To be published in the SPIE International Technical Group on Robotics and Machine Perception Newsletter.

Controller Driven VRML Animation of a Real-Time Inspection System

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Virtual objects in a web-based environment can be interfaced to and controlled by external real world controllers. A Virtual Reality Modeling Language (VRML) inspection cell was created that models a real-time inspection system The inspection system consists of a Cordax coordinate measuring machine (CMM), an inspection probe, a vision system for determining the part position and orientation, and an open architecture controller [1]. The controller performs real-time processing of sensor data for feedback control of the inspection probe. The open architecture controller permits access to data, such as the probe position and the part position and orientation, to drive a VRML model of the system.

The VRML CMM is driven by the real world controller. This is accomplished by a socket connection between the collaborator's web browser and the real world controller. When a client visits the remote access web page (Figure 1), a VRML model of the Cordax CMM is downloaded to their machine. Once the VRML model of the Cordax has been downloaded to the client's machine, only the current joint positions need to be sent across the socket from the controller (server) to the web browser (client) to move the joints of the VRML CMM model to the current controller position. All of the graphics are handled on the client machine. The data that is sent across the socket consists of 3 floating point numbers (x, y, and z position of the measurement tool center point). This information (3 floating point numbers = 12 bytes) is sent across the socket every 30 ms, giving a data rate of 400 bytes/sec. This low bandwidth is usually handled easily, even with a slow network connection.

Figure 1: Remote access page with the client controllable pan/tilt/zoom camera and controller driven VRML model of the inspection cell.

The current probe position, which is stored in a world model buffer in the controller, is collected by a Java applet running on the web page. For communication between a VRML world and its external environment an interface between the two is needed. This interface is called the External Authoring Interface (EAI) [2] and it defines the set of functions on the VRML browser that the external environment can perform to affect the VRML world. In essence, the EAI provides a method for developing custom applications that interact with, and dynamically update a 3D scene. The interface is designed to allow an external program (referred to here as an applet) to access nodes in a VRML scene using the existing VRML event model.

Before a part can be inspected, the coordinate transformation between the part coordinate system and the machine coordinate system must be calculated during a setup process. The vision system automates setup using monocular vision for parts with 2D features. The automated setup algorithm consists of an image processing algorithm and a pose estimation algorithm. The image processing algorithm, called Lola [3], produces line segment features and constant curvature arc features. The pose estimation algorithm matches sensed with model features and performs pose clustering and pose verification (Figure 2).

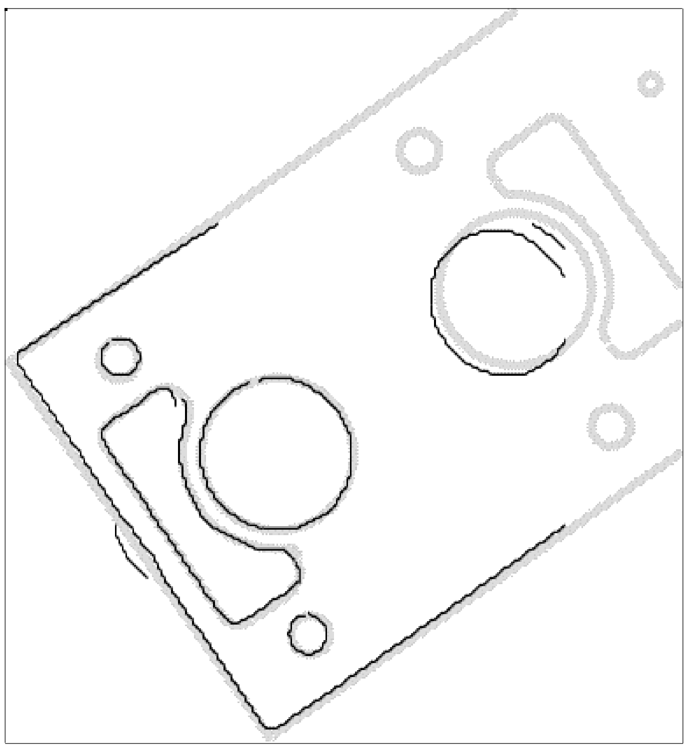

Figure 2: The black features are the sensed features and the gray features are model features translated and rotated by the computed pose estimate. Note that a correct match is made in spite of warped, occluded, and spurious sensed features.

The matching segment relates the problem of finding a correspondence between sensed and model features to that of finding a word in a dictionary. A dictionary of words is formed where the letters consist of translation and rotation invariant geometric attributes of all possible sets of k model features. Each word in the dictionary is sorted by canonical order of the letters within the word and the entire dictionary is sorted according to the canonical order of the words. At run-time, $k < s$ sensed features are randomly selected from s sensed features. The sensed word is formed and all matches between sensed and model words are found. After the part position and orientation is obtained from the vision system, it is then updated in the VRML model to represent the part's real world position and orientation.

The remote access web site also contains a client-controlled pan/tilt/zoom camera which sends video to the client. This allows a client to monitor a remote inspection with a PC and an internet connection. The video within the remote access page is a server-pushed JPEG image with an imagemap overlaid on it. The resolution of each image is 320 x 240 pixels. Each image is fairly large (20 Kbytes), therefore, frame rates are slow (1 frame per second). Each image of the video has an overlaid imagemap, allowing the collaborator to click on the image where the new center of interest should be. The required pan/tilt angles are calculated and the camera moves to recenter the image.

DISCLAIMER:

Certain commercial equipment, instruments, or materials are identified in this paper, Such identification does not imply recommendation or endorsement by NIST, nor does it imply that the materials or equipment identified are necessarily best for the purpose.

References:
[1] Horst, John, *"Architecture, Design Methodology, and Component-Based Tools for a Real-Time Inspection System"*, The 3rd IEEE International Symposium on Object-oriented Real-time distributed Computing (ISORC 2000), Newport Beach, CA, March 15-17, 2000

[2] External Authoring Interface Working Group: http://www.vrml.org/WorkingGroups/vrml-eai/

[3] Sarkar, S. and Boyer, K. L., "*Perceptual Organization in Computer Vision: A Review and a proposal for a Classificatory Structure*," IEEE Transactions on Systems, Man, and Cybernetics, vol. 23, no. 2, pp. 382-399, Mar. 1993.