ON THE EXTRACTION OF TEXTURAL AND STRUCTURAL FEATURES IN REMOTE SENSING DATA

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ABSTRACT

Remote sensing problems are discussed in those cases where the extraction of textural and structural features is reasonable additionally to multispectral features. For texture analysis great importance is directed to the determination of the extraction area and the geometric resolution.
Various methods are tested to derive general rules for these measures used in techniques for texture analysis. At this the extraction area should enclose at least 5 x 5 texture generating objects. The resolution should be selected in this way that at least 20 x 20 pixels are placed in the extraction area.

As an example the correlation between natural textures in remote sensing data and surface reliefs of the objects is demonstrated on spruce and pine stocks. This results in instabilities and limitationes of applying the statistical approach for texture analysis. This plight can be shifted in deriving a more structural approach for texture analysis.

1. Introduction

Textures and structures are of special interest for the interpretation of remote sensing imagery. For more than 10 years scientific work has therefore been performed to use, in addition to spectral signatures, features of texture and structure for the numerical classification of remote sensing data [1, 3, 5, 6]. The results obtained hereby turned out to be partly satisfactorily but also contradictorily. On the one hand progress has been made to increase the accuracy of recognition to about 95 %, on the other hand deterioration of accuracy has to be realised. In this article the experiences of the authors in testing various texture measures for remote sensing problems are presented. Those critical aspects of texture analysis which could lead to inconsistent results are also discussed.

2. Problems for textural and structural analysis in remote sensing data

The concrete formulation of tasks for the analysis of texture and structure are strongly correlated with the general aim of applying methods for remote sensing. In the GDR the principal aim of developing remote sensing methods consists of acquisition of actual information on

a) nature and geometrical arrangement of soil covering

b) state of individual agricultural areas

Generally speaking the tasks for textural and structural analysis can be classified into 3 ranges of resolution:

0,5 - 3 dm, 1 - 5 m, 10 - 100 m.

Table 1 contains the goals of textural and structural analysis which are mainly referenced to the acquisition of knowledge on the state of an agricultural area. Moreover features for texture and structure have also principal importance for determination of object type. For many relevant problems in the national economy however the object type can be assumed as known, i. e., its determination can be obtained by spectral signatures exclusivly. In addition to land use problems lined up in table 1 textural and structural features take a role in analyzing oceanic wave fields and geological problems. Summing up the existing problems, it is clear that textures in a "classical" sense may be rated as of minor importance. "Pure" textures properly appear only in forest areas and possibly in oceanic wave fields. For the majority of problems structures respectivly strongly "disturbed" textures prevail. Concerning the present sensor devices applicationes in the resolution range 0,5 - 3 dm are still practical meaningless. Applications in the range 1 - 5 m are valid for high altitude aerial photographs, in the range 10 - 100 m for space photographs.

3. Determination of geometrical resolution and size of extraction area required

Textural features are determined over an extraction area (operational unit = OP) which consists of a definite number of resolution cells. Size of both extraction area and resolution cell are of fundamental importance for the stability of the features derived [2, 6, 7]. Generally speaking these quantities are to be determined in such a way that the features become invariant to displacements of the extraction area.
To get experience in optimizing these quantities the following investigations on the field of geo-remote sensing were carried out:

a) Study on the bahaviour of the gray level coefficient of variation as a function of geometrical pixel size

The results for some object types are shown in fig. 1. Assuming coefficients of variation of about 10 - 20 % to be reasonable (zero approximation), this yields to the following size dimensions of resolution cells required for texture analysis:

cereal crops	c. 0,5 - 1	dm
root crops	c. 1 - 5	dm
orchards	c. 1 - 3	m

b) Studying the influence of pixel size on the texture's autocorrelationfunction (ACF)

Results for the one-dimensional ACF are presented in the figures 2.1 and 2.2 for two objects (forest and orchard). Also it turns out that deteriorating the geometrical resolution beyond a fixed value (forest: 12 m, orchard: 3 m) the ACF becomes instable. The corresponding values can be considered as lowest resolution to be needed for texture analysis.

c) Investigation of gray level histogram change within the OP. The OP will be stepwise reduced, with the resolution being unchanged.

For pine forest the results of histogram change are shown in fig. 3. Starting with a 80 x 80 image the OP will be stepwise diminished (geometrical resolution c. 3 m). The typical shape of histogram is left unchanged until a size of 30 x 30 pixels is attained. More reduction of OP causes instabilities on the form of histogram.

d) Study on the stability of textural features based on cooccurence statistics as a function of OP-size

Fig. 4 shows the results obtained for the feature SDM (second difference moment, derived on cooccurence matrices, which in their turn set up for different directions and counting distances). Examples of artifical texture sets show, that the feature SDM can be considered as stable down to a 100 x 100 image size. Further reduction leads to oscillations of the feature values.
These methodical investigations were supplemented by the following methods:

- run length statistics
- local detection of gray level maxima
- coherent optical Fourier transformation

As above stated in addition to natural textures a series of artificial texture sets generated by stochastic arrangements of peas, some of which were taken photographs under various conditions of illumination, were also studied in a likewise manner (fig. 5). By this means textures could be simulated which are similar to those ones occured in aerial photographs of pine and decidnous forests.

The results concerning dimensioning of extraction area and geometrical resolution allow the following general conclusiones to be drawn:

a) The extraction area should contain at least 5 x 5 generating texture objects (forest texture: 5 x 5 tree tops, respectivly "melted" groups of tree tops).

This means, that a minimum size of extraction area for pine and deciduous forest of about 40 x 40 m is reasonable.

b) The geometrical resolution should be at most half the object dimensiones

These conclusions are mainly valid for statistical methods of texture analysis. Concerning the syntactical methods criteria which are inherent to specific applications have to be developed for the determination of the OP size. The OP dimensions derived here and the politico-economical needed areas which are to be applied for texture analysis lead to further restrictions of application.

4. Remarks on the significance of formalised textural and structural features for data interpretation

Owing to the surface relief of natural objects textures in remote sensing data depend in general on the angle of illumination (altitude of sun) and inclination of terrain [4].
Nevertheless a visual operating scientist may be able to recognize and to classify textures belonging to natural objects from aerospace imagery even under different recording conditions.
By means of numerical textural analysis however these properties could not be achieved satisfactorily by now. In spite of size optimization of the extraction area and geometrical resolution in some cases strong instability was evident with regard to the recording situation. Fig. 6 verifies a good correlation between the cooccurence feature SDM and the age of pine stands. It should be taken into account however, that the results presented here refer to an only aerial photograph. In the case of homogenous spruce stands texture measures are depending on angles of inclination and illumination in a higher degree. By means of statistical methods in these cases it was not possible to extract consistent features which could be brought in good correlation to phenological parameters.

Similar results were obtained by other sets of natural textures. The conclusion can be drawn that statistical methods on texture analysis by interpreting remote sensing data can sucessfully applied only in special cases.
For the structure analytical methods texture can be characterized as a pattern consisting of primitives which in their turn possess properties of shape, size and arrangement in a definite manner. The task can be defined as extraction of features describing these properties fully or in part.
First results which turned out to be quite satisfactorily have been obtained by a method which determines number, size and practically shape properties of texture primitives. For isolating the primitives and respectivly the objects the discriminance criterium operates level oriented, e. g. gray level differnences between "object" and "background" (noise) serve as criterium of decision. For some problems the features mentioned represent texture measures which can be used in a direct way. Taken forest as an example the measures correlate with the number of tree tops and average diameter.

Because of the results obtained so far, it seems conceivable to use practically these structural features for woodstock estimations. The isolation of texture primitives does not work always well defined in a gray level related manner, so a hierarchical combination by means of clustering or shape filtering will be required. In connection with this the sharp increase of costs in computer time has to be accounted for. That depends on selecting measures which on the one hand are suited for solving the tasks to be faced and on the other hand are become invariant to influences which cause structure properties of textures to be changed. Absolute gray levels however play a role of minor importance.

5. References

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Table 1 Classification of tasks for textural and structural analysis on the field of land use

Resolution	Object	Goals	mean object size
0,5 - 3 dm	Agricultural areas	Relations between yield and texture Recognition of vitality state	50 ... 100 ha
1 - 5 m	Forest areas	Relation between wood-stock and texture	max. 50 ha
	Orchards	Recognition of deficit places as well places with shortfall of yield	
	Specklike structures in agricultural and forest areas	Detection of defined specks and their influence on yield	
	Structures of cultivation on agricultural areas	Recognition of cultivation state	
10 - 100 m	Townships, Settlements	Relation between texture and type of settlement as well geographical information	20 ... 100 ha
	Greater specklike structures in agricultural and forest areas	Detection of specks and their influence on yield	

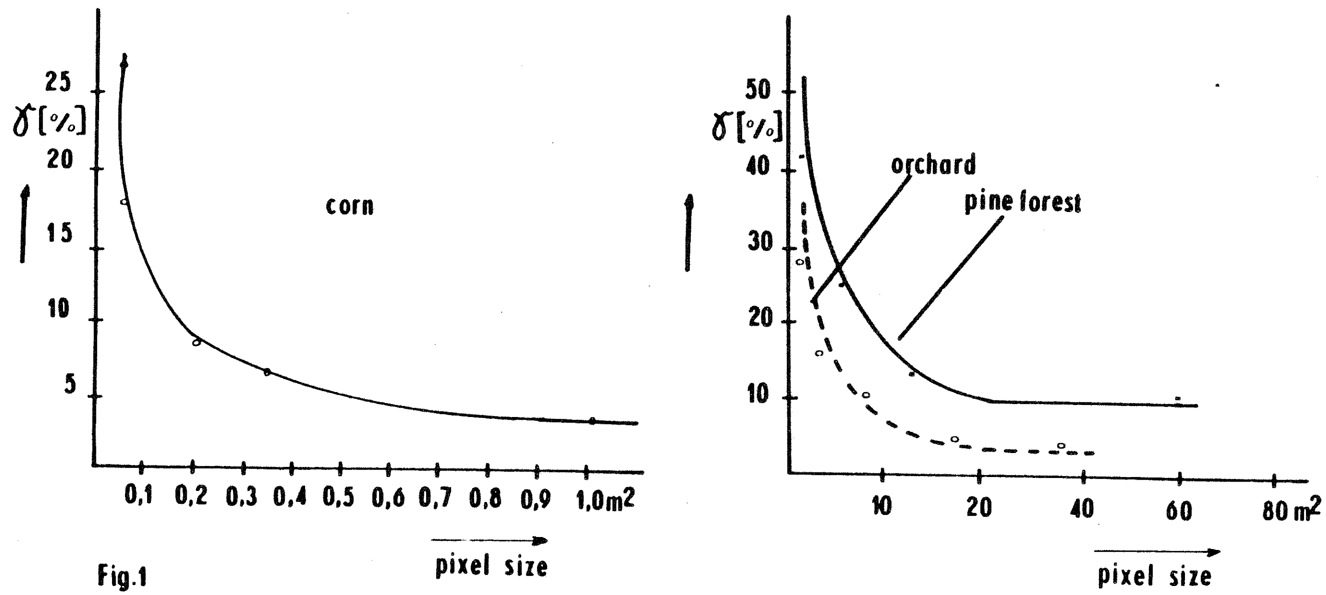

Fig.1

Behaviour of gray level coefficient of variation vs geometrical pixel size

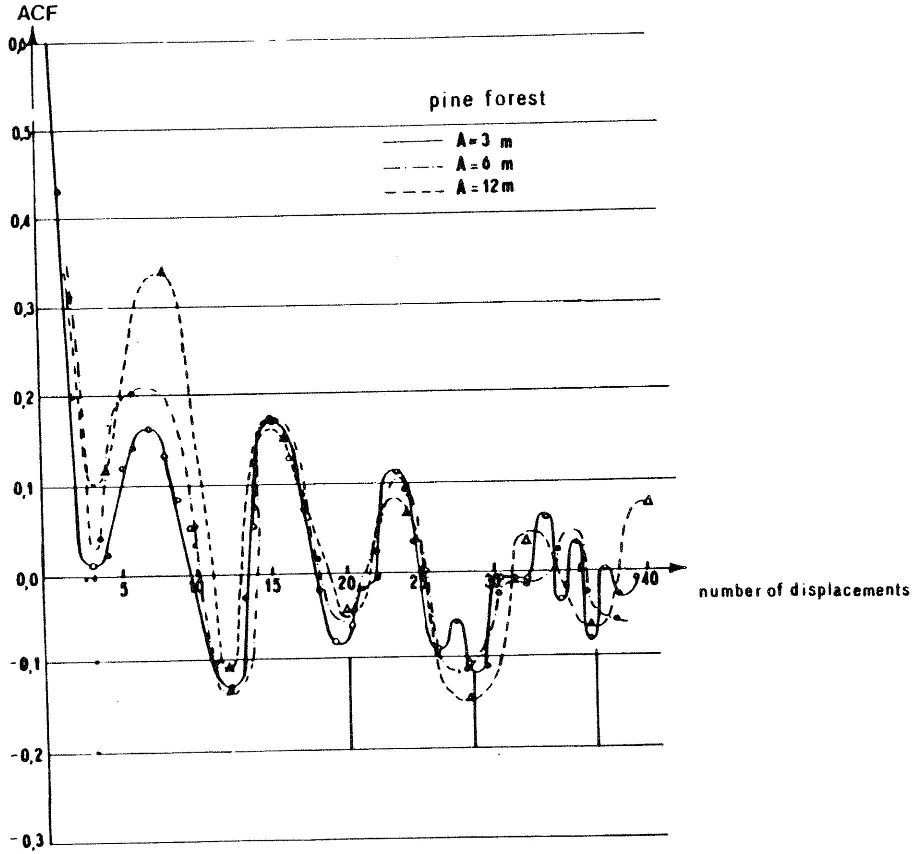

Fig. 2.1

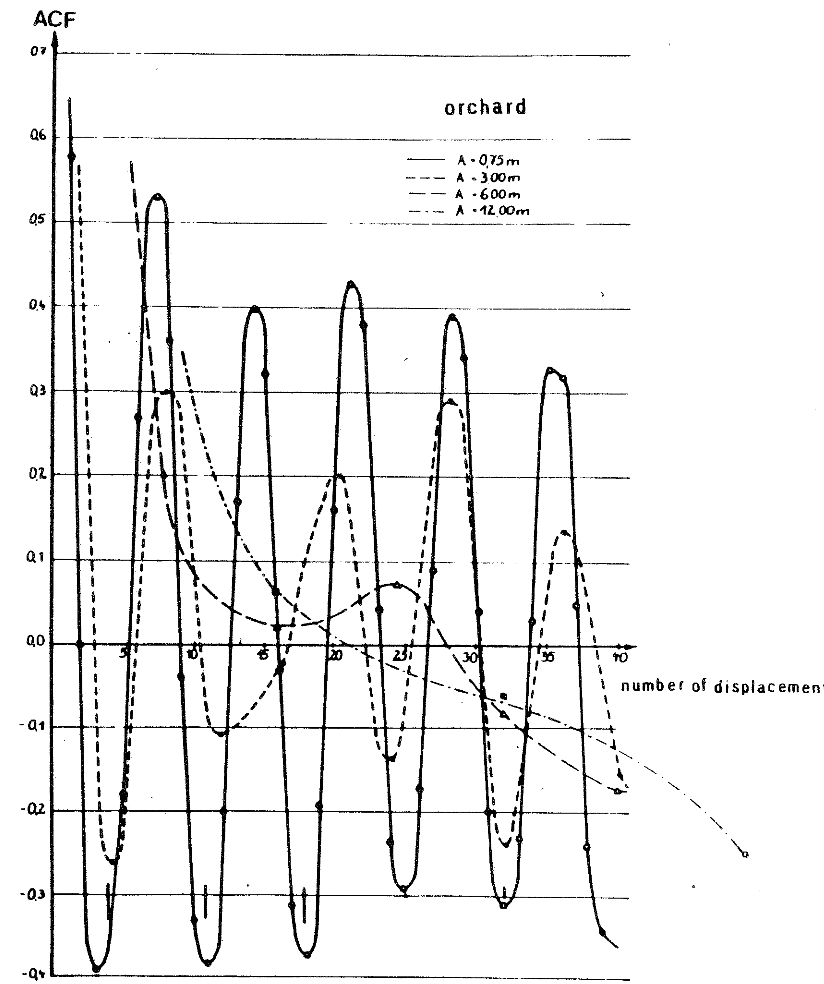

Fig. 2.2

Influence of pixel size on the texture's autocorrelation function for pine forest

Influence of pixel size on the texture's autocorrelation function for orchard

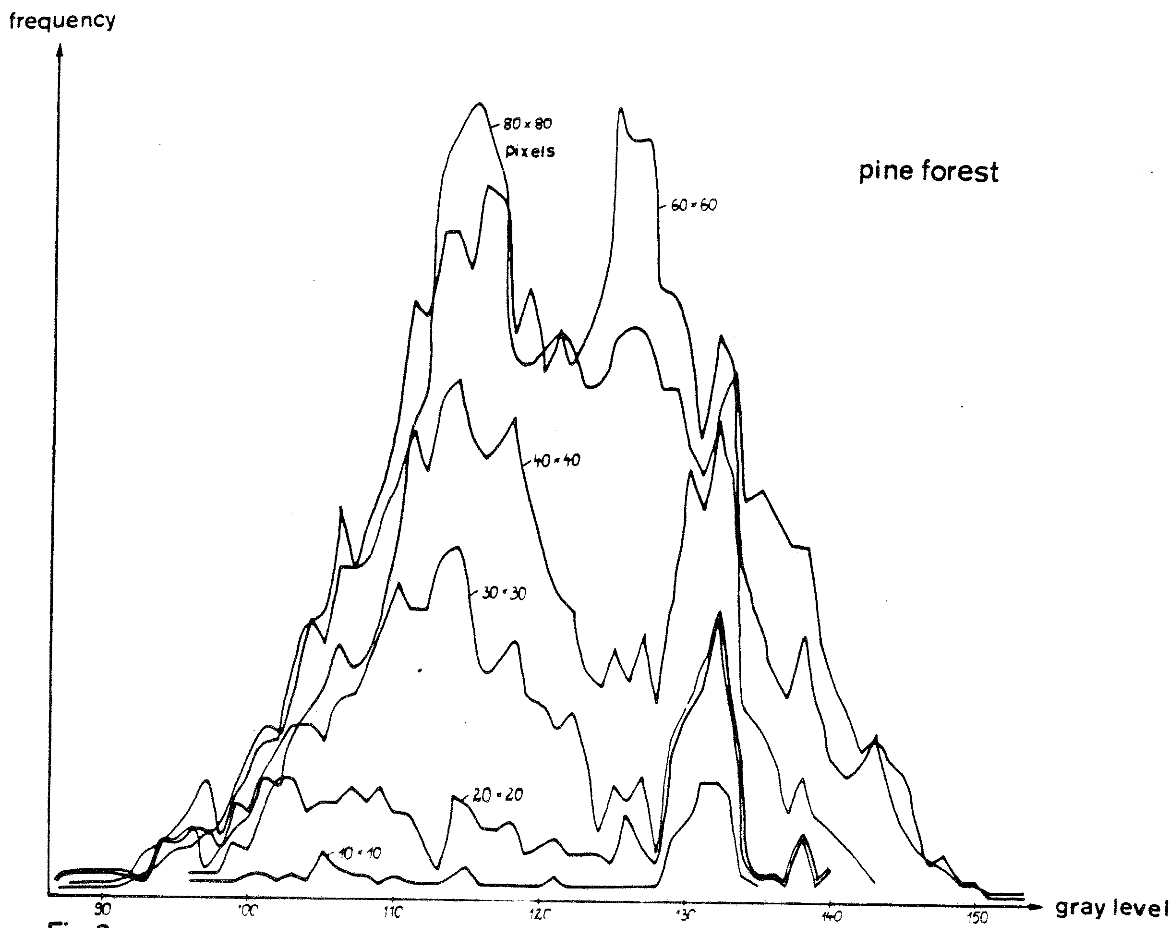

Fig.3

Investigation of gray level histogram change within the OP.
OP will be stepwise reduced, while the resolution being unchanged.

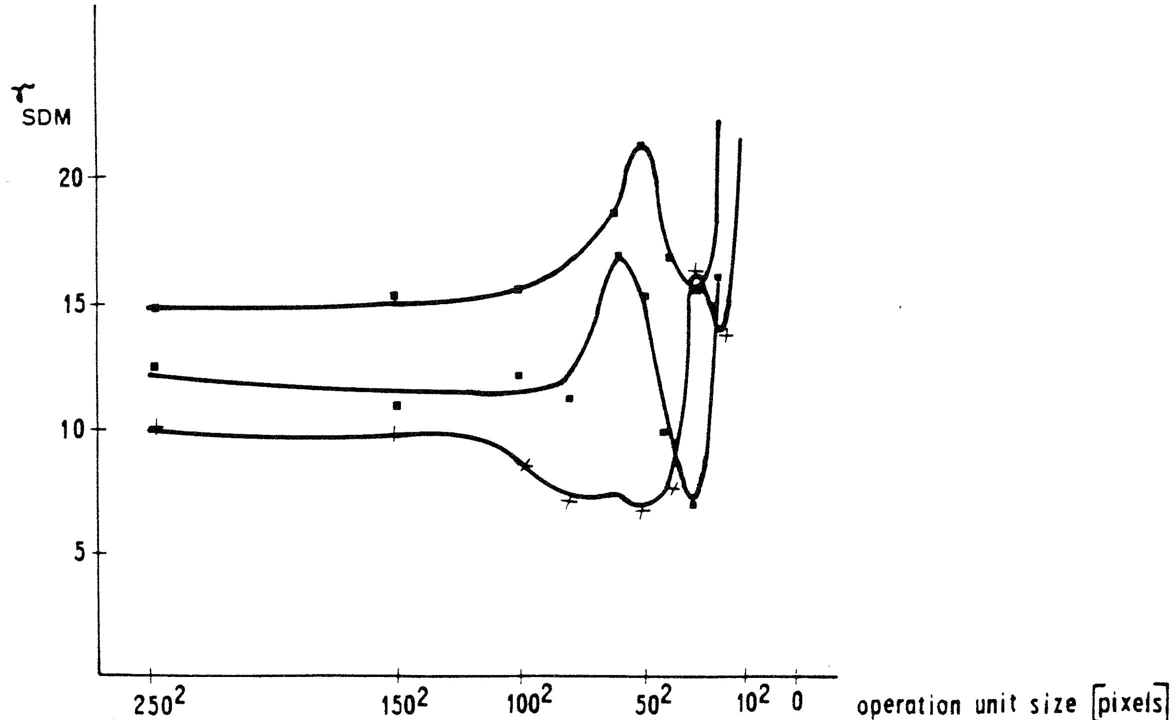

Fig.4

Study on the stability of textural features based on cooccurrence statistics vs operation unit size

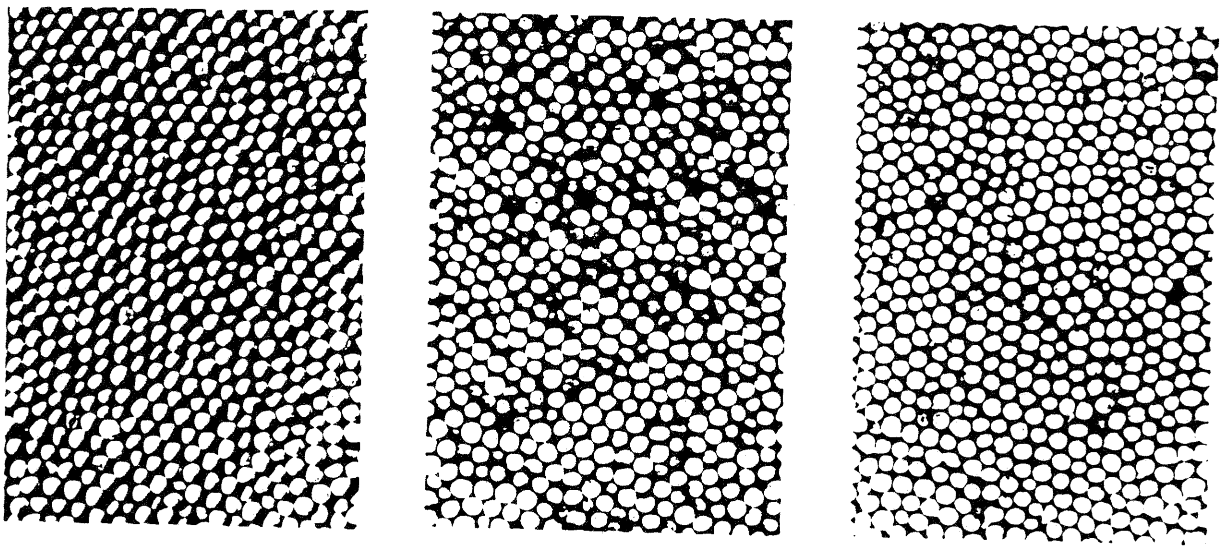

Fig. 5

Artifical texture sets generated by stochastic arrangements of peas under various conditions of illumination

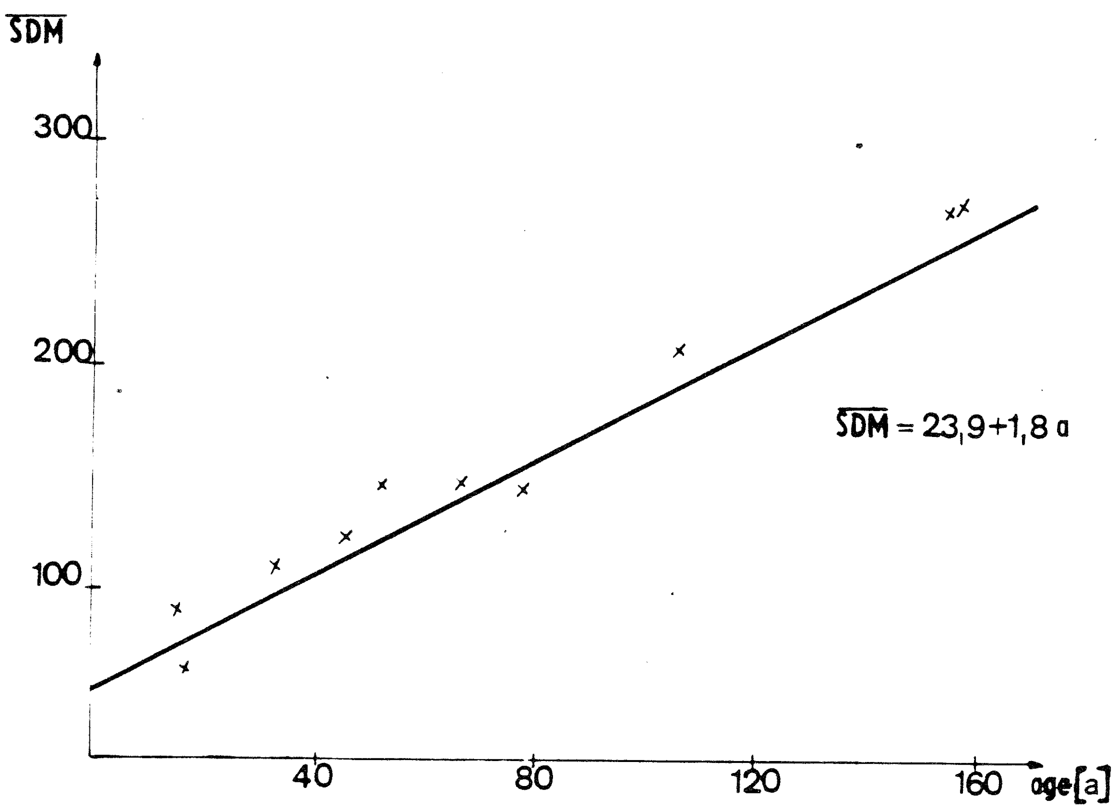

Fig. 6

Correlation between the cooccurrence feature SDM and the age of pine stands