

IMAGE ANALYSIS AT THE INSTITUTE OF CYBERNETICS E. CAIANIELLO

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Abstract: The biennium 2012-2014 is the last period of activity at the Institute of Cybernetics E. Caianiello (ICIB-CNR) of the GIRPR unit composed by C. Arcelli, M. Frucci, G. Ramella, G. Sanniti di Baja, and L. Serino. In fact, during year 2014, G. Ramella moved to the "Istituto per le Applicazioni del Calcolo" (IAC-CNR, Napoli), while M. Frucci and L. Serino moved to the "Istituto di Calcolo e Reti ad Alte Prestazioni" (ICAR-CNR, Napoli). In turn, G. Sanniti di Baja will retire in February 2015, following C. Arcelli who already retired in 2003. The above researchers will continue, most possibly in cooperation, their research activity in the field of image analysis, even if no longer as ICIB GIRPR research unit. The activity performed by the ICIB GIRPR unit in the period 2012-2014 has been concerning with both theoretical and applicative aspects of the design and the implementation of discrete methods and tools to process and analyze 2D and 3D digital images.

Key words: Skeletonization, object decomposition, image processing, biometrics

1. ACTIVITY OF THE ICIB GIRPR UNIT

During the biennium 2012-2014, the research activity carried on by the ICIB GIRPR research unit has been mainly concerned with skeleton computation and manipulation, object decomposition, image processing, and biometrics. Some results obtained in the first part of year 2012 and already presented at the National GIRPR Congress, Pontignano, 2012, can be found in [1], while the remaining articles published by the group during this biennium can be found in [2-17].

1.1 Skeleton computation and manipulation

As concerns computation and manipulation of the skeleton, emphasis has been given to skeleton pruning, i.e., to the technique that can be used to trim skeleton branches both to simply remove spurious branches whose presence in the skeleton is due to noise along the boundary of the object, and with the purpose of producing representations of the skeleton at different scales, by resorting to a pruning process employing a variable threshold.

For a context dependent pruning, a shape parameter, measured while tracing a skeleton branch, should be used to evaluate the perceptual relevance of the object region mapped into that skeleton branch. The branch is removed from the skeleton or is retained depending on whether the parameter is below or above the threshold. Activity on pruning has been carried on together with Luigi Cordella.

In [7], theoretical aspects have been discussed dealing with the influence of the parallel or sequential way in which pruning is accomplished on the obtained results, and a new hybrid approach has been suggested that exploits the advantages offered by the parallel and sequential approaches while being less affected by their drawbacks. See Fig. 1.



Fig. 1. A skeleton and its pruned versions by using parallel, sequential and hybrid approaches.

A new pruning method for the curve skeleton of 3D objects is currently under development. The suggested algorithm does not require fine tuning of the parameters involved in the criteria suggested to evaluate branch significance. Finally, as concerns representation and use of the skeleton, in [8, 13] a curve skeletonization algorithm is presented and its manipulation via polygonal approximation is discussed. In particular, in [13] we show that by increasing the threshold used for polygonal approximation, fine-to-coarse different representations of the skeleton become available. See Fig. 2.



Fig. 2. An object and different polygonal approximations of its skeleton.

1.2 Object decomposition

Object decomposition via skeleton decomposition has also been deeply investigated during the biennium. Our decomposition methods can be

framed in the category of the methods based on the approach of recognition-by-component followed by the human beings, according to which an object having complex shape is divided into a number of regions with simpler shape, and the description of the object is given in terms of the features of the obtained regions and of their spatial relationships.

The general scheme of the suggested methods [3-5, 16] is the following. The distance labeled skeleton is polygonally approximated by taking into account spatial coordinates and distance values of its voxels. The so obtained skeleton segments are characterized by absence of significant changes of curvature. Moreover, distance values are constant or linearly change along each skeleton segment. Segments are interpreted as the spines of simple regions, characterized by absence of significant curvature changes along the boundary, and by constant or linearly changing local thickness. Methods [3-5] differ from each other mainly for the criteria used to obtain the object parts starting from the corresponding skeleton segments. These can be achieved by resorting to the use of the distance transformation and constrained distance transformation, or by subtraction from the input object of the so called overlapping regions, which are suitably detected in correspondence of the branch points of the skeleton. Some results obtained by using the algorithm [4] are shown in Fig. 3.



Fig. 3. Some results obtained by using the object decomposition method [4].

The simple parts can be described without resorting to their construction. In fact, by using only spatial coordinates and distance values of the vertices of the spines, quantitative information on shape, size, position and orientation of the corresponding simple parts can be obtained. This has been accomplished in [16], where alternative decompositions can be computed by selecting different values for the threshold used during polygonal approximation of the skeleton. Moreover, criteria have also been suggested for the selection of optimal threshold values originating approximated skeletons having a small number of segments, but still producing decompositions rather well adapting the input object boundary. See Fig. 4.



Figure 4. Alternative approximated decompositions obtained by using the algorithm [16].

1.3 Image processing

As for image processing, we have continued to work on discrete techniques for image zooming and have suggested a new method that automatically computes the resized image, obtaining satisfactory results even when using large zooming factors [2]. We have also been working on color quantization [6, 9, 10, 14], with the aim of producing a version of an input image that, though having a smaller number of colors, is still visually similar to the original image. Color quantization can also be seen as a step towards color image segmentation. To cope with the generally very large number of initial colors, we perform color quantization in two steps. The first step reduces the number of colors by reducing the size of the input image. In fact, the number of colors in an image cannot overcome the number of pixels in the image. We have suggested alternative techniques for the second step to gather into clusters colors that sufficiently similar to each other. See Fig. 5.



Fig. 5. Images with at most 128, 256, 384 and 512 colors obtained by the algorithm [9].

1.4 Biometrics

The application oriented research activity has mainly regarded biometrics, in particular iris detection and recognition [11, 12]. In this framework we have devoted our efforts in particular to noisy images, as those resulting from an acquisition accomplished under uncontrolled conditions. We have suggested a watershed based iris detection method that, even if running on degraded iris images acquired in visible wavelength, allows us to identify as much precisely as possible the iris boundary. In fact, after circle fitting is applied to the binarized watershed partitioned image, the limbus boundary is more precisely detected by taking into account features of the regions of the watershed transform that are at least partially overlapping the circle. See Fig. 6.

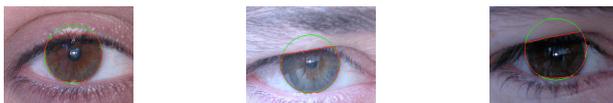


Fig. 6. The detected iris boundary is shown in red.

Finally, we have used some of the tools typical of image analysis in the field of bioinformatics [15] and genetics [17].

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