

TEXTURE ANALYSIS BY MEANS OF C-CALCULUS

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This work utilizes the concepts of C-Transform and C-Space in order to discriminate and classify some textures. By getting some filtering properties of C-Calculus we adopt the C-Filter in order to filter different textures and to extract objects from a textured picture. Some experimental results among many carried out onto several different textures, are presented. The philosophy on which the proposed method is based is briefly discussed against the other existing in literature.

INTRODUCTION

We live in a world very rich in textures that we recognize and, also if in gross and empirical terms, we are able to describe and classify them. The texture plays an important discriminant role among the objects of a visual field because any object has its own texture, but yet it determines the depth of the field in the image and the distances within the different planes of visual field (1). A very difficult and extremely important problem concerning the pattern recognition is to individuate a texture by the means of the computer.

Several authors (2,3) are trying to study texture by the computer even if many difficulties arise from using a model that is quite impossible to describe accurately. Textures can be considered as a repetitive lay-out of some subpatterns or unit-pieces. This idea has suggested two different approaches for the study and classification of the textures: the structural one and the statistical one.

From a structural point of view texture is considered made by subpatterns dimensionally constant that repeat themselves periodically in the whole visual field (4).

The statistical approach makes us considering the texture as a whole of statistical properties extracted from a large number of measures made onto the image. Let us observe, now, that a first order statistics, for instance average and standard deviation of grey tones in a pattern is not sufficient to completely describe a texture.

More significant is the second order statistics to analyze textures; Julesz (5), for instance, used transition probability from a level to another, still in order to describe the textures.

Some techniques referring to the probability of transition have been studied by other searchers (6,7). A further approach to describe the textures is based on the probability by which several features are present in a certain pattern: for example the frequency of angles, of lines or of others features in a model may be considered parameters useful to describe the textures (8,9).

The standard operators to outline the angles work by considering the differences of the levels of greyness between couple of points near that under consideration.

Some authors (10,11) resorted to measures of this kind, in order to select different textures present in the same visual field. Instead of single points couples the use of couples of average values calculated on not overlapping wholes is advisable: this approach decreases noise effect. The differences between values depend on dimensions of intervals considered; in fact the dimensions for which the differences are major trend to correspond to the dimensions of the elements of the textures, so that this optimal dimensions can be itself used as texture measure (12).

In this paper, we are going to give an application of C-Transform (13) and, at same time, a filtering method based on C-Calculus (14) that seems to emphasize the above mentioned properties of textures. This method we have already experimented on different types of textures, gives very appreciable results: either in the classification of textures in the C-Space, or in the extraction of objects from a textured picture.

We have used the C-Filter also to select and to reconstruct just one texture from a matrix hosting two different textures.

C-TRANSFORM

Method proposed takes the start-up by the observation (7) that visual feeling of a texture is due to combined action of two events: the dimensions quite almost constant of the "pieces" making texture and a rule in the layout of the pieces, even if gross, onto the whole region of the texture.

So we naturally spend our attention not to an eventual substructure that can leak the elementary "pieces", but moreover to the differences between external greyness tones of the elementary patterns and to their dimensions.

Events and correspondent parameters chosen may be easily correlated to the wellknown concepts of the contrast and of the resolution power of the human eye both found in the vision physiology (15).

In a previous work (16) we have introduced the (row) C-Transform as follows: in a row-by-row scansion of the matrix which hosts the texture, all the differences between extrema values of tones of greyness in

the monotonic region of "signal" are computed and reported on the axis "u" of a tridimensional space called C-Space.

On "v" axis of such a space half distance plus one between the extrema values of monotonic region. The why this distance has been considered will be cleared further on. Each point in the image under analysis will occur with a frequency t that will be reported on third axis x of C-Space.

It is quite easy to check that as the amplitude of a signal constant in the period changes, so the position of C-Space representative point changes along a direction parallel to "u" axis. Instead period variations occurring in a signal constant in amplitude, generate a shift of the point along directions parallel to "v" axis.

So we can say a sinusoid in C-Space is represented by a point and, generally speaking, all signals having equal amplitude and equal frequency are associated to the same transform. Consequently we can also say that C-Transform does not have only one inverse transform.

Let us present now, a new observation that can better introduce us in the C-Space philosophy: the max-min and their relative distances give us measures affected by a precise meaning regarding the signal; "v" value of C-Space is able to inform us about major spectral properties of signal, whilst "u" variable refers to the phenomenon (well accepted by the vision physiology) by which human eye can compare luminances, whereas it is not able to appreciate their absolute value.

In order to introduce our filtering method (9) we are here-after presenting basic features of C-Calculus, and we refer the reader interesting in a more complete explication to our previous works (17,18).

C-CALCULUS

The main idea of C-Calculus is to take over from the ordinary number system the two distinct roles of figures, values and position, so to define, with appropriate interpretation, strings of sets and operation on them. Its core definition and rules can be listed in a very compact form;

a) if a_n, a_{n-1}, \dots, a_0

represents some covering of a given set U , the corresponding C-set is described by the strings

$$a_n a_{n-1} \dots a_0$$

b) sum (\oplus) and product (\otimes) among describing strings are dealt with like the corresponding operation of arithmetic, with the only prevision that the sum (product) of digits be substituted with the union (intersection) of sets.

Assuming that a digitized picture be presented as usual as a non matrix

$$A = [y_{i,j}]$$

a C-set is, then, readily associated with A in the following way.

Suppose that an instrument is provided, which can tell the maximum M and minimum m values attained by y_0 over some finite area w , when A is looked at through a window matching w .

Further, arrange a scanning of the picture that leads the reader successively on to contiguous non overlapping position within the same row and then on the other rows so as to "cover" completely the matrix.

This is tantamount to looking at A through a grid that partitions A into a set of rectangles, each bearing information about maximum and minimum value assumed by y within its area.

If position in the grid are ordered now in some way and the numbers within each quadruple are regarded as closed intervals in the continuum, then the alignment of all quadruples in a string represent a C-set, for instance C_1 . Thus, C_1 clearly is a sampling of A by means of quadruples, as rough as the window is wide.

Have now the grid undergo a rigid translation and let C_2 be the second C-set thus obtained. Upon a multiplication of C_1 and C_2 , not only a finer partition is achieved of the supporting euclidean space, but also a more detailed description of the picture itself.

If several such products are carried out among appropriately chosen C-set, one would intuitively expect to get, eventually, a complete resolution of the picture under conditions that we are going to recall.

For the unidimensional case, it has been shown (17) that a sufficient condition for the procedure to "converge" at each point of y is that:

$$w \leq \frac{D}{2} + 1 \quad (1)$$

where D is the length of the smallest interval within which y displays a monotonic behavior.

C-FILTER

This circumstance (1) enables to consider a very peculiar mapping of the variation of y in a neighbourhood of some point onto the point itself and is at the basis of our filtering procedure. Thus, for instance, considering a signal that shows some periodicity in a certain region and a non periodic behavior outside that region, we can isolate these two different behaviors and screen out one of the two, without blurring the other in any way. The underlying principle is that, for a window width larger than the period, all C-sets in the family will display constant (m, M) values. Reconstruction with such window width leads therefore to non convergence in all points in the region of periodicity, while in the non-periodic region some convergence necessarily arises, thus enabling to select automatically a window width and a scanning pattern that extract the region that displays the wanted characteristics or features from it alone.

The condition before explained that the window width plays a relevant role in analysis of the images; in fact convergence occurs only for regions of picture where the distances involved among contiguous grey tone extrema are constrained by the inequality.

By concluding we may say that, due to the peculiarity of window consisting "generating signal convergence only in some regions our method operates as a filter that we call C-Filter.

C-Space is able to evidenciate quite well the opera

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tion of C-Filter: we can easily see that the plane view divides C-Space into two regions so that convergence and consequently reconstruction will be obtained only for points which fall in the semiplane $v \geq w$.

APPLICATION OF TEXTURE-ANALYSIS

The above mentioned concepts seem to put at our disposal two devices such as C-Transform and C-Filter that quite well adapt themselves to the textures. The uses possible already experimented as we have seen early in this paper are the following:

- 1) classification of textures
- 2) extraction of objects from textures
- 3) textures filtering

and finally

- 4) biomedical applications.

1) Classification of the textures.

Textures have been visualized as pattern with following characteristics

- a) constituted by pieces roughly uniform either in dimensions or in greyness-tone variations
- b) the number of such "pieces" is extremely large against the features of others objects in the texture such a characterization of texture let-us forecast a texture transform extremely clasterized in C-Space. We have considered several textures (19,20) that we have digitized in eight greyness levels in a 256x256 matrix and, finally, reported their transform into C-Space by applying a well known algorithm of clasterization (21,22).

Experimental results have fully supported our forecasts.

2) Extraction of objects from textures.

A very important problem is represented by the extraction of objects from a textured background. In the case in which dimensions and form of the object are not comparable to them of "piece" of textures. As first experience we procede to digit several textures: by overlapping to them some objects formally and dimensionally differents and, in all cases, we extracted the object. The second experiment realized has interested the extraction of some objects having the same texture as the picture had (fig.1).

Fig.2 shows the objet extracted.

Fig.3, instead, shows the complement of initial image. It results necessary to outline that C-Filter operates without distroing any information, reason for wich the union of matrices shown in fig.2 and 3 gives again the matrix input reconstructed point by point.

3) Textures filtering.

We have examined some matrices hosting two textures and we have discovered the problem of texture discrimination. To solve the problem we have C-Transformed the whole matrix obtaining two different spicks in C-Space corresponding to the two textures.

By chosing the dimanions of wu (where u is the axis of sciss of scilla-point between two spicks) we can reconstruct only one texture whereas the second-one is completely cancelled. We have, then, considered a matrix hosting two textures partially overlapping this time: the problem is still the same; to discriminate one of two textures (fig.4). Following the same way above used we "filtered" one texture (fig.5).

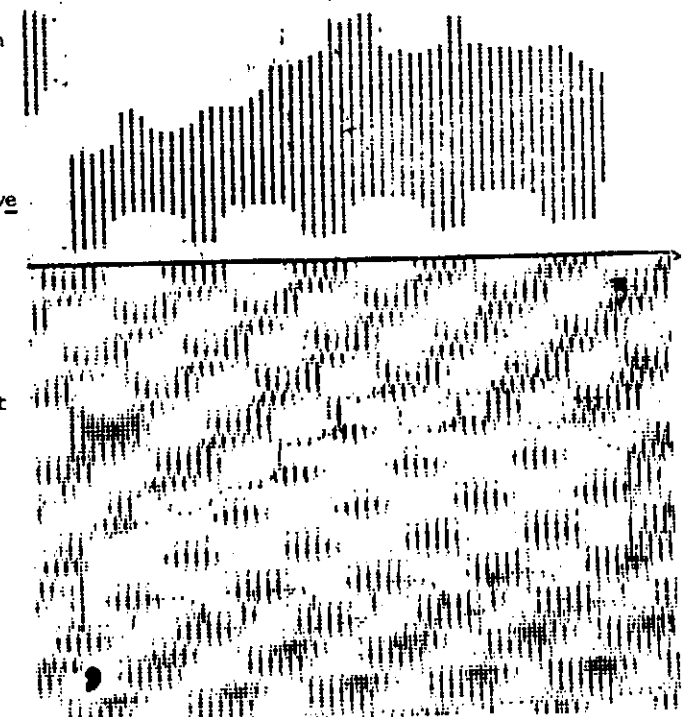
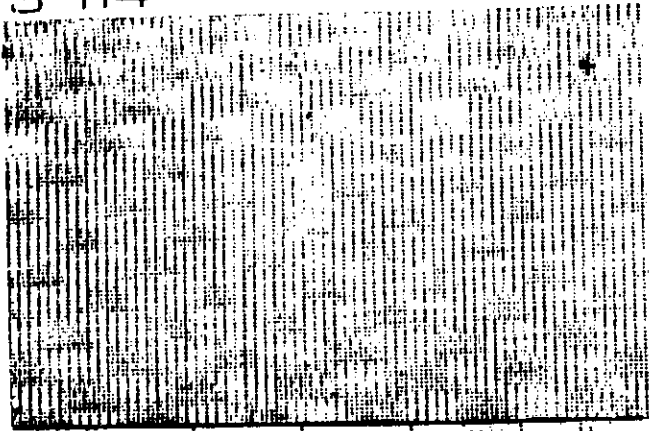


Fig.6 displays the input matrix after extraction of one of textures.

4) Biomedical application.

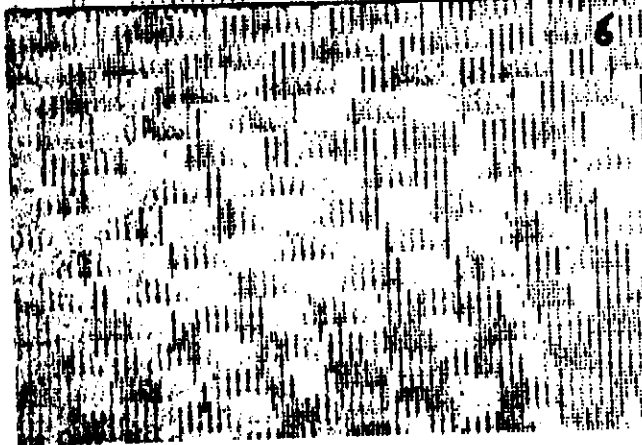
Somebody proposed we select human cariotypes in metaphase from a biomedical support. Cariotype in metaphase rapresents a texture, even if gros and with not very high multiplicity but, in any case, so that by C-Transforming we obtain a relevant spick in C-Space. By choosing in right way the rates of w it was possible to reconstrait only the cariotypes in metaphase, whilst other cellulas of biological support were fully filtered. The results obtained on a narrow size sampling, incourage to extend the research on a wide size sampling.



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Conclusions. The experimental results outlined the good filtering capability of C-Filter, against existing methods, either for discrimination of several textures or for the extraction of objects from a texture. C-Transform and C-Space showed, with considerably easy calculus, their idoneity to classify the textures. Basic features of our method, well supported by obtained results push us not only to continue the study onto biological supports but also to carry on the theoretical studies concerning the scansion of the images area-by-area more than only row-by-row from last hypothesis exposed, that is able to make our method to be still more flexible, we expect useful experimental results.

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