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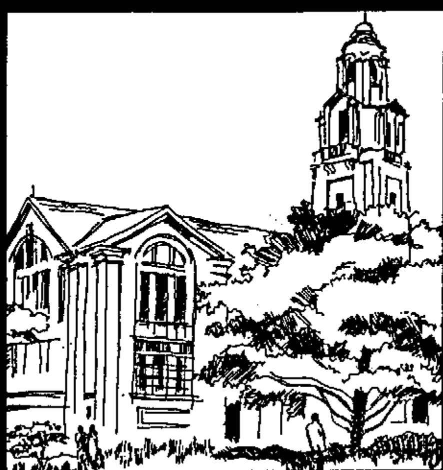
SYSTEMS AND SIGNAL PROCESSING

DECEMBER 11-13, 1986



DEPARTMENT OF ELECTRICAL ENGINEERING
INDIAN INSTITUTE OF SCIENCE
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PLATINUM JUBILEE CONFERENCE
ON
SYSTEMS AND SIGNAL PROCESSING

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A STRUCTURAL APPROACH TO IMAGE SEGMENTATION

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ABSTRACT

In this work we intend to propose an original algorithm for image segmentation by textures properties.
A lot of algorithms proposed in literature, make use of an "atomistic" approach for the solution of the problem: in fact they totally leave out of consideration from a contestual analysis of the whole image. The algorithm we are presenting here, on the contrary, utilies a "structural" approach to same problem. In the next paragraphes, we are going to present the algorithm description and may be some experimental results we obtained will better clarify which is our proposal.

INTRODUCTION

In the broad and diverse landscape of the existing literature on automatic pattern recognition, one often come across the definitions which are derived by appealing to the theory of form (Gestalt), which is the theory of the "totality".
Nevertheless such an appeal is somtimes realized by making use of certain axioms proper to the theory of associations or atomistics to which the Gestalt theory is opposed.
It has been said that the Gestatlt is the theory of the totality (it is superfluous to add that in as much as the whole is something more than the simple sum of the parts, that the properties that the total set enjoys as the whole cannot be reduced to those of its single parts) of that very same totality which is necessary but not sufficient in order to define a structural analysis. In fact what is peculiar to a structural type of orientation is an explicative attitude toward the structures.
More precisaly, one is not interested in considering them simply as "emerging totalities" in contrapposition to "atomistic" entities, but one want to analyze them with respect to their internal structure. So, since the concept of structure works on all levels, one wants to consider them in terms of relations, namely as forms.
We have introduced the word "form" without giving a definition of it, not even a non rigorous one. Since we have not found any satisfactory definition of "form", we will try to explain such a concept by defining its laws, which are laws of organization:

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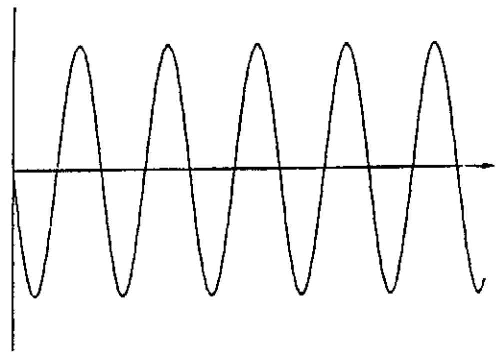
3) The condition of the field and the formal relations between its elements determine the emergence of form. The relations are those of similarity, proximity, symmetry, closure, continuity of direction.

After having proposed some laws for the form, our aim is to try out a possible meaning for such a word, setting apart from the philosophical problem. The first meaning of the word form is the figure, the exterior picture of a thing. The form is then opposed to the different appearences caused by the changes of prospective, orientation and distance. Thus, one notice that this meaning coincides with one of the functions of the Gestalt theory. So, between Euclid's two fondamental geometric relations - equality and similarity between geomatric figures - it is the latter which properly defines the form, since the form is invariant under the action of the group of its similitudes.
Let's go back to the dialectic between local and global or, in a more traditional way to the "structural" understanding of the organized whole. We can interpret a structure as a system of transformations. This implies that we have certain laws which evolve through the transformation itself and which realize themselves in the universe under consideration.
Hence a structure enjoys the following features: totality transformations and self relugation.
A further fundamental characteristic of structures is the following: they regulate themselves, and the self-relugation determine their conservation and certain closure. So the transformations inherent in a certain structure do not lead outside its borders, but generate elements which always belong to the same structure and which preserve its laws. It is in this sense that the structure is

closed within itself.
This does'nt imply that it can not be part of a second structure containing it. We can then talk about self relugation of the structure, and determination of the self-regulated structure leads us to conclude that we have arrived at a more intimate knowledge of the system.
So we have introduced two different types of magnitutes: structured and structuring and we have hinted at how the letter are bewarers of information. As an example the sound may be a single note hold to infinity or a homogeneous natural scene do not give any information or - and this is the case which interestes us in this paper - don't give rise to any form. We claim that the variations, or alterations of the structured magnitudes are the sources of information. In fact in natural scene, it is the variation among the various structures which allows the emergence of the contours, the forms or more clearly the object contained in the natural scene.

STRUCURED MAGNITUDINES: AN EXAMPLE, TEXTURES

Two different motivations lead us to consider, in this paper, the problem of textures: the rule this plays in the entire process of perception and the problem itself; indeed the study of textures can be considered a scince in itself.
Obviously, texture also plays a determinat rule in automatic pattern recognition and the literature contains very many articles which illustrate a great variety of algorithms dedicated to the description of classification of textures.
In spite of this, still today there is no definition, not even a coarse one, of texture, and the entire problem of its elaboration and classification has to be regarded as unsolved.
We think of a wett, or a texture, as a stazionary oscillation in a domain of arbitrary dimension.
The wish to formalize our idea of texture leads us to:
Def. 1:
A discrete function z=f(x,y) defined in a discrete two-dimensional domain is a texture if there exists at least a partition of the domain such that all partition-elements are isomorphic among themselves.
Def. 2:
The function z=f(x,y), which isdefined in a partition element, is called "piece of texture".
The following simple examples clarify the definition given above.
Let'sconsider the periodic function in fig. 1. Such a function represent a texture since there exists at least a partition of the domain, whose amplitude equals the period of the function satisfying condition 1 (of the fig. 2). It is worthy to notice that a generic translation of the partition in the domain of the function, still satisfies condition 1.
This fact implies that our definition is invariant under translation of the partition (of fig. 3).
We notice that the arguments given so far for a unidimensional periodic function still continue to be valid for any discrete function z=f(x,y) defined in a discrete bidimensional domain (of figg. 4,5,6).


Ffg. 1

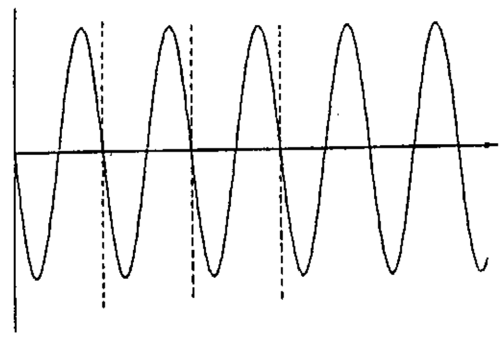


Fig. 2

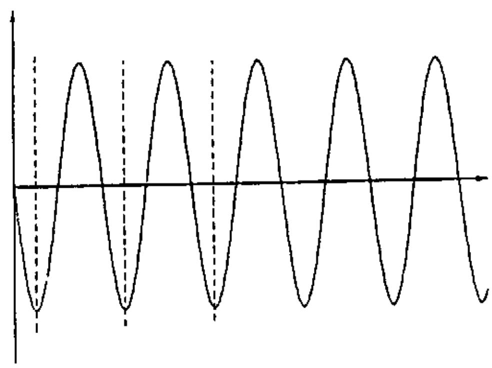


Fig. 3

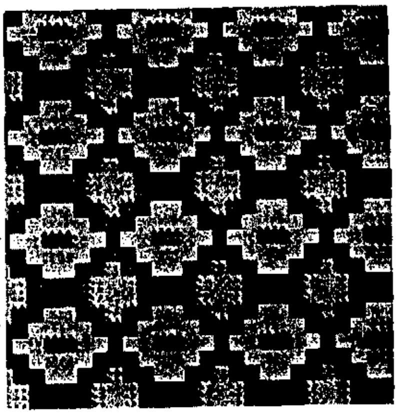


Fig. 4

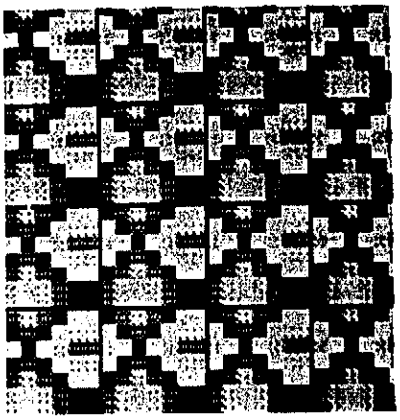


Fig. 5

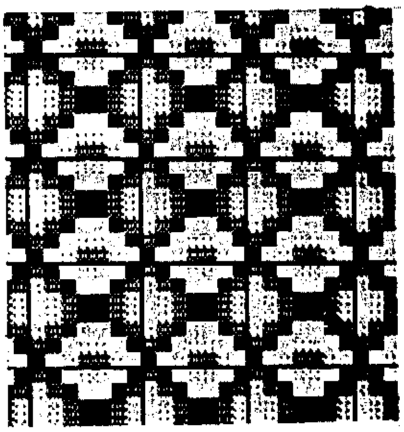


Fig. 6

Each piece of the texture can be described by a structure which might be rather complicated or not; then it follows almost immediately that a texture is nothing but the very same structure which repeats itself as many times as the number of partition elements occourring in the domain.
One immediately notices that once the structure is determined then a correct and complete description and classification of the texture follows naturally.

ALGORITHM DESCRIPTION

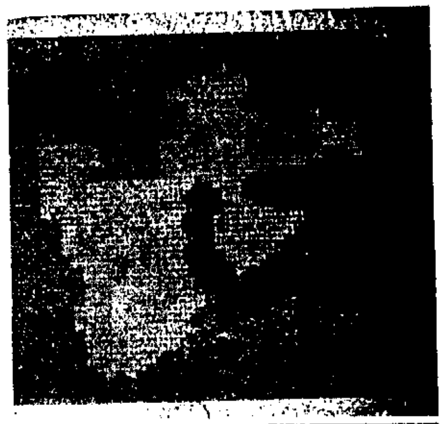
In this paragraph we give the algorithm description proposed for image segmentation.
Generally, the problem of dividing (segmenting) an image in its different components, can be considered as a decisional process, through which we can assign a valus k identifing the k-th region that the pixel is assigned to.
A lot of algorithm proposed in literature, makes use of an "atomistic" approach for the solution of the problem: in fact they label the only pixel of the image indipendentely from the value of the surrounding pixels. Then such algorithms totally leave out of the consideration from a contestual analysis of the whole image: e.g. the simplest of such algorithms give the segmentation fixing in the same region all the pixels presenting the same gray-tone or, with a little more refined technics, graytone compouned in a fixed threshold.
The algorithm we are presenting here, on the countrary, utilies a "structural" approach, because it segments the image through a comparede analysis of the different regions already located.
The algorithm can more precisaly be articulated in two phases: in the first phase the several structures present in the image and those areas not classificable as single regions, bacause place of transiction among different regions (contours) are evidencied.
Then the first phase begin with the research of any pixel of the image which has not been classified yet as belonging to some region.
Called p such a pixel, the algorithm goes on the formulation and the control of different hypothesis, about the possibility of identifying an uniform region starting from it.
Expressing a hypothesis means to try a partition of the neighbouring region of the pixel with elements (windows or pieces) of $W_r x W_s$ dimensions, similar among them in a Δ percentual.
Verifying the hypothesis means to calculate the ratio:

$$S_{rs} = \frac{\text{number of the pieces found similar}}{\text{total number of considered pieces}}$$

The tipically "bell" behaviour of the law describing the S_{rs} ratios when varying r and s in:

(1,2,..........,n), allows to individuate the W_r and W_s dimension of the piece in corrispondence of its maximus, which gives the best partition of the neigbouring region of the starting pixel.
After labelling all the pixels belonging to the region individuated in a such a way with the k value, the first phase of algorithm again start from the initial point for the research of an eventual k+1st region of the image.
In the second phase, there is a compared analysis of the individuated regions in the precedent phase, trying to put them in corrispondence, utilizing proper functions of similarity. Some of the function of similarity we utilize are: rotations, roto-translations, shape-comparision, upsetting, etc.
For example, we utilize the shape comparision in order to be able to recognize as equal two regions resulting different just for different illumination; rotation and translation study instead, allows to uniform different regions that can be put in corrispondence through an appropriate rotation or translation.

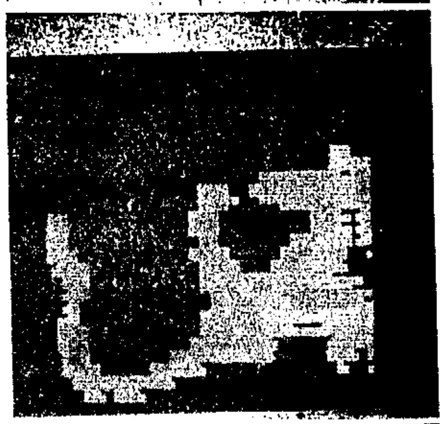
A-2



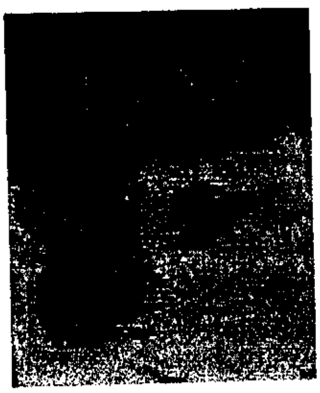
A-3

EXPERIMENTAL RESULTS

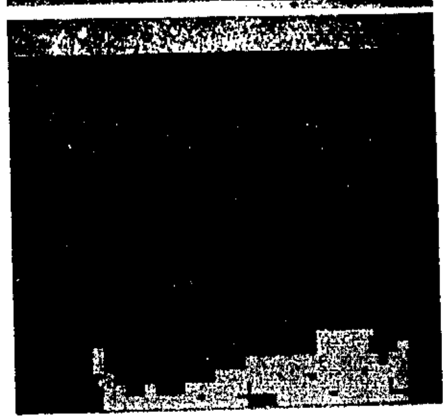
In this partagraph there are some of experimental results get through the algorithm application, both to theoric images and to real ones.
For some of the presented results, in addition to the input image and to the segmented output one, we have thought opportune to evidence some intermedial phases of the elaboration too.
In picture A-1 a radiographic image relative to an abdominal section is presented, in which we can recognize parts of different organs.
The pictures A-2,A-3,A-4,A-5 shawn the different individuated regions on the source image; and the picture A-6 shaws the final result of the effectuated segmentation.



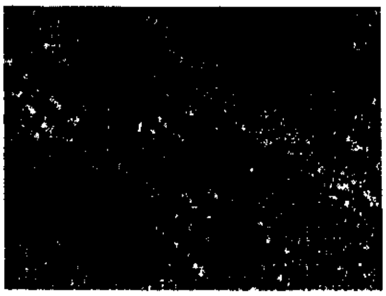
A-4

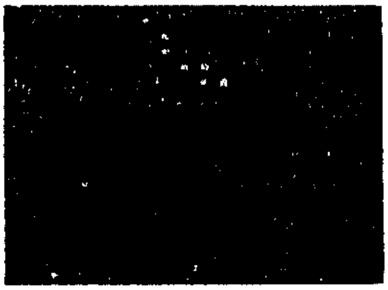


A-1



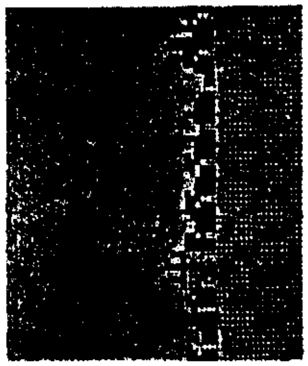
A-6





In picture B-1 we have an aereal images, and in picture B-2 is reported the same area of source image in which the algorithm has recognized an uniform background.

C-2



C-2

-In picture C-1, we have an image where is possible recognize the same real texture illuminated with two different source of light. The result of segmentation obtained on this image is presented in picture C-2.

CONCLUSION

What we have precedentely shown, in our opinion, finds several application to different real problems such as:
1)Texture classification
2)Elaboration of aereal images
3)Elaboration of biomedical images, etc.
The experimental results we obtained have been very good and they encouraging us to further research and to a much more sistematical experimentation of the algorithm in wider and wider fields.

REFERENCES

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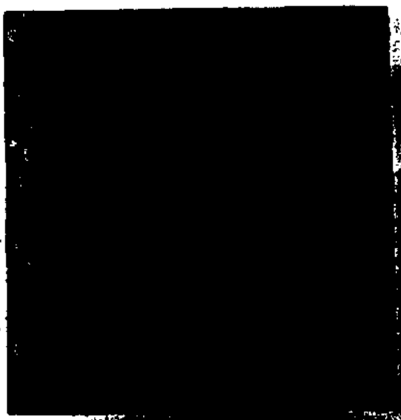

Fig.

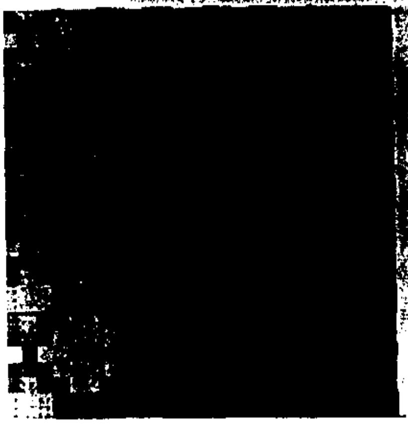

Fig. 5

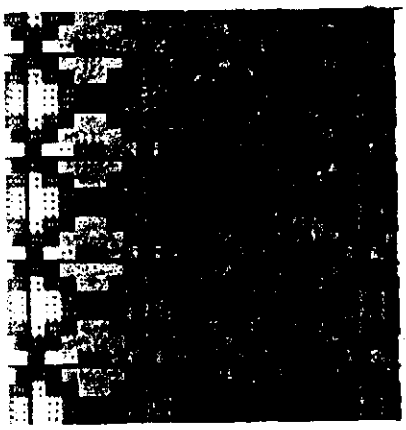

Fig. 6

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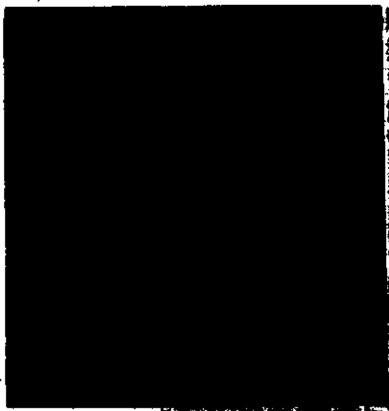
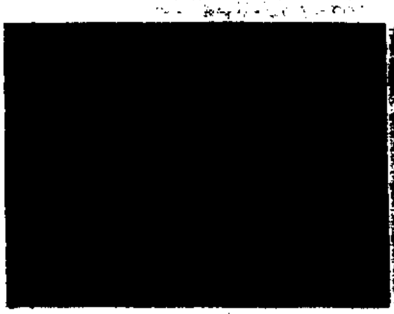
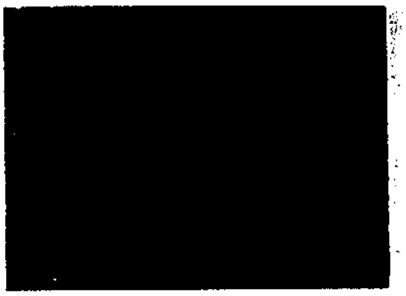


A-6





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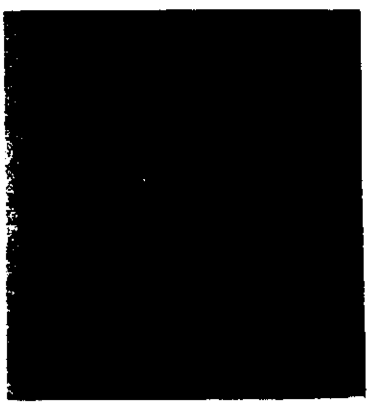
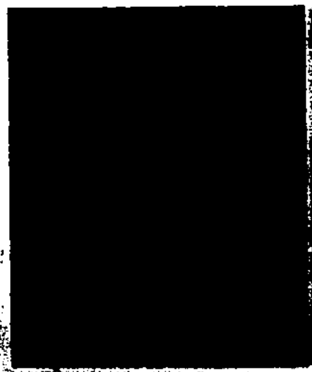


C-2



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