A Novel Machine Vision Algorithm for a Fast Response Quality Control System

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Abstract

We are investigating the design of machine vision algorithms for real time inspection of filter components for quality assurance. Filter components are rigid 3D objects with predefined geometry so that a good deal of knowledge can be incorporated into the system design. However, while the objective is to reason about 3D structure, current machine vision techniques only allow the acquisition of 2D object descriptions and this is normally referred to as a 3D-2D correspondence problem. We have investigated geometrical techniques in 2D and in 3D and have developed a novel method to analyse rigid body transformations that have been successfully applied to machine vision calibration problems. In this paper, we first describe a geometrical analysis of image correspondence applied to 2D rigid body transformations. We then develop a novel calibration algorithm that, given a 3D model of an object and a set of 3D-2D image correspondence points allows the calibration of all transformation parameters of interest. The calibrated parameters can then be used to verify the physical dimensions of the object under inspection. For a comparative analysis, we also develop a calibration algorithm based on epipolar geometry applied to the same task. Experimental results have shown that our novel algorithm performs much better than the algorithm based on epipolar geometry and that it is well suited to the real time requirements of the task.

1 Introduction

The research reported in this paper is concerned with an industrial application of 3D machine vision to quality inspection. We are investigating the design of a real time, automatic vision system for inspection of filter components in a manufacturing line. Several types of filter are manufactured by our industrial collaborator, including filters for petrol and diesel engines, pollution control, and other industrial applications. Variations in size and shape for each kind of filter are significant aspects to be incorporated into the system design. The main parameters of interest, which vary widely for different kinds of filter, include physical dimensions such as width, height, depth, and diameter. The task requirements in terms of speed and accuracy are demanding: production levels stand at around 4 million filter units per year where each filter – a 3D object – must be inspected at the production line in just 1.8 seconds, and that includes setting-up time, image acquisition, processing, and flagging out of defective components. Typical accuracies are described in terms of deviation from standard values which are $\pm 0.5\%$ of the expected value for any measurement. While some parameters can be rigorously controlled, others are more problematic such as thermal properties of metallic heating plates. These plates are used to bake a polystyrene compound whose final configuration depend on the baking temperature, amount of compound dispensed, and baking time.

Through analysing the essence of the problem, given that our aim is to verify conformance to specifications in terms of filter dimensions within stringent performance requirements, a good deal of knowledge can be incorporated into the system. For instance, filters can be mechanically driven to predefined positions in a reference coordinate frame and a camera would acquire images from a known, suitable place. Once the camera has been installed, the theoretical orientation and position of the camera in the reference coordinate frame together with the depth of each visible point on the filter in the camera centred coordinate frame can be exactly determined, as we have full knowledge of the 3D structure of an ideal filter. Thus, a real time automatic inspection of filter production would only require the acquisition of 2D image data. This reduces the problem to the determination of which points on the 2D image correspond to points on the 3D filter in the reference coordinate frame. This is called a 3D-2D correspondence problem and landmarks can normally be used to determine such correspondences.

Many algorithms have been proposed to solve 3D-2D problems, such as techniques based on conservation of distance [2], triangular geometry [9], [12], iterative least