COLOUR IMAGE RECOGNITION BASED ON SINGLE-LAYER NEURAL NETWORKS OF MIN/MAX NODES

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Abstract: An image recognition system can be based on a single-layer neural network composed of Min/Max nodes. This principle is easy to use for greyscale images. However, this article deals with the possibilities of utilising neural nets for colour image recognition. Several principles are demonstrated and tested by recently developed software. A new modified Min/Max node Single Layer Net, suitable for recognition in HSV (Hue Saturation Value) colour space, is presented in this paper.

Key words: *Neural network, image recognition, Min/Max nodes, colour, face recognition*

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1. Introduction

Image recognition systems are now subject to intensive development. One of the possibilities is that of utilising neural nets. This option has been the main subject of cooperation between the Dept. of Applied Electronics and Telecommunications, University of West Bohemia, and the Dept. of Electrical and Electronic Engineering (now Electronic and Computer Engineering) at Brunel University, U.K. over the past two decades. A great part of this research work is documented in the literature [1, 2, 3, 4].

One topic of cooperation was focused on single-layer neural nets with Min/Max nodes [5, 1]. The single-layer network using Min/Max nodes is similar to the technique of Aleksander and Stonham [6] using logic nodes and based upon the original concepts of Bledsoe and Browning [7]. The network of Min/Max nodes could respond directly to multi-level values and so it could provide powerful pattern recognition properties. The natural progression of this technique was to consider the recognition of coloured images and the feasibility of such a system was later proposed [2, 3].

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Several software systems [4, 8, 9, 10] were designed which implemented the method of image recognition based on Min/Max nodes.

The possibilities of hardware realisation are presented in [9, 10, 11] where a single-layer network based on Min/Max nodes is implemented in programmable logic devices, specifically with Field Programmable Gate Arrays (FPGAs).

This present work is focused on the utilisation of neural networks based on Min/Max nodes for colour image recognition and their modification for recognition in different colour spaces.

2. Background

The method based on Min/Max nodes is very similar to template matching. The difference between template matching (which measures the nearest distance, either 'Euclidean' or 'Square', of the test pattern to the stored reference patterns) and Min/Max nodes is that no distance measure calculations are required. The Min/Max node operates as a simple 'Look-Up Table'. This is the main advantage because it allows fast operational speeds and easy hardware implementation. Also, several similar training images can be stored within each net and thereby allow for small changes in position, size, rotation and illumination.

2.1 Min/Max node

The neural networks comprise a high number of executive units; i.e. neurons. In this case, the executive unit is a Min/Max node (Fig. 1). In principle, for the relevant class, each node stores the absolute Minimum and Maximum (Min/Max) values, which occur during training. 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, an offset may be added to the maximum value and an offset may be subtracted from the minimum value. Primarily, this procedure allows for noise and minor variations of illumination which have not been included in the training set. Additionally, this also provides some generalisation for small changes of position and orientation.

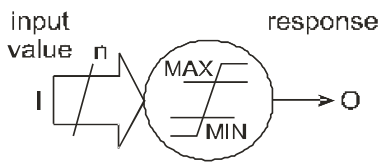

Fig. 1 *Min/Max node.*

2.2 Single Layer Network (SLN)

There are many different types of neural networks; for example, structures defining the numbers of layers, the use or not of feedback and the choice of either analogue or logic nodes. For the present purposes a single-layer network with the structure shown in Fig. 2 was used.

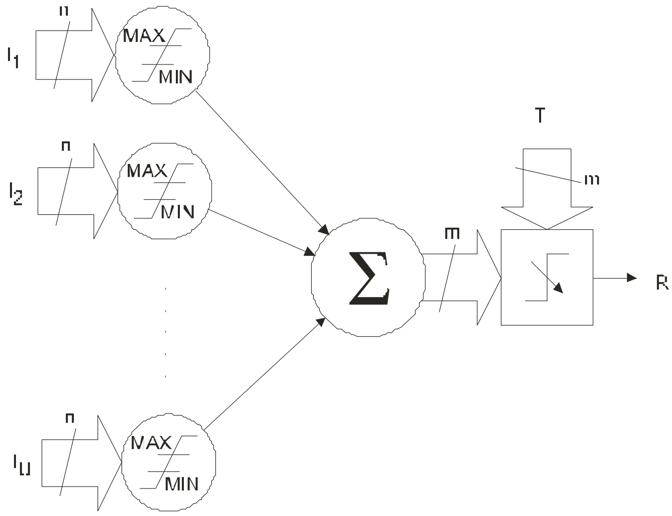

Fig. 2 *Single-layer neural network based on Min/Max nodes.*

This network is composed of one layer of Min/Max nodes. Their responses are added together by a summation unit. This summation response may be used as the ‘score’. Alternatively, this ‘score’ can be suitably thresholded by a preset value so that the final response of the network is 1 (for similar images) or 0 (for different images).

After training, the network operates as a pattern ‘detector’ and is termed a ‘discriminator’. In principle, the image recognition systems operate in a multi-discriminator configuration. In the training mode, each discriminator is trained on each class of patterns. The number of discriminators is equal to the number of classes which are defined for future classification. The classification mode can be started when all discriminators have been trained. Each discriminator gives a response to an unknown input image. The input image is assigned to the class which corresponds to the discriminator with the highest response.

3. Principles of Colour Image Recognition

A neural network based on Min/Max nodes can be used directly for greyscale image recognition because the input to the Min/Max node is a multi-level value. The question is: “How to apply this method for colour image recognition?” The possible approaches described in this work are the following:

a. Using the green colour component.

b. Conversion to the greyscale image from the RGB components.

c. Using all (R, G, B) colour components as the input space.

d. Using trixel Min/Max nodes.

e. Using HSV colour space with modified Min/Max nodes.

3.1 Using the green colour component

This is the simplest way to use neural networks based on Min/Max nodes for the recognition of colour images. This method directly applies the multi-level value of the green input image to the Min/Max nodes. The green component is used because it is the most significant one in a colour image and, to human visual perception, roughly approximates to a monochrome (greyscale) image. It is evident from equation (1) that this approach (assuming separate R, G and B components) compared with that of (b), requires no further processing of the input image.

3.2 Conversion to greyscale image

More accurate than the previous method is the use of conversion to a greyscale image in accordance with equation (1) because it covers the influence of all the colour components. The acquired greyscale image is afterwards used as the input image for the neural net.

$$GS = 0,299 \cdot R + 0.587 \cdot G + 0.114 \cdot B \tag{1}$$

3.3 Using all (R, G, B) colour components as the input

This method is very simple and, similar to using the green colour component, it does not require any colour conversion. In principle, the input multi-level value is pseudo-randomly mapped from all colour components (see Fig. 3). This method takes into account all (R, G, B) components of the input image but without any additional 'weightings'.

This principle was used with n-tuple logic nodes using a Multi-Bit Plane Frame Store (MBPFS) more accurately a MBP Field Store, constructed by Roth in 1989 [12]. Originally, it was designed to enable stereoscopic recognition with 2 gen-locked cameras (i.e. 2 planes of the output from the MBPFS could be pseudo-randomly mapped for each discriminator).

As 4 planes were available, it was possible to gen-lock 4 cameras and thereby facilitate quadrascopic pattern recognition. Using this method each discriminator could be trained on 4 views of an object simply by pseudo-randomly mapping throughout the 4 planes.

Additionally, each plane consisted of 4 sub-images with the option of representing either the 4-bit binary encoded image or the 4-bit gray encoded image. Therefore, pseudo-random mapping could be implemented throughout any encoded 16-level greyscale image.

With colour requiring only 3 planes the MBPFS provided an ideal starting platform for colour recognition and this technique utilising n-tuple logic node nets was used with success in 1995 [13].

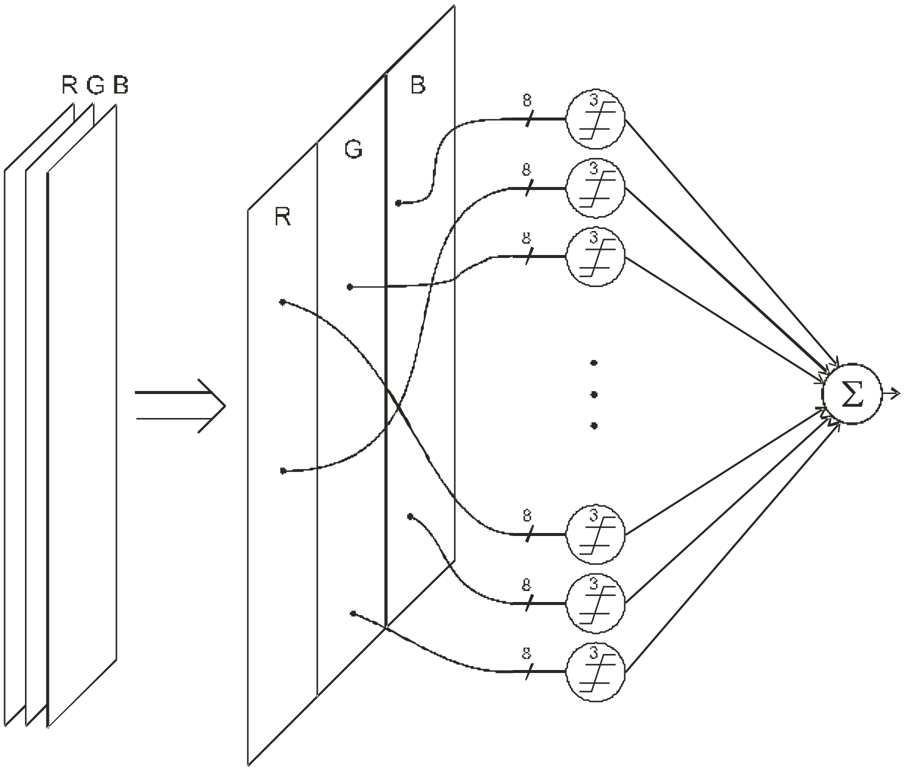

Fig. 3 *Principle of using all colour components as the input.*

3.4 Using trixel Min/Max nodes

The previous method uses all colour components but each Min/Max node can be trained on one component only. This disadvantage is tackled by using trixel Min/Max nodes. This approach samples all colour components of the pseudo-randomly mapped pixels of the input image. This solution is discussed in many publications [2, 3, 4, 8]. The 'trixel' Min/Max node, shown in Fig. 4, is composed of three Min/Max nodes, each for one colour component, and a logical AND operation which generates the final response of the node. The number of 'trixel' nodes is equal to the number of pixels in the patterns which are used for training.

3.5 Using HSV colour space with modified trixel Min/Max nodes

HSV (hue-saturation-value), HSL (hue-saturation-lightness) and HSI (hue-saturation-intensity) colour spaces belong to a group of HSL type colour spaces. They are the three most common cylindrical-coordinate representations of points in an RGB colour model. Unfortunately, these definitions are not standardized and there are several different cylindrical models with these abbreviations. HSL type spaces are more intuitive for humans and they are used widely in computer graphics.

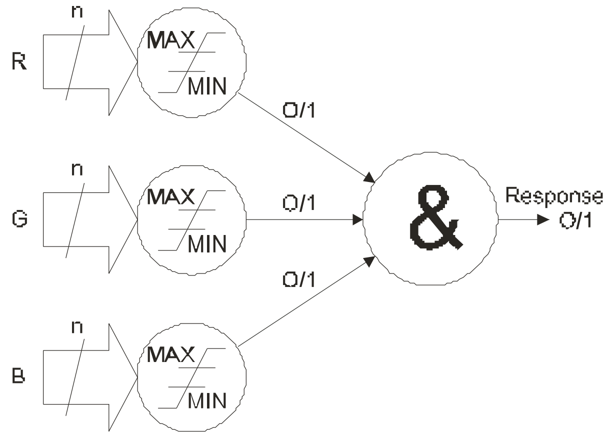

Fig. 4 *Trixel Min/Max node.*

Colour space HSV, which is used in this work, is given by the definition in MATLAB documentation [14].

One of the goals of this work was to try HSV colour representation for image recognition based on neural nets. For this purpose, it was necessary to modify the general Min/Max node. It follows from the HSV representation where the H (**H**ue) colour component has a wrap-around effect. This means that a small difference in colour (near red) may cause a change of hue from the minimum value to the maximum value. For this reason, it is not possible to use standard Min/Max nodes because the small difference in colour causes the saturation of a given node. The novel principle of the modified 'Hue' Min/Max node is shown in Fig. 5 where it is possible to compare behaviours of this node with the standard Min/Max node. Fig. 5a presents a situation where the case of the "wrap-around effect" occurs. The state of nodes after training is shown in Fig. 5b (modified node) and Fig. 5c (standard node) where it is possible to observe a potential risk of the saturation in the case of standard node and relatively small change in colour (red hues – Hue is around 0 degrees).

Mathematical description of nodes is following:

$$O = f(i) \tag{2}$$

Where

O logic output value of node (0 or 1)

i n-bits input value from set $\{i \in \mathrm{N} | i < 2^n\}$

Function $f(x)$ is defined for a standard node or a modified node with condition MIN value is less or equal to MAX value as

$$f(x) = \begin{cases} 0, & x \in [0, MIN) \vee x \in (MAX, 2^n] \\ 1, & x \in [MIN, MAX] \end{cases} \tag{3}$$

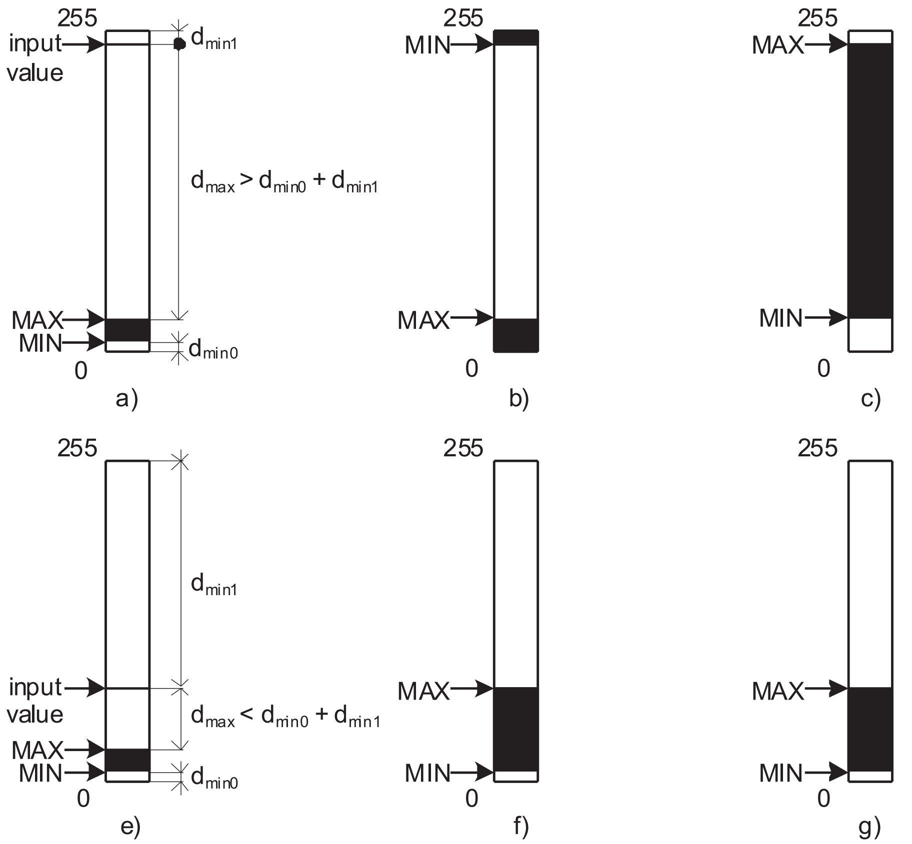

Fig. 5 *Principle of the modified Min/Max node in comparison with the standard Min/Max node.*

And for a modified node with condition MIN value is greater than MAX value as

$$f(x) = \begin{cases} 0, & x \in (MAX, MIN] \\ 1, & x \in [0, MAX) \vee x \in [MIN, 2^n] \end{cases} \tag{4}$$

The principle of SLN for pattern recognition in HSV colour space is based on the utilisation of a modified Min/Max node for the colour component H, and standard Min/Max nodes for the components S and V. The concept that the results of Min/Max nodes are logically ANDed is left unchanged.

4. Software Used for Testing

As outlined in Section 3, several SW (software) systems for testing neural nets based on Min/Max nodes have been designed [8, 4, 9, 10]. These systems are able to test the recognition of greyscale images or colour images with trixel Min/Max nodes.

A new SW system has been developed for testing new methods for colour recognition. This system, which is based on MATLAB, can test and compare the methods mentioned above. The program supports a technique for improving the response by adding tolerance bands, changing the input mapping coverage and displaying the colour components of the input image. The maximum number of discriminators is five. The system works with input images in either bmp, tif or jpg format. A screenshot is shown in Fig 6.

Fig. 6 *Screenshot of the developed system.*

5. Tests and Results

For the testing of colour image recognition, the images of human faces from the VidTIMIT database [15, 16] were used. The datasets were comprised of the faces of five women with slightly rotated head positions (left, right, up and down). The number of images used for training and recognition is presented in Tab. I and examples are shown in Fig 7. The training sets and the recognition sets have similar or the same size but they contain different images.

Object	Person 1	Person 2	Person 3	Person 4	Person 5
Training set	75 images	79 images	83 images	77 images	106 images
Recognition set	75 images	78 images	82 images	77 images	106 images

Tab. I *Datasets for training and recognition.*

Fig. 7 *Examples of input images from all classes.*

The resolution of the images was 512 x 384 pixels, and the format used was JPEG with a 90% quality setting. Two different settings were chosen for the presentation of the results. Both have 10% mapping coverage and the tolerance bands were set to 0 or 5. The results are shown in Fig. 8 for tolerance bands of 0 and 5. The bar graphs in Fig. 8 indicate the minimum differences between the responses to a correct image compared with those of the other four different classes.

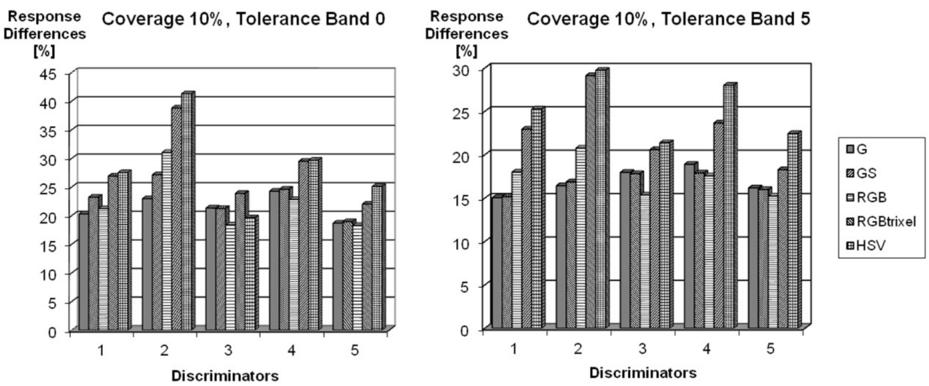

Fig. 8 *Dependencies of response differences on recognition methods.*

From these bar graphs, it is evident that the RGB trixel Min/Max nodes and modified HSV trixel Min/Max nodes usually provide the best performance. However, this performance is partially dependent on the objects and their training sets. From Fig. 9, a comparison of the results with different tolerance band settings shows that the response differences decrease with a wider tolerance band but the absolute responses increase.

It is very useful to use the 'grouping node' technique [1, 2, 3] with a high group threshold value. The grouping technique is a powerful tool for increasing response differences.

Another observation is that the wider tolerance band can be set for HSV trixel Min/Max nodes without a rapid decrease in response differences. Also, the wider tolerance band provides better tolerance in varied illumination.

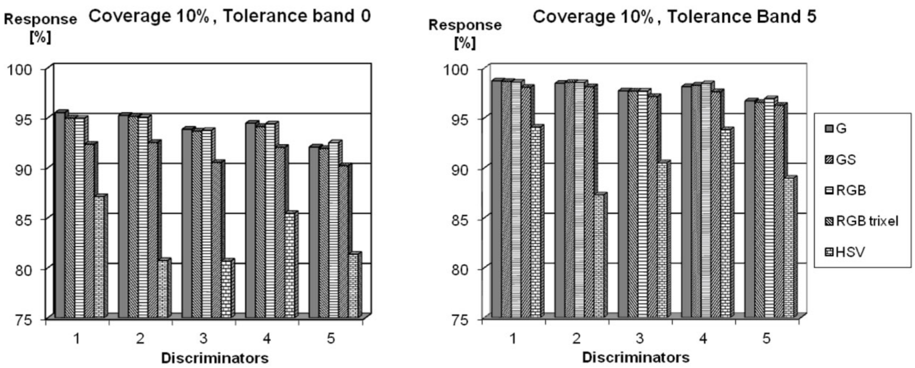

Fig. 9 *Dependencies of minimum response.*

6. Conclusions

This work presents novel approaches to colour recognition utilising single-layer neural networks based on Min/Max nodes. A new modification of the standard Min/Max node is introduced. This modified node solves the problem of the "wrap-around effect" of the H (hue) colour component and can be used in a trixel node. The neural net based on the modified trixel Min/Max node is able to recognise colour images in HSV colour space. The new SW system was developed in MATLAB and five methods of colour recognition were compared.

The results obtained indicate that, compared with monochrome; the use of colour improves recognition performance. For a relative assessment of the methods tested the response differences (confidence levels) are used. RGB trixels perform marginally better than using all RGB components as the input and it is possible to observe a slight improvement in performance by using HSV trixel nodes. This latter improvement is evident mainly in the case of the wider tolerance band. A detailed study of this effect and a comparison with other colour spaces are the subjects for future investigation.

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