ISSN 2229-5518

A Reverse Engineering Technique for Reproducing Spare Parts using Computer Vision System

A. A. Alshennawy

Abstract— With the great progress in the industrial technology, raise the efficiency of public and private sector and reduce dependence on imports of spare parts, Taking the direction of research in the field of reverse engineering have a significant impact on the greater reliance on domestic production engineering.

A reverse engineering technique for reproducing small spare parts of the machines was proposed by using computer vision system, the damaged spure gear was used as spare part. The sensor in this study is a CCD digital Camera with high resolution for more accurate images and more details (non contact sensor). The images of the spare part was integrated by image processing algorithms which were designed. The contents of the images was recognized and analyzed to extract dimensions and engineering data through designed algorithms. The data collected was transferered to 3D solid model to reconstruct the 3D spare part which will translated to constration drawings required for poduction department for reproduce the part. The proposed system will be a kernel that can be continuously developed to include a wide base of spare parts that we need to change and constantly adjusted.

Index Terms— Reverse Engineering - Spare Parts - Computer Vision.

---

1 Introduction

Engineering fields are constantly improving upon current designs and methods to make life simple and easier. When referring to technology, simple and easy can be directly related to fast and accurate. Simple meaning that, you do not use up valuable time in assembly or doing a specific task. Easy meaning how many times you will have to do the process or task. When we think of engineering we think of the general meaning of designing a product from a blue print or plan. Engineering [1,2] is described as "the application of scientific and mathematical principles to practical ends such as the design, manufacture, and operation of efficient and economical structures, machines, processes, and systems". This type of engineering is more commonly known as Forward Engineering. An emerging engineering concept is utilizing forward engineering in a reverse way. This method is more commonly referred to as Reverse Engineering. Reverse engineering is the opposite of forward engineering. It takes an existing product, and creates a CAD model, for modification or reproduction to the design aspect of the product. It can also be defined as the process or duplicating an existing component by capturing the components physical dimensions. Reverse engineering is usually undertaken in order to redesign the system for better maintainability or to produce a copy of a system without access to the design from which it was originally produced. With this knowledge, computer vision applications have been tailor to compete in the area of reverse engineering. Computer vision is a computer process concerned with artificial intelligence and image processing of real world images. Typically, computer vision requires a combination of low-level image processing to enhance the image quality (e.g. remove noise, increase contrast) and higher level pattern recognition and image understanding to recognize features present in the image. Three-dimensional (3D) computer vision uses two-dimensional (2D), images to generate a 3D model of a scene or object

The most different task in computer vision is in extracting knowledge from the information contained in the input image [2-4]. The complete computer vision system is composed out of three components, these are:

- **a) Image acquisition model:** this model includes the CCD-camera and the interface card. This part is the eye of the system that is used to acquire an image for the inspected part and to send the image to the personal computer.
- **b) Personal computer:** it is responsible for receiving the acquired image and to carry out the selected image processing algorithms on the image.
- **c) Image processing and pattern recognition module:** this module is implemented as software program that manipulates the acquired image to get the necessary information to carry the direction code of the profile.

Bardell et al. [3-6] defined reverse engineering as systematic evaluation of a product with the purpose of replication which involves either direct copies or adding improvements to existing design They have also proposed a method of automating the verification of an acceptable free-form surface, using coordinate measuring machine (CMM). Computer-aided .geometric design (CAGD) is used to analyze the surface for optimum continuity and assess the CMM data accuracy The study [7] has been made to find out the dimensions of pre-

- *A. A. Alshennawy is currently with College of Engineering, Taif University, Taif, 888, Saudi Arabia.*
  E-mail: abd_alshennawy@yahoo.com.
  Permenant address of A. A. Alshennawy is Mechanical Eng. Dept., Faculty of Engineering, Tanta University, Tanta, Egypt

ISSN 2229-5518

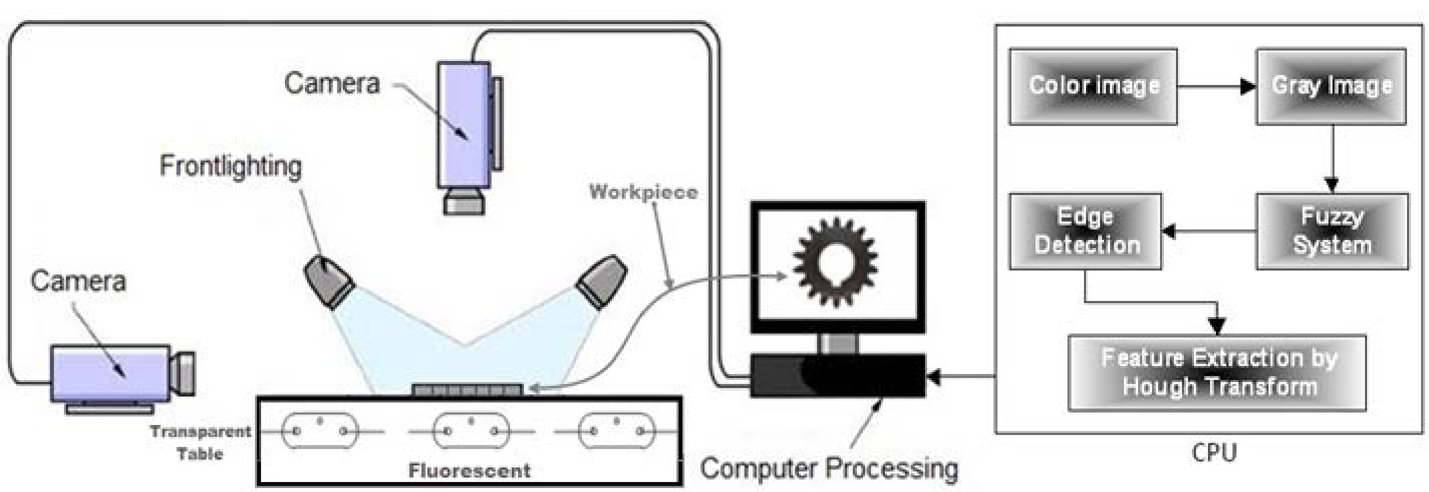


Fig.1 Computer Vision System

existing splineshaft of gearbox using reverse engineering. Splineshaft is an essential component which establishes a power transmitting between the various gear assembly of gearbox. The geometric data of undertaken component has been obtained by using CMM. The 3D model of splineshaft has been created by using CATIA. The analysis of splineshaft has been performed at various loads ranging from minimum value to maximum value in order to study the behavior of splineshaft by using ANSYS. And the finally for computer aided .manufacturing NC part programming is generated by using CATIA. One of study [8-12] taking the spur gear as the study object, this paper introduces the method of reconstruction wear gear model by reverse engineering for gear laser cladding repairing. Using the laser scanning measuring sys tem, through the reverse digital, point cloud pre-processing technology, matched 3D CAD model of the impaired standard involute gear. Through point cloud alignment theory and method of gear damage, made the alignment analysis for the CAD model before wear and after, and the quantitative analysis of wear layer is achieved. The method provides conditions for laser cladding .repairing of wear gear Specific CMMs were used in the past to perform such complex analyses. When propellers were mounted on ships on dry dock, inspections became nearly impossible to be performed. So, A study [13] of propellers were introduced, both photogrammetric and laser scanning low cost methodologies for 3D reverse modeling of complex objects with high level of detail were proposed. Three photogrammetric software for both commercial and research uses have been tested for generating high density point clouds. The feasibility of using a low cost triangulation scanner for high accuracy purposes has been studied in the case of small screw propellers. The problem of bringing together all the measurements in a single reference frame with high accuracy is solved by means of color information. The study shows that a hybrid approach that integrates both photogrammetric and laser scanning methods is necessary. Screws of different sizes, surveyed in laboratory and on the field, such as in dry docks, are modeled and inspected. Different procedures for determining geometrical parameters are shown. Geometrical characteristics derived by 3D models of screws, are compared both with .those expected by original plans and CMM measurements Damaged or broken parts are generally too expensive to replace, or are no longer available and this is particularly relevant to the automobile industry owing to the ever - increasing accidents. Reverse Engineering (RE) has been successfully employed to for possible recovery of a damaged broken part. In a certain study [14-20], a present framework which successfully uses RE to generate a CAD model of a damaged internal combustion (IC) engine piston and then use the state - of - the- art ANSYS finite element analysis package to perform a linear static and a coupled thermal - .structural analysis of the component The automotive industry has an increasing need for the remanufacturing of spare parts through reverse engineering. A study [21] were reviewed the techniques of laser scanning and structured lighting for the reverse engineering of small automotive parts. Laser Range Scanning is the use of a CCD camera that captures the profile of the laser as it passes on an object. Structured light is the projection of a light pattern on an object also with the use of several cameras to obtain a profile of the object. The objective of the study was to be able to generate part-to-CAD and CAD-and CAD-to-part reconstruction of the original for future usag. Due to the rapid progress in the modern manufacturing technology, reliable Automated Visual Systems that offer high speed in conjunction with flexible design are becoming a must. As stated above, this work is an introductory study to apply the computer vision techniques to the field of treatment of the two dimensional digital images. The proposed vision system is based on a matrix CCD-Camera as an image acquisition module and a PC computer, see Fig.1. The captured color image is converted to gray image then the proposed algorithms are applied.

In this study a reverse engineering technique for reproducing small spare parts of the machines is proposed by using computer vision system, for instance a spure gear. The sensor in this study is a CCD digital Camera with high resolution for more accurate images and more details (non contact sensor).

ISSN 2229-5518

The images of the spare part will integrate by image processing algorithms which will design. The reconstruct 3D model will rebuild through the other integration algorithms with solidworks 3D modeling. A stress analysis can be introduced for this part.

2 BOUNDRY EXTRACTING USING FUZZY SYSTEM

Fuzzy image processing is the collection of all approaches that understand, represent and process the images, their segments and features as fuzzy sets. The representation and processing depend on the selected fuzzy technique and on the problem to be solved. Fuzzy image processing has three main stages: image fuzzification, modification of membership values, and, if necessary, image defuzzification as shown in Figs. (2-4). The fuzzification and defuzzification steps are due to the fact that we do not possess fuzzy hardware. Therefore, the coding of image data (fuzzification) and decoding of the results (defuzzification) are steps that make possible to process images with fuzzy techniques. The main power of fuzzy image processing is in the middle step (modification of membership values).

After the image data are transformed from gray-level plane to the membership plane (fuzzification), appropriate fuzzy techniques modify the membership values. This can be a fuzzy clustering, a fuzzy rule-based approach, a fuzzy integration approach and so on, [22-26]. The FIS system, in turn, allows edges to be detected even in the low contrast regions as illustrated in part c. This is due to the different treatment given by the fuzzy rules to the regions with different contrast levels, and to the rule established to avoid including in the output image pixels not belonging to continuous lines.

The result from the above filter is the boundary pixles of the images which is the input of the feature extraction algorithm.

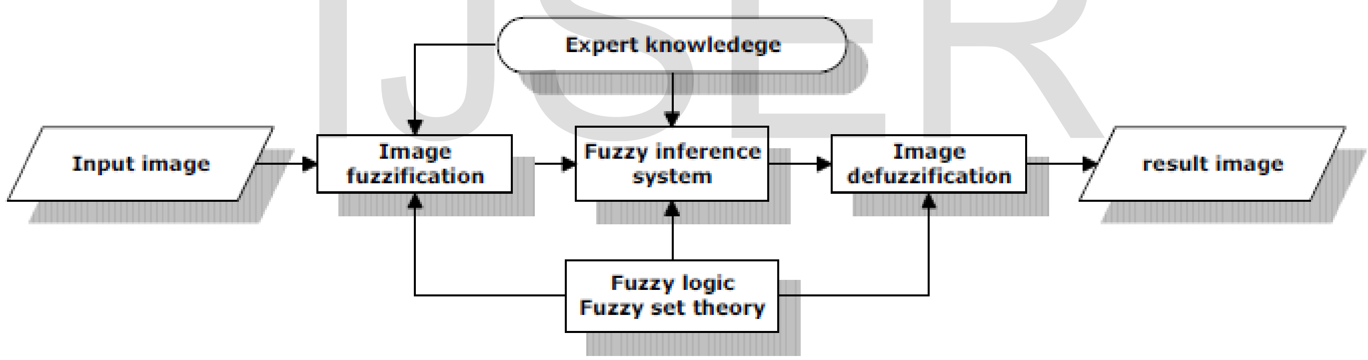


Fig. 2. Fuzzy General Structure

3 FEATURE EXTRACTION AND EXTRACTION OF CIRCLES

In automated analysis of digital images, a subproblem often arises of detecting simple shapes, such as straight lines, circles or ellipses. In many cases an edge detector can be used as a pre-processing stage to obtain image points or image pixels that are on the desired curve in the image space. Due to imperfections in either the image data or the edge detector, however, there may be missing points or pixels on the desired curves as well as spatial deviations between the ideal line/circle/ellipse and the noisy edge points as they are obtained from the edge detector. For these reasons, it is often non-trivial to group the extracted edge features to an appropriate set of lines, circles or ellipses.

The purpose of the hough transform is to address this problem by making it possible to perform groupings of edge points into object candidates by performing an explicit voting procedure over a set of parameterized image objects

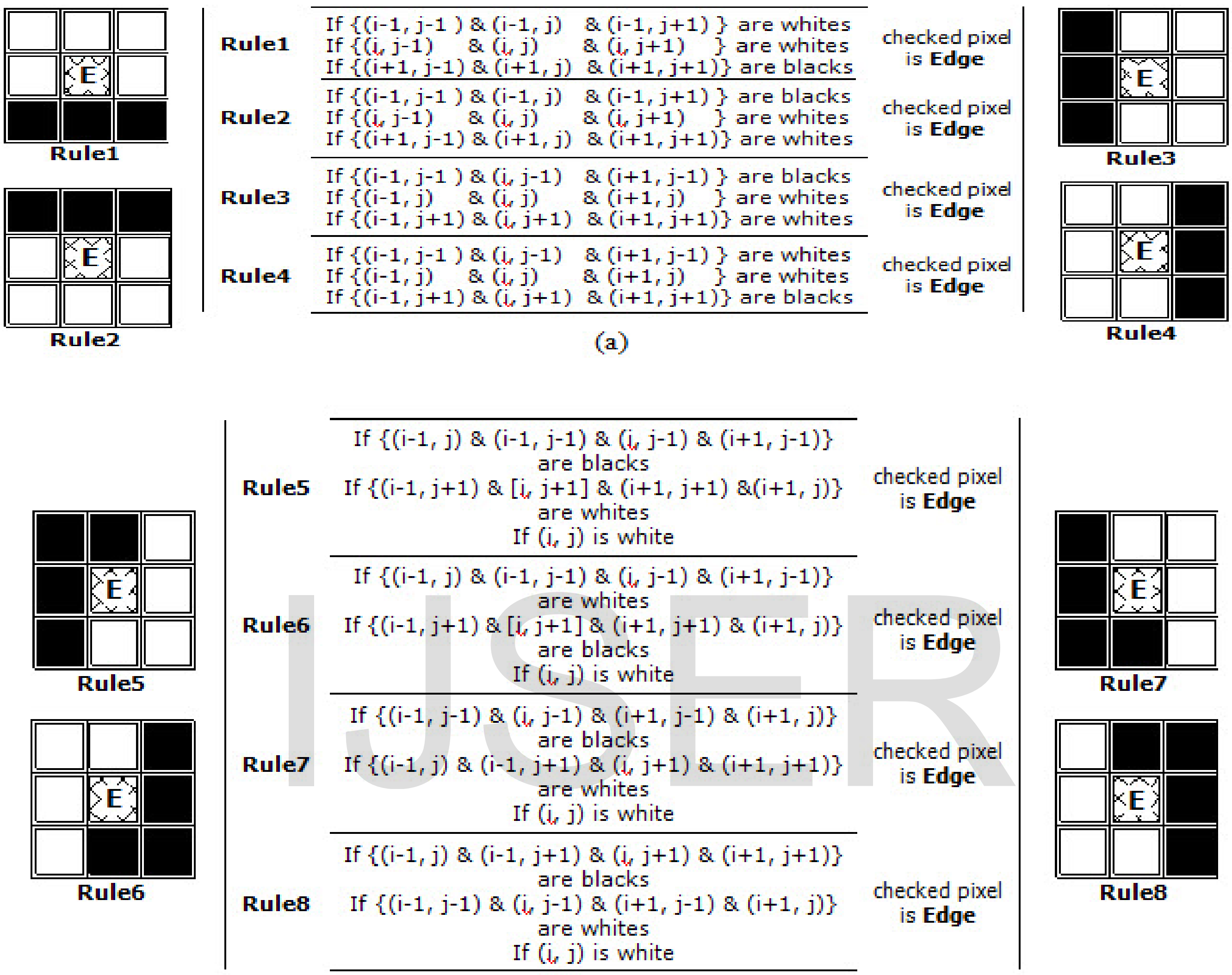
Edge detection which was detected from the fuzzy system forms a pre-processing stage to remove the redundant information from the input image, thus dramatically reducing the amount of data to be processed while at the same time preserving useful information about the boundaries. Thus edge detection provides basic information which is used for extracting shapes like lines, circles and ellipses by Hough Transform technique. In order to simplify the image, it is typically broken into features. It is very important that we eliminate the edge pixels which are not part of the circle. At the same time, it is important to retain all the information required to track the circle [1,27-29].

The edge extracted image is used by many algorithms, such as the circular hough transform and the Linear Square method, to further extract shape information like straight lines, ellipses, circles, etc. The most widely used circle detection algorithm is the Circular Hough Transform. Circular Hough Transform has been widely successful in meeting the real time requirement of being able to detect the circles in noisy environments [1,30]. The edge detected from the fuzzy tracking forms the input to extract the circle using the Circular Hough Transform. The circle detection as per the following procedure:

- A circle that first they give edges xi,yi (i=1,..N) is
- We need to find the center (xc,yc) and radius (r)
- Each edge point gives a cone (if r is not fixed, if r is fixed they are circles on a plane) at different locations in Hough space
- The intersection of all these cones is the solution. for xc,yc,r .

To show the basic concept, If r is known, it is a 2D problem

ISSN 2229-5518
and using 2D Hugh space: circles on a plane. Fig. 5. Illustrate the principles to detecting the circles.



(b)

Fig. 3. The Fuzzy System rules.

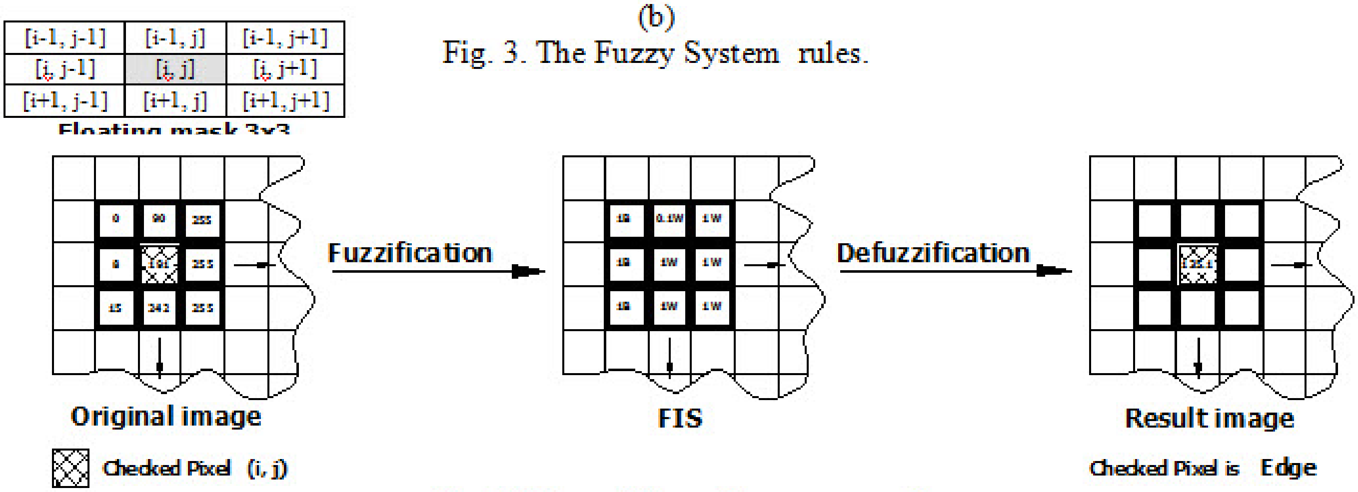
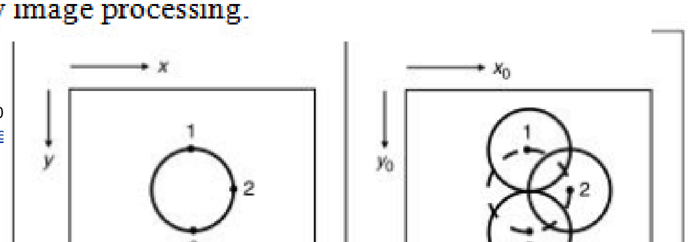


Fig.4. Steps of fuzzy image processing.



ISSN 2229-5518

Fig. 5. The principles to detecting the circles

5 Experimental Results

The proposed system was tested with different images. A presented nonlinear fuzzy filter, is based on applying local grouping of pixels within a 2-D moving window, such as a square mask, over the 2-D input image. The two images of the front and side views are analysed using the fuzzy proposed and hough transform to extract the overall dimentions. The collected data transfer to the solidworks for recontract the complete 3D part. The Fig. 6. show the failure part and Fig. 7. shows the rebuild perfect part which will reproduced by the required machines.

Fig. 6. Failure Spare Part Image

6 Conclusion

Machine vision-based inspection of mechanical components has been a continually expanding area in the field of industrial inspection. In this paper, a machine vision based inspection system for mechanical components has been presented. Here, the two dimensional mechanical components have been projected on the two-dimensional inspection plane and the recognition and analysis modules have been applied to these two-dimensional images. Machine vision algorithms have been developed using the relevant expressions for extracting and inspect the mechanical component. From the experimental results as obtained, it has been observed that the detecting of straight lines, holes and circles are more fast and reliable for any mechanical parts. Further, the extracted data from the images are very important to reconstract the spare part complete geometric dimentions for reproduce and companste the part.

In the future work, the data collected from the proposed system can be used for extracting the program code through the solidwork for CNC machines.

Acknowledgements

This study is supported by Taif University under a contract NO. 1-435-3632. The University is highly acknowledged for the financial support.

References

[1] A. A. Alshennawy, and Ayman A. Aly, “Intelligent Vision Methodology for Detection of the Cutting Tool Breakage," I.J. Information Technology and Computer Science, 2013, 06, 41-49.

[2] Z. Zhang, “Iterative Point Matching for Registration of Free-Form Curves and Surfaces”, International Journal of Computer Vision, 13(2):119–152, 1994.

[3] R. Bardell, V. Balendran, and K. Sivayoganathan, “Accuracy Analysis of 3D Data Collection and Free-Form Modeling Methods”, Journal of Materials Processing Technology, 133, pp. 26-33, 2003.

[4] Vishesh Jain, Shikha Jain and Khushbu Yadav, “FRE: Functional Reverse Engineering for Mechanical Components”, International Journal of Advanced Mechanical Engineering. ISSN 2250-3234 Volume 4, Number 2 (2014), pp. 139-144.

[5] Ronald Barr, Thomas Krueger, Billy Wood, and Mostafa Pirnia, “Introduction to Engineering Design Through a Freshman Reverse Engineering Team Project”, 6th First Year Engineering Experience (FYEE) Conference August 7 – 8, 2014, College Station,TX.

[6] Pranthaman.M, Loganathan.P, Vignesh. E, Sathish Kumar. D, EzhilNilavan. K, “Design and Analysis of Piston Head Through Reverse Engineering”,ISR NATIONAL Journal of Advanced Research in Mechanical and Production Engineering and Development Volume: 1 Issue: 1 08-May-2014.

[7] A. V. NICHAT, N. W. KALE, Dr. A. U. AWATE, M. R. DHARME, “Application of Reverse Engineering using CMM for Manufacturing Intricate component: a case study”, Nichat AV, IJPRET, 2013; Volume 1(8):336-347

[8] Shi Juan, Bai Shunqin, “Research on Reverse Engineering Technology of Laser Cladding Repairing Gears”, Proceedings of 2012 International Conference on Mechanical Engineering and Material Science (MEMS 2012).

[9] Cheng siyuan, Xie shaowang. “Geomagic Studio reverse engineering technology and applications,” Tsinghua University Medical Press, 2010.

[10] Zhang changxue，Zhang xue，Gaoxuejun, “Reverse modeling technology and product innovation designs”, Peking University Press, 2009.

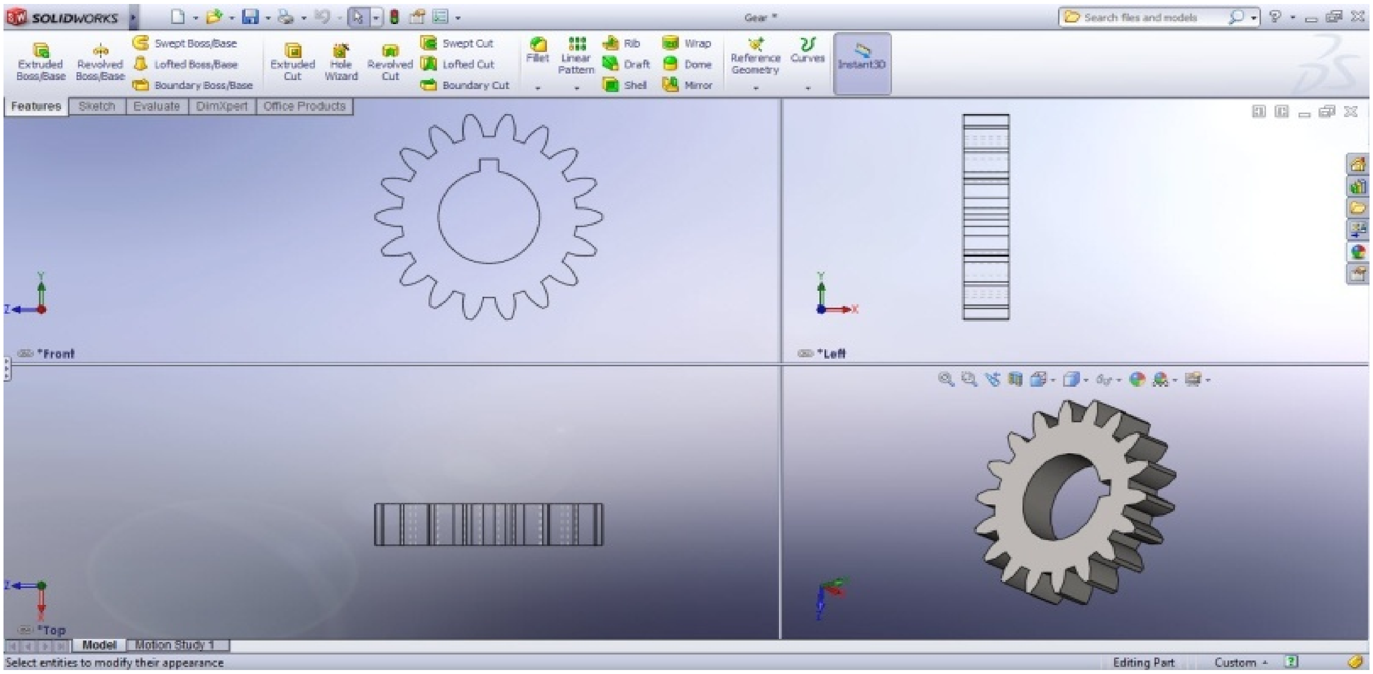


Fig. 7. The perfect spare part

[11] Xu bingshi, State of the art and future development in remanufacturing engineering. Transactions Ions of Materials and Heat Treatment, 2010, 31(1): 10-14.

[12] Chen jiang, Liu yulan, "The E ngineering Application of Laser Remanufacturing Technology," China surface Engineering, 2006, 19(5) : 50-55.

[13] F. Menna, S. Troisi, "LOW COST REVERSE ENGINEERING TECHNIQUES FOR 3D MODELLING OF PROPELLERS", International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. VIII, Part 5, Commission V Symposium, Newcastle upon Tyne, UK. 2010.

[14] Gudimetal P., Gopinath C.V., "Finite Element Analysis of Reverse Engineered Internal Combustion Engine Piston", AIJSTPME (2009) 2(4): 85- 92

[15] Chiang Y. M. and Chen F. L. , 1999. Sculptured surface reconstruction from CMM measurement data by a software iterative approach, Int. J. of Production Research, 37(8) .

[16] Chang- Xue Feng and Shang Xiao., 2000. Computer - Aided Reverse Engineering with CMM for digitization and LOM for duplication, in Proceedings of the 4th Int'l Conference on Frontiers of Design and Manufacturing, Int'1 Academic Press, Beijing, China, 256- 262.

[17] Tzung- Sz Shen., J. Huang and C - H Menq., 2000, Multiple- Sensor Integration for Rapid and High - Precision Coordinate Metrology 110 IEEE/ASME Trans. on Mechatronics , 5(2) .

[18] Feng C. - X., 2003. Internet - Based Reverse Engineering, Int. J. of Advanced Manufacturing Technology , 21(2): 138 – 144.

[19] Zhongwei Y. and Shouwei J., 2003 . Automatic segmentation and approximation of digitized data for reverse engineering, Int. J. of Production Research, 41(13): 3045 – 3058.

[20] Swanson J., Schok D. , Kelley A. and Callow D., 2003. Investigation of Reverse Engineering and Redesign of Milkshake Maker, Internal report submitted for Mechanical & Aerospace Engineering Department, Arizona State University.

[21] Ngozi Sherry Ali, "Reverse Engineering of Automotive Parts Applying Laser Scanning and Structured Light Techniques", Project in Lieu of Thesis presented for the Masters of Science Degree, The University of Tennessee, Knoxville, May 2005.

[22] Abdallah A. Alshnnaway, Ayman A. Aly, ‖Fuzzy Logic Technique Applied to Extract Edge Detection in Digital Images For Two Dimensional Objects ‖, International conference in Production Engineering, METIP 4, 15-17 December 2006.

[23] Ayman A. Aly and A. A. Alshnnaway, "An Edge Detection and Filtering Mechanism of Two Dimensional Digital Objects Based on Fuzzy Inference", International Conference in Mechanical Engineering, ICME, pp. 247-251, Tokyo, Japan, May 27-29, 2009.

[24] B.-G. Hu, R. G. Gosine, L. X. Cao, and C. W. de Silva, ‖ Application of a Fuzzy Classification Technique in Computer Grading of Fish Products ‖, IEEE Transactions on Fuzzy Systems, Vol. 6, No. 1, February 1998.

[25] S. Singh and A. Amin. Fuzzy Recognition of Chinese Characters, Proc. Irish Machine Vision and Image Processing Conference (IMVIP'99), Dublin, (8-9 September, 1999).

[26] Ayman A. Aly, H. Ohuchi and A. Abo-Ismail, ―Fuzzy Model Reference Learning Control of 6-Axis Motion Base Manipulator ‖, 7th IEEE International Conference on Intelligent Engineering Systems, Luxer, March, 2003.

[27] Jonathan Killing, "Design And Development Of An Intelligent Neuro-Fuzzy System For Automated Visual Inspection", thesis submitted to the Department of Mechanical and Materials Engineering in conformity with the requirements for the degree of Master of Science (Engineering), Queen's University, Kingston, Ontario, Canada July 2007, Copyright © Jonathan Killing, 2007.

[28] Safaa L. Diab, Abedl Halim Bassiuny, Mohammed Hussein, Reham Ahmed, " Designing a Visual Inspection System for Quality Characteristics Dimensions", URL: http://dx.doi.org/10.5539/mer.v1n1p12.

[29] Prajwal Shetty, " Circle Detection In Images", A Thesis Presented to the Faculty of San Diego State University, In Partial Fulfillment of the Requirements for the Degree Master of Science in Electrical Engineering, Summer 2011.

[30] Prajwal Shetty, " Circle Detection In Images", A Thesis Presented to the Faculty of San Diego State University, In Partial Fulfillment of the Requirements for the Degree Master of Science in Electrical Engineering, Summer 2011.