# COMPUTER AIDED REVERSE ENGINEERING SYSTEM USED FOR CUSTOMIZED PRODUCTS

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***Abstract:*** *Computer Aided Reverse Engineering (CARE) system is used for products in the design or redesign process, when technical documentation is not available. Any CARE system uses different types of software tools, technologies and equipment which depend on the product shape. The paper presents a Computer Aided Reverse Engineering system configured at Manufacturing Engineering Department from Transilvania University of Brasov, and a few case studies developed in the system for industrial and non industrial products. The system consists of 3D scanners used for parts digitization, software systems for point clouds handling, customized software tools for automation part recognition, CAD systems used for parts designing or redesigning, and equipment with associated software tools for part manufacturing.*
***Key words****: Computer Aided Reverse Engineering, Customized Products, Point Clouds, Software Systems, Part Manufacturing*

## 1. INTRODUCTION

It is well known that the Reverse Engineering (RE) is a technique which uses different approaches to obtain characteristic data of a physical object for which no drawings, documentation or computer model are available. The data associated to the object is used in the process of object reproduction using manufacturing equipments under manual or computer control (Vinesh & Kiran, 2008).

The RE process is used in a large variety of domains such as: automotive industry, aerospace industry, medicine, architecture and arts (Vinesh & Kiran, 2008), (Majstorovic et al., 2013), (Sokovic & Kopac, 2006). In practice, the RE can be used in a lot of situations (Vinesh & Kiran, 2008), (Panchal, 2013):

- part is damaged and the original manufacturer is not able to manufacture the part;
- product is working but its geometry has to be improved because it has some bad features after usage;
- product documentation does not exist;
- customization of clothing or footwear;
- data obtaining to create dental or surgical prosthetics;
- manufactured product is compared to its CAD model;
- analyzing the competitors' products;
- architectural documentation has to be created;
- three dimensional data from an art object is generated and used to recreate or reproduce the object.

Nowadays, the Reverse Engineering, from industrial point of view, is considered one of the engineering techniques that provide short time in product development cycle (Vinesh & Kiran, 2008) with real benefits on the customization of the products. It can be also used in the rapid product development allowing, in the final stage, fabrication of different industrial parts and tools like moulds, dies, and press tools (Sokovic & Kopac, 2013).

In the RE process the following main steps have to be performed (Bagci, 2009): digitization of the part, processing of acquired data; product redesigning-surface approximation and solid modelling, NC part programming and CNC machining to obtain the product.

In the literature, the automation of the RE process is named Computer Aided Reverse Engineering (CARE) and it is in connection with Computer Aided Engineering (CAE) which is used like a tool in Forward Engineering (Vinesh & Kiran, 2008). The CAE process is implemented through CAD, CAPP and CAM technologies. All these technologies are used in the Forward Engineering where a project starts from an idea and using complex manufacturing systems a new product is obtained. The complex manufacturing systems contain specific software tools and manufacturing equipment which are used in the fabrication process of the new product.

CARE process which followed RE steps, in an automatic mode, also needs a complex system with a variety of software applications and equipments dedicated to the original products digitization and new products manufacturing (Panchal, 2013). The complexity of the products, which have to be designed or redesigned, impose what software systems and equipments will be used (Panchal, 2013).
This paper presents a CARE system which has been developed since 2006 at Manufacturing Engineering Department from Transilvania University of Brasov. It also presents a few case studies developed in the system for industrial and non industrial products.

## 2. CONFIGURED COMPUTER AIDED REVERSE ENGINEERING SYSTEM

According to the stages of RE technique, the following components belongs to a CARE system: 3D scanner used for part digitization, software systems dedicated to the point clouds handling, customized software tools developed for part recognising, CAD systems used for part modelling and designing/redesigning, equipments and associated software tools for part manufacturing. The product complexity dictates which software systems and equipments will be used.
The CARE system presented in the figure 1, configured at Manufacturing Engineering Department, Transilvania University of Brasov, contents the following equipments:

- 3D scanning system:
  - COMET L3D scanning system which uses blue structured light;
  - LPX-1200 scanner;
- manufacturing equipments which uses additive and cutting technologies:
  - Mori Seiki NVX5080/40+5AX DDRT200 – full 5 axis vertical machining centre with 1,5 micron precision;
  - Victor Centre V55 – 4 axis vertical machining centre;
  - SLM 250-Selective Laser Melting equipment which works with 20-40 microns layers;
  - MAXIEM 1530 system - cutting water jet equipment;
  - 3D printer - OBJET EDEN 350 equipment which works with 16 microns layers;
  - 3D printer - ZPRINTER 310Plus.

In the CARE system, a lot of commercial software systems used in Forward Engineering and/or Reverse Engineering are integrated. The integrated software systems are the following:

- used for point clouds handling:
  - CometPlus is the software associated to the COMET scanner;
  - Dr. PICZA software belongs to the LPX-1200 scanner;
  - Geomagic Studio which allows data finishing and part generating with polygons and surfaces;
- used in the automatic part recognition:
  - Rotational Primitives and Axis Recognition -RPAR conceived for using in RE process of rotational parts recognizing developed in the department (Oancea et al., 2013);
- CAD/CAM software systems: Catia, ProEngineer, PowerShape, PowerMill, SolidWorks, AutoCAD.

The main stages which have been performed, in the process of CARE system using, are the following:

- part digitization using one of the scanning systems;
- point clouds processing using associated software system to the scanner;
- points clouds finishing with the dedicated Geomagic Studio system;
- if the part are from rotational family type, the data can be recognised through the RPAR software tool (Manolescu et al., 2011), (Manolescu et al., 2012), (Oancea et al., 2013);
- part designing or redesigning using one of the available commercial CAD system mentioned above, and different software tools developed in the department (Pescaru et al., 2012), (Pescaru & Oancea, 2012), (Pescaru et al., 2013), (Oancea et al., 2013), to obtain a part families in a parametric mode;
- selection of the manufacturing technologies and equipments, which depend on the part features and the available machines from the CARE system architecture (Fig. 1);
- designing the manufacturing technology in the available CAD/CAM commercial software system mentioned above and/or software systems associated to the manufacturing equipments;
- part manufacturing on the selected equipment using the technological data.

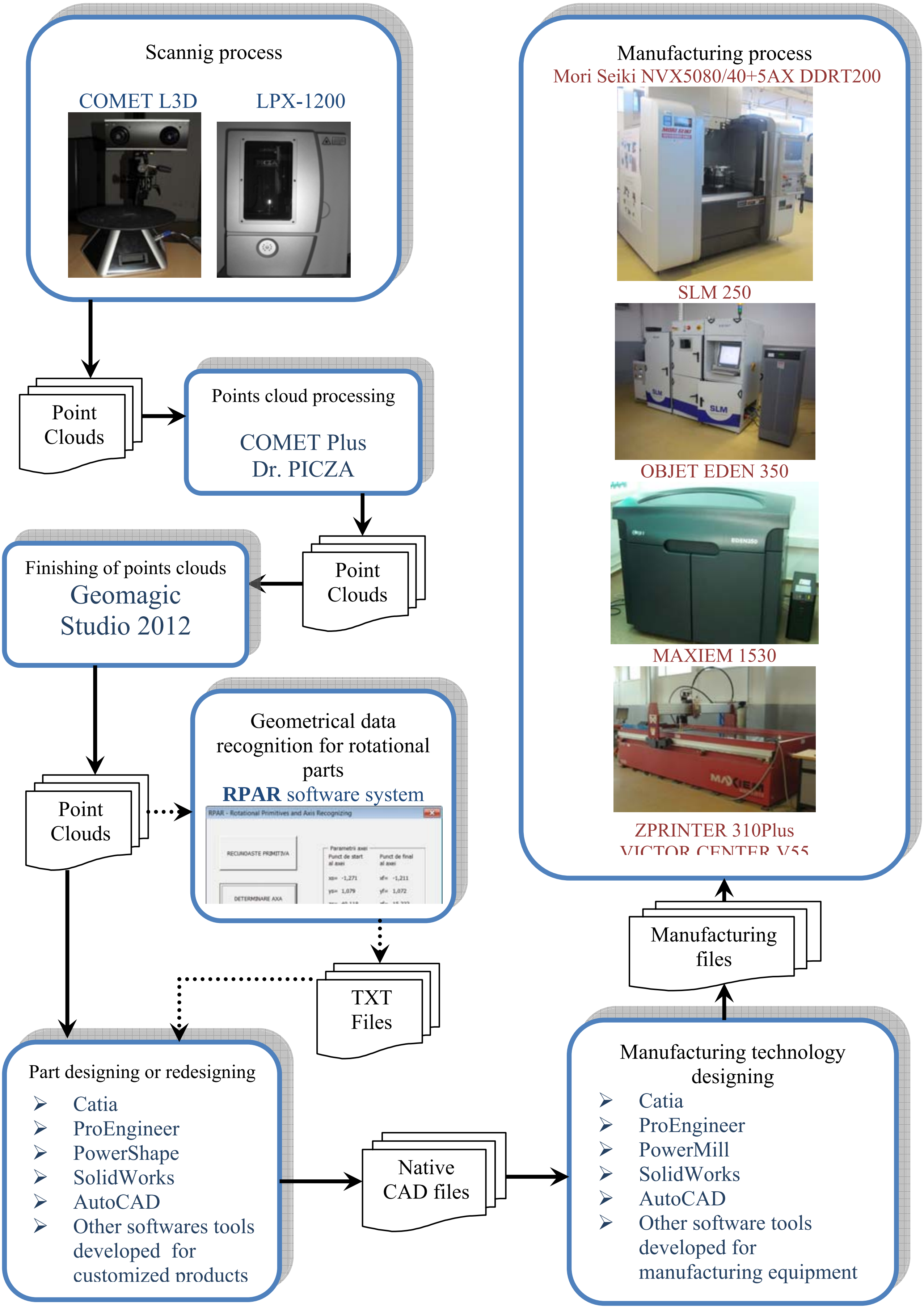



Fig.1. CARE system architecture

## 3. CASE STUDIES

The CARE system has been used for different industrial products such as: gears, pistons, tools, rectangular parts with holes, assemblies and nonindustrial parts such as: teeth, shoe lasts, shoes and toys.

### *3. 1 Remanufacturing of a damaged gear*

Redesigning and remanufacturing of a damaged gear from a fishing reel, with missing teeth (Manolescu et al., 2011), which has about 14 mm diameter, presented in the figure 2, was performed using the configured CARE system.


Fig.2. Damaged gear (Manolescu et al., 2011)

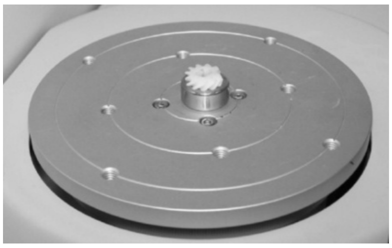


Fig.3. Scanning process (Manolescu et al., 2011)

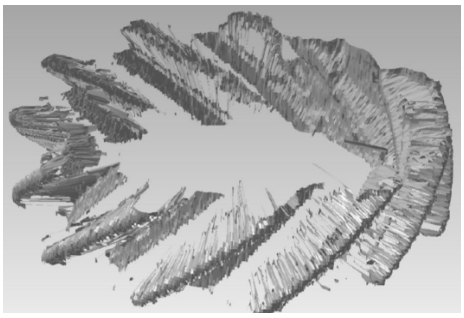


Fig.4. Point cloud associated to gear (Manolescu et al., 2011)

The part was digitised using LPX-1200 scanner (Fig.3); point cloud was processed with Dr. PICZA (figure 4) and exported for main section determining with RPAR software system. The gear was redesigned in ProEngineer CAD system (Fig. 5) and then manufactured using an additive technology available on OBJET EDEN 350. The new gear was successful assembled in the fishing reel (Fig. 6).

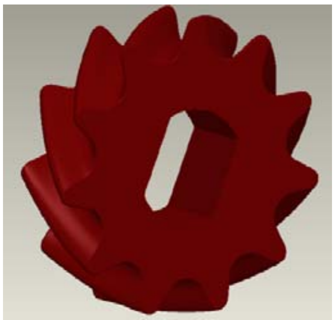


Fig.5. Redesigned gear (Manolescu et al., 2011)

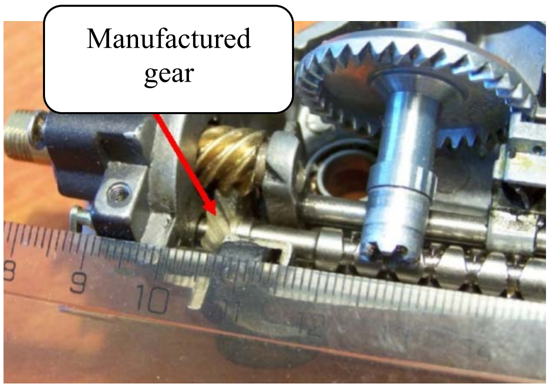



Fig.6. New gear assembled in fishing reel (Manolescu et al., 2011)

### *3. 2 Designing of shoe lasts*

Using the CARE system a new method for designing of the shoe lasts was developed, based on an original algorithm (Pescaru et al., 2012a)
The algorithm for the designing of parametric shoe lasts has been conceived for CATIA system and main steps of the proposed algorithm are the following (Pescaru et al., 2012a):

- scanning the shoe last (Fig. 7) to be analyzed, using COMET 3D scanning system;
- importing the point cloud into the Geomagic Studio software package and finishing the point cloud obtained in the previous step (Fig. 8);
- defining the characteristic curves of the shoe last onto the finished point cloud and exporting it in CATIA;
- identification of the shoe last areas;
- defining the origin point and identifying, defining, initializing the parameters required for creating the parametric shoe lasts;
- determining the base points according to the origin, parameters defining and calculations of the intermediate points associated to the characteristic curves of the shoe last;

- generating the parametric curves through the points and higher order surfaces (figure 9);
- modifying the values of the parameters taking into account the obtaining of new parametric shoe lasts.

Fig.7. Shoe last subject of case study (Pescaru et al., 2012a)

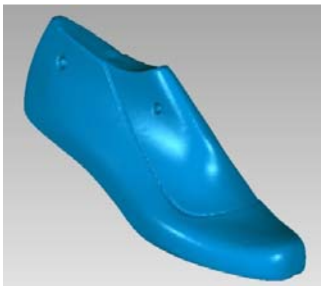


Fig.8. Obtained point cloud (Pescaru et al., 2012a)

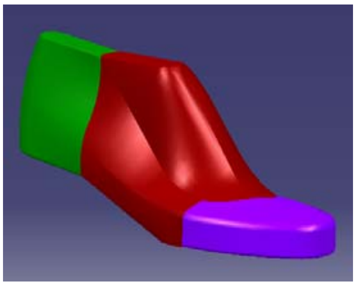


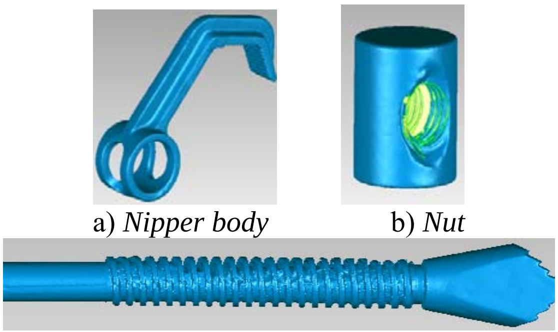
Fig.9. Parametric shoe last modelled with surfaces (Pescaru et al., 2012a)

***3. 3 Parametric redesign of an assembly***

The utility of the configured CARE system in the area of industrial assembly was demonstrated for an antique trimowrench presented in the figure 10 for which no documentation was available (Pescaru & Oancea, 2012).

Based on the physical components of the trimowrench, the specific CARE stages were performed, the parts were digitized with the COMET 3D scanning system, followed by the point clouds finishing in Geomagic Studio software package (Fig.11) and finally the assembly was redesigned in CATIA using the solid type parts in a parameterization mode (Fig. 12) (Pescaru & Oancea, 2012).

Fig.10. Screw trimowrench, subject of case study (Pescaru & Oancea, 2012)



a) *Nipper body* b) *Nut*

c) Jaw

Fig.11. Point clouds finished in Geomagic Studio (Pescaru & Oancea, 2012)

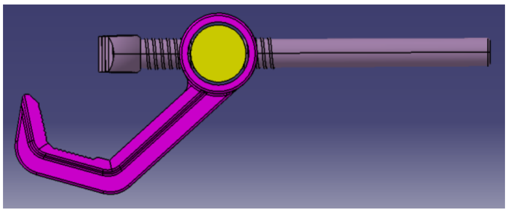


Fig.12. Parametric reconstructed trimowrench assembly (Pescaru & Oancea, 2012)

Fig.13. Studied toys and associated point clouds (Pescaru et al., 2013)

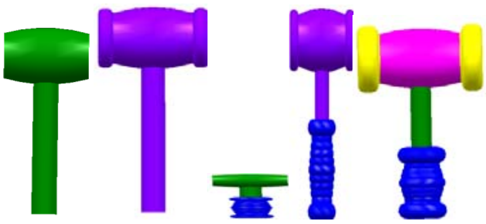


Fig.14. Toys family (Pescaru et al., 2013)

Fig.15. Redesigned parts from entertainment industry (Pescaru et al., 2012b)

***3.4 Parts family generation***

The CARE system can be used for objects from the entertainment area. In the department there were been developed algorithms and applications for toys redesigning in a parametric mode (figure 13 and 14) and for products from entertainment industry (figure 15) (Pescaru et al., 2012b), (Pescaru et al., 2013).

## 4. CONCLUSION

The CARE system configured at Manufacturing Engineering Department, Transilvania University of Brasov, has been used in the design/redesign and manufacturing process of customized industrial products for which no technical documentation is available. It also has been used for different products from footwear and entertainment industry. The architecture of the CARE system is an open one and, in the future, it can be developed by adding new equipments and software systems.

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