Chapter XX
Intelligent Laser Scanning of 3D Surfaces Using Optical Camera Data

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ABSTRACT

In CAD/CAM, reverse engineering involves obtaining a CAD model from an object that already exists. An exact replica can then be produced, or modifications can be made before manufacture. Single-perspective triangulation sensors provide an inexpensive method for data acquisition. However, such sensors are subject to localised distortions caused by secondary reflections or occlusion of the returning beam, depending on the orientation of the sensor relative to the object. This chapter describes an investigation into integrating optical camera data to improve the scanning process and reduce such effects, and intelligent algorithms, based on image analysis, which identify the problem regions, so that the sensor path and orientation can be planned before the scan, thereby reducing distortions.

INTRODUCTION

Ideally an object is designed on a CAD system to provide the data needed to control the CAM equipment to manufacture the object. However, there is often a need to copy objects for which no prior CAD data are available, for example, when making replacement parts. Machining such objects by hand is possible but expensive, as is redesigning the objects on a CAD system. Therefore there is a real need for an inexpensive method for generating the required data from the object which maintains an acceptable degree of accuracy.

One approach is to use a laser sensor to measure the surface. Unfortunately, laser scanning is subject to localised distortions, which are often caused by occlusion or secondary reflections of the beam, depending on the orientation of the laser head relative to the object. Without prior knowledge of the object, a 'blind' scan must be implemented. We have investigated the integration of an optical camera into the system to provide such knowledge. Image analysis allows the path and orientation of the laser sensor to be planned before the scan, thereby reducing the distortions. Scanning time can also be shortened by reducing scan resolution in 'low interest' regions.

It has been found that simple edge detection algorithms such as Canny can determine a single best orientation, but a combination of algorithms is needed to eliminate noise and create continuous edge segments, which can then be used to develop scan regions of appropriate orientation. We have developed new vectorisation algorithms to identify edge segments. Calibration of the camera image relative to the scanner is important to avoid errors. Discrepancies between scan data from different orientations can be prevented by careful calibration of the scanner rotation system.

BACKGROUND

In traditional 'forward' engineering, concepts and models are transformed into real parts. Reverse engineering starts with real parts or prototypes and transforms them into engineering models. Typically, the process begins by measuring an existing object to provide a model, in order to exploit the advantages of CAD/CAM technologies. Such techniques are used in a wide variety of applications, including medicine and animation as well as more traditional production. A typical application is the re-engineering of an existing structure for input into a CAD or other 3D modeling program, where analysis and modifications are required to make a new, improved product. The data acquisition phase is a crucial step in this procedure and data acquisition methods can be either tactile or nontactile.

Laser triangulation is a popular nontactile data acquisition method in which a laser beam is projected onto the surface of interest and the reflected spot is detected by one or more photosensitive devices. The position of a surface point is then calculated using triangulation. Laser triangulation can acquire data at very fast rates; however the technique is subject to errors, as shown in Figure 1. Before describing the types of errors that occur, we explain how the triangulation process works.

The laser scanner consists of a unit with an emitter and detector which moves over an object and outputs readings corresponding to the distance of the object from the scanner. The emitter projects a laser beam onto the object in a (normally) vertical direction, as shown in Figure 2. For ease of explanation we have based our descriptions on the assumption that the beam is vertical but the principle can equally well be used for other configurations. The sensor detects light return-

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