE system can be used to extract the dimension information of parts and compare with CAD models; this can be used full to measure the deviation of the final product from the original modeled design [5].

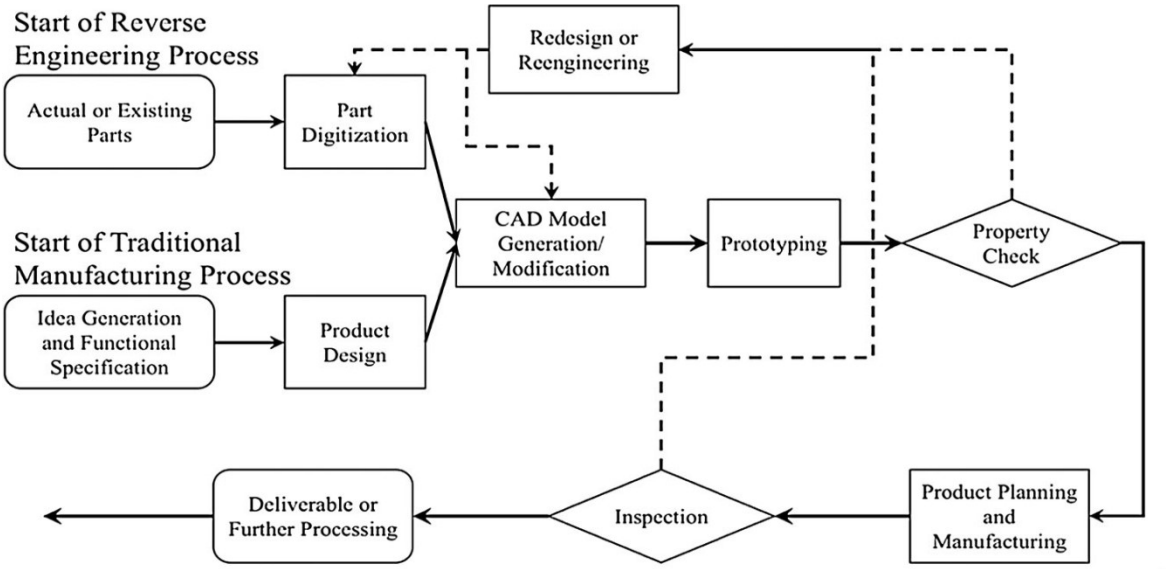

Figure 1 Comparative production layout for RE and Traditional Manufacturing System [5]

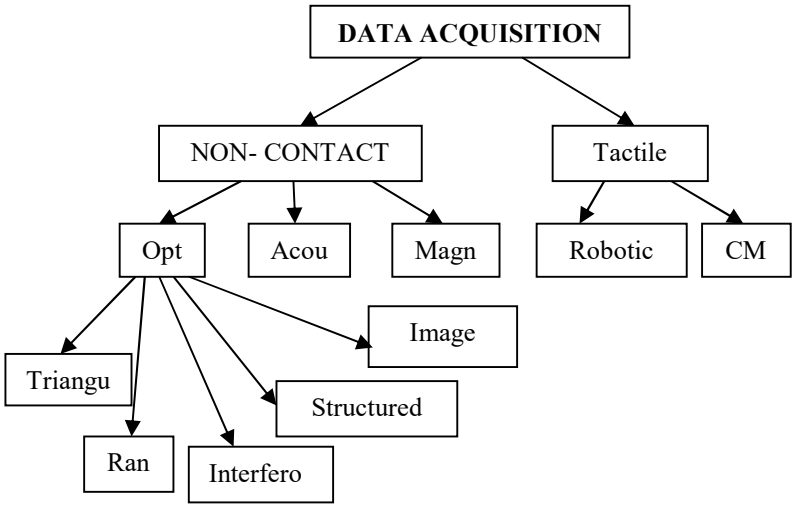

Figure 2 Different Data Acquisition Methods [6]

In RE technology, as per above elaborated applications data acquisition is necessary from the existing or previously manufactured or damaged model. There are few techniques which are employed for data acquisition. The classification of different techniques is given bellow in classification Figure 2.

There are two types of cases in RE where FR plays vital role. They can be classified from the above applications as; one is to reverse the previously manufactured part to copy the geometry to design same model to manufacture same part and another is to reverse the damaged or missing part for the existing geometry to manufacture new model for the old one. For Reverse Engineered part geometries need to be represented in terms of manufacturing format to manufacture the part.

Along with mechanical engineering, other several fields of applications of RE includes medical science, electrical and electronics engineering, civil engineering, architecture development, aerospace engineering and many more.

III. Application of Reverse Engineering for Feature Recognition

Reverse Engineering is useful in 3D shape engineering and even in design parameterization which makes discrete clouds and then convert into the feature based parametric modeling. In 3D shape engineering, the different solid features and relative dimensions are recognized. In shape engineering there is a general process, the relative steps are – point cloud data collection, triangulation, generation of polygon mesh, segmentation of the part, solid modeling, generation of parametric solid model and the last step is model translation in to CAD software. There are various non CAD software used to perform shape engineering; they are Geomegic, Rapidform, etc. because CAD software such as Solidworks, Pro/Engineer wildfire, CATIA had couple of limitations for the same [7]. Even there are some practical challenges also observed at the time data acquisition process, such as calibration, accuracy, accessibility, occlusion, fixturing, multiple views, noise and incomplete data, statistical distribution parts and also surface finish to be addressed carefully [6]. To overcome such problems in contact type (Tactile) data acquisition methodology it is advisable to calibrate Digitizer with any of the prescribed methodologies [8]. Researchers also suggested integrated solution schemes where they integrated sectional feature base strategy and surface feature based strategies. In which sectional feature based strategy was introduced with slicing, curved feature recognition and constrained features are introduced to generate feature architecture patterns from 2D to 3D. Surface feature based strategy estimates different geometric attributes and diverse feature extraction techniques. Such feature based RE modeling strategies gives the forward design as well as more new concepts from the view point of methodology. Such developed algorithms were programmed using RE-SOFT modeling tool and more than 100 industrial products of automobile and aircraft were modeled and got verified such concept of RE for FR [9]. The very initial form of any model is represented in B-rep model, which has to get discretized in to a 3D mesh in order to simulate with metal process stamping die part which have no longer correspondence with finally generated B-Rep model for final processing. To overcome such difficulty one methodology is suggested, in which after generation of 3D mesh model in next step the geometric primitives are extracted there after they are reconstructed in wire model form and then automatically B-Rep models can be created by software. Thus the final model can be created easily and by giving less efforts; though in this method geometric primitives are limited but still more primitives such as ruled and tore surfaces are also can be generated. Even this model can be easily fit with B-splines also [10].

Interactive 3D graphical programmed LaserCAM is used to study development of simple shapes like square block as well as some un-usual shapes like cylinder, sphere and truncated cone with help of CMM attached with laser scanning probe. By this non-tactile machine set-up, higher rate of data is collected and easy collect intricate data for complex shapes also. Such re-constructible are easy to transfer data to any CAD/CAM software for manufacture the same shape [11]. Even the laser scanning and model generation process has very good advantages over other techniques of FR, such as ease and speed as well as compatibility with mostly new developing software in data acquisition, even the ability to reconstruct the data using multiple surface patches. These techniques have good compatibility to transfer most of data from real environment to the true virtual RE environment [12].

When topology of the surfaces are not available, the data acquisition become less accurate for which Automated Reverse Engineering (ARE) methodology has been developed with use of CMM and laser scanning set-up. For that automated segmentation of digitized data is achieved using Artificial Neural Network (ANN) algorithms. Different Neural Network are developed and trained for automated homogeneous segmentation of object without human interference [13]. ANN is basically biologically inspired models. They are resembled to a human brain. They can be trained well. They have highly interconnecting processing small networks called as neurons; they tried to work on the problems raised and process on input data. They process the data as per given training. In the ANN feature recognition system age detection algorithms are created and played vital role to generate virtual models. Pre-defined basic features shapes are already available in the library such as holes, steps, blocks and bosses. Depending on the

accuracy of developed ANN models and its training, the model can be developed after processing the scanned points using 3D position scanning. They also predict the loss features of the geometry by processing the neutrals [14].

Advanced Manufacturing Technologies are using Rapid Tooling (RT) and Additive Manufacturing (AM) methodologies in different tooling like moulds, dies, press tools, etc. where RE has its significance role for fine dimension finished product [15].

In electrical and electronics applications also RE evolves some pioneer roles. Apart from destructive applications, RE has been employed for non-destructive applications on developing Printed Circuit Boards (PCBs) based on X-Ray tomography. By saving time and cost as well as by saving the old PBCs; RE develops new copied PCBs can be developed even if they are more complex. RE is also employed for failure analysis and fault isolation, obsolescence management, proof of IP rights infringement, security assessment, development of attack and counterfeiting [16].

In medical science, the human bones anatomy can be copied and reverse by using RE. Without RE it was difficult to join the fractured bones of human or to manufacture the well finished shape of knee joint. But after employing RE, it becomes easier to manufacture customized implants comfortable to the patient. With the help of Computer Technology scanning (CT scan) and Magnetic Resonance Imaging (MRI) technique the data is acquired for the replacement of knee or any bone can be manufactured easily with required finishing. This gives comfort to the patients after operation for fast recovery [17, 18]. Similarly dental and heart blockage surgeries can also be done by employing RE. Even in modern stem cell therapy, which is trending in latest research and developments, RE also has its essential role. Haematopoietic stem cells from bone marrow are able to cure the blood infections and immune system infections, even major malignances can also be cured by transplant of these stem cells. For that RE is used to copy and redevelop human cell anatomy and its morphology with its mechanical and molecular path ways in newly developing cells [19]. Development of embryo with help of RE is also interesting topic of research now a days [20].

IV. **Emerging applications integrating RE and FR**

All the CAD models and CAM simulations takes place within 2D virtual environment of computer screen where one can only get some graphical representation of 3D model in 2D environment. This has some limitations such as some mating parts of assembly cannot have some exact dimensions in case of redeveloping the damaged part without sufficient data due to legacy for that particular part. The complete integration of 3D designs and manufacturing tools is essential for creators. For that Virtual Reality (VR) technology is used which took the developer out of the world in a virtual environment of 2D computer screen. VR is often regarded as a natural extension to 3D computer graphics with very advanced input and output devices [21]. VR gives a virtual environment where developer can design any part and also simulate whole geometry. It is essential to simulate RE part with the assembly where the part has to be used. VR gives opportunity to correct the RE designs as per the actual environment.

Even the accuracy of the complex surfaces and shapes can also be controlled using RE [22]. This gives good application for Civil and Architecture developments while maintaining the old monuments and gigantic civil structures. By recognizing the features with the help of VR the reconstruction work can be done easily, even in more efficient way.

Space crafts and aero dynamics parts also got damaged after a certain applications and usage of the vehicles. By employing FR in RE, manufacturers have good chances to develop such damaged parts as per the dimensions even if it is in small and precise magnitude. VR also has tremendous role to play to develop, simulate and manufacture the new component. Integration of Reverse Engineering Technology with Feature Recognition covers wide spectrum of product development including household products to engineering products. [23, 24, 25]

FR also may contribute to recognize failure of any component in any machine or any structure, especially very sensitive parts of any assembly to generate orders for servicing the part or replace it with newly developed part. There after by using RE, the reconstruction of damage geometry or manufacturing of that specific component is possible before those failures. This feedback and maintenance system may prevent very big accidents in industry. Even in these fast and continuous developments in technology different mobile applications are also available to perform RE. Such one of kind of application to perform RE is available on iOS platform [26]. IoT can also connect to such mobile application for faster tracking of data. IoT facilitates with its advance applications such as Radio Frequency Identification (RFID), Wireless Sensor Networks (WNS), Cloud Computing as well as Machine to Machine monitoring [27].

V. Summary

RE has potential coverage on wide spectrum of applications over several fields from entertainment to medicine as mentioned in previous sections. As far as design and manufacturing of engineering product is concern, RE is generic technology either in new product development or to recover damaged component without any technical document. Recognized features available in library can be imported into other commercial feature based modelers, and then they can be applied in a variety of applications such as process planning, integral property computation, assembly analysis, Computerized Numerical Controlled (CNC) machining or even for Additive Manufacturing (3D printing) which is latest development in the field of manufacturing. In this sense Feature Recognition and Reverse Engineering are complementary integral with each other as both can be possible in mutual support.

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