The intersecting cortical model in image processing

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Abstract

The Intersecting Cortical Model (ICM), or ICM algorithm, is presented. It is a reduced set of equations of the Pulse-Coupled Neural Network (PCNN) model. The ICM algorithm is especially designed for enhancing features without sharp edges or straight lines in images. The ICM is tested on a series of images of an aircraft moving in the sky in order to detect its motion. The ICM algorithm is shown to be useful even when there is a deficiency in reference points. In another test, the ICM is applied to two images taken from a helicopter over a town area.

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1. Introduction

The Intersecting Cortical Model (ICM), introduced in Ref. [1], is a simpler version of the Pulse-Coupled Neural Network (PCNN) model of Eckhorn [2]. The ICM is based on neural network techniques and is especially designed for image processing. It was introduced as a tool for image processing that is computationally faster than the full PCNN model. It was derived from several visual cortex models and is basically the intersection of these models, i.e. the common elements amongst these models. Two similar images will produce similar pulse images. On the other hand, images that differ will produce pulse images that differ in the corresponding regions of the input images. The change detection is then obtained from comparing the corresponding pulse images. Some advantages of the ICM are: distinct objects are readily detectable through the highlighting due to the pulse stimulations; aligned images remain aligned after the ICM process; image features, that cannot be easily enhanced with other more conventional image enhancement techniques, get enhanced; small features are subject to disappear.

Attempts to detect motion in imagery started early in computerised image processing. The first paper on the subject known to us is Ref. [3] in which an autocorrelation model for motion detection is presented. Since then, there have been many papers published. One of the early papers on motion detection is Ref. [4] where the effects of occlusions were analysed in order to detect...
motion. Here we will use synchronised pulses from a neural network as the foundation of our attempt to solve the motion-detection problem in imagery.

2. The intersecting cortical model

In the ICM the state oscillators of all the neurons are represented by a 2D array $F$ (the internal neuron states; initially $F_{ij} = 0 \forall i, j$) and the threshold oscillators of all the neurons by a 2D array $\Theta$ (initially $\Theta_{ij} = 0 \forall i, j$). Thus, the $ij$th neuron has state $F_{ij}$ and threshold $\Theta_{ij}$. They are computed from

$$F_{ij}[n + 1] = fF_{ij}[n] + S_{ij} + W_{ij}\{Y[n]\}$$

(1)

$$Y_{ij}[n + 1] = \begin{cases} 1, & \text{if } F_{ij}[n + 1] > Y_{ij}[n] \\ 0, & \text{otherwise} \end{cases}$$

(2)

$$Y_{ij}[n + 1] = g_{ij}[n] + hY_{ij}[n + 1].$$

(3)

where $S_{ij}$ is the stimulus (the input image, scaled so that the largest pixel value is 1.0); $Y_{ij}$ is the firing state of the neuron ($Y$ is the output image); $f$, $g$, and $h$ are scalars (examples of values are 0.9, 0.8, and 20.0, respectively); $W_{ij}$ is the connection function through which the neurons communicate; in the first test below it modifies the neural connections as centripetal autowaves according to a curvature flow model; pulse segments in iteration $n$ will modify the neural connections such that neurons near the edge of the segment will increase their connection strength towards the local centre of curvature; in the second test below it is just a smoothing function; the smoothing of image pixels will affect neighbouring pixels, i.e. creating a connection between them; the actual choice of smoothing function is not crucial; and

$$n = 1, \ldots, N$$

is the iteration number. The scalars $f$ and $g$ are decay constants and thus less than 1. In order to ensure that $F_{ij}$ eventually becomes $\Theta_{ij}$, we have $f > g$. The firings computed from Eq. (2) are the output images of the ICM. Hence, the images are called pulse images.

3. Tests of the ICM on imagery

3.1. Aircraft detection

The ICM algorithm was used on a series of 16 images of an aircraft moving with the blue sky in the background. The sky looks rather homogeneous to the unaided eye. Apart from the aircraft, the only other object in the images is the moon. The images are roughly equally spaced in time. The first of the 16 images are shown in Fig. 1. The algorithm was implemented in Python (an interpreted, interactive, object-oriented programming language) and the values of the scalars $f$, $g$, and $h$ were 0.9, 0.8, and 20.0, respectively; this choice was based on values used in the predecessor algorithm—the PCNN. Since the aircraft does not experience any significantly intensity changes, its pulses for each time image occur in the same iteration. Examples of third iteration images are shown in Figs. 2 and 3. Many of the iteration steps resulted in completely black images or images where the aircraft and the moon were hardly visible, but not those of the third iteration and hence those images were chosen for the fusion process. As can be seen in Figs. 2 and 3, the images contain a high degree of noise, clutter or “speckle”. In order to remove, or at least diminish, the noise, a median filter of kernel size 5 was

![Fig. 1. The first of the 16 images of the series before application of the ICM algorithm. Photo: Prof. T. Lindblad.](image-url)
chosen for filtering before the image fusion. Since the images were photographed without the use of a fixed mounting, there is no perfect match of the images. There are very few image points that can be used for matching. In fact, it is only the moon that should be in the same position in each image and that is not enough for obtaining a good match. The result of this can be seen in the fused image in Fig. 4 as a misalignment of the aircraft.

3.2. Car detection

In the second test, the ICM algorithm was implemented in Matlab and applied on two IR images registered from a helicopter over a town area (Figs. 5 and 6) showing, among other things, two cars moving on a street. First both images were contrasts enhanced using histogram stretching and then the 8-bit images were changed to 1-bit images. Images of iteration 14 of the ICM algorithm (Fig. 7 shows this for the first image) were chosen for subsequent analysis because, as in the first example, they are not completely black.
This step of choosing iteration step for subsequent analysis has not been automated so it still needs the interaction of the photo interpreter. The chosen image was then lowpass filtered (Fig. 8 shows this for the first image) and made into its negative (Fig. 9 shows this for the first image). Then these two were approximately adjusted geometrically in order to subsequently compare them with each other. This adjustment included a $\frac{1}{14}$ rotation of the second image. Note that no exact rectification has been performed. An operation of subtracting the value 125 was then carried out on the images (Fig. 10 shows this for the first image). Adding these two images shows the two cars at the two times in one image (Fig. 11).

4. Conclusions

As the misalignment of the aircraft in the fused image (Fig. 4) shows, at least one of two prerequisites has to be fulfilled in order to obtain a good result from the fusion process: either the images must be photographed from a perfectly fixed camera or each image must contain enough identifiable non-moving pixels so one is able to perform a matching of the images. Hence, in cases when detecting moving objects, as aircraft, against a more or less homogeneous background or a background devoid of reference points, as the sky, one should use a fixed mount for the sensor. We have shown, however, that the ICM works even in
such circumstances, i.e. with a series of images not perfectly matched to each other. Furthermore, the noise, which is shown in many of the iterated images, is probably due to the fact that the sky is not that homogeneous as the inspection by the unaided eye would suggest. The colour and intensity in the pixels varies probably somewhat from one image to another.

In the second test, we have shown that the ICM algorithm proved useful without any precise rectification of the images to each other. We have shown that the ICM works for this test case. Further testing of the applicability of the ICM are to be performed on other images with varying complexity, noise, etc.

In these tests of the ICM algorithm, we have used different methods to enlighten the changes or the movement of objects in the images. It is difficult, if not impossible, to come forth with one and only one method suitable for all images and all types of changes. The pulse images of the ICM can be used as input to subsequent steps, outside the subject treated here, in the motion estimation analysis, i.e. the ICM is one way of enhancing changes in images that then can be used subsequently. The suitability of the ICM algorithm in image processing and change detection has to be investigated further. These two simple tests, however, show that the ICM may turn out quite useful.

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References