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Performance analysis and optimisation of shape recognition and classification using ANN

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Abstract

Machine vision systems are being increasingly used for sophisticated applications such as classification and process control. Though there is significant potential for the increased deployment of industrial vision systems, a number of important problems have to be addressed to sustain growth in the area of industrial machine vision. Artificial neural networks (ANNs) coupled with machine vision systems offer a new methodology for solving difficult computational problems in many areas of science and engineering. As a consequence, the research work presented in this paper investigates several novel uses of machine vision and ANNs in the processing of single camera multi-positional images for 2D and 3D object recognition and classification. Many industrial applications of machine vision allow objects to be identified and classified by their boundary contour or silhouette. Boundary contour information was chosen as an effective method of representing the industrial component, a composite signature being generated using vectors obtained from the generation of multi-centroidal positions and the boundary pixels.

The composite signature can be re-sampled to form a suitable input vector for an ANN. Three different ANN topologies have been implemented: the multi-layer perceptron (MLP), a learning vector quantisation network (LVQ) and hybrid self-organising map (SOM). This method of representing industrial components has been used to compare the ANN architectures when implemented as classifiers based on shape and dimensional tolerance. A number of shortcomings with this methodology have been highlighted, most importantly the identification of a unique sequence start point, vital for rotation invariance. Another problem may arise due to the conflict between the inherent robustness of ANNs when dealing with noise, and classifying components which are similar but display subtle dimensional differences.

1. Introduction

With escalating pressure being placed on industry to, increase efficiency, improve quality and reduce cost, the need for more flexible and "intelligent" inspection systems has never been greater [1–14]. An important milestone in the development of "intelligent" inspection systems has been the rapid growth of computing power in recent years, coupled with the idea that we could successfully emulate the low-level mechanisms of the brain. The human visual system has the ability to recognise an object despite changes in the object's position in the input field, its size, or its orientation. For many industrial applications involving classification of components machine vision systems must also have this ability. A simple approach to recognition/classification of industrial components is to segment the image into two major stages, these being extraction and the actual analysis and processing stages. Many current and recent artificial neural network (ANN) classifiers require a 2D shape to be presented in a fixed position, orientation and dimension. Methods have been proposed for rotation normalisation where the network is trained with a set of rotated signatures. The network was then capable of classifying the shapes/signatures in all possible angles. However, rotation of shapes may produce disconnected decision regions leading to problems in network convergence.

The programs which attempt to emulate the low-level mechanisms of the brain are neural networks and fuzzy logic. Over the years there has been increased interest in the synergistic combination of machine vision, neural networks and fuzzy systems in the classification of industrial workpieces [15–29]. The synergism of machine vision, neural networks and fuzzy logic seems natural. This paper describes part of a continuing program

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of work developing an artificial vision system, applicable to real-time recognition/classification of industrial components.

2. Methodology

The experimental set-up used for the case studies presented in this paper follow a fairly conventional approach, as shown in Figs. 1 and 2. The hardware was comprised of a host PC, with maths co-processor and colour monitor, colour CCD camera, image processing unit and a video monitor. The UMI RTX robot was used to position the CCD camera in the various target locations. The PC houses and controls the IPU, and the IPU (IV120C) utilises the Texas Instruments TMS320C25 digital signal processor.

Before proceeding in greater detail it is necessary to gain a very brief understanding of the basic concepts of neural networks. Neural networks have gained approval for solving problems in a way that seems natural to people [30–44], that saves the programmer from having to write exacting hierarchies of rules to define all eventualities. Instead, they elicit general rules from a set of example problems and answers, or inputs and outputs.

The majority of neural network applications focus around the techniques of auto-association or pattern matching [45–53]. Often multi-layers are used to describe the structure of the network, such as input, output and hidden layers with 'weights' adjusted during learning to give an ideal representation.

The specific approach used in this particular research program is to use algorithms of boundary information and ANNs. The neural network model partitions the input space and identifies the classes. Since neuron output has a characteristic, this input space will not be divided, even if two-valued supervised data are used for learning. This is similar to the membership function of a fuzzy set. That is, pattern identification of a neural network is similar to fuzzy partitioning of the input space.

For the management of uncertainty in rule-based systems, fuzzy logic is a powerful tool, but it imposes an increased burden on the inference engine. Neural network architectures offer a means of relieving some of the computational burden inherent in fuzzy logic. These structures can be trained to learn and extrapolate complex relationships between antecedents and consequence, they are relatively insensitive to noise in the inputs, and they provide a natural mechanism for conflict resolution. The centroidal profile representation technique was chosen to generate a boundary vector sequence, which is a suitable form of input vector for an ANN.

3. Implementation of an ANN

The input layer of an ANN has a fixed number of nodes and consequently the original boundary sequence must be re-sampled such that a relevant number of input values are obtained. In this case the distance between re-sampled boundary points is equal. However,

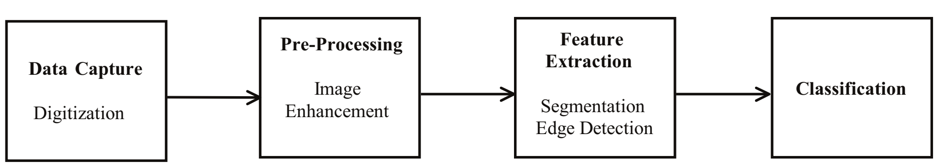

Fig. 1. Block diagram of a conventional visual pattern recognition system.

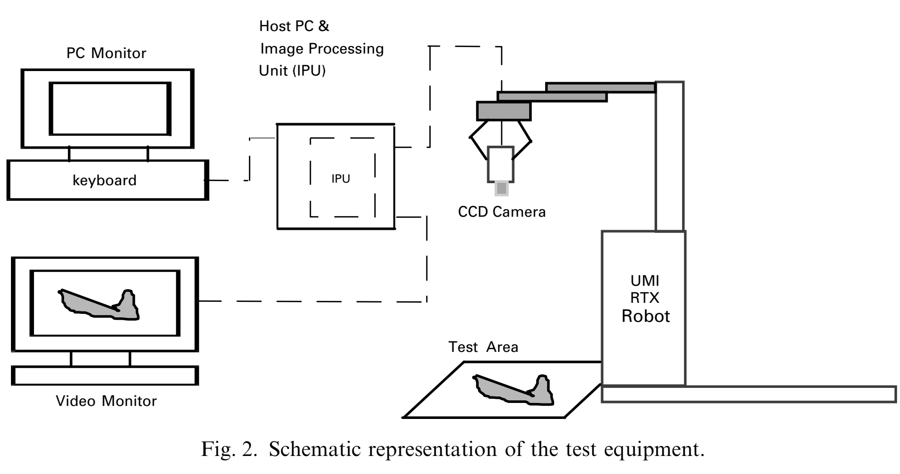

Fig. 2. Schematic representation of the test equipment.