A Perception Framework for Inspection and Reverse Engineering

Tarek M. Sobh, Mohamed Dekhil, Chris Jaynes, and Thomas C. Henderson

Department of Computer Science
University of Utah
Salt Lake City, Utah 84112

Abstract

We address a perception framework for intelligent inspection and reverse engineering in this work. In particular, we investigate the use of discrete event dynamic systems (DEDS) to guide the sensing of mechanical parts. We introduce dynamic recursive finite state machines (DRFSM) as a new DEDS tool for utilizing the recursive nature of the mechanical parts under consideration. The proposed framework uses DRFSM DEDS for constructing an observer for exploration and inspection purposes. We construct a sensing $\longrightarrow$ CAD interface for the automatic reconstruction of parts from visual data. We also implement a graphical interface for designing DRFSM DEDS controllers.

1 Introduction

In this work we construct a framework for solving a class of inspection and reverse engineering problems. We use an agent to sense the environment and to feed the relevant data to a control module that makes design and sensing strategy choices. We use a recursive dynamic strategy for exploring machine parts. A discrete event dynamic system (DEDS) framework is designed for modeling and structuring the sensing and control problems. The dynamic recursive context for finite state machines (DRFSM) is introduced as a new DEDS tool for utilizing the recursive nature of the mechanical parts under consideration.

The autonomous sensing system can be modeled efficiently within a DEDS framework. DEDS are dynamic systems in which the use of discrete control events ensure stability and observability [1]. It is possible to *control* and *observe* hybrid systems (systems that involve continuous, discrete and symbolic parameters) under uncertainty using DEDS formulations [1,2]. The Dynamic Recursive Context for Finite State Machines (DRFSM) is a new methodology to represent and implement multi-level recursive processes using systematic implementation techniques. By multi-level process we mean any processing operations that are done repetitively with different parameters. DRFSM has proved

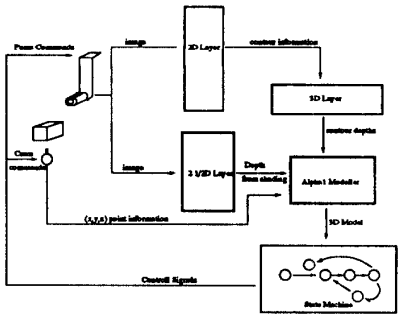

Figure 1: The role of CAD in inspection

to be a very efficient way for solving many complicated problems in the inspection paradigm using an easy notation and a straight forward implementation, especially for objects that have similar multi-level structures with different parameters (like machine parts, which have closed contours that can be explored recursively as new parts.) The main idea of the DRFSM is to reuse the conventional DEDS Finite State Machine for a new level after changing some of the transition parameters. After exploring this level, the DRFSM DEDS will retake its old parameters and continue exploring the previous levels.

We design an automatic interface that transforms visually sensed data into a CAD model for subsequent inspection and/or manufacturing. We also modify an existing graphical reactive behavior design tool to facilitate the construction of software DRFSM DEDS controllers.

2 Methodology

We use a B/W CCD camera mounted on the tip of a robot and a coordinate measuring machine (CMM) probe with the necessary interface to a Sun Sparcstation as the sensing machines. The DRFSM DEDS controller guides the movable camera into the relevant features of the mechanical part under consideration recursively. The part is then probed by the CMM probe and an illumination table is formed for getting measurements in the feature-less regions of the part. The sequence of

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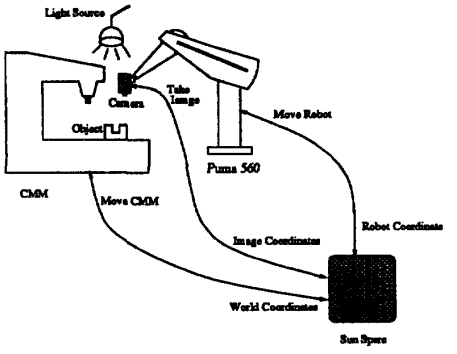

Figure 2: Inspection and Reverse Engineering

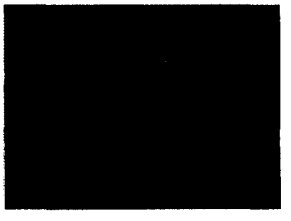

Figure 3: A part used for CAD reconstruction

visual events occurring in the recursive system is observed in order to determine the state of the inspection machine.

An automatic interface uses the recursive definition of the recovered features, the estimated depths and the contour points and creates a CAD model of the part, which is to be used for subsequent manufacturing and/or inspection.

3 Results

Figure 1 illustrates the role of CAD in the inspection and reverse engineering paradigm. Figure 2 illustrates the machines' connection. Figures 3 to 6 depicts reconstruction results for two parts.

References

[1] C. M. Özveren, *Analysis and Control of Discrete Event Dynamic Systems : A State Space Approach*, Ph.D. Thesis, Massachusetts Institute of Technology, August 1989.

[2] T. M. Sobh, J. Owen, C. Jaynes, M. Dekhil, and T. C. Henderson, *Active Inspection and Reverse Engineering*, Technical Report UUCS-93-007, Department of Computer Science, University of Utah, March 1993.

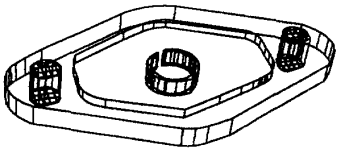

Figure 4: A rough model extracted from vision

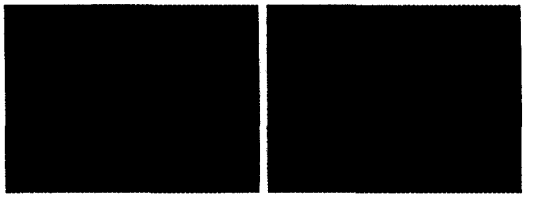

Figure 5: Two stereo images for a mechanical part.

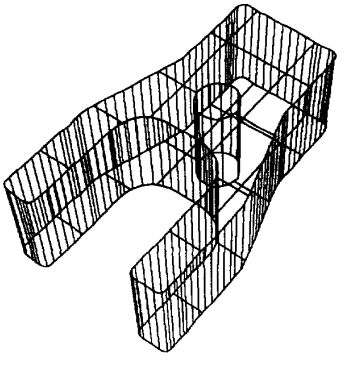

Figure 6: The recovered CAD model