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Cellular neural networks for welding arc thermograms segmentation

Wojciech Jamrozik *

Silesian University of Technology, Institute of Fundamentals of Machinery Design, Konarskiego 18a Str., 44-100 Gliwice, Poland

HIGHLIGHTS

- 2D discrete time CNN was studied for welding arc thermogram segmentation.
- For welding arc segmentation CNN provide good arc-joint region separability.
- Batter diagnostic signals as in the case of region growing can be obtained with CNN.
- Emissivity setting error has marginal influence on CNN segmentation.

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ABSTRACT

Machine vision systems are used in many areas for monitoring of technological processes. Among this processes welding takes important place, where often infrared cameras are used. Besides reliable hardware, successful application of vision systems requires suitable software based on proper algorithms. One of most important group of image processing algorithms is connected to image segmentation. Obtainment of exact boundary of an object that changes shape in time, such as the welding arc, represented on a thermogram is not a trivial task. In the paper a segmentation method using supervised approach based on a cellular neural networks is presented. Simulated annealing and genetic algorithm were used for training of the network (template optimization). Comparison of proposed method to a well elaborated segmentation method based on region growing approach was made. Obtained results prove that the cellular neural network can be a valuable tool for infrared welding pool images segmentation.

1. Introduction

Machine vision systems play nowadays important role in the field of monitoring of technological processes. Application of more and more sophisticated imagining devices requires use of complex image processing and analysis methods. Those methods are often connected with assessing of some topological features of objects represented in an image. To calculate features with desired precision or to reveal changes in their values when a sequence of images is processed, an exact shape of certain object is needed. Taking into consideration all elements of the scene present in an image, extraction of particular objects is a difficult task.

Applications of machine vision systems in on-line monitoring of welding process are gathered around the observation of welding arc, welding poll and the fresh made joint [1]. Two device types are mainly used: cameras taking images in the range of visible light (TV cameras) and cameras taking images in various intervals of infrared band (IR cameras). Analysis of thermograms is particularly interesting, as it can be assumed, that change of welding process condition will cause changes in the temperature distribution and shape of welding arc and welding pool. Generation of diagnostic signals, being result of image analysis, that are informative in terms of welding inconsistencies recognition requires the use of suitable segmentation method.

To locate objects in images and extract boundaries of those objects various image segmentation methods were elaborated [2,3]. In practice image segmentation is an operation of assessing label referring to proper segment to each image pixel such, that pixels with the same label are similar with respect to some user demanded property. In most cases this property is colour, grayscale intensity or texture type. The main difficulty is that even highly uniform and homogenous image regions are often affected with a number of small holes and ragged boundaries. Many methods of segmentation were elaborated in past years, as problem of segmentation has been, and still is, an important research field. This is because of the fact, that there is no general theory of image segmentation, which is generally made with one of available ad-hoc techniques. The wide group of methods is based on one of two basic properties of the pixels in relation to their local

* Tel.: +48 32 237 10 63.
E-mail address: wojciech.jamrozik@polsl.pl

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neighbourhood: discontinuity and similarity. Region growing is an approach of region segmentation algorithms where assigned the adjacent pixels or regions to the same segment. Another group of methods gathers supervised approaches, where the way of image division into regions is revealed during the training process.

According to above mentioned limitations of various image segmentation algorithms taking into account the need for diagnostic signals, suitable for welding process monitoring and condition diagnosing, a segmentation technique of welding arc thermograms using a Cellular Neural Networks (CNNs) is described. CNNs are regarded as array of nonlinear analog processors (called cells), connected in a way allowing parallel computations [4]. According to a specific model, state of each cell changes in time, influencing the output in a nonlinear manner. In CNNs there are interconnections between cells, defining area of influence that formed in a local cell neighbourhood.

It is an original attempt to thermogram segmentation, especially for those of welding arc, for which CNNs with optimized template were not applied. Through the dynamic character of the welding process it is necessary to apply highly selective segmentation/thresholding algorithms in order to avoid situation, where the one separated segment contains not only arc area but also torch or hot joint.

Segmentation results obtained with the CNNs are compared to other, generated using the region growing method. Additionally for sequention of images, simple topological features of the segmented welding arc region are compared to the values of welding current, taken during the same active experiment.

2. Method

IR images are useful in monitoring and control of welding process, because of the information content. Correct segmentation of this kind of images if difficult because there is lower signal to noise ratio as in the visible light images. Additionally the blurring effect is present on infrared images. Cellular neural network (CNN) were successfully applied for image segmentation, inter alia in outdoor scene objects segmentation [5] and medical image segmentation [6,7]. To apply CNN for image segmentation, a optimization procedure for determination of network parameters must be carried out. Thus before the use of CNN, training stage is required (Fig. 1), where the supervised learning procedure is applied. In the particular approach application of a heuristic optimization method is especially suitable because there are no universal methods which allow for an analytical description of welding arc geometry nor the incorporation of their recognition into the CNN structure. Additionally post processing operations are possible to perform on segmented images (it is not an obligatory stage of segmentation method). In proposed approach only one processing method is considered: convex hull is stretched on segmented welding arc area to make the segmentation method more robust in terms of avoiding oversegmentation. The complexity of a CNN makes it hard to trace how a slight change in the template values will influence the output. According to this manual setting of template parameters is in considered case impossible. In an iterative way genetic algorithm or simulated annealing are applied to reveal optimal form of CNN steering template. Based on the obtained template values in the application stage (Fig. 1b), segmentation procedure can be performed to generate images with separated welding arc region that can be assessed with various types of features (geometrical, topological, statistical, etc.).

2.1. Cellular neural networks

A Cellular Neural Network (CNN) is a system of cells defined on a normalized space. It can be spread on any dimension, but for application in image processing, two-dimensional CNNs are most interesting ones [4]. The key idea behind the CNN paradigm is to combine the main advantages of Cellular Automata [8] with those of artificial neural networks (ANNs) [9,10]. CNNs uses only local information (as CA) to perform real time computations on large amount of data, as it is in the case of ANNs. Additionally each cell is a system that evolves in time.

To deal with images, a standard CNN 2D architecture is used (Fig. 2). It is a rectangular 2D array of cells $C(i,j)$ with Cartesian coordinates (i,j), where row number $i = 1,2,\ldots,M$, an column number $j = 1,2,\ldots,N$. Because each cell interacts only with neighbouring cells, a sphere of influence $Sr(i,j)$ has to be defined. For a radius $r > 0$, the sphere of influence of cell $C(i,j)$ is a set of neighbouring cells satisfying property given by following equation:

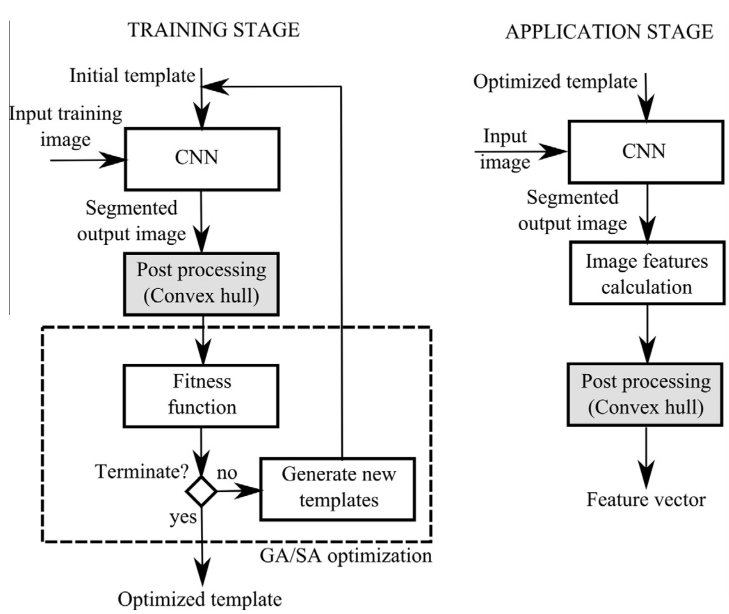

Fig. 1. Segmentation method diagram.