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AN OBJECT DECOMPOSITION AND SUBPART CLASSIFICATION ALGORITHM

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RESUME

La décomposition d'objets peut être considérée comme l'un des problèmes les plus importants dans les secteurs interdépendants du traitement numérique d'images, de la reconnaissance de structures et de l'intelligence artificielle.

Dans cet article, les Auteurs présentent une méthode complète qui se fonde sur un algorithme pour la décomposition d'objets et la classification de sous-ensembles. Les phases principales du traitement sont les suivantes: acquisition, préfiltrage, segmentation et classification.

L'acquisition monochromatique ne donne pas, généralement, d'informations suffisantes pour distinguer les sous-ensembles dont un objet complexe est formé. A cette fin, trois acquisitions différentes du meme objet dans les bandes optiques du rouge-vert-bleu sont considérées afin d'obtenir aussi l'information sur la couleur.

Quant au préfiltrage, le bloc proche de chaque pixel est analysé. La décomposition de l'image dans ses éléments s'obtient en effectuant une extraction de contours généralisés pour chaque bande de couleur.

Pour la classification, certain caractéristiques des différents sous-ensembles de l'objet ou des objets existant dans l'image sont extraites (telles que position du barycentre, superficie, moments d'inertie, quatre invariants de Fu) afin d'obtenir une description géométrique des sous-ensembles memes.

La méthode susmentionnée pour la décomposition d'objets et la classification de sous-ensembles a été réalisée en software et largement essayée en utilisant un minicalculateur PDP 11-34 avec une caméra de télévision et une interface de conversion sous forme numérique. On a effectué beaucoup d'expériences pour différents objets complexes: en particulier, on a analysé un circuit imprimé avec plusieurs éléments, en obtenant une décomposition et une classification parfaites des éléments memes.

SUMMARY

Object decomposition can be considered one of the most important problems in the interconnected areas of digital image processing, pattern recognition and artificial intelligence.

In this paper a complete procedure is presented for object decomposition and subpart classification algorithm. Acquisition, prefiltering, segmentation and classification are the main processing steps.

Monochromatic acquisition doesn't give in general sufficient information to distinguish the subparts composing a complex object. To this purpose, three different acquisitions of the same object in the red-green-blue optical bands are considered to add colour information.

For prefiltering, the neighbourhood of each pixel is analysed. The decomposition of the image in its components is obtained by performing a generalized boundary extraction over each colour band.

For classification, some features of the various subsets of the object or the objects present in the scene are extracted (as centroid position, area, inertial moments, four Fu's invariants) to allow a geometrical description of the subsets.

The above object decomposition and subpart classification procedure was implemented in software and widely tested by using a PDP 11-34 minicomputer with a TV camera and a digitizing interface. Many experiments were performed on different complex objects: in particular a circuit board with several components was analysed and the decomposition and components classification were perfectly accomplished.

1. INTRODUCTION

Object decomposition is to be considered one of the most important problems in the interconnected areas of digital image processing, pattern recognition and artificial intelligence. Indeed little experience has been up to now gained of automatically recognizing subsets or subparts composing complex objects, while much more emphasis has instead been devoted to identifying single objects from single or multiple image frames. The solution of the above problem can be in particular of high interest in robotics to analyse complex objects, bodies or systems.

In this paper a complete procedure is presented for object decomposition and subpart classification algorithm: acquisition, prefiltering, segmentation and classification are the main processing steps.

Results of experiments performed on different complex objects are reported, regarding in particular a circuit board with several components.

2. IMAGE ACQUISITION AND FILTERING

Monochromatic acquisition is currently used in analysis and processing of the global shapes of objects in single or multiple image frames. Several experiments have shown that monochromatic acquisition does not give enough information to distinguish the parts composing the single object. Therefore additional processing is required. Three different acquisitions of the external scene (containing the objects) in red, green and blue (R,G,B) colour bands are here performed to add colour information [1] .

Further, to make the subsequent step easier, a suitable filtering is applied on each acquired image. The filter uses the algorithm proposed by Moring and Pietikäinen [2], suitably modified. The 3x3 A-neighbourhood of each pixel is analysed: the pixel satisfying the three following conditions in the grey-level histogram is selected to replace the central pixel

$$p(f_i) - p(f_c) > 0$$

$$\frac{p(f_i) - p(f_c)}{\alpha_\ell |f_i - f_c|} < 1 \qquad \alpha_{\ell+1} = \alpha_\ell/2, \quad \ell \in N \qquad \alpha_0 = k = 10 \tag{1}$$

$$p(f_i) - p(f_c) = \max_A [p(f_i) - p(f_c)]$$

where $p(f_c)$ represents the probability of the grey level of the central pixel, while $p(f_i)$ is the probability of the i-th grey level for each pixel in the A-neighbourhood; α_ℓ is a sequence of positive numbers that decreases at each iteration (N is the set of integers). The histogram is used as an approximation of the grey-level probabilities. Iterative application of this methodology leads to a smoothed image and to a certain degree of segmentation very useful for subsequent processing steps.

3. OBJECT DECOMPOSITION IN SUBPARTS

To achieve automatic object decomposition, it is necessary to derive the significant subsets of a complex object. An initial step is performed, corresponding to a generalized boundary extraction.

The following symmetrical algorithm is applied

$$E_m(i_0,j_0) = \frac{1}{8}\sum_{i,j} |I(i_0,j_0) - I(i,j)| \ , \ i,j \in A(i_0,j_0)$$

$$E(i_0,j_0) = \frac{1}{3}\sum_{m=1}^{3} E_m(i_0,j_0) \tag{2}$$

$$A(i_0,j_0) = \{i,j: |i - i_0| < 1 \ \text{ or } \ |j - j_0| < 1\} \quad \forall\, i,j \in [1,M]$$

where M is the image size, E_m is the contour map in the m-th colour band, E is the final contour map in the image, I(i,j) is the grey level at the (i,j) pixel, and (i_0,j_0) denotes each central pixel of the 3x3 pixel block (A-neighbourhood). Thus the contour information is obtained, by using the three different colour bands.

A second step is performed to obtain homogeneous different subregions of the analysed object. To get a good decomposition of a complex object, grey-level clustering is not enough: spatial relations and proximity information have also to be used [3] [4] . A decomposition threshold, unique to a single class of objects, is chosen according also to experimental tests. The used procedure starts from the pixel on the extreme lower left-hand corner and proceeds from left to the right connecting the neighbouring pixels and avoiding closed loops: the final result is the identification of a unique root of an oriented "tree" for each homogeneous region. In this way, each region is identified unambigously by the tree which connects its pixels.

To test the reliability of the above procedure, it was compared with an "interactive" procedure, in which a human operator gives information about the object components: very satisfactory results were obtained.

4. DEFINITION OF A DESCRIPTIVE SYNTAX

At this point, some features of the various subsets of the object(s) present in the acquired scene are extracted (as centroid position, area, inertial moments, four Fu's invariants) to allow a geometrical description of the subsets [5] .

Mutual spatial relations among the various subsets are evaluated. These relations are based on a scheme, in which the positions are suitably coded (as: above, above and left, left, below and left, below, below and right, right, above and right). In addition three relations - inside, outside, partially surrounding - are defined, which describe relative positions.

Information provided by the relative positions of the centroids of the various subsets is seldom good enough to specify spatial relations. Therefore, in evaluating relative positions, this procedure is followed: the angle of sight by which a particular subset is viewed by a "hypothetical observer" from the centroid of another subset is considered. Suitable angular functions are hence evaluated.

5. EXPERIMENTAL RESULTS

Experimental tests have been performed, according to the above processing system, by using a PDP 11-34 minicomputer with a TV camera (having colour filters) and a digitizing interface. In particular circuit boards with several components were analysed.

Fig. 1 shows the original digitized image, representing a circuit board: great acquisition noise is here present (to test the good performance of the proposed system).

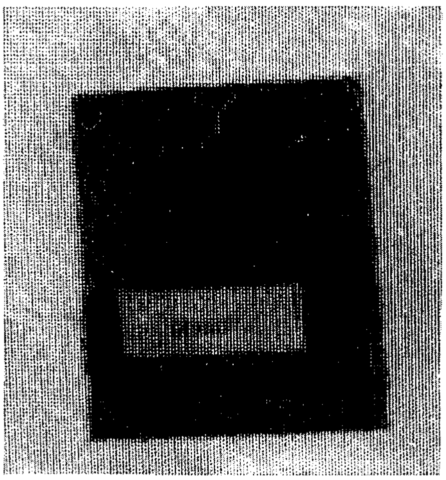

Fig. 1 - Original digitized image: a circuit board (digital acquisition with great noise).

Fig. 2 shows the object decomposition into subparts after boundary extraction: the board and four components are clearly identified and three components are extracted from the board.

Fig. 3 shows the automatic identification of mutual spatial relations among the different components: in particular a component 2 is identified and its position is described in a syntactical form. The component 2 is a capacitor, which is inside part 1 (the board), below on the left of part 3 (a resistance), below relatively to part 4 (an integrated circuit), below on the left of part 5 (a trimmer).

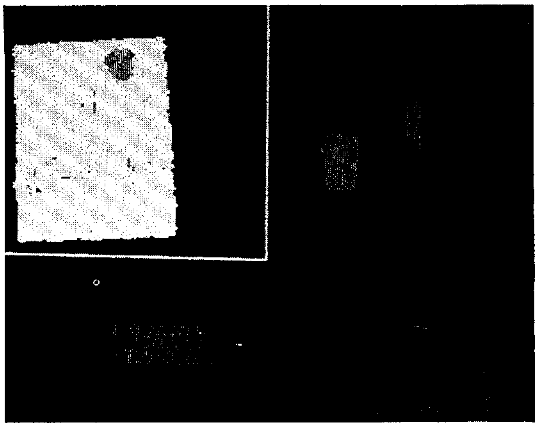

Fig. 2 - Object decomposition into subparts: board and four components (three are isolated).

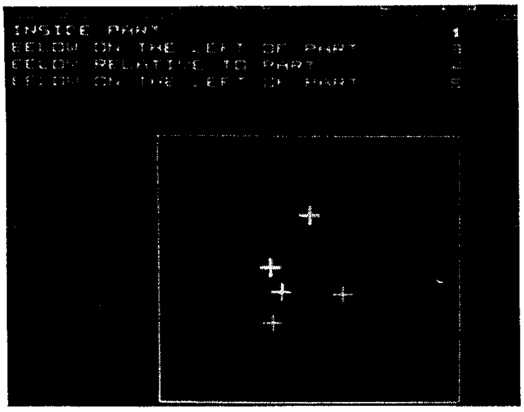

Fig. 3 - Identification of mutual spatial relations among the different components: a component 2 (a capacitor) is here identified (colours are appearing as different grey-levels).

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