THE OEBSYS BINARY MATCHING SYSTEM

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INTRODUCTION

Automatic visual inspection technology developed in the mid 1970's as an outgrowth of general computer vision research. By 1980 there were around 100 companies in the United States and a few in Europe which specialized in automatic inspection. That was followed in the mid-1980's by a period in which a number of companies failed, especially in the United States. One of the principal reasons for their failure was the unexpectedly high cost of implementing inspection systems for companies with very specialized requirements, the technology for which could not be reused easily for other applications. A second cause for failure was the high cost of inspection technology which could not be justified by the companies for which it was developed. Even companies such as Machine Vision International which had developed its own processors and morphology-based technology eventually left the marketplace.

There are a number of different dimensions for classifying inspection systems - sensor type, image type, reference model, and inspection task, and the technologies utilized for the different types of systems differ widely. Most of the inspection tasks today are 2-dimensional low-resolution inspection tasks in which the inspection system must determine whether or not a particular set of features is present in the image. A typical example of such a system would use a low-resolution video camera to acquire a 2-dimensional image of a component, determine the component location and orientation, and then determine whether the desired holes were present in the expected locations or whether a label had been attached.

The OEBSYS system addresses the particular market niche consisting of applications that require extremely high accuracy geometric measurements over large spatial areas. An attractive feature of OEBSYS is its achievement of high performance on a low cost computing platform (the PC/AT). Even today there are not to my knowledge any other general systems of its type. OEBSYS is a binary matching system in which a workpiece is scanned by a linescan sensor, converted to a 2-level black/white image, and then compared picture element by picture element with a similar scan of a standard reference workpiece. Binary matching technology is the oldest inspection technology, but the OEBSYS implementation combined that technology with a number of important innovations:

* High performance on a low cost computing platform was achieved by a specially designed sensor system that converts the scanned image into a compressed form called a runlength encoded image. The encoded image is matched against the reference image without decompression, resulting in an extremely high matching rate.

* High resolution was achieved by the use of multiple linescan sensors. Linescan sensors with resolution of over 3,400 picture elements have been available for a number of years. Due to manufacturing difficulties it has been impossible to produce area sensors at any comparable resolution. The use of lower resolution sensors would require either a prohibitively large number of sensors or a prohibitively expensive motion control mechanism.

* The matching system in OEBSYS utilizes a third image in addition to the images of the workpiece and reference piece. This is called a DON'T-CARE (or just DC) mask, and it is used to select the picture elements to be matched. The DC mask is fundamentally important because it allows the system to ignore variable or unimportant regions of the workpiece. A mask editor is provided for defining these regions, and a special automatic facility is provided for masking out edge boundaries whose image values are unreliable due to their spatial proximity to the edges of the regions in the workpiece.

* The sensor system is especially designed to facilitate system setup by providing oscilloscope outputs for monitoring the video signal. The video signal is multiplexed with the binary threshold reference level so that the light level can be monitored and so that video signal can be directly compared with the threshold level.

* The sensor system in OEBSYS automatically compensates for the gain and offset for each camera picture element so that lighting and camera variations can be removed completely.

THE SWISS PROTOTYPE

An early prototype of the OEBSYS software was deposited in Switzerland in July, 1987. This software was designed and programmed by ICRA in Blacksburg, Virginia and supported the single buffer line scan camera system designed by Frank Greenlee and implemented by Don Queijo in Blacksburg. Each board with a single camera was capable of scanning at a rate of up to 775 scan lines per second provided sufficient illumination was available. The system was fully functional, and in June, 1987, a paper, Precision of Binary Matching Systems, was presented in Lugano. This paper presented upper bounds on the inspection accuracy achievable from this system; it should be noted that in reality, performance on the average is substantially better even than these bounds. This paper also presents all the operational considerations for a binary matching system such as this one that need to be taken into account in the design of the lighting system, the physical environment, and the system integration.

Two aspects of this system are fundamentally important to those responsible for system/application integration:

* A binary matching system such as this makes dimensional comparisons across all portions of the workpieces, and that requires that the workpieces have dimensional stability and are not subject to dimensional deformations that exceed the desired accuracy tolerances.

* The camera system did not at this time support pixel-by-pixel gain and offset compensation. This required either that the lighting system have adequate uniformity and stability or that the workpiece images have high contrast, such as that which would be obtained by measuring light transmitted through the workpiece.

SUBSEQUENT OEBSYS DEVELOPMENT

Since 1987 substantial technical advances have been made in the OEBSYS implementation.

* A new generation of camera systems have been implemented by ICRA which are just now going into actual production. The new camera system is a single board PC/AT bus device with an external camera control/connection box implemented with programmable gate array devices. The system supports two cameras with a total scan line capacity of up to 65,536 pixels. Each pixel has independent on-the-fly gain and offset compensation with which to compensate for camera or illumination nonuniformities. The cameras are double buffered so that one buffer can be filled with new runlength codes from the next scan line at the same time the other is transmitted to the host computer. Special facilities are provided for on-site system setup. The previous camera control boxes and power supplies have been eliminated. Provision has been made for storing an intensity reference model in the hardware on an auxiliary memory board so that it may be matched against the workpiece as the workpiece is being scanned. Automatic gain control is provided so that long term drift in the intensity of the illumination source as well as AC ripple in the illimination may be eliminated. Finally, a window comparator has been included so that the reference may be compared with the workpiece using both upper and lower thresholds.

* The workpiece is now registered with the reference piece by using features on the workpiece itself. Thus it is no longer important if the workpiece is not completely aligned with the workpiece carrier.

* Implementation is proceeding on software that will measure the locations of features on the workpiece to determine whether or not the workpiece is deformed from the reference by linear expansion/contraction or by a small angle rotation. The matching system then takes into account these transformations. The theory for this is found in the SDAL technical report, Fast Geometric Transformations for Matching Algorithms.

* The system is now based upon PC/AT platforms whose performance/price ratio is an order of magnitude better than in 1987, and the hardware/software platform performs image matching at up to 5,000,000 pixels per second.

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