A colour image recognition system utilising networks of n-tuple and Min/Max nodes

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Key words: image processing, image recognition, N-tuple node, MIN/MAX node

Abstract

This paper outlines the general concepts of the use of networks of 'trixel' 'n-tuple and 'Min/Max'node techniques for the recognition of coloured images.The developed software system, which also includes the options for position, size and rotation normalisation, is briefly described.
Finally, some results are presented which illustrate the performance obtainable from the developed software colour recognition system.

1 Introduction

Over the past decade there have been several collaborative links between the Dept. of Applied Electronics, University of West Bohemia and the Dept of Electrical and Electronic Engineering (now Electronic and Computer Engineering) at Brunel University.
Early work involved the recognition of complex coloured images using suitable image pre-processing and networks of n-tuple nodes [1].
Later work at Brunel indicated that networks of grouped MIN/MAX nodes , which could respond directly to multi-level (i.e. analogue) values, could also provide powerful pattern recognition properties [2,3,4,5,6]. The natural progression of this technique was to consider the recognition of coloured images and the feasibility of such a system was later proposed [7]. Consequently, under the auspices of the Erasmus Student Exchange Scheme, the design of a software system was initiated at Brunel University [8,9] but, unfortunately, due to the lack of appropriate computational resources at that time, the system was only partially operational. Subsequently, a system, which operated successfully, was implemented and included an image pr-processing stage [10] and an image recognition stage [11,12].
This system, only for historical reasons, concerning past work at Brunel over the past two decades, was designated 'Wisard ll Mk 1'. It was later modified in June 2001 to provide further functions and to make it more 'user-friendly'. At the time of writing (June 2001) the current version is Mk 1.1.
An overall block diagram of the system is shown in figure 1 and a flow diagram is shown in figure
2. The present hardware is comprised from a Matrox Meteor I Frame Grabber, a Matrox G400 graphics card and an AMD 650Mhz processor with a storage of 256 Mb.

2 Image recognition

2.1 The N-Tuple Methodology

The n-tuple methodology was originated by Bledsoe and Browning in 1959 [13] for the purpose of recognising printed characters. In principle, their technique is equivalent to that of using Single Layer Networks (SLNs) consisting of 'deterministic' logic nodes.
In its simplest form, a logic node of these SLNs can be realised by a Random Access Memory (RAM) consisting of 'n' address spaces. The pattern applied to the address inputs is comprised of 'n' sample points taken pseudo-randomly from the input data and is termed an 'n-tuple'. During training, each RAM stores the relevant sampled n-tuple 'n-bit' data words.

After training, the RAM, in ‘read’ mode, operates as a look-up table representing a full functionality logic node. The summation of the logic node outputs represents the response of that particular SLN (or ‘discriminator’).
In general, ‘n-tuple’ classifier systems operate in a multi-discriminator configuration where each discriminator can contain from several hundred to several tens of thousands of logic nodes. During training, each discriminator is trained on each class, or classes, of patterns it is later to classify. After training and when in the classification mode, the discriminator which gives a higher response than any of the others is considered to represent the correct decision. The discriminators’ responses may be represented either numerically or as a bar graph (histogram) display. It should be noted that each bar in the bar graph display represents the sum of the individual responses obtained from the logic nodes that constitute each discriminator.
In order to perform colour recognition, the networks are configured from ‘Trixel’ N-tuple nodes (TNT nodes) as shown in figures 3 and 4.

2.2 The 'MIN/MAX' node

Networks of grouped MIN/MAX nodes incorporate many of the techniques employed by the n-tuple classifier methodology. The MIN/MAX node technique may be considered similar to template matching, which measures the nearest distance of the test pattern to stored reference patterns. However, unlike template matching, for MIN/MAX nodes, no distance measure calculations are required as each MIN/MAX node operates as a simple ‘look up table’ and thereby enables fast operational speeds. Also, several training images can be stored within each net and thereby provide several patterns per class (as in an n-tuple system).
Early software and hardware implementations of networks of grouped MIN/MAX nodes at Brunel University [2,3,4,5] indicated that they provided powerful pattern recognition properties. Of importance, if sub-grouping of these nodes was implemented and variable thresholding applied to these groups, then both the generalisation and discriminatory characteristics could be controlled and optimised for specific applications.
Subsequently, work at both the University of West Bohemia and Brunel University [6,8,9,10,11,12] was undertaken to provide ‘user-friendly’ software operational systems.
In principle, during training, for the relevant class, each node stores the absolute Minimum and Maximum (MIN/MAX) values, which occur. On classification, each node will then respond with a '1' to any level between, and including, the 'MIN/MAX' values, which were stored during training. In order to improve generalisation, offsets, greater than the maximum value and less than the minimum value, may be added, or subtracted, to allow for noise, illumination, translational and rotational variations not included in the training set.
The classical n-tuple techniques adopted are in that the pixels must be pseudo-randomly mapped from the input pattern space, and a group of 'G' 'MIN/MAX' nodes corresponds to an n-tuple node; for example, if G = 8, then this is analogous to an 8-tuple node.
In order to perform colour recognition, the networks are configured from ‘Trixel’ MIN/MAX nodes (TMM nodes) as shown in figures 5 and 6.

3 Results

3.1 Examples of the results obtained

Figure 7 shows two of the typical images used for the training and testing sets. Images similar to those on the left hand side of the figure were used to trained and classify discriminators 1 and 3, and those on the right hand side used for discriminators 2 and 4. Figures 8, 9, 10 and 11 indicate some of the typical results obtainable from the system. In this example, two VHS video tape box containers were used to provide the training and test images. These boxes were chosen because they were of a similar colour and complexity, and only had minor differentiating features. The processing window and the training and recognition dialogues are displayed in the figures. These figures effectively represent two separate sets of results.

Figures 8 and 9 indicate the results obtained using monochrome images, whilst figures 10 and 11 display the results obtained when using coloured images.
From figures 8 and 9, it can be observed that the correct decision is marginal. It was also found during the experimentation that, at times, arbitrary decisions were made by the system. However, as indicated in figures 10 and 11, the correct decision levels were obtained when processing coloured images. It was also noted that, during the system evaluation, the decisions were always correct.

3.2 System performance

The operational speed of the software system is very dependent on the performance of the computer used. All rates, which are tabulated, were achieved with an AMD processor operating at 650MHz with a memory of 256Mb.

System performance without normalisation						
Image size	Number of discriminators	Coverage %	Tuple size	N-tuple speed (train./rec.)	MIN/MAX speed (train./rec.)	Combined speed (train./rec.)
256x256	4	10	6	12.81/12.84	14.29/16.95	8.57/9.03
256x500	4	10	4	8.09/8.33	9.78/10.11	5.27/5.65

4 Conclusions

Of importance, the documented results indicate that, both for networks of trixel n-tuple and MIN/MAX nodes, improved recognition performance is obtainable. However, future work must establish suitable 'benchmarks' to ascertain the effectiveness of coloured image recognition.
The 'Visual C++' software realisation of the image recognition system with the image normalisation part was developed and successfully tested. The results indicate that the software realisation is suitable for the demonstration, testing and research of both image recognition and normalisation techniques, but, as yet, it is not suitable for real-time applications. To reach a 'real-time' TV frame rate of 25 frames per second, then either the use of specialised hardware is necessary or a higher processor speed is required. For example, it is considered that many of the functions might be implemented by FPGA devices. Nevertheless, the developed system is sufficient for evaluation purposes before proceeding to any hardware implementation of the software methods employed.

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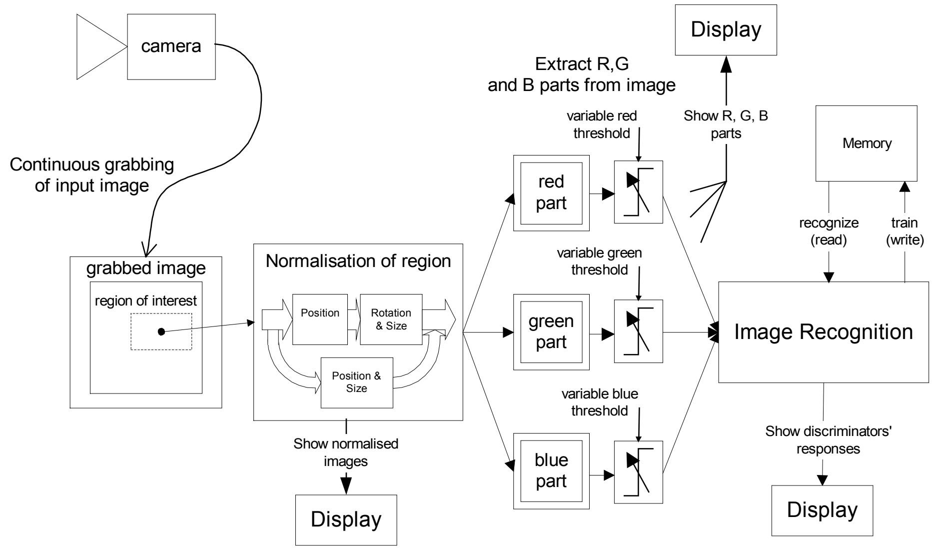

Figure 1. Overall block diagram of system

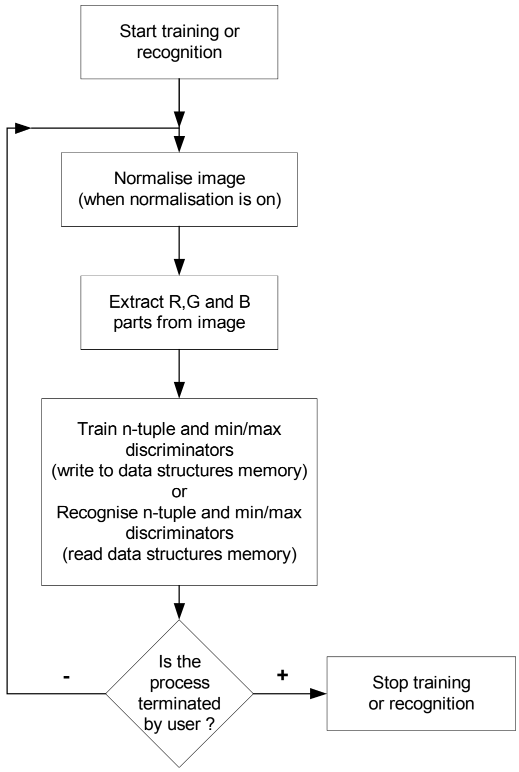

Figure 2. Flow diagram

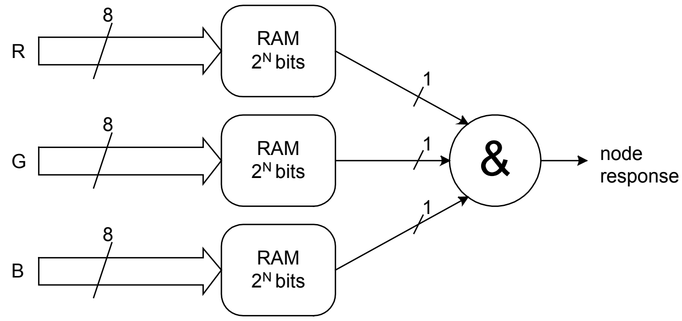

Figure 3. RGB 8-tuple node (the 'Trixel' N-tuple node)

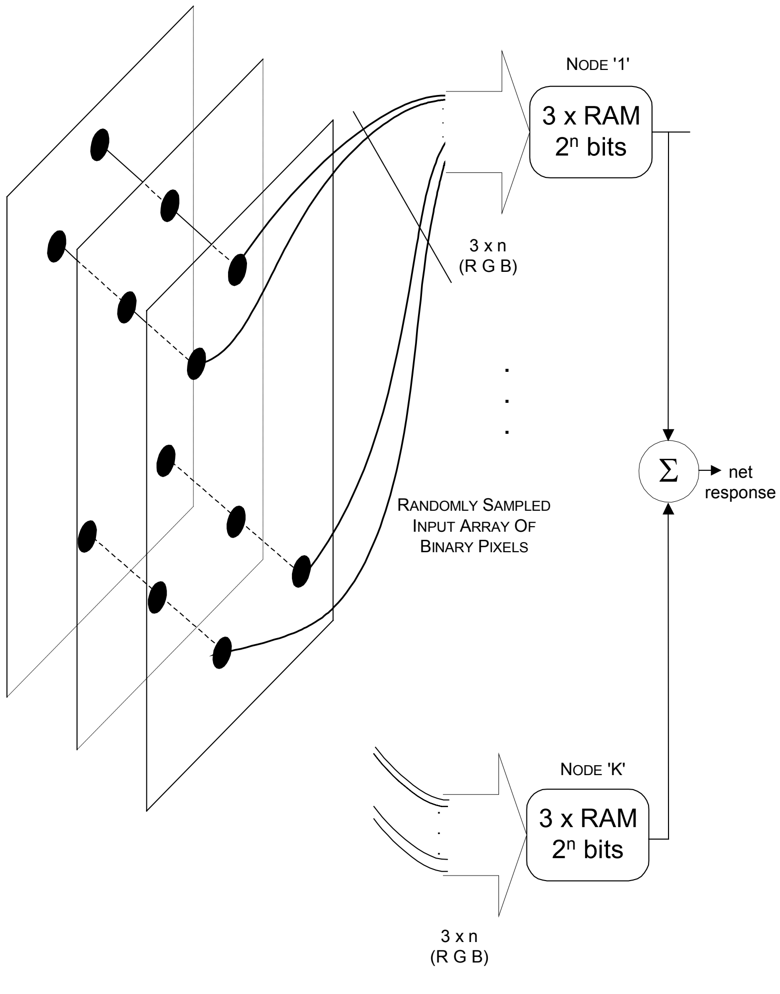

Figure 4. Single discriminator 'Trixel' N-tuple node SLN

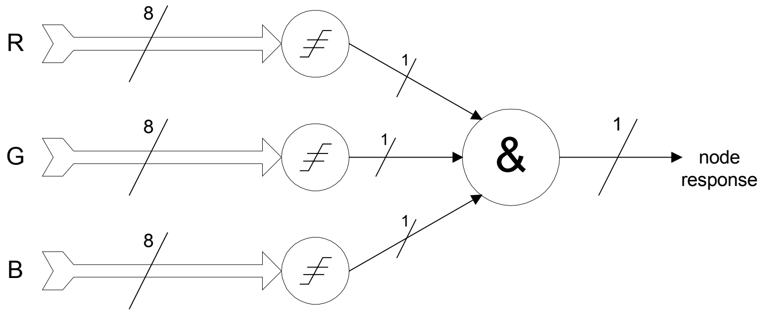

Figure 5. RGB Min/Max node (the 'Trixel' Min/Max node)

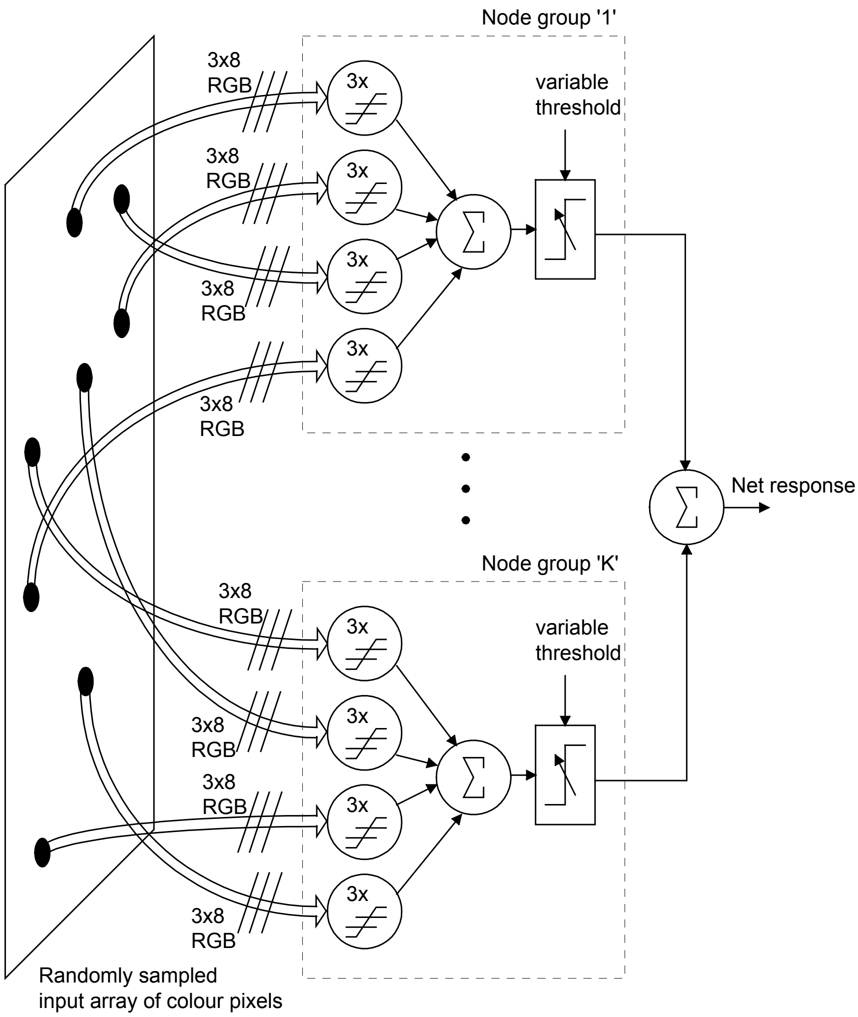

Figure 6. Single discriminator TMM node SLN

Figure 7. Archetypical images of video tape container boxes 1 & 2

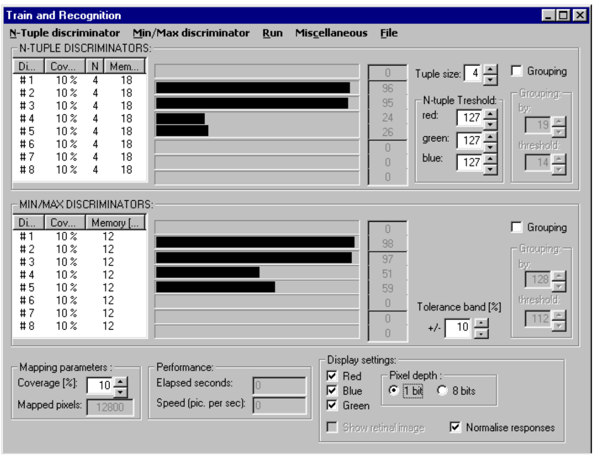

Figure 8. Monochrome responses – box 1

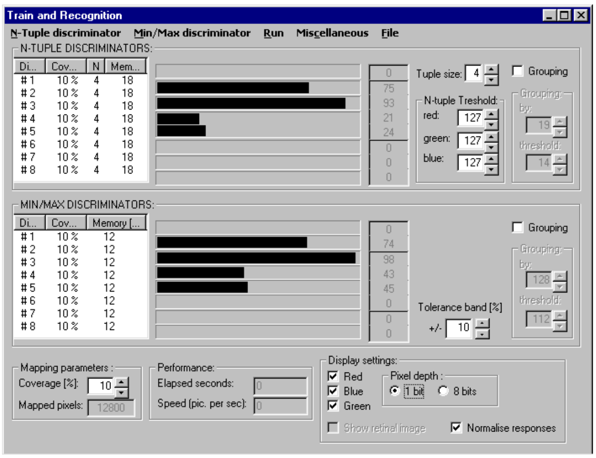

Figure 9. Monochrome responses – box 2

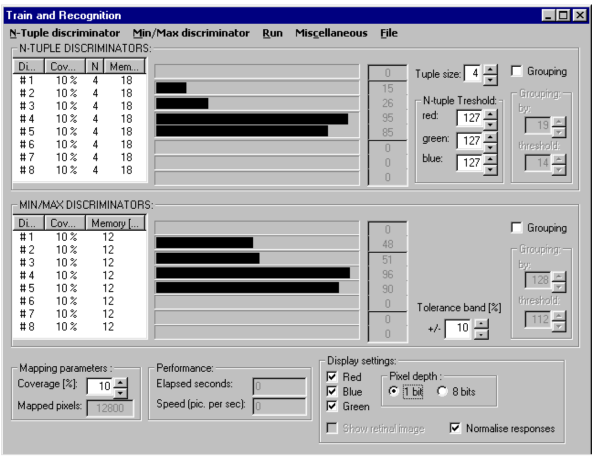

Figure 10. Colour responses – box 1

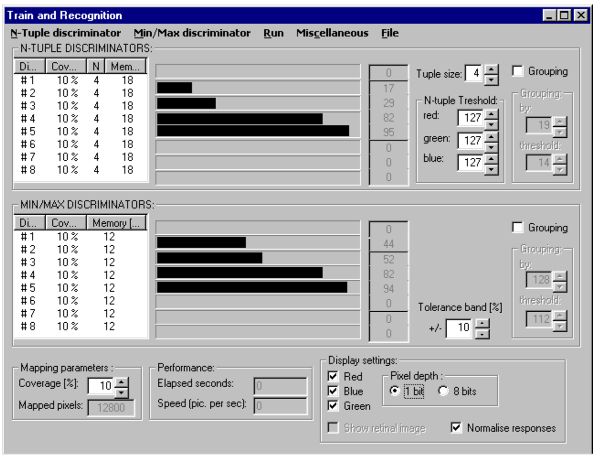

Figure 11. Colour responses – box 2