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FAST AUTOMATED ANALYSIS AND CLASSIFICATION OF COLOR PICTURES BY SIGNATURE AND PATTERN RECOGNITION USING A COLOR SCANNER

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I. ABSTRACT

A commercial color scanner with high resolution is used for picture processing. The scanner is modified and additional electronic instruments are connected to the built-in color computer. The operations are carried out in an on-line process, simultaneously with the scan of the picture a processed picture is recorded on a special scanner film.Because there is no storage of image datas short processing times are obtained. The image datas are handled in a color computer, a gradation processor, an operational amplifier and a comparator to realize various procedures of picture operations.

The procedures are classified here in global, local and point operations. Global operations refer to the whole picture, these are for instance rectification, enlargement, density transformations. Local operations are mostly used for texture and pattern recognition and are related to the scanned picture element and its surrounding area. Point operations manipulate the information of a single picture element. The scanner generates three color signals from each picture element, which are handled in the color computer for color and signature recognition.

Several operations may be carried out in the same scan. The processed picture is displayed on a b/w transparency or on a color film. A suitable display for thematic mapping is essential for a correct interpretation of the processed picture.

II. THE NEED OF PICTURE PROCESSING

Picture processing was always done, when pictures are taken. But earlier non-reproducible photographic methods are used, like changes of gradation, color filtering ect.. During the last years the interest in picture processing is strongly grown. This is caused by the extensive application of image forming sensors for remote sensing. The subjective visual methods of picture evaluation and interpretation had to be replaced by objective, automatic procedures for handling a great mass of datas. So picture processing is placed between data requisition and interpretation. The task of picture processing is defined in the reduction or elimination of redundant and undesired information in the picture and the enhancement of those information, the user needs for interpreting the picture.

The human eye is always the best instrument for qualitative evaluation of pictures, but has only poor quantitative efficiency. To develop good programs for machine processing it is helpful to find out, how the eye can detect and recognize features in a picture. Using the knowledge of physiological optics, better procedures for signature and pattern recognition and modes of displaying processed pictures may be find out.

An example may illustrate this. For thematic mapping and classification coded pictures are used. The coding can be made by symbols, gray-tone levels or colors. The use of symbols is not recommended, if the size of the marked areas is not greater than the symbol, or if the areas are dispersed. The use of gray-tone coding allows not more than eight different marks. Otherwise, a coordination of the different gray levels by the eye may be incorrect. Using colors for coding, the number of different color tones the eye may distinguish and coordinate lies between 10 and 20. For the selection of the colors the McAdam's theory of the color discrimination of the eye had to be regarded.

Another example for the application of physiological optics are the criteria for the selection of equidensities. One criterion for the settingfor the setting of equidensities is the division of the picture into equal sized parts. To do this, a histogram of the density distribution of the picture elements is made. By this way, the equidensities do not always coincidence with the edges of natural objects in the picture. The eye recognize an edge on that place, where the density or color gradient is a maximum. This means, a differential density distribution analysis is better suited to determinate the position of the equidensities.

The technique of picture processing may be divided into three groups: photographical, optical and electronical methods. The electronical methods include the computer data processing. The procedures described here are a combination of this three methods. The main instrument is an opto-mechanical scanner, which transforms the optic image datas into electronic signals. The main picture processing is done by forming the electronic signals. The output signal is transformed back to an optical signal, which exposes a photographic film. Standardized development is used to make the process reproducible. Further photographical treatment is needed for a color display. The special feature of this concept is the great flexibility and versatility. The high spatial resolution utilizes the full information of a color picture. There is no limitation by data storage. But it is a shortcoming, that it is not possible to process pictures direct from data tapes. Another disadvantage is the line-scanning of the picture. The scanning line by line destroys the correlated information. But the scanner has an additional data channel, which gives an information of the surrounding area of the picture element. This channel was originally used for electronic unsharp masking, the significance for the picture processing is described later at the local operations. All signals are processed in real time by analog electronics. A short technical description of the scanner is given in the next chapter, following the different operations are explained.

III. WORKING PRINCIPLE OF THE COLOR SCANNER

The color scanner is manufactured by the HELL CO., Kiel, type Vario-Chromagraph C 296 and normally used for the production of color separations in the graphic arts industry. For picture processing the electronic part has been modified and addtional electronic instruments are connected. A more detailed description of this machine had been given on the Tullahoma and Ann Arbor Remote Sensing Conferences 1972.

The machine is provided to use color and b/w pictures, transparencies or prints. Positives or negatives may be scanned or recorded by pushbutton selection. But no processing of masked color negatives is possible. The flexible pictures are mounted on a drum. The maximum size is 350 mm x 460 mm (14 x 18"). A simultaneous enlargement up to 20 times is possible, the size is then limited to 60 mm x 90 mm.

A b/w scanner film on estar base is used to record the processed picture. A direct record on high sensitive color film is possible. Color filters are mounted then on the writing optics. The photographic development is standardized, a half-automatic rotary drum machine is used, which is also good for color development. The films are punched by Kodak register system, this gives an accuracy of 1/20 mm for additive color compositions from different separations of the same original picture.

The scanning allows a spatial resolution up to 100 lines/mm, the writing resolution of the recorded picture can be selected among 10, 20 or 40 lines/mm. The time of a full scan of a picture depends on the size and writing resolution. For maximum size and resolution the time is 40 minutes, the processing time for an aerial photography of the size 230 mm x 230 mm with 20 lines/mm writing resolution is about 10 minutes. Usually more than one scan is made, to find the optimal adjustment for the controls, the scan had to be repeated.

The adjustment of the optics can be widely adapted to the picture by different field of view (FOV) and aperture stops, optical filters and changes of the illumination. The light through the picture element is divided into four signals by a beamsplitter, three signals represent the color densities of the three basic colors red, green and blue, the fourth signal gives an information of the surrounding area of the picture element. The four signals are processed in the built-in color computer. A single output signal modulates the brightness of a glow discharge lamp.

The instrument has numerous continously variable controls. A meter and an oscilloscope serves for measuring and monitoring the settings of the controls and the programmed procedure. The settings are noted, so the procedure may be repeated later with the same result. A step wedge and a color test chart are always processed together with the picture. A small strip of the film is exposed by a lamp to monitor the constancy of film development. The oscilloscope shows the signal amplitude at different positions in the electronics and is also used to display the gradation curve, i.e. the relation between the recorded and the scanned (color) densities.

The maximum density resolution on the scanning and writing side is 0.5 % in the density range from 0.1 to 2.0. The maximum useful density is 3.0 for the scanned picture. The density resolution depends on the constancy of the development conditions. In most cases a density variation of o.1 is allowed, the more as the density variation in aerial photographs, caused by vignetting and shadowing, is greater.

To measure the size of coded areas or the space between two equidensities, a digital counter is used, the absolute accuracy is 1 mm^2.

IV. GLOBAL OPERATIONS

The division into global, local and point operations (see table) is adapted to the electronic configuration of the machine. Global operations change the picture as a whole. These are geometric distortions like co-ordinate transformations, rectification, enlargement, also color changes, density shifting and the fourier transformation of the lateral density distribution. With this machine global operations are only very limited practicable, due to the scanning of the picture.

Changing the scale is easy carried out using the enlargement device of the machine. The enlargements in the vertical and horizontal direction can be set independently to another from 1.7 to 20 times. A linear change of the enlargement from one side of the picture to the other is possible by an electric drive of the enlargement control. In this way, pictures taken with central perspective may be rectified. No other rectifications, like used in photogrammetry, is possible. The evaluation of the height of objects from stereoscopic pairs is also not possible.

To study temporal changes, pictures had to be compared which are taken from the same object to different times. These b/w pictures are copied all on the same color film, using filters for color coding. The color film is then processed with the machine. The analysis of dynamic processes is done by forming the difference of two colors. A picture is obtained, where the temporal change is transformed into a density change.

In a similar manner inscriptions, symbols, grids and masks are copied into a picture. If they are coded by different colors, they can be eliminated or extracted without interfering with the remaining information.

V. LOCAL OPERATIONS

Local operations are related to the information of the picture element and its vicinity. Scanning the picture line by line, the information of the adjoining picture elements in one line is converted into a time-varying signal. With this machine it is not possible to correlate adjacent lines or picture elements which lie not in the scan direction. This means a limitation of local operations to one dimension.

An additional optical device gives yet an information of the two-dimensional surrounding of the picture element, used originally for unsharp masking. The beam from the picture is split by an elliptical mirror with a centered hole. The hole defines the FOV for the picture element, the mirror reflects the light from the surrounding area through an exchangeable color filter on a photomultiplier. The FOV can be changed in six steps from 15 μm to 60 μm diameter for the picture element and from 50 μm to 300 μm diameter for the vicinity. The four output signals from the multipliers and the four input channels of the color computer can be combined in any way using a crossbar distributor.

The local operations are used essentially for texture and pattern recognition. The human eye is very sensitive to local density and color variations. On that the human pattern recognition is based. The density gradient is increased (Mach's phenomenon), at the places of the maximum gradient the contours of the object are seen. This fact shows, that not the density value itself but the gradient can be used for automatic pattern recognition and to find the contours of objects.

Another attempt for pattern recognition was made, analysing the frequency distribution of the scan signal. The electronics functions as a low-pass filter for the signal. The electronic bandwidth is from d.c. up to 30 kc/s, the upper band limit corresponds to the spatial resolution of 100 lines/mm. The frequency response of the electronics is equivalent to the modulation transfer function (MTF) between the scanned and recorded picture. A change of the frequency response effects a change of the MTF. Because an alteration of the frequency response is only effective in the scan direction, it may be supported by a change of the FOV, which is nondirectional. The change of the MTF is carried out practically by feeding the picture signal through an operational amplifier, which is wired as an active frequency filter. Following types of filters are used: low-pass, high-pass, band-pass and notch filter. The operational amplifier can also operate as a differentiator with an adjustable characteristic. This gives a similar effect as a high-pass filter. Another method is the comparison of the signals from picture element and vicinity in a differential amplifier or the difference generation of two color signals.

The application of these local operations for pattern recognition and classification is explained in the following. Agricultural and forestry cultivations show in an aerial photograph a specific frequency distribution. For example, fields cultivated with potatoes or rapes are modulated in the density with the frequency of the furrows. Fields with corn have another spatial frequency spectrum than fields with grain, at the last the higher frequencies dominate. Similar are the conditions for coniferous and decideous trees or between small or large trees. Damaged plants, caused by the attack of parasites or immission of industrial waste, or the windfall of grain is also observeable by a change of the frequency spectrum. A damage of potatoe plants by the attack of heterodera is not visible by a change of the color tone, also for ir-color film, compared with healthy plants. The habitus is that of a stunted plant. But the infected areas show a stronger modulation index for the furrow frequency. The work is to find out the characteristic frequencies and to build high-Q selective filters with high skirt selectivity. The investigations are made by multiple scanning of the picture, using small band-pass filters to cover the frequency spectrum.

A notch or frequency rejection filter is used for the suppression of scan lines of MSS pictures. A better visual quality is obtained and for the generation of equidensities a finer graduation is possible. The lines of the MSS picture are mounted perpendicular to the scan direction of the machine. The oscilloscope is used for measuring the line frequency and also for the adjustment of the notch filter.

A high-pass filter is used for the enhancement of fine details. The photographic optics and the film act like a low-pass filter, the contrast of fine details is weak. An emphasis of the high frequencies gives a better quality and sharpness of the picture. Some methods of photographical and electronical detail contrast enhancement are also used earlier (unsharp masking, Logetronic).

The differentiation of the density signal leads to a picture which is known as pseudo relief and gives a plastic three-dimensional impression. This procedure is used for the improvement of under- and overexposed pictures. Slight density variations in the dark and light parts of the picture are amplified and the picture has a uniform average density. It is to observe, that the grain of the film is not also enhanced.

The formation of the difference between the density of the picture element and its vicinity is a function of the two-dimensional gradient of the gray-tone density, but not the gradient itself. The undistortedpicture signal can be added to this value. The electronics allows the setting of a threshold for the signal level. By this an enhancement of lines and edges is gained, depending on the size of the FOV. By density slicing it is possible to separate linear and sharp bordered objects like streets, houses, rivers.

The manifold investigations of the application of local operations for pattern recognition and classification are continued and give a promising scope.

VI. POINT OPERATIONS

The point operations are limited to the comparison of the three color signal levels or the manipulationof the density signal of one channel or the signal from a b/w picture. The purpose of point operations is to get an information about the spectral remissivity of the object, i.e. the signature.

Color film has normally three layers, which are sensitive in three spectral bands in the visible or near infrared spectrum. By a dichroitic beamsplitter and color filters the color densities of the three layers are separated. The spectral impurity of the used dyes in the color film lead to aninterference or crossmodulation in the other bands. If the spectral transmission of the dyes is known or measured by photograph a color test chart, the interference can be reduced or eliminated by an adjustment of the color computer. With this correction, the color film can be used as a three-band sensor. Multispectral pictures are processed in the same manner after making a color composition from three spectral bands. In this way the signals of the three bands are handled simultaneously in the color computer.

For understanding the point operations, a short introduction into color metric is given. The three color density signals are the base of a three-dimensional orthogonal color space. The three signal levels are the components of a color vector. If the levels are equal, the vector is diagonal in the space and on this diagonal lie the colorless gray-tones with white at the origin of the co-ordinates.

The machine was designed for the production of corrected color separations from color pictures. In the color space, defined above, this means a projection of the points in the color space to one co-ordinate axis. This projection is not parallel, due to the correction of the interference by the other two basic colors. The projection point on the co-ordinate axis for the three basic colors red, green and blue and the three complementary colors cyan, magenta and yellow are determined by the setting of the controls of the color computer. A deformation of the scale, this means here the density scale, may be produced by the gradation processor. This is used for standardizing the colors and density levels of color pictures and requires to photograph a color test chart under equal conditions like the picture. This procedure releases the color variations of the signature from the influence of changing illumination and manufacturing conditions.

The color computer allows the selection of certain color tones, this means the filtering of special vectors in the color space. This classification of colors is equivalent to the clustering techniques. Generally it is not necessary to select all existing colors in a picture. For example on ir-color film the vegetation appears in different red color tones, changing from light red to violett. These colors are projected on a gray scale, transforming the light red into a dark gray and on the other end the violett into a light gray, all other colors, which are not on the line between red and violett, like blue and green colors, result in clear white. By this, a classification of vegetation is obtained. The different different classes may be color coded using density slicing and color equidensities for the display.

Having a b/w picture or a color separation, the three dimensional problem reduces to one dimension. The only operations applied here are to map the density. The procedures are the quantisation of gray levels, density slicing and equidensities generation. Normally color coding is used for the display, particular for thermal mapping of line-scanner pictures taken in the infrared band from 10 to 15 μm wavelength.

VII. PICTURE DISPLAY

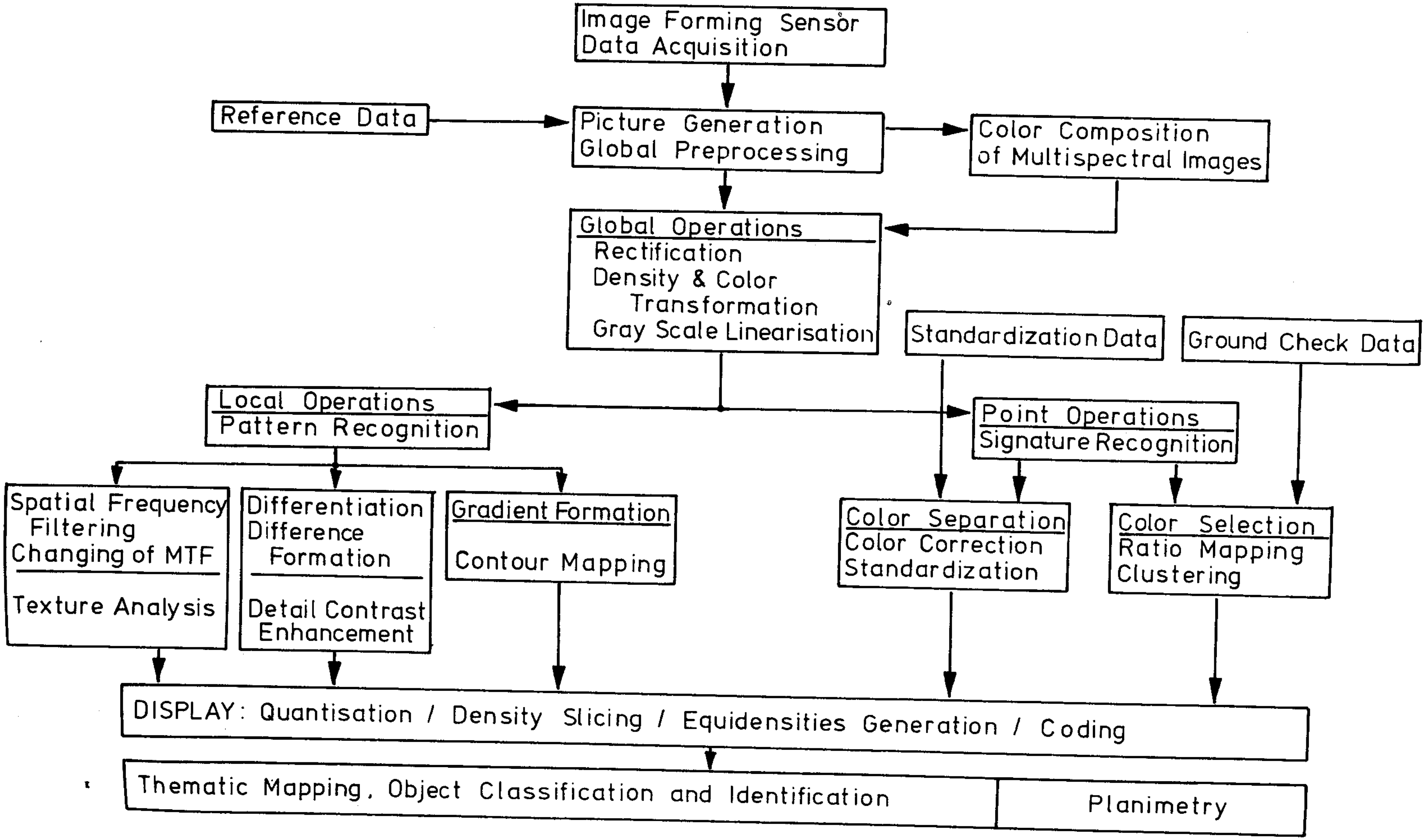
Like mentioned in the introduction, the kind of display, the selection of gray tones, colors or symbols for coding is of significance for the interpretation. It is usual to get a processed picture with the same geometric correlation of the picture elements, aside from some rectified images. A check is easy made then by mounting the original photography and the processed picture one upon another.

For a display with quantized gray levels or color coded equidensities it is significant to bring the code in a natural sequence, this means for gray levels to remain the original sequence and for colors a natural sequence like the arrangement in the visible spectrum. Another way is the coding of objects by its dominant color, for instance water blue, vegetation green, rocks brown. Then no training for the interpretation of processed pictures is required.

But this is not correct for all purposes. For the color display of ERTS-MSS pictures a color composition is made, which the same color association like picture from false-color film. For vegetation analysis by the eye another color composition yields better discrimination of the vegetation. Copying the MSS-4 channel with blue, MSS-5 with red and MSS-6 with green light on a color reversal film, the colors appear in a nearly natural way and a visual discrimination of the blue-green colors of the vegetation is better.

VIII. CONCLUSION

It is shown in the preceding description, that the number of different procedures for picture evaluation can be done in a relative simple manner using a color scanner which combines optical, electronical and photographical methods. The emphasis of the investigations lies on the application of these operations for interpretion, thematic mapping and classification of aerial photographs. The try is made to develop standard programs for diverse scientific field, including also medical applications. To optimise the processes and to eliminate errors a close cooperationbetween picture processing and user is necessary.



Picture Processing with Color Scanner