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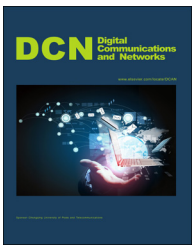

Automatic gear sorting system based on monocular vision

Wenqi Wu, Xingang Wang*, Guan Huang, De Xu

Research Center of Precision Sensing and Control, Institute of Automation, Chinese Academy of Sciences, Beijing 100190, China

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Abstract
An automatic gear sorting system based on monocular vision is proposed in this paper. A CCD camera fixed on the top of the sorting system is used to obtain the images of the gears on the conveyor belt. The gears' features including number of holes, number of teeth and color are extracted, which is used to categorize the gears. Photoelectric sensors are used to locate the gears' position and produce the trigger signals for pneumatic cylinders. The automatic gear sorting is achieved by using pneumatic actuators to push different gears into their corresponding storage boxes. The experimental results verify the validity and reliability of the proposed method and system.

1. Introduction

Small-modulus plastic gears are widely used in instruments, household appliances, toys, machinery and other fields because of their low cost, light weight, low transmission noise and so on. Plenty of different gears are assembled in these products. In the assembly process of these products, different gears need to be detected and sorted, especially on the production line. The quality of products and the work efficiency of the production line are directly affected by the accuracy and the efficiency of sorting the gears. The traditional manual sorting is extremely difficult when the number of gears is large, the alveolar space is small and different gears are very similar. Automatic gear sorting has been largely considered as a solved problem.

The automatic gear sorting remains a challenging task due to the structure of the gears. The gears have the characteristics including serried teeth, small alveolar space and high similar in different gears. The accuracy of the gears' classification is decided by feature selection and extraction, which is the key problem in automatic gear sorting. On the other hand, the small-modulus plastic gears have the specialty of being light and thin, thus it is hard to adopt the contact trigger mode on the automatic gear sorting. System efficiency is reduced by the contact trigger mode on general production lines. While there is a high request for stability of the system and classification pattern if the system adopts a non-contact trigger mode.

*Corresponding author.
E-mail address: xingang.wang@ia.ac.cn (X. Wang).
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In order to solve these problems and improve the accuracy and efficiency of this system, in this paper, an automatic gear sorting this system based on monocular vision is presented. It includes a method of image processing, feature extraction and non-contact pneumatics. The system can classify different gears automatically, and it uses the pneumatic cylinder to push the gear to its corresponding boxes at the rear of the transmission belt [1,2]. The gears' images are captured by the camera while the conveyer belt moves the gears under the camera. The image segmentation [3,7,8], morphological transformation, connected region labeling [10], edge image extraction, and the distance set computing are used in the image processing algorithm module [4] in the computer to get the gears' features including the number of holes, number of teeth and color. These features can be used to give a unique classification result. The recognized gear's type is used to control the effectors in order to push the gear into the correct storage box. The developed automatic gear sorting system has the advantages of non-contact measurement and high efficiency.

The rest of the paper is organized as follows. An overview of our system configuration is introduced in Section 2. The algorithm of image processing and feature extraction is presented in Section 3. The cylinder push logic is minutely illustrated in Section 4. Experiment and conclusion are given in Sections 5 and 6, respectively.

2. System configuration

The designed automatic gear sorting system consists of a conveyor belt, a CCD camera, a LED light source, 6 photoelectric sensors, a computer, 5 pneumatic cylinder effectors and an air pump, etc. Its sketch is given in Fig. 1. The conveyor belt is used to move the gears on it. It is driven by a servo motor to move at a given speed. A mechanism with two guide boards is fixed at the beginning of the conveyor to arrange the gears in a queue. The camera is mounted at a position upon the conveyor. It is downward and its optical axis is vertical to the conveyor. The ring shaped LED light source is mounted below the camera to provide illumination for the camera. The 6 photoelectric sensors are placed at 6 positions to detect the gears. A photoelectric sensor is at the position to indicate the camera, whose signal is input into the computer to trigger the camera. The other 5 photoelectric sensors are at the positions to represent the 5 storage boxes, whose signals are input into the computer to trigger the pneumatic cylinder effectors. The computer is used to control the camera to capture images and to process them. It is also used for the control of the 5 pneumatic cylinder effectors. The air pump works as the air source to drive the pneumatic cylinders.

First of all, different types of gears are selected for registration, as a reference for the classification of gears. The gears on the conveyor are moved forward by the conveyor. A triggering signal is formed when a gear is moved to the photoelectric sensor's position under the camera. The camera is triggered by the signal. The gear's image is captured by the camera and sent to the computer. The computer processes the image to extract the features such as number of holes ,number of teeth and color. Then the gear is classified according to its features. The gear's type is storage in a queue, which is used to activate the corresponding pneumatic cylinder effector be active. The pneumatic cylinder effector quickly pushes the gear into the corresponding storage box when the photoelectric sensor at the position of the storage box detects the gear according to the sequence in the queue.

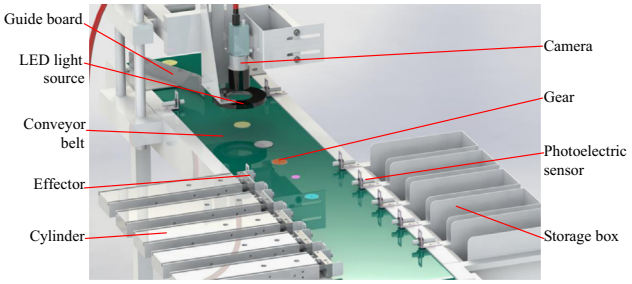

Fig. 1 The sketch of automatic gear sorting system.

Fig. 2 Different kind of gears.

3. Image processing and feature extraction

As shown in Fig. 2, different kinds of gears have different number of holes, teeth or different colors. So these three features can be used to uniquely determine the gears' categories. The number of holes is the number of holes inside the gear, tooth number is the number of the gear's teeth and the color value is the average color value of the gear's surface in RGB space.

The flow diagram for extracting the three features of a gear in an image obtained by the CCD camera is shown in Fig. 3. It consists of three steps including color extraction, hole number extraction and teeth number extraction.

3.1. Color extraction

The gear's average color values for different types of gears are extracted before detection. The gear area of the color image is obtained by image segmentation according to the color of the back ground. Then the gear's average color values (V_{Rj}, V_{Gj}, V_{Bj}) are calculated, j is the class of different gears, it is in the range of [1, N_c] and N_c is the total number of classes.

In the process of detection, the average RGB values (V_R, V_G, V_B) in the gear area of the color image obtained by CCD camera are calculated. The minimum Euclidean distance L_j is used to discriminate the classification of the gear. The class j with the smallest Euclidean distance is taken as the gear's class if $L_j < L_T$, L_T is the threshold of the Euclidean