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Development of a programme system for data-point pre-processing in reverse engineering

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Abstract: Reverse Engineering, even with the fast developing over the last few years, still has certain drawbacks. One of the main problems is related to the quality of 3D-digitization result. In this paper the programme system for the pre-processing of 3D-digitization data-point in Reverse Engineering has been presented. The developed solution is verified in practical application and some of experimental results are presented in the paper.

Keywords: Technological sciences, Mechanical engineering, CAD/CAM, CAMS

1. INTRODUCTION

Current global market requirements imply, on one side, constant shortening of time necessary for new product development - by fast and frequent product (re)design - as well as more complex shapes (packaging, toys, automobiles…) dictated by aesthetic and ergonomic demands on the other side. Those requirements are more and more difficult to achieve by conventional engineering tools, that imply developing the abstraction – an idea, through conceptual, and then by detailed CAD/CAM designing. In that sense, the technique of Reverse Engineering, providing solutions for the most of contemporary market's requirements, started to develop [1,2].

Reverse Engineering (RE), until about ten years ago, presented a notion not so often found in literature, and shyly used in practice. Today, the reverse engineering technique is commonly applied in many fields: production engineering, software engineering, film industry, entertainment industry, chemical engineering, electro technical industry, and recently there are first examples of RE-application in industry of MEMS (Micro Electro-Mechanical Systems).

RE, in the broadest sense, includes every activity done with the purpose of determining ways in which a certain product functions or of analyzing ideas and technologies applied in the development of an original product [3]. Without any doubt, RE is becoming a significant tool within the process of CAD product modelling, especially when concerning complex surfaces, which are often very difficult or almost impossible to model by using tools offered in modern CAD-systems. Thus, those shapes can be made by "artistic modelling" (in clay, gypsum, polymer materials, wood etc.), and then finished physical models can be

transformed, by RE, into CAD- models. Furthermore, RE-application in the redesigning process of either one's own or competition's product can significantly accelerate and improve the process itself. In the case of the necessity of producing the copies of parts and products without adequate technical documents, RE is almost certainly without any alternatives [3,4].

2. PROBLEM DEFINITION

The starting point of RE-process is a physical object which can be an existing part or product, handmade (sculptured) model or model gained from some technique for Rapid Prototyping. This physical object is, through the phases of 3D-digitization, pre-processing and surface reconstruction, transformed into CAD-model suitable for usage in modern CAx-technologies [2]. However, this process is not at all simple. Even though the technologies included in the RE-process have been significantly improved in the last couple of years, there are still certain problems influencing significantly the quality of the process. One of the most important problems concerns the quality of 3D-digitization results, known as point-cloud, and it considerably influences the quality of the resulting model [4,5].

A large number of different 3D-digitization systems has been developed, among which the most prominent are coordinate measuring machines (CMM), laser scanners, pantographs, CCD cameras, computer tomography (CT), etc. [2]. Common to them all is the presence of noise and measuring errors in the results, which most often implies generating inadequate model. Also, modern 3D- digitization systems (especially laser based systems) generate a large amount of points, which on one side can considerably slow down, and in extreme situations also prevent data-point processing, while on the other side too large number of points can as a result have inadequate surface model. Therefore, before the surface reconstruction process, it is necessary to prepare the point-clouds [4,5]. The preparation consists of noise and error filtering, as well as of reducing number of points, and it is usually described by the term *pre-processing* [1,3].

With respect to previous, the aim of this research is the development of a module for data-point pre-processing applicable with different 3D-digitization systems as well as with different surface reconstruction software.

3. PROGRAMME SYSTEM FOR DATA-POINT PRE-PROCESSING

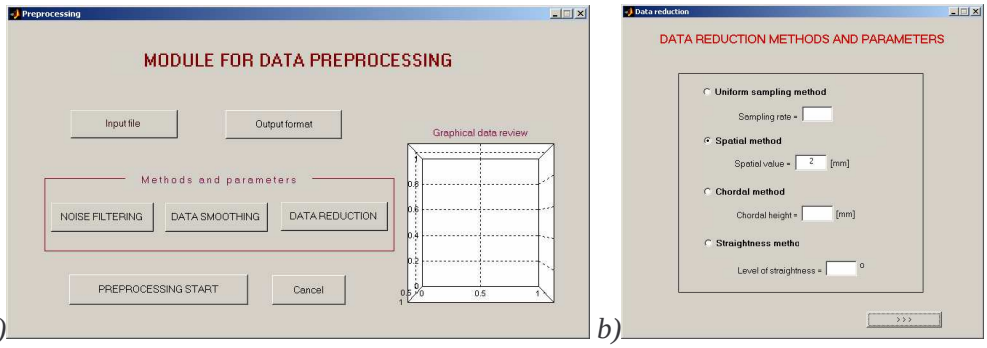
Considering the facts that one of the leading problems, within RE process, concerns the quality of 3D-digitization result that significantly complicate processing and surface generation, as well that in the most of the contemporary CAD-software systems with built-in modules for surface reconstruction, functions for data-point pre-processing are either very poor or do not exist at all, this research is focused on development of a programme-system for pre-processing of 3D-digitization results. As basic elements of the suggested system, the following can be singled out:

- Data-point preparation,
- Error point filtration,
- Data-point smoothing,
- Data-point reduction and
- Output format generation.

System for data pre-processing developed within this research is based on the cross-sectional RE-methodology. It enables data-points obtained from 3D-digitization system to be accepted, adequately prepared, and adapted for the reconstruction in a CAD-model.

Developing this module, prominent methods have been used. For filtering - volume and angle methods; for data smoothing - median and average value methods; and for data

reduction - uniform sampling, spatial, tangent and straightness methods. By embedding of several methods for same functions, a possibility of the application on data-points with different characteristics received from different systems is ensured [3,4]. The complete programmed solution of this module is original and it is realized in the program environment Matlab 6.5. Main graphical user interface – GUI (a) of the developed programmed system and GUI for definition of the methods and parameters for data reduction (b) are shown in Figure 1.



a) *b)*

Figure 1. GUIs of the developed programme system for data-point pre-processing

4. RESULTS AND DISCUSSION

Functionality and the efficiency of the developed programme system are checked through a practical application. The components of the experimental system, together with their connection, are presented in Figure 2.

As an input physical object, engine cover of the Volkswagen's car model from the '60-s - "Karmann-Ghia", has been used. Figure 3 shows a 3D-digitization result of contact scanning from commercial system Cyclone 2, Renishaw. Example of the final result of pre-processing is shown on Figure 4. This result is obtained by applying volumetric method for pre-filtering, angle method for filtering, median method for data smoothing and space method for data reduction.

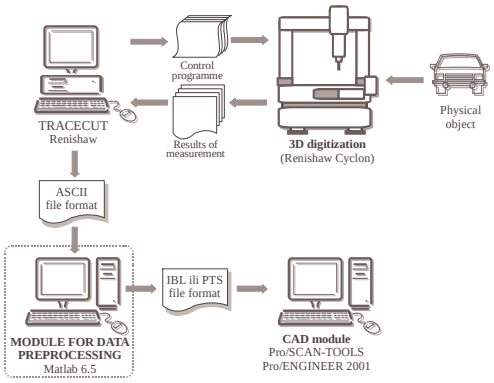


Figure 2. Components of the experimental system for practical verification

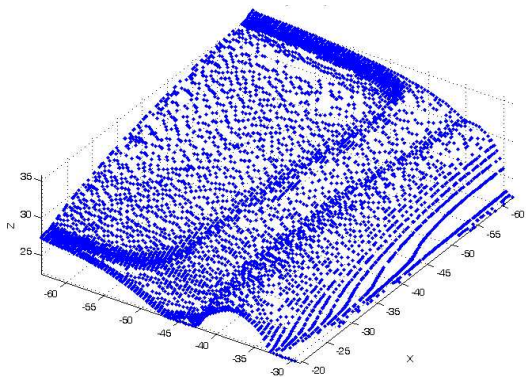


Figure 3. 3D-digitization result (7652 points)

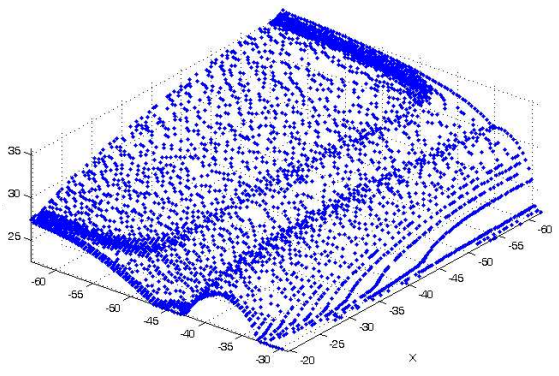


Figure 4. Result of pre-processing (3946 points)

Comparing the surface model generated from original digitization result with the model generated from pre-processed data approves validity of the gained result. Comparison is done in Pro/ENGINEER using the *Compare Part* option and the result is shown in Figure 5.

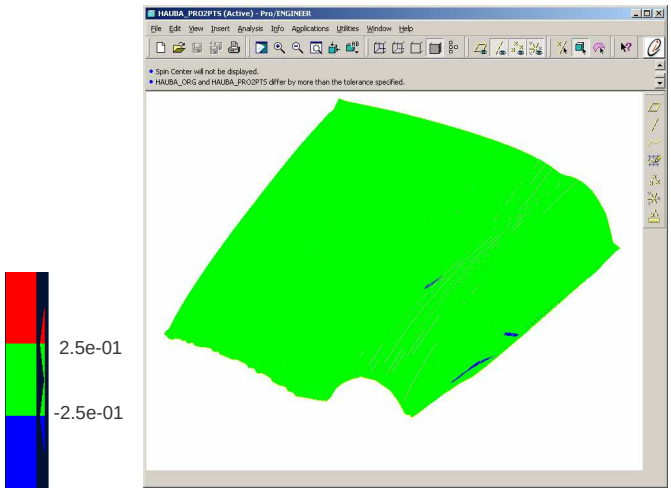


Figure 5. Result of models comparison in Pro/ENGINEER

5. CONCLUSIONS

In order to obtain adequate CAD-model, since surface reconstruction on the bases of raw 3D- digitization data often results in unsatisfactory CAD-model, pre-processing of data-points before surface reconstruction is needed. In this paper programme system for data-point pre-processing have been presented. The entire procedure involves data preparation, error filtering, data smoothing, data reduction, and output file format generation. Developed programme system for data pre-processing has been realized on the basis of known methods for noise filtering, data smoothing and data reduction. Programme solution has been developed in software Matlab 6.5. Experimental results obtained from practical application have proofed the functionality of the developed system and its procedures.

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