DETECTION OF HOMOGENEOUS REGIONS BY STRUCTURAL ANALYSIS

Fumiaki Tomita, Masahiko Yachida and Saburo Tsuji
Department of Control Engineering, Osaka University
Toyonaka, Osaka, Japan
+On leave to Cordinated Science Laboratory
University of Illinois, Urbana, Illinois

Abstract

A method is proposed for partitioning input scenes into regions in which selected picture properties are regarded as uniform. In this procedure, usual statistical methods of inspecting average gray levels are not used, but the uniformity of complex picture properties such as shapes, sizes or arrangements of subpatterns in the pictures is examined by a structural analysis. The analyzing process is controlled by a supervisor which gives the order of changing the depth of interest in each picture property, and successive partitioning of the pictures is made toward an interpretable goal partition.

Introduction

In recent years, many interesting papers on automatic scene analysis systems have been published for the recognition or identification of three dimensional objects. Most of their methods transform digitized pictures into line drawings, which are then analyzed and matched to one of models of the objects. The importance of the transformation is widely known, because the success of the recognition procedures highly depends on the correctness of the line drawings. Roberts is the first man who applied a local edge operator to find points where abrupt change in gray levels seems to occure. He then fitted straight lines to these points, and extracted the line drawings from the input pictures.[1] His technique has been improved to find better edge detectors and line finders.

Brice and Fenneman proposed another elegant method for the transformation of gray scale pictures into line drawings by breaking the digitized pictures into atomic regions of uniform gray scale, which are joined into regions by a pair of heuristics.[2] The procedure is successful to a class of input pictures, and each region obtained by these heuristics coincides with that human eyes perceive as one homogeneous region. Colors in the pictures are also important for visual perception and one can utilize color information instead of brightness to find uniform color regions.[3]

These approaches, however, assume that each plane of the objects and background has almost uniform brightness or color, and considerable modification is necessary if one wishes to apply the procedures to objects on which some patterns or textures are observed. Texture can be studied on two levels: statistical and structural.[14] Rosenfeld showed the applicability of the statistical methods to texture discrimination, and defined the texture edge, a generalized edge, as a series of points where abrupt change in the average values of local picture properties occure.[5,6] Several types of local edge detectors were proposed which compare the average gray levels in pairs of nonoverlapping neighbourhoods of various sizes.

This paper describes a generalized method for dividing the input scene into regions, which are useful to describe the scene in a compact form. In this procedure, statistical inspections of the neighbourhoods of individual points are not used, but a structural analysis is applied for examining the uniformities of complex picture properties such as sizes, shapes or arrangements of subpatterns. The analyzing process is controlled by a supervisor which gives the order of changing the depth of interest in each picture property, and successive partitioning of the picture is made toward an interpretable goal partition.

Region Detection

Homogeneous Regions

Observing a scene in which many objects are covered by patterns or textures, a human being can easily recognize each object if it has a different pattern or texture on it from those of adjacent ones. In other words, human visual systems pay their attention to some picture properties, and find a region such that these properties of the subregions or elements in it are considered to be almost uniform. These selected picture properties and the allowable limits of their nonuniformities in a region are not same in all cases. Suppose a human being sees a newspaper. If he has no interest in reading it, he may regard it as a sheet of paper having almost same texture. Of course he can recognize each character or discriminate difference between each atomic region of the texture, when his interest in reading is deep enough to decrease the threshold value for discriminating regions.

In this paper, a method is proposed for finding regions in the complex scenes which contain many objects and backgrounds on which different textures or patterns are observed. A simple example is shown in Fig.l

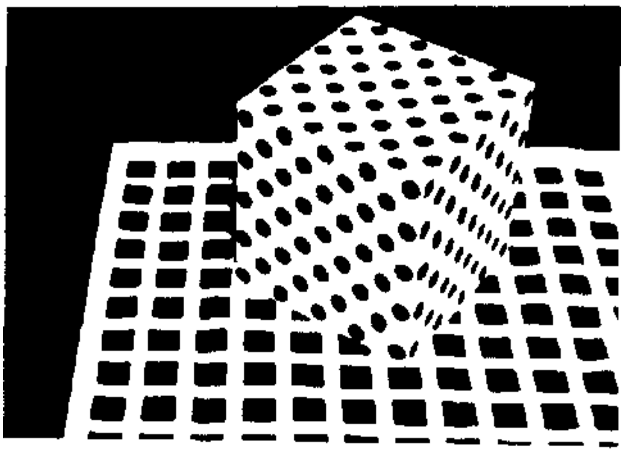

Fig.1 An Example of Input Pictures.

which includes a cube and a plane covered by two different patterns. We intend to describe more complex scenes having much information in terms of regions in which some picture properties are regarded as uniform. Statistical methods for finding the abrupt changes in the average gray levels seem to be inadequate for our purpose, because these approaches are not useful to distinguish differences between patterns of complex structures. Thus a structural analysis on homogeneities of several picture properties such as shapes or sizes of atomic regions in the input picture, as well as their relations, is used to find the regions.

Picture Properties

Before descibing the procedures for examining the uniformity in the region, we must clarify what picture properties are used for the analysis. In this paper, the atomic region is defined as a connected set of picture elements having almost same gray level or color. A preprocessor of the system finds these atomic regions in the digitized picture from a TV camera, and sends to the homogeneity analyzer the information of these atomic regions characterized by their average gray levels and colors, as well as their boundaries written in chain coding. There are many atomic regions in an input picture, therefore an efficient representation of their characteristics is needed in order to save memory space and computing time. Several picture descriptors of the atomic region are selected. They are shape, size, position, color and average gray level descriptors, although last two *are not used* in the partitioning process. Area and perimeter of each atomic region are specified by the size descriptor, and the position descriptor gives the two dimensional cordinate at the center of gravity of the atomic region.

Because of the limitaion in the resolution of the TV camera, accurate shape of the atomic region is not available, and the shape descriptor must be selected in such a way that it gives coarse information of the shape and it is not sensitive to sampling noises in the process of digitizing picture. A set of ijth order moment *M. .* seems to satisfy these conditions. A combination of M_{20} $M_{a?'}$ M_{2I*} M_{12} *and* M_{11} *is* adopted as the shape descriptor, since a series of experiments shows that it is adequate for detecting shape differences of small size domains.

Another type of picture properties used for the analysis is relation between two atomic regions or regions. For simplicity, only the density descriptors are used for representing the relation between atomic regions in a group. Let define the distance between two atomic regions as the distance between their centers of gravity. An atomic region *A* in a given set S has a density descriptor *D* whose value is the minimum distance frorn[8] *A* to other atomic regions in *S.*

Regions

Examining the similarities of the picture properties by comparing the values of these descriptors, the system will classify the atomic regions into sets S_1, S_2,..., S_n

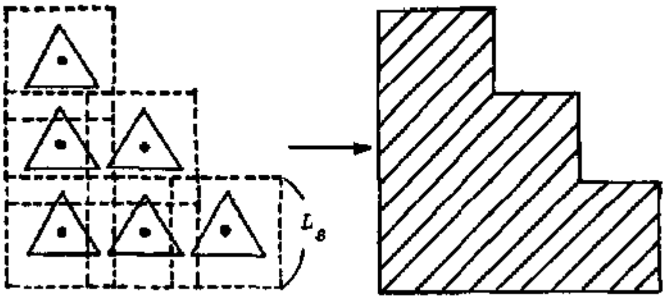

Fig.2 Area Covered by Elements of a Region.

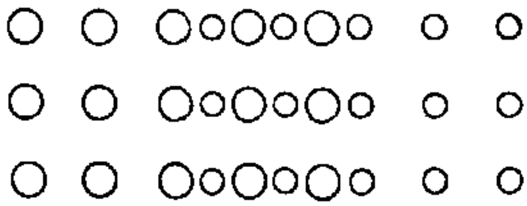

Fig.3 An Example of Three Regions Constructed by Two sets S_1 and S_2

which are candidates for the regions. The region *R* covered by m elements in the set *S* is defined as follows. Let denote the maximum value of the density descriptors in *s* by L_s . ft is a connected area covered by squares whose length of edge is L_s and centers are located at centers of gravity of all members of *S (Fig.2).* Sometimes there are plural regions whose elements belong to one set *s.*

The analyzer also examines a relation between regions. Fig.3 shows a simple example in which there exist two classes of atomic regions. Let R_1, and R_2 be regions covered by small dots and large dots.respectively., Since common area of fljf\ /? of two regions has considerable size, it seems reasonable for the analyzer to regard these areas as ▪three regions R_1 \ *$_{2>}$ *Rj* O ff_g and R_1 O R_2 instead of two.

Therefore the system checks whether each region has any overlapped part or not, but neglect ones whose size is less than a certain threshold value.

Structural Analysis

Structural Analysis

Fig.4 shows an overall diagram of the scene analyzer. Output of a standard vidicon camera is transmitted to an analog to digital converter which produces one of 64x64, 128x128 or 256X256 digitized pictures with 64 gray levels. A preprocessor searches in the digitized picture for the atomic regions. We consider that color information is more useful to our purpose, however only gray level information is used in the experiments. In this paper, an assumption is made that each atomic region has a clear outline. Thus we put little emphasis on the process of finding the atomic

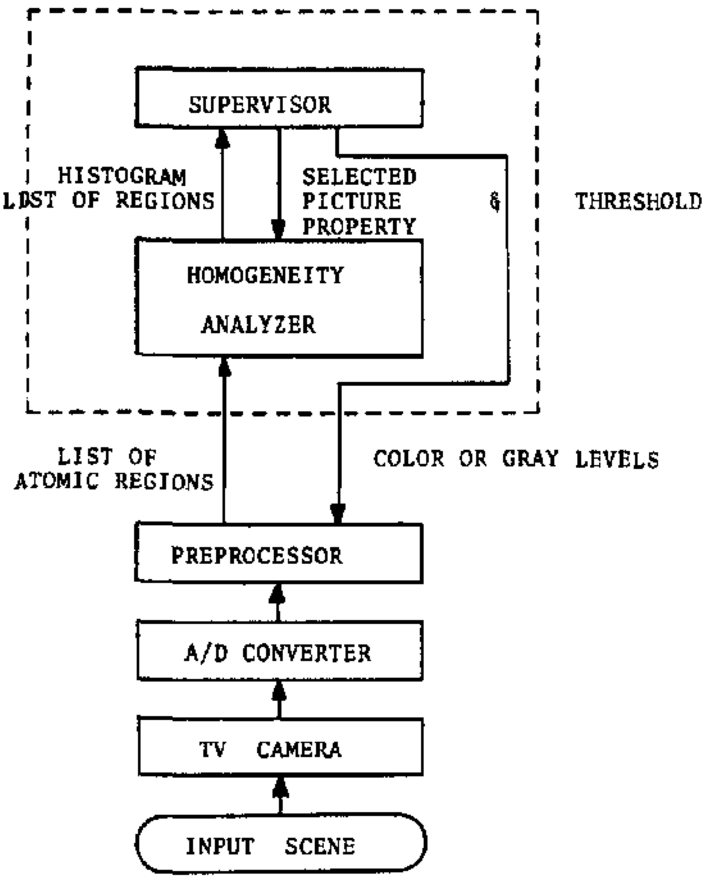

Fig.4 Overall Diagram of the Scene Analyzer

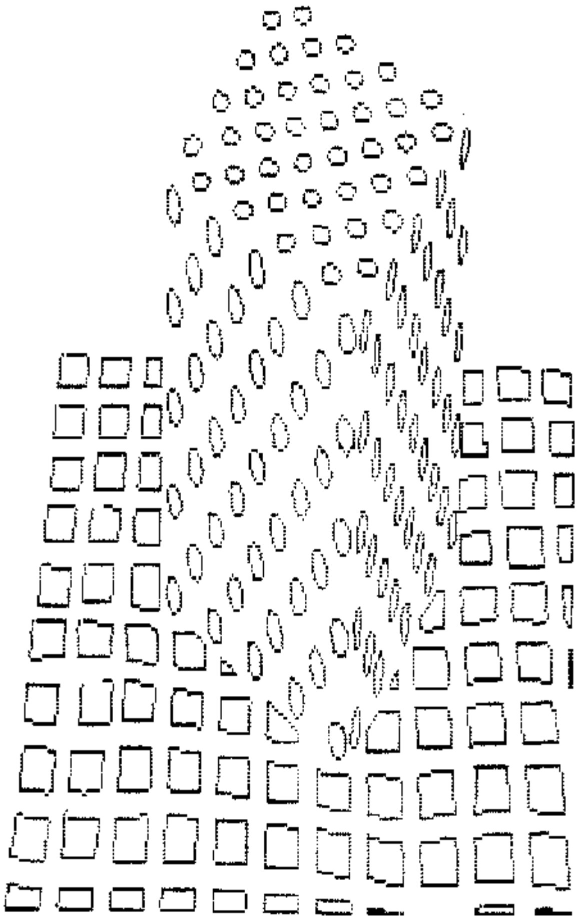

Fig.5 Detected atomic regions in 256x256 Digitized Picture of Fig.I.

regions, and usual procedures are used for detecting the contours of the connected areas in which gray level of each point is lower than the threhold value decided by the gray level histogram.[7] Fig.5 shows the result for the input scene of Fig.I which is digitized in a 256x256 array.

A list of these atomic regions with their boundaries described in chain coding is sent to the homogeneity analyzer. The analyzer divides the same input scene in different ways depending on the depth of interest in particular picture property. Since we intend to apply the descriptions of the scene in terms of regions to automatic recognition or identification of objects, successive partition must be made in heuristic ways to find an interpretable goal partition whose structure matches one of combined models of the objects. Therefore the system is provided for a supervisor which receive the information from the analyzer, and then plans the sequence of partitioning which is sent back to the analyzer.

Homogeneity Test

A detailed block diagram of the homogeenity analyzer is shown in Fig.6. First of all, the picture descriptors are evaluated and their list is constructed. Secondly, histograms of values of the descriptors are computed and small fluctuations in them are suppressed by a filter which smoothes the small peaks standing close to each other. These frequency distributions are examined by the supervisor to select the most promising descriptor for classifying the atomic regions into groups. We consider that a descriptor is promising to initial partitioning if the atomic regions are definitely classified into a few groups by it. Choosing the descriptors whose histograms have deep valleys between prominent peaks, the supervisor sets thresholds at the bottoms of the valleys. Since validity of classifying the members in the valleys by thresholding is ambiguous, the descriptor having the minimum number of such members is selected by the supervisor. Fig.7 shows the histograms of the descriptors of the input scene of Fig.I, and the perimeter term of the size descriptor is selected for the first stage partitioning.

Next the density descriptors of members in each group are evaluated. If some members have the density descriptors whose values are larger than a predetermined threshold value, they are regarded as isolated atomic regions and are excluded from the groups. Thus the first stage partitioning has groups S_1 S_2 ....s_n as candidates for regions. As mentioned in the previous section, the areas covered by these groups are decided, and then their connectivity and overlapping are examined to decide re-

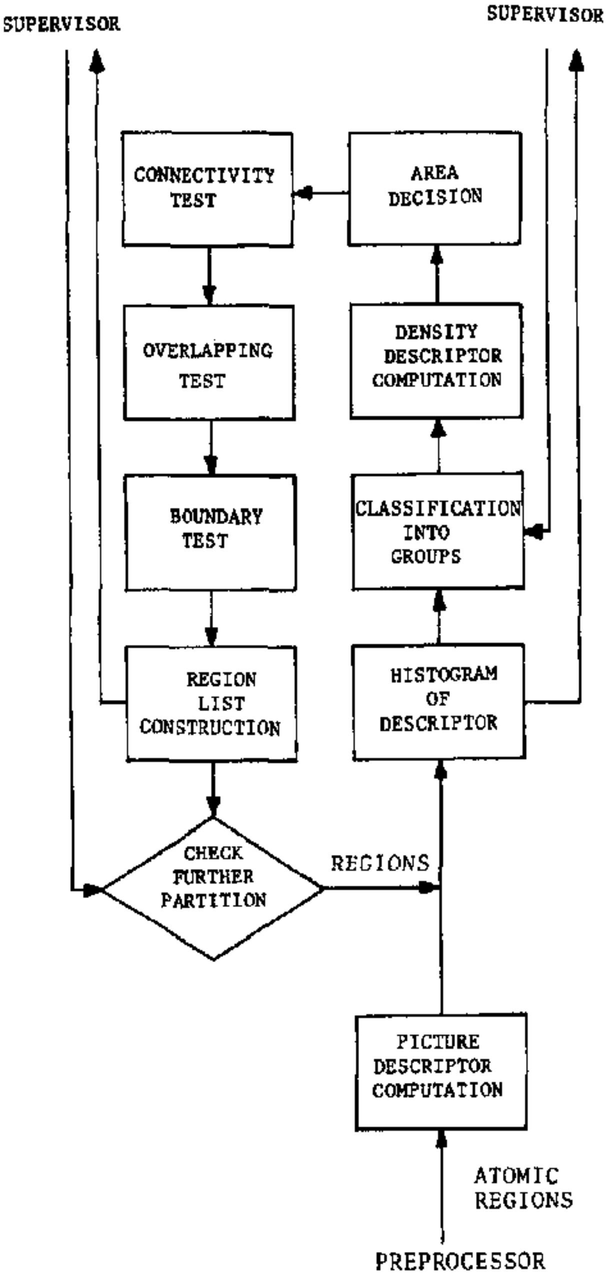

Fig.6 Detailed Block Diagram of Homogeneity Analyzer

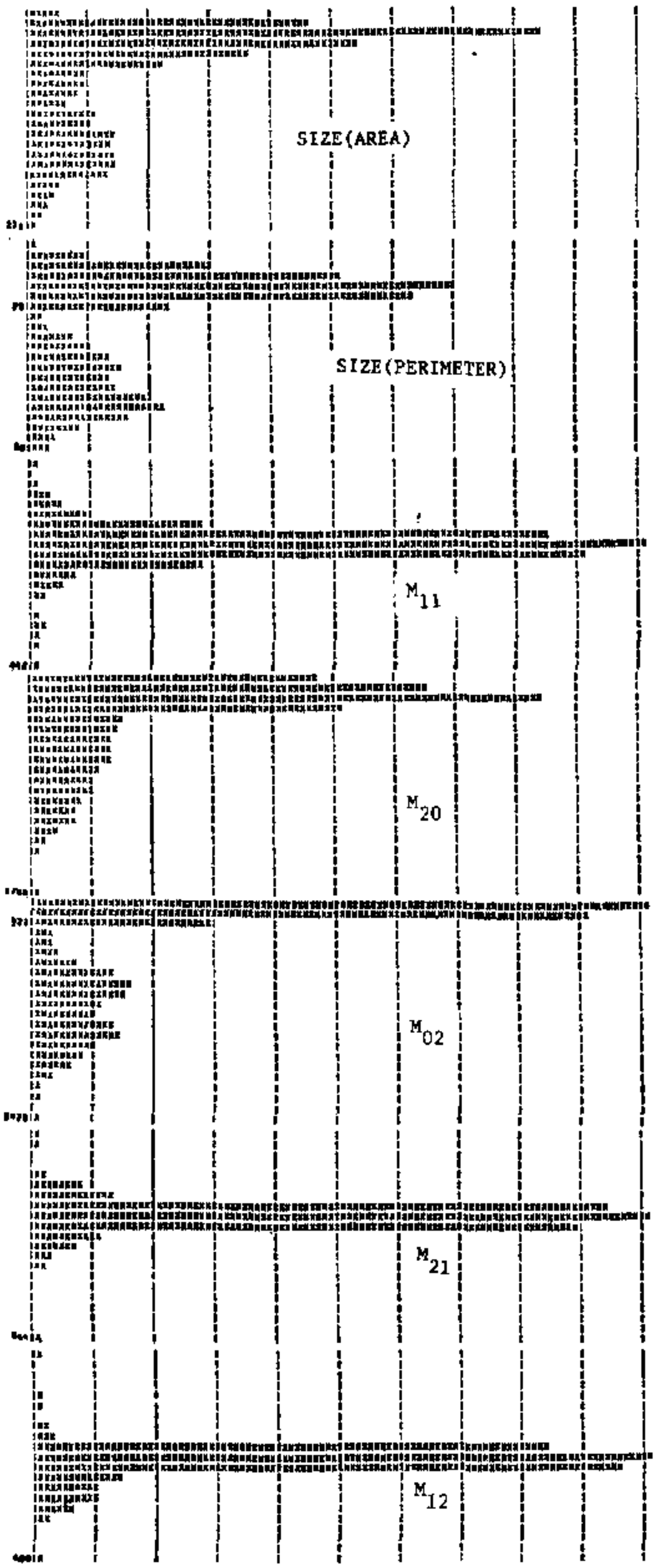

Fig.7 Histograms of Picture Descriptors of Atomic Regions in Fig.5

gions. If a connected area of region candidates has less than five members, the analyzer does not regard it as a region and registers its members in a group of isolated atomic regions. Next, a boundary test is done to check whether any atomic regions in the group of isolated elements are located between two regions OT surrounded by a region. They are joined to the region if only one region touches them. However they are left in the isolated member's group if two regions touch them, because we cannot find any simple methods for finding which region is more adequate for merging them. Fig.8 shows the results for cassifying into regions by the size descriptors. The regions R_1 and R_2 correspond to the cube and the plane, respectively. Small size atomic regions at the boundary of the picture are not classified into region candidates of R_2 but the boundary test joins them to R_2.

The regions described by their boundaries and elements are sent to the supervisor which fitts straight lines to the boundaries to get a line drawing. If any part of the line drawing does not match the structure of the models, the supervisor considers the result of the partition is not successful and further partitioning is done. There are three methods to change the partition: 1) deeper partitioning, 2} modified partitioning after changing threshold values, 3) new partitioning by another descriptor. In our experiments only deeper partioning is programmed, then the iterative partitionings are terminated when any matched part of the regions to the model structures is found or no further partitioning is possible. Satisfactory results are obtained for simple input scenes, however other type modifications are necessary for complex inputs.

Regions R_1 R_2, ... found by the first stage partitioning are processed independently to obtain deeper partition R_{11} R_{12} R_{21} R_{22},.............The procedures are Same as those of the first stage. Fig.9 shows the

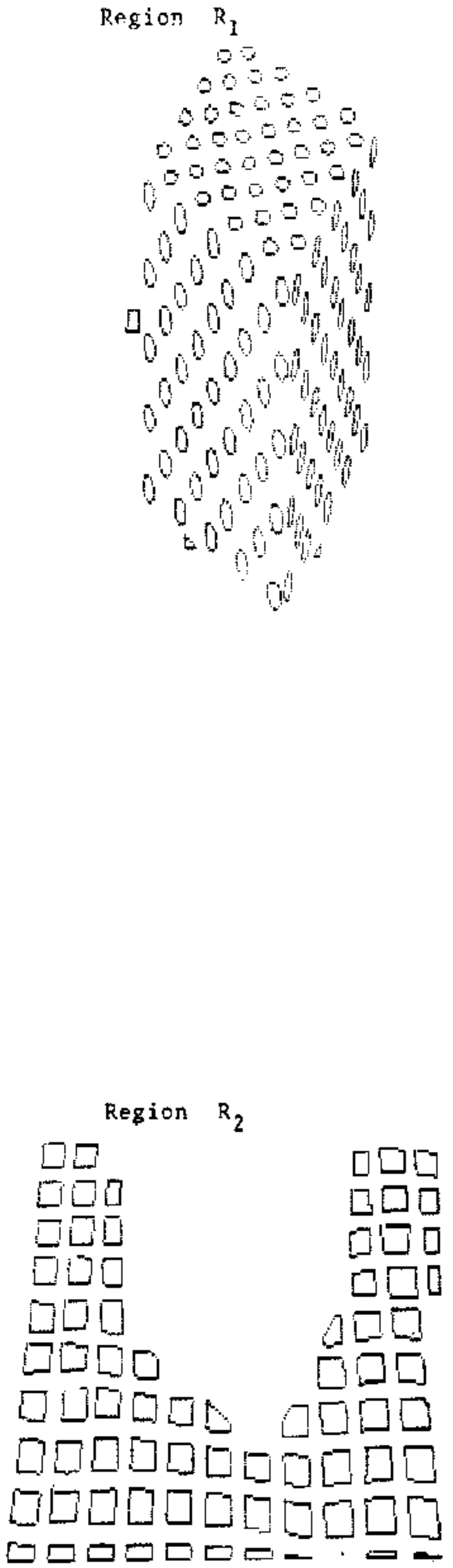

Fig.8 Partitioned Results by Size Descriptor

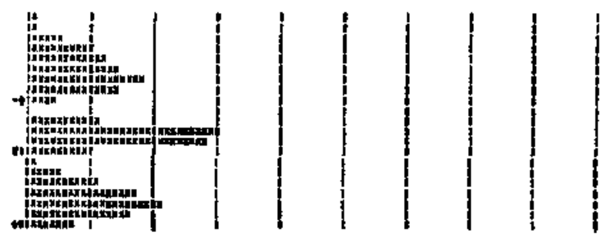

Fig. 9 Histogram of M_{11} in R_1 (Cube).

histogram of M_{11}, in R_1. (cube) in which three groups are observed. It must be noted that M of Fig.7 has not any deep valley. That is, the successive procedures can detect finer difference between members having a almost same feature, if the previous partition is adequate. The results of partitioning R_1 into three regions R_{11}, R_{12}, R_{13} which correspond to three planes of the cube, are shown in Fig. 10. Two small triangles and a square at the boundary of R_1 in Fig.8 are classified into the isolated member's group and eliminated from the regions. The histograms of descriptors in R- have no deep valleys., and further partitioning is not

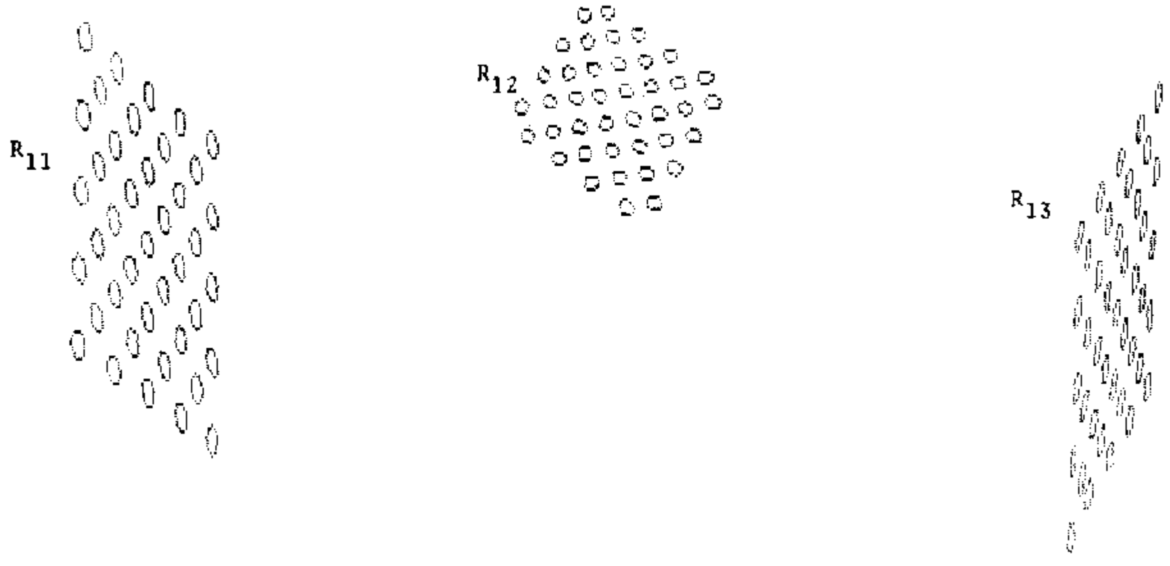

Fig. 10 Further Partitioning R_1 into Three Regions

possible.

The scene analyzer is programmed in FORTRAN, and total cpu time of a medium size computer HITAC8350 (196kbytes 1.8 μsec memory) for the analysis of Fig.1 is 5 minutes 25 seconds.

Experimental Results

Experiments for several input pictures are done to check the validity of the method. Fig.11 shows an example in which six regions exist. The system classifies it into two regions R_1 and R_2 by the size descriptors. The results are illustrated in Fig.12. R_1 is further divided into three regions R_{11}, R_{12} and R_{13} by the density descriptors.

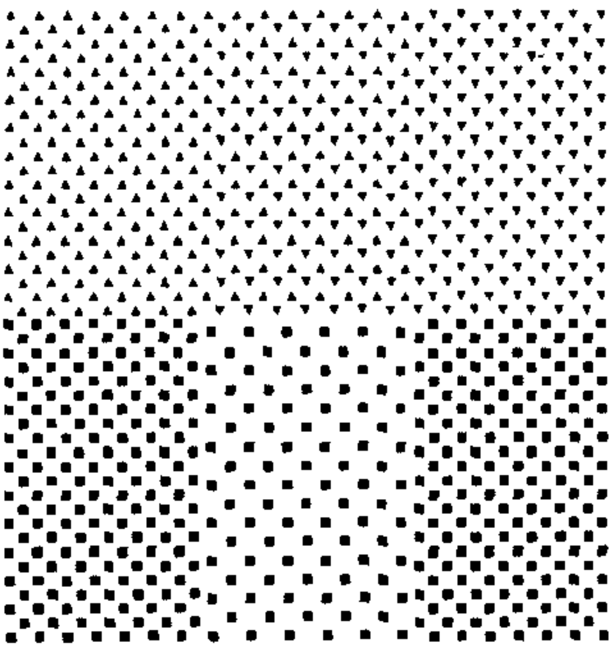

Fig.11 An Input Picture with Six Regions.

R_{12} and R_{13} have same picture properties, but are separated by the connectivity test. (Fig. 13)

R_2 is divided into R_{21}, R_{22} by examining M^2_{12}, and then the density descriptors are checked for further partition. There are four regions R_{211}, R_{221}, R_{212} and R_{222}, however the overlapping test joins two regions R_{212} and R_{222} and obtains a region R_{23}.

Another example of input pictures is shown in Fig.15. The atomic regions in this example are randomly arranged. Some of the histograms of the picture descriptors are shown in Fig.16. Testing these data, the supervisor finds that the density descriptors are applicable to partitioning.

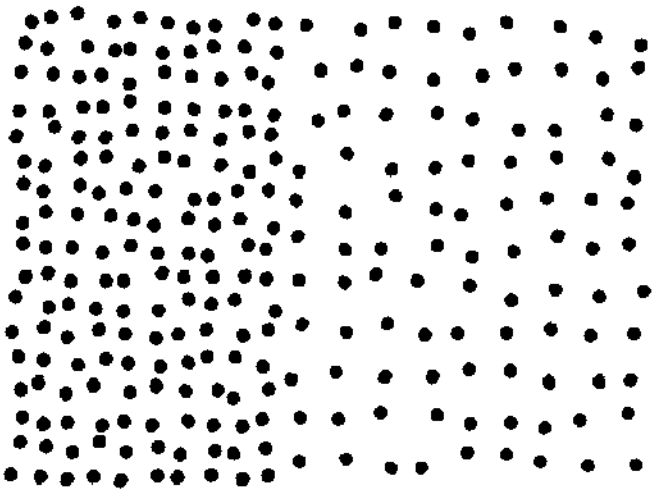

Fig. 15 An Examples of Input Pictures in Which Atomic Regions Are Randomly Arranged.

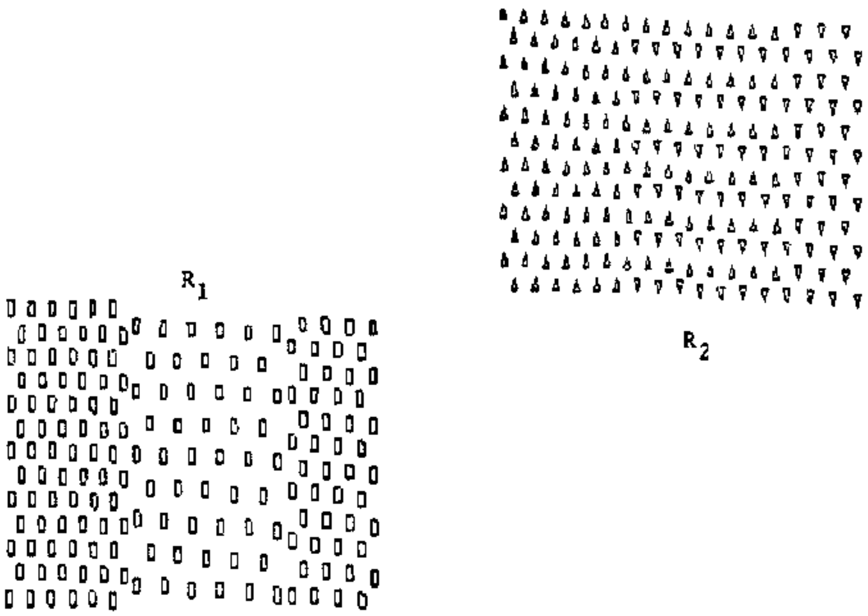

Fig.12 First Stage Partitioning into R_1 and R_2

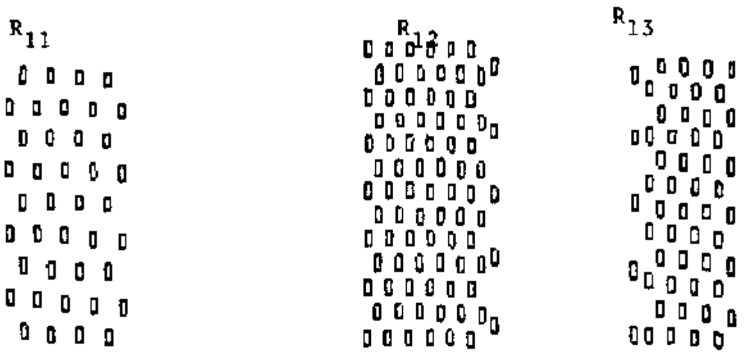

Fig.13 Second Stage Partitioning R_1 into R_{11}, R_{12} and R_{13}

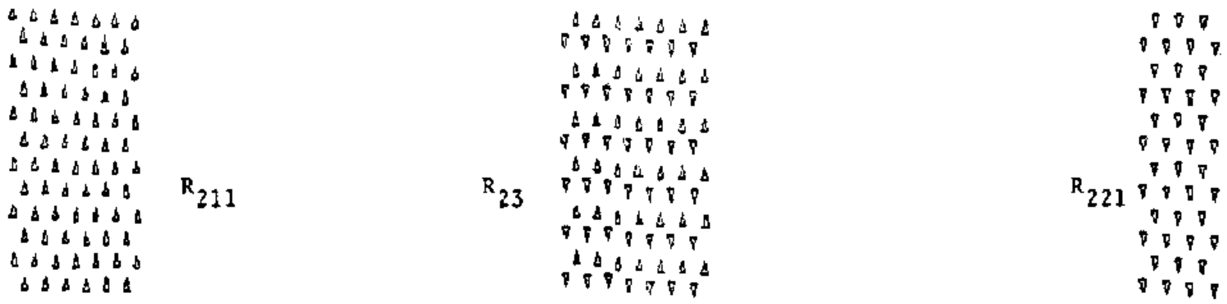

Fig.14 Second and Third Stage Analysis Yield a Partition of R_2 into Three Regions R_{211}, R_{221} and R_{23}

(A) Histogram of Size Descriptors

(B) Histogram of Density Descriptors

Fig.16 Some of Histograms of the Picture Descriptors of Atomic Regions in Fig.15

Fig.17 shows the results of classifying the atomic regions into two sets *S.* and *S.* in which several isolated region candidates exist. Examining the boundary test, the system merges them into regions, and obtains two regions R_1 and R_2 shown in Fig.17.

Discussion

In this paper a method is proposed for detecting the regions in which some picture properties are almost uniform. We use a structural analysis on the picture properties instead of usual stochastic methods, and we find it is useful when the structure of patterns or textures in the picture are complex. However, an assumption that discrimination of the elementary subpatterns or grains in the Picture is easy, is necessary. Applicability of the simple thresholding based on the histogram of brightness is shown if the boundaries of elementary grains have sharp edges. The heuristics by Brice et al. would give better results when average gray levels in atomic regions distribute in wide range, and this average gray level information might be used in the partitioning process.* Color information seems to be more useful than gray level information.

The method proposed in this paper would be applicable to detecting iterative structures of artificially constructed objects or recognizing objects covered by almost regular subpatterns. Computing time of the partitioning is rather lone because any attempt is made to save it, and we consider some programming effort could decrease it considerably.

Since the job of the supervisor is simple one which iterates partitioning unitil it finds matched structure of regions to the models, future study is necessary to make the supervisor powerful, especially to find better heuristics to modify the depth of interest in particular picture property.

Acknowledgement

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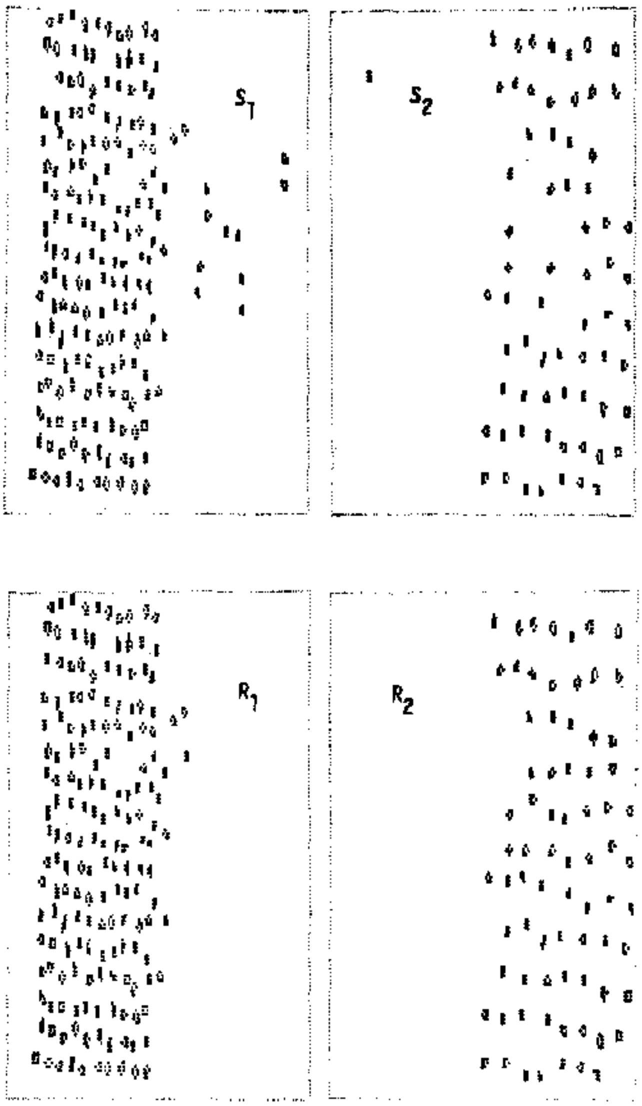

Fig.17 Partition of Picture Arranged Randomly.

References

1] Roberts, L. G. "Machine Perception of Three Dimensional Solids" *Optical and Electro-Optical Information Processing,* Tippell et al., MIT Press (1965)

2] Brice, C. L. 5 Fennema, C. L."Scene Analysis Using Regions" *Artificial Intelligence,* 1, p205, (1970)

T] Yachida M. 5 Tsuji S. "Application of Color Information to Visual Perception" *Pattern Recognition!* 3, p307 , (1971)

4] Rosenfeld, A, & Thurston, M. "Edge and Curve Detection for Visual Scene Analysis" *IEEE Trans. Comput.* C-21, p677, (1972)

5] Rosenfeld, A. & Thurston, M. "Edge and Curve Detection: Further Experiments" *IEEE TRANS, Compt.* C-21, p677., (1972)

6] Rosenfeld, A. *Picture Processing by Computer,* pl29, Academic Press, (1969)

7] Lipkin, B. S. % Rosenfeld, A., Ed. *Picture Processing and Peyahopictoriea*, p289, Academic Press, (1970)