COMPUTER AIDED SPUR GEAR DATA EXTRACTION BASED ON IMAGE PROCESSING TECHNIQUE

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ABSTRACT

This paper proposed a computerized methodology of spur gears reconstruction and feature extraction using image processing technique. The methodology was prepared, by building a suitable logical program in Matlab environment, to process the captured gear image using mathematical and logical relationships for the purpose of spur gear data extraction required for 3D spur gear modeling which is include No. of teeth, tooth height, Pitch circle, … etc.

The proposed system has been tested on different spur gears, and the extracted data shows reliable spur gear modeling, which generates accurate and efficient model and provides substantial saving in time and cost of production.

Keywords: CAD/CAM, spur gear, image processing, feature extraction, machining parameters.

إستخلاص بيانات التروس العدلة المعان بالحاسوب بالأعتماد على تقنية معالجة الصورة

الخلاصة

يقترح هذا البحث طريقة معانة بالحاسوب لإعادة إنشاء التروس العدلة وأستخلاص السمات بأستخدام تقنية معالجة الصورة. تم تهيئة هذه الطريقة من خلال إنشاء برنامج منطقي مناسب ضمن بيئة الماتلاب (Matlab)، لمعالجة الصورة الملتقطة للترس باستخدام العلاقات الرياضية والمنطقية لغرض استخلاص بيانات الترس اللازمة لنمذجة الشكل ثلاثي الأبعاد للترس والمتضمنة عدد أسنان الترس، إرتفاع السن، دائرة الخطوة، ... الخ.

تم أختبار النظام المقترح على تروس عدلة مختلفة، وأظهرت البيانات المستخلصة معولية في نمذجة التروس العدلة، من خلال توليد تصاميم دقيقة وكفؤة وبالتالي إستثمار زمن وكلفة الأنتاج.

INTRODUCTION

Experienced designers often are able to create successful initials designs because of their years of design experience and their acquired knowledge of manufacturing processes. However, less experienced designers often require input from experienced personnel in both the design sector and the manufacturing sector [Nedebragt, et al 1999].

Spur Gears are very useful in numerous applications. Not only can they transfer velocity and torque from one shaft to another, but, by using different size gears, they can alter the ratio between velocity and torque as they transfer them.

Spur Gears require a very specific shape for their teeth to work smoothly. The tooth of a Spur Gear is based on a mathematical shape known as an involute. Since each tooth can be described by a series of mathematical equations, it is possible to define a gear in terms of a few key parameters, such as the number of teeth, module, and the Diametral Pitch. These parameters make it easy to tell if two gears can mesh together. Similarly, by specifying the parameters first, it would be simple to design a gear for any given application.

SOME RELATED WORKS

Nordiana, J. O. et al [2007] present a new design system of how the spur gear can be designed and detailed with computer aided design known as Cadgear. The system permits proper communication / interface with users (user-friendliness) having a common input / output language familiar to them. The developed system was able to produce precise and efficient two dimensional design drawings of the gears.

Sukimin, Z. and Haron, H. [2008] present a system of six phases, starts with reading the converted drawing in DXF format, classifying this format to produces the features of the drawing, obtaining dimension of machining parameter, synthesis analysis, simulate and actual machining for result analysis. The limitation of the presented algorithm is not focuses on curve object in the DXF format, the considerations of the features is only for hole, pocket, step and slot.

In the study of Yildiz, Y., et al, [2006] an automatic feature recognition and CNC code generation system was developed for rotational parts. The data input to the system is done by DXF prepared in any CAD program. Sample parts were machined by the generated tool paths and part geometries were obtained accurately. All of the internal and external machined features of complex parts such as grooving, threading and boring can be defined automatically using the proposed system.

Nasr, E. S. and Kamrani, A. K. [2006] proposed a new methodology for extracting manufacturing features from CAD system presented the methodology consists three main phases: (1) a data file convereter, (2) an object form feature classifier and (3) a manufacturing features classifier.

The main goal of this research is to investigate the feasibility of spur gear design by using image processing technique. A technique is proposed that has several advantages over traditional gear design technique in that it requires only inexpensive equipments, allows fast and accurate computation due to the compact images data that can be used to obtain gear features with little or no user intervention.

BASIC SPUR GEAR GEOMETRY

The fundamentals of gearing are illustrated through the spur-gear tooth, both because it is the simplest, and hence most comprehensible, and because it is the form most widely used in industry. Hence, the basic geometry and essential features of a spur gear could be summarized in Table (1) [Faydor, 2004].

IMAGE PROCESSING TECHNIQUE AND EXPERIMENTAL INVESTIGATION

Visual information is converted to electrical signal by use of visual sensors, where the most commonly used is CCD digital camera.

Image processing techniques have many advantages when used for industrial applications such as object recognition, inspection, dimensioning, etc. the base of most image processing techniques can be explained as follows: a picture from CCD camera is digitized into an array of picture elements, known as pixels, corresponds to its relative intensity in the original scene. Usually these intensity values are referred to as logical color values of the perspective pixels. The resulted array is called digital image and any processing of this array, image, and are referred to as digital image processing [Gonzalez, 2002 and Umbaugh, 1998].

PROPOSED ALGORITHM

Image processing can be divided into pre-processing and post-processing. Image pre-processing combines all operations, which transform the digital image into more beneficial data. These data therefore may become easier to be manipulated by mathematical tools for a certain application; hence such act could be considered as post-processing of the image. Consequently, the proposed algorithm, as shown in Fig. 1 as a flow chart, includes the following sections:

1-Image Pre-processing

A colored image of a spur gear captured using a digital camera type genx GDV 720 Ultra. The image was digitized at 1600 × 1200 pixel. The camera is gripped using its holder and connected with the PC using serial cable to perform image transfer and then image processing.

Because of very high information of the colored images, the first step in our algorithm is to apply down sampling technique to convert this image to grayscale image and then to binary image for reducing the computation time and focusing on the object of the interest.

The process of converting grayscale image to binary image, that has only two values (0) and (255) i.e. black and white, is called thresholding, where each pixel in gray scale image is checked if its intensity above or below a specific threshold value. Applying this technique will divide the image into two regions, one is white and the other is black [Gonzalez, 2002 and Umbaugh, 1998].

In this work, the pixel intensity above the threshold value is set as black and below is set as white, this produces a black object on a white background. Fig.2 and Fig.3 represent the gray scale image and the binary image of the tested spur gear respectively.

2-Image Post-processing

In many image analysis applications, such as industrial computer graphics applications, filling, subtracting, labeling and counting operations of objects are of particular interest [Umbaugh, 1998].

The proposed algorithm for filling the gear root circle is based on 8-neighborhood mask, as shown in Fig.4, where the image is scanned column by column and pixel by pixel until a pixel with intensity (0) is reached then the scan stops. Hence, the mask of 8-neighborhood is applied to this pixel, where the pixel is positioned in the origin of the mask. The mask will work clockwise, with a unit pixel circle, searching of any neighborhood which has intensity of (0) to let this neighborhood as the new origin. Thus when such pixel from the neighborhood set is found, its location will be recorded and a small circle, with gray intensity level, is generated. The searching process continues until there is no other neighborhood that has the value of (0), and the circle diameter will be increasing step by step until the circle encloses the gear root circle.

This circle will be subtracted from the entire gear binary image to starting gear teeth labeling and counting operations. In this algorithm, the separated teeth will be processed as different objects in the scene, and the 8-neighborhood mask will be applied again to find every object in the input image and start marking them by numbers and certain intensity level, in the order it finds them. Then the primary intensity level of this object is compared with the level of the second object. Thus, If both levels are identical adjacent object is also labeled by new level and set all the pixels in the object to 2; in the third object all pixels are set to 3, and so on, as shown in Fig.5.

3-Feature Extraction

In this stage, after data extracted from different manipulated binary images, a set of mathematical computational processes is done automatically by the proposed feature extraction algorithm. The feature extraction algorithm focuses on extracting the main gear parameters, based on the gained binary image shown in Fig.4, which are needed to compute the outline of the spur gear and the resulted physical geometry and features extracted, are shown in Fig.6.

FURTHER EXPERIMENTAL WORK

To assess the potential of the proposed algorithms, further investigation was carried out using different spur gears. The aim is to highlight any problem areas that encounter the execution of the proposed algorithms and to evaluate the accuracy level that could be achieved in real applications.

Fig.7 shows acceptable spur gears extracted geometry while Table 1 summarized sufficient physical features extracted and listed compared with their real dimensions, each attribute set resulting from ten times repetition of the experimental procedure.

CONCLUSIONS

The proposed method incorporates the theories and techniques of principles of both spur gear geometry and digital image processing techniques for automatic feature extraction. This paper concentrates on overcoming some of the difficulties of capturing images with more than enough information. The proposed algorithm is able to process this information through the use of computational methods to create gear physical dimensions.

This study therefore present a new method of how the spur gear can be modeled and then detailed with computer aided design, previously, emphasis was laid on primitive and probabilistic modeling processes which resulted in high operation cost and prolong time. The results shown in Table 1 indicate that the proposed algorithm is accurate and acceptable for the experimented gears. However, there are a number of points where the features are not extracted correctly, especially around the gear boundaries, and this can be attributed to the fact that the captured image resulting in some noise near the gear boundary, or the complex edges of the gear have caused the lighting to be distorted, thus affecting the entire proposed algorithm and its accuracy.

Table 1

Extracted physical features of spur gear studied cases compared with the real dimensions

Spur Gear Extracted Features	Gear Labeled (A)		Gear Labeled (B)		Gear Labeled (C)	
	Extracted Dimensions	Real Dimensions	Extracted Dimensions	Real Dimensions	Extracted Dimensions	Real Dimensions
No. of Teeth	30	30	21	21	19	19
Tooth Height (mm)	6	5	5	6	6	6

Tip Diameter (mm)	50	52	38	37	33	35
Pitch Circle (mm)	47	45	36	35	30	30
Base Diameter (mm)	45	43	34	32	28	28
Root Diameter (mm)	40	38	27	26	23	24
Module (mm)	6	6	8	8	12	12
Addendum (mm)	3	3	3	3	3	3
Dedundum (mm)	3	2	2	3	3	3

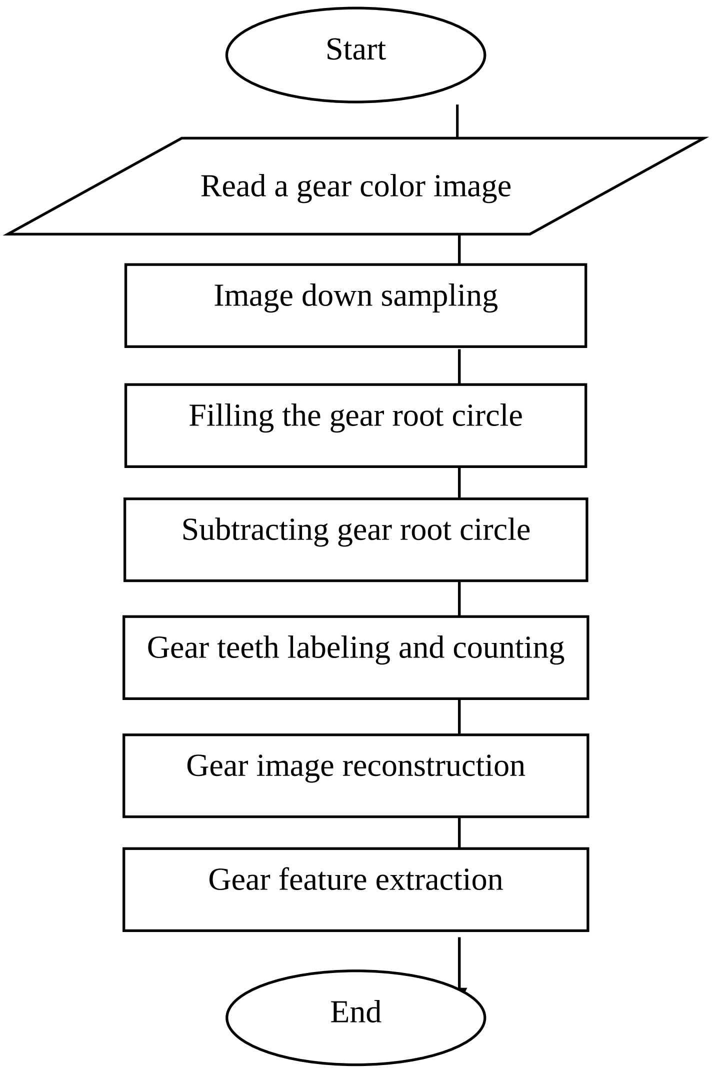


Fig.1: The proposed flow chart

Fig.2
Gray scale image of the spur gear

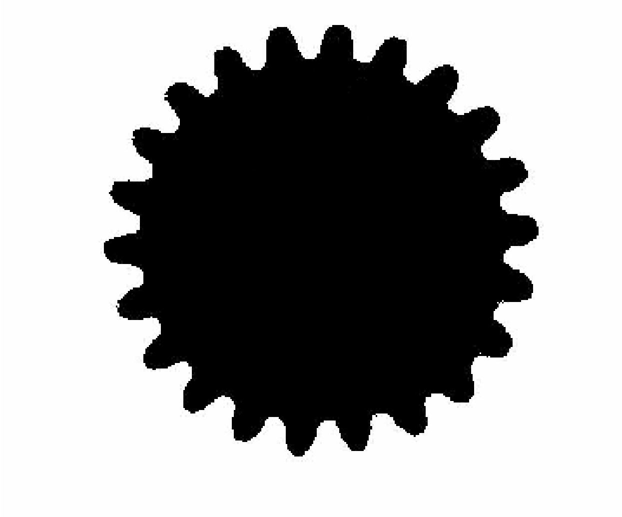


Fig.3
Binary image of the spur gear

X-1, Y+1	X, Y+1	X+1, Y+1
X-1, Y	X, Y	X+1, Y
X-1, Y-1	X, Y-1	X+1, Y-1

Fig.4 [Gonzalez, 2002]
Image 8-neighborhood mask

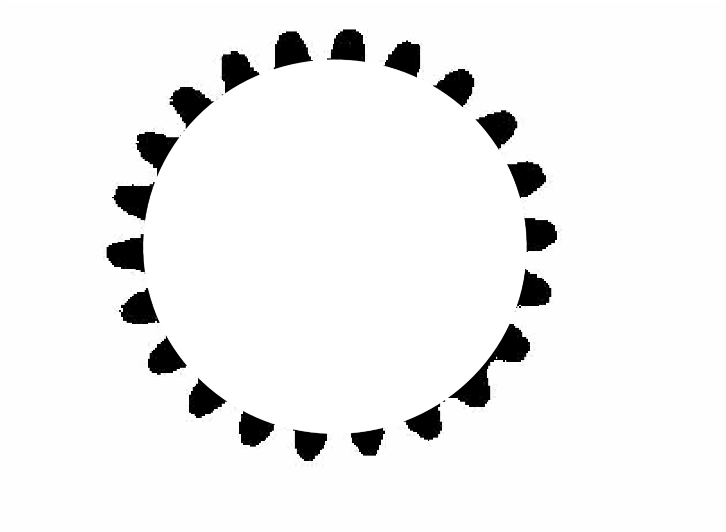
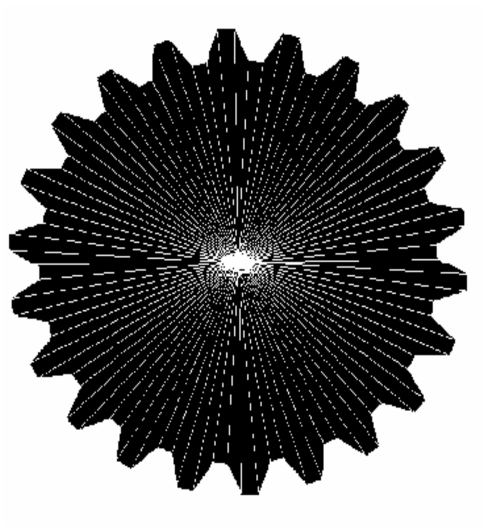
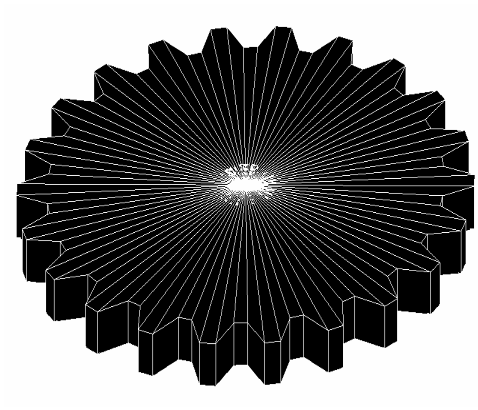


Fig.5
Gear root circle and tooth labeling process



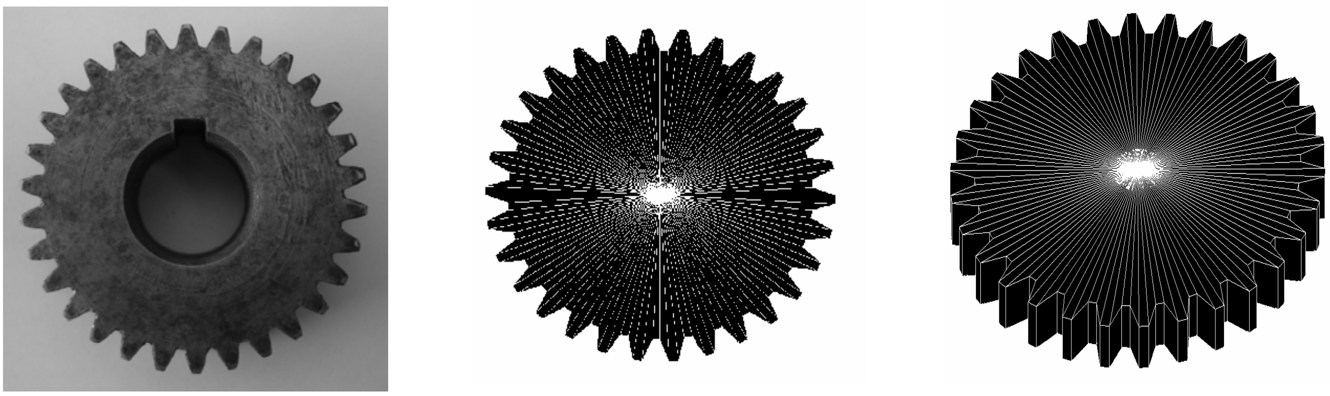
a



b

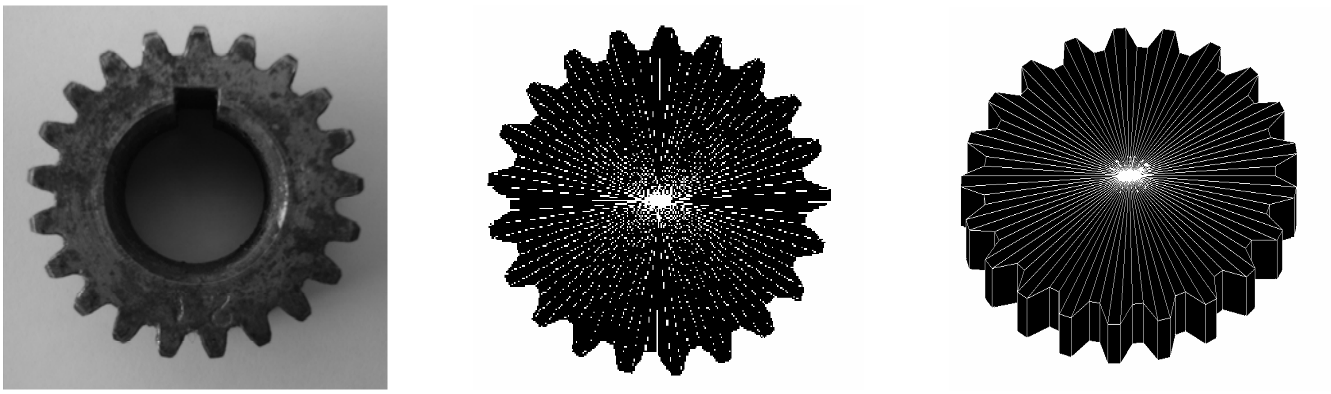
No. of teeth = 22, Tooth Height = 5 mm, Tip Diameter = 61 mm,
Pitch Circle = 56 mm, Base Diameter = 54 mm, Root Diameter = 50 mm,
Module = 8, Addendum = 2 mm, Dedundum = 3 mm

Fig.6
Generated spur gear geometry and the extracted features using the proposed algorithm a-Top view b- Isometric view



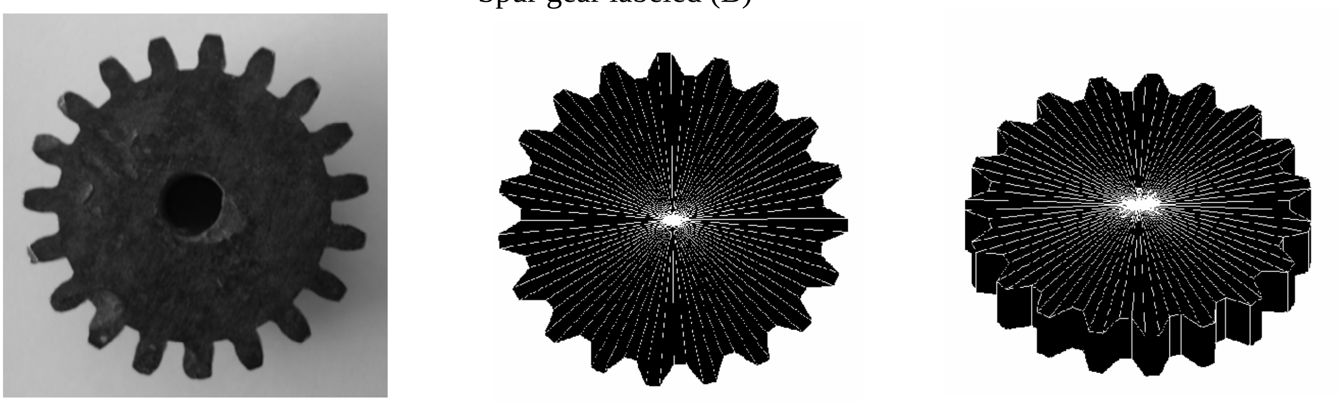
a b c

Spur gear labeled (A)



a b c

Spur gear labeled (B)



a b c

Spur gear labeled (C)

Fig.7

a- Gray scale image of the gear, b- and c- are the generated top and isometric view respectively

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