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Computers in Industry 44 (2001) 105–115

COMPUTERS IN INDUSTRY

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A multi-sensor approach to automating co-ordinate measuring machine-based reverse engineering

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Received 6 December 1999; received in revised form 26 June 2000; accepted 1 December 2000

Abstract

Co-ordinate measuring machines (CMMs) have been widely used in industry for reverse engineering. In an ideal reverse engineering system, the object would be automatically digitised, the data would be segmented into constituent surface patches, and an accurate solid model would be generated. However, at present, the time-consuming manual digitisation of many objects discourages the implementation of reverse engineering. As a major step toward attaining this goal, a charged coupled device (CCD) camera and a CMM touch probe digitiser are used together in a novel reverse engineering process. Neural network based stereo image processing is used to locate the object in the CMM work space, and to generate the CMM touch probe path. Precise data is then collected using the CMM touch probe, from which a CAD/CAM model can be constructed.

Keywords: Machine vision; Reverse engineering; CMM programming; CAD/CAM; Neural networks

1. Introduction

The process of creating a geometric CAD solid model from an existing physical part is often referred to as geometric reverse engineering. Using 3-D data collected by a tactile probe that is mounted on a machine tool or a co-ordinate measuring machine (CMM), a CAD model can be created and employed in many subsequent manufacturing processes. Reverse engineering applications can range from the creation of drawings for an aircraft turbine engine air intake [1] to the digitisation of a telephone handset for the creation of a plastic injection mold [2]. An in-depth review of reverse engineering is discussed in a paper by Varady et al. [3].

Reverse engineering methods currently require that the CMM operator, through the use of a pendant, to manually guide a digitising sensor to gather hundreds, or possibly thousands, of data points on the object to accurately define surface contours. This is a slow process, requiring the use of an expensive piece of equipment for what can be from hours to days. Although research has been done in the past on directing a CMM from CAD data [4] and using a machine vision data to calculate the orientation of a part on the CMM [5,6]. Research in directing a CMM without prior knowledge of the part shape has not been found. In this paper, a solution to this problem is presented that utilises stereo vision to generate the necessary spatial information to plan and control the

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0166-3615/01/$ – see front matter
PII: S0166-3615(00)00087-7

movement of a tactile touch probe mounted on a computer numerically controlled CMM.

1.1. Proposed digitisation methodology

In this work, two sensors are used to digitise an object to be reverse engineered. First, a charged coupled device (CCD) camera is used as a low-level 3-D sensor, to determine the spatial location of a part on the CMM bed and to recognise individual surface patches on the object's surface. Precise 3-D information is then collected using a CMM touch probe. By using both the CCD camera and the CMM touch probe together, the following two main advantages are realised.

- The tool path for the CMM touch probe can be programmed off-line, saving valuable machine time on the CMM, and providing a more efficient use of the CMM system.
- Different surfaces and types can be pre-determined before digitisation by the touch probe, thus, allowing the use of specialised touch probe routines.

A pair of images must be taken for each side of the object for which surface data is required. Typically, stereo images from the top, front, back, left and right sides are taken with the CCD camera. Surface patch location is achieved by matching the segmented patches between the stereo image pairs. A Kohonen neural network base segmentation algorithm is used to segment the CCD images. Fig. 1 graphically illustrates the two sensor reverse engineering process.

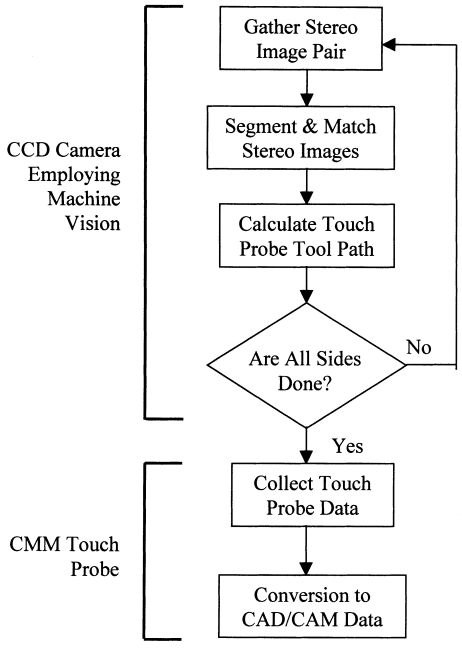

Fig. 1. Two sensor reverse engineering process.

1.2. System description

A Renishaw touch probe system is mounted on the z-axis arm of a gantry style CMM end effector for the collection of 3-D data. The system components are outlined in Table 1.

A silicon graphics indy (SGI) work station is used for video image capturing and processing. A personal computer connected to the CMM controller to allow for programmed armature movements of the CMM. A photograph of the CMM touch probe and the mounted CCD camera is shown in Fig. 2 and Fig. 3 illustrates the interconnection of the major components in the system.

2. Applying stereo vision for object localisation

The CMM is employed to provide an accurate and repeatable platform from which the stereo image pair can be gathered. This allows the CCD camera to be in

Table 1
Equipment specifications

Equipment	Specifications
Mitutoyo BHN710 CMM	Working volume: 700 mm × 1000 mm × 600 mm, encoder resolution: 0.5 mm, controller: CMMC 35
Renishaw touch trigger probe	PH8 probe head, TP2 touch probe maximum repeatability at stylus 0.35 mm
Black and white CCD camera	NEC model TI-324A, 380,000 pixels, Computer 8.5 mm f/1.3 close focus lens
PC	386 based PC, linked to CMM controller
Work station	Silicon graphics indy, VINO video capture board