AN IMPROVING MULTISPECTRAL RECORDING SET ANALYSIS METHOD

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ABSTRACT: An analytical method to select the best combination out of a multispectral image set is presented, starting from the spectral signature of a certain class of the study. Parameters established analytically are then used in an analogical process using MSP-4C multispectral projector (made in Carl Zeiss Jena - The German Democratic Republic) to obtain the best resolution of an involved spectral class.

The MSP-4C multispectral projector made by Carl Zeiss Jena (DDR) is meant for the multispectral and/or multitemporal analysis of the records taken by MSK 6 or MSK 4 cameras mounted on aircrafts and space platforms, or LANDSAT,SPOT etc.records.

The MSP-4C has four independent projection optical channels. In this way, almost unlimited combinations of simple images, colours and projection luminosity are possible.

Every optical channel contains (Figure 1):
- A special illumination device with a concave mirror, a halogen lamp (24 V/250 W), two heat absorbtive filters and four condenser lenses;
- A film holder for plane films with dimensions up to 70x91 mm, with a good horizontalization and with elimination of Newton's rings properties;
- A shutter for every channel which does not change the thermic equilibrium in the film holder;
- Seven colour filters setted on a rosette;
- A panchromatic projective lens, corrected for aberrations;
- Electric engine units to adjust contrast, image translation and rotation, and scale correction.

The images supplied by the four channels are projected on a 350x455 mm screen, five times enlarged by a mirror, under a 4.75° projection angle.

The main purpose of this device is to transform the little density differences (tones of gray) of the black and white images taken by the six camera channels (spectral bands) in contrasting colour tones into mixed images, using colour and neutral filters adequately combined.

The CIE 1931 chromaticity diagram, on which the areas denoting the same colour name (according to Kelly and Judd) are represented, is well covered by the colour shade areas derived from an all possible filter combination set.

The visual interpretation of the remote sensing multispectral or multitemporal images is difficult enough as compared the conventional photographic material interpretation. Besides reliable processing techniques, we must know these image interpretation requirements very well, and we must have a great experience on the field works. The main interpretation problem requires the specific information contents in many images to be combined (extracted) according to our purpose in order to be easily grasped from the mixed image.

During supervised analysis using MSP-4C multispectral projector, some problems are to be solved, in order to avoid subjective factor as much as possible. These problems are:
1. Selection of the strip set containing the maximum information (Figures 3 a, 3 b);
2. Filter combination selection among MSP-4C available set, so that the resulted image colour should emphasize the wanted phenomenon as well as possible (Figures 4, 5).

So, to get the best colour composite in three bands, it is necessary to select the best one out of 20 possibilities (C^3_6). Each band can have any colour, so we'll have 3276 different possibilities for image colour presentation.

Considering the three dimensional space defined by any spectral band triplet, the associated variance-covariance matrix defines an ellipsoid, in this space. In this case, only the computation and the ordering of the determinants which correspond to every 3 x 3 main submatrix from M variance-covariance matrix are required. Than, the band triplets associated with these determinants will be decreasingly ordered depending on the information content. This method, proposed by Sheffield in 1985 has a great advantage, the elimination of the possibility to choose a spectral band triplet closely correlated. The logical scheme of the computational programme which can solve the above problem can be found in the Apendix (Figure 3).

The second great problem reffers to the set of best filter combination chosen from the device's set of filters to:
- emphasize the class of interest for a maximum colour contrast;
- have the possibility to obtain again the same colour image, at a new analysis;
- reduce the human operator's subjective factor.

The available inputs are:
- selected multispectral photographical records using the maximum volume ellipsoid method;
- spectral signature of the involved classes (that is gray tone intervals of these classes in each image);
- the device optical characteristics:
    - the spectral radiation distribution of the sources;
    - the colour filter transmittance curves;
    - the neutral filter transmittance curves and the heat filter curves.

The chosen set of filters should provide, within a metric chromatic space, the maximum distance between the colours (a maximum difference of colouring, respectively). In this case, it is better to consider colours in CIE 1976 (L^*, u^*, v^*) three dimensional space.

The colour difference will be:

$$\Delta E = \left[(\Delta L^*)^2 + (\Delta u^*)^2 + (\Delta v^*)^2\right]^{\frac{1}{2}}$$

The first term represents the psychometric lightness difference:

$$L^* = 116 \left(Y/Y_n \right)^{1/3} - 16 \qquad (1)$$

and the other two terms represent CIE 1976 psychometric chromaticity difference

$$u^* = 13 L^* (u' - u'_n) ; \quad v^* = 13 L^* (v' - v'_n) \qquad (2)$$

where:

$$u' = \frac{4X}{X + 15Y + 3Z} ; \qquad v' = \frac{9Y}{X + 15Y + 3Z} \qquad (3)$$

and u'_n, v'_n are computed in a similar way, using X_n, Y_n, Z_n which correspond to the source.
X,Y,Z are three stimulus values of the considered colour and are given by the following expressions:

$$X = K \int_\lambda \varphi(\lambda)\bar{x}(\lambda)\, d\lambda$$
$$Y = K \int_\lambda \varphi(\lambda)\bar{y}(\lambda)\, d\lambda \qquad (4)$$
$$Z = K \int_\lambda \varphi(\lambda)\bar{z}(\lambda)\, d\lambda$$

$\bar{x}$, $\bar{y}$, $\bar{z}$ represent three stimulus spectral values.
The colour stimulus function: $\varphi(\lambda) = S(\lambda)\, \tau(\lambda)$
The transmittance:

$$\tau = \tau_{fc} \cdot \tau_{fn} \cdot \tau_{ft} \cdot \tau_{tg}$$

τ_{fc} = the colour filter spectral transmittance from MSP-4C
τ_{fn} = the neutral filter spectral transmittance from MSP-4C
τ_{ft} = the heat absorbtion filter spectral transmittance
τ_{tg} = the film transmittance in the area (or areas) of the considered class.

$$\tau_{tg} = \left(1 - \frac{\text{the level of gray}}{255}\right)$$

$S(\lambda)$ = the spectral power distribution of the illuminating source.

The K constant = $\dfrac{100}{\int_\lambda S(\lambda)\bar{y}(\lambda)\, d\lambda}$

Because on the projector's/multispectral display we receive the light from three channels, it results:

$$X = \frac{K}{3} \int_\lambda S(\lambda)\left[\tau_1(\lambda) + \tau_2(\lambda) + \tau_3(\lambda)\right]\bar{x}(\lambda)\, d\lambda$$

$$Y = \frac{K}{3} \int_\lambda S(\lambda)\left[\tau_1(\lambda) + \tau_2(\lambda) + \tau_3(\lambda)\right]\bar{y}(\lambda)\, d\lambda$$

$$Z = \frac{K}{3} \int_\lambda S(\lambda)\left[\tau_1(\lambda) + \tau_2(\lambda) + \tau_3(\lambda)\right]\bar{z}(\lambda)\, d\lambda$$

$$X_n = \frac{K}{3}\int_\lambda S(\lambda)\cdot 3\cdot \bar{x}(\lambda)\,d\lambda$$

$$Y_n = \frac{K}{3}\int_\lambda S(\lambda)\cdot 3\cdot \bar{y}(\lambda)\,d\lambda$$

$$Z_n = \frac{K}{3}\int_\lambda S(\lambda)\cdot 3\cdot \bar{z}(\lambda)\,d\lambda$$

For a certain set of filter the algorithm takes into consideration the computation of the X,Y,Z three stimulus and of the L^*, u^*, v^* for the considered class and for the whole remainder image is made from 5 to 5 mm.

Finally, the COLOUR subroutine computes ΔE^* (the average distance betwwen colours in CIE 1976 (L^*, u^*, v^*) metric space, from the class of interest to the remainder image.

As the general algorithm computes all colouring possibilities, it is necessary to eliminate those combinations which do not give significant distances in the considered metric space.

Further on, the average distances are computed for the rest of filter sets, and these are decreasingly ordered, the maximum value giving the best filter combination.

The method is not yet implemented and experimented, that's why the results are not presented here. Because this problem is analytically treated, we expect an improvement of the processing resolution for the multispectral and multitemporal images given by the remote sensing records.

RÉSUMÉ: À partir de la signature spectrale d'une certaine classe impliqué dans l'étude, on présente une méthode analytique de choix de la combinaison optimale d'un set d'images multispectrales. Les paramètres déterminés analytiquement sont puis utilisés dans un processus analogique qui utilise le projecteur multispectral MSP-4C (production VEB CarlsZeiss Jena - RDA) pour obtenir une résolution maximale de la classe spectrale impliqué.

ZUSAMMENFASSUNG: Auf Grund der spektralen Antwort einer gewissen studierten Klasse, wird eine analytische Methode für die Auswahl der optimalen Kombination aus einem Satz multispektraler Bilder, beschrieben. Die analytisch bestimmten Parameter werden dann in einem analytischen Prozess, unter Anwendung des Multispektralprojektors MSP-4C (vom VEB Carl Zeiss Jena - DDR) zur Erzielung einer maximalen Auflösung für die betreffende spektrale Klasse, verwendet.

REFERENCES

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THE OPTICAL CONFIGURATION OF MULTISPECTRAL PROJECTOR MSP-4C

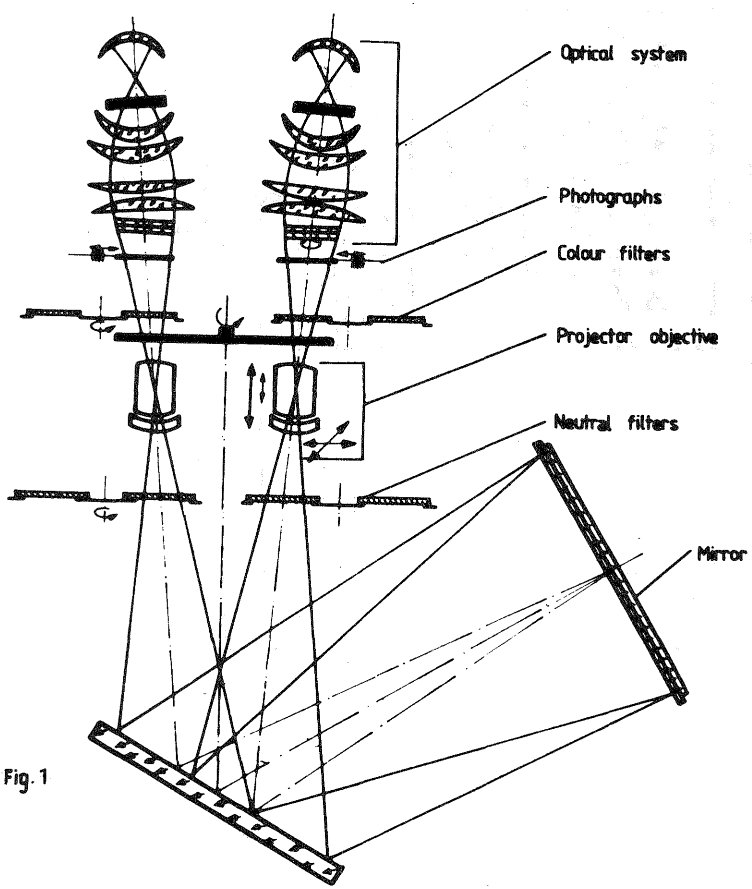

Fig. 1

THE POSITION OF THE COLOUR FILTERS IN THE CIE 1931 CHROMATICITG DIAGRAM AND THE AREE OF POSSIBLE COLOURS DEFINED BY THESE

IN ADDITION ARE ILLUSTRATED THE COMNON NAMES OF COLORS ASSIGUED TO VARIOUS AREAS OF THE CIE 1931 CHROMATICITG

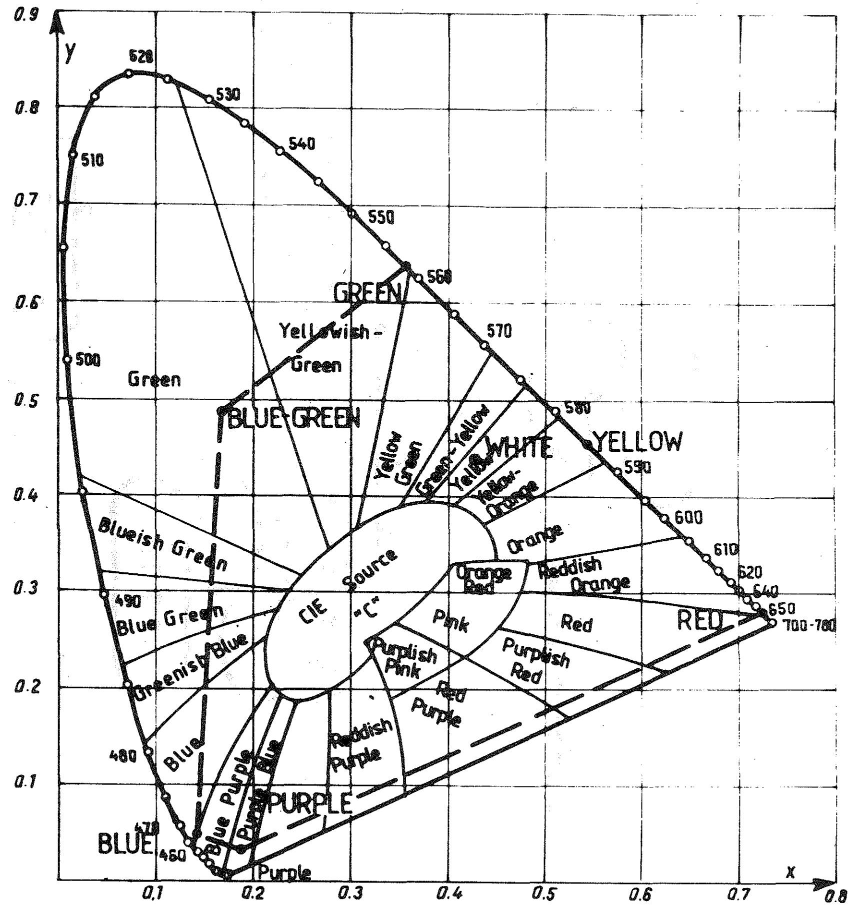

Fig 2

THE SELECTION OF THE BEST TRIPLET OF CHANNELS

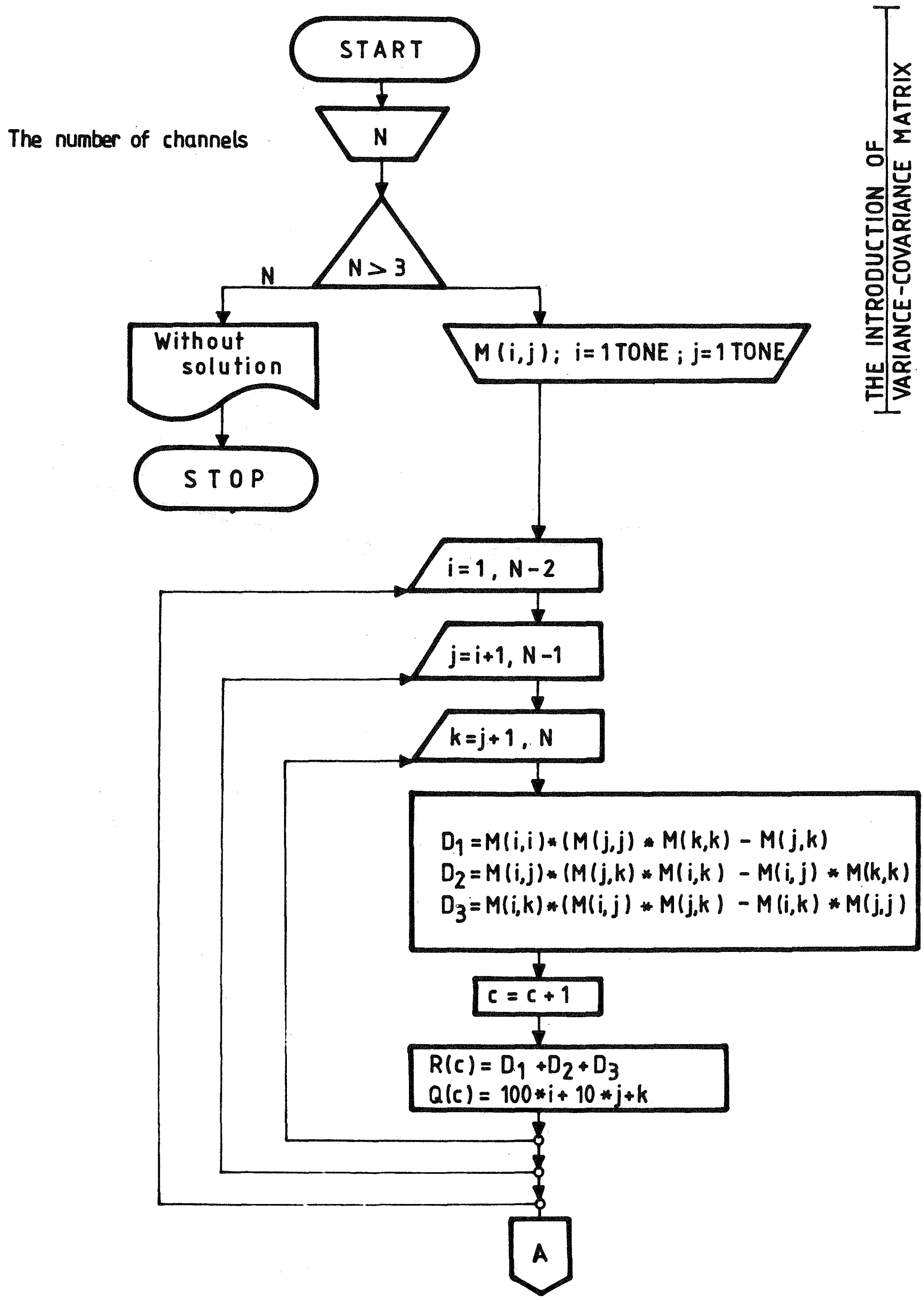

Fig. 3a

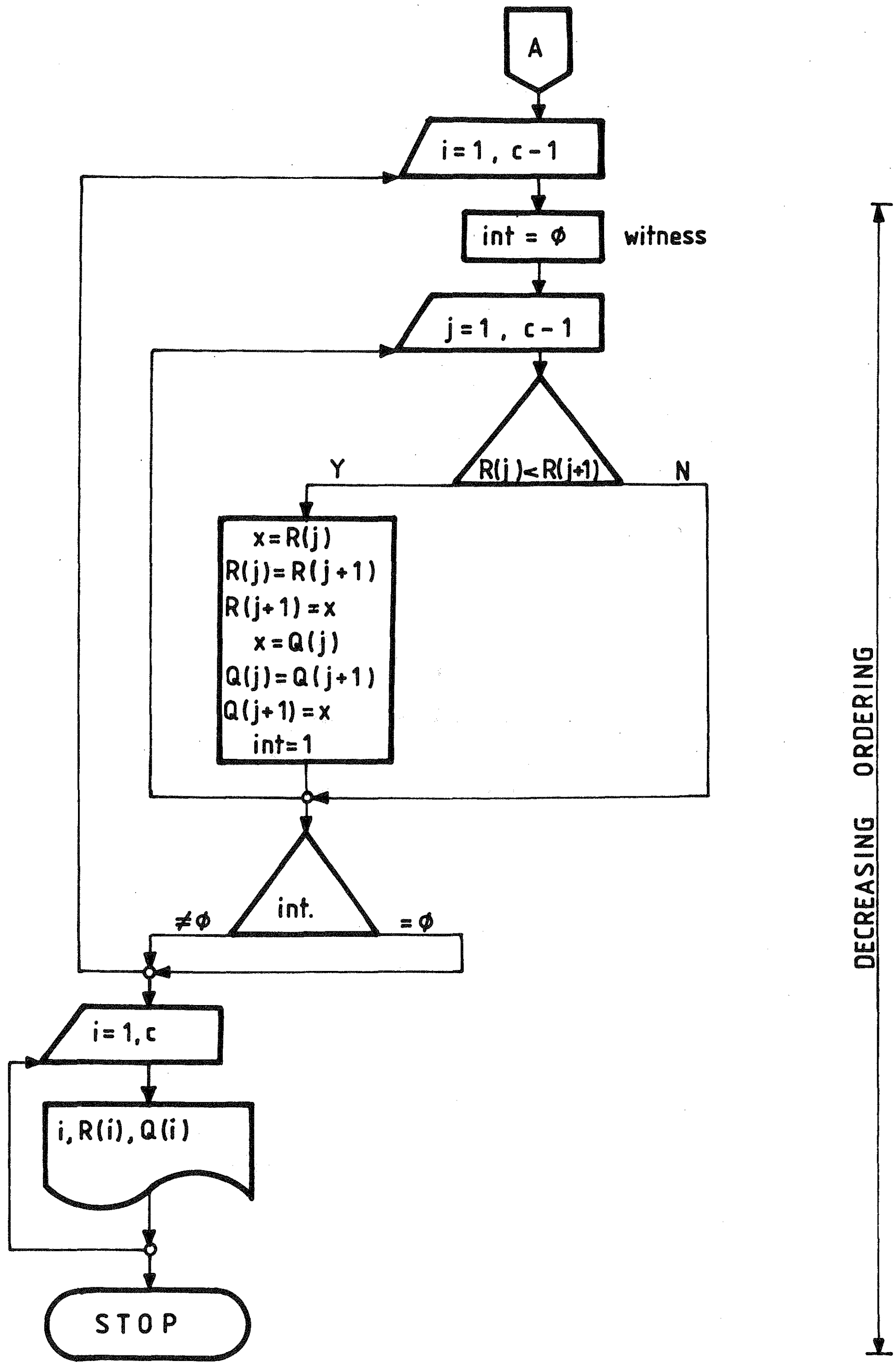
A
i = 1 , c − 1
int = Ø
witness
j = 1 , c − 1
R(j) < R(j+1)
Y
N
x = R(j)
R(j) = R(j+1)
R(j+1) = x
x = Q(j)
Q(j) = Q(j+1)
Q(j+1) = x
int = 1
int.
≠ Ø
= Ø
i = 1, c
i, R(i), Q(i)
STOP
DECREASING ORDERING

Fig. 3b

AN ALGORITHM FOR THE BEST SET OF FILTERS DETERMINATION SO THAT THE COLOR CONTRAST BETWEEN THE CLASS OF INTEREST AND THE REMAINDER IMAGE TO BE MAXIMUM

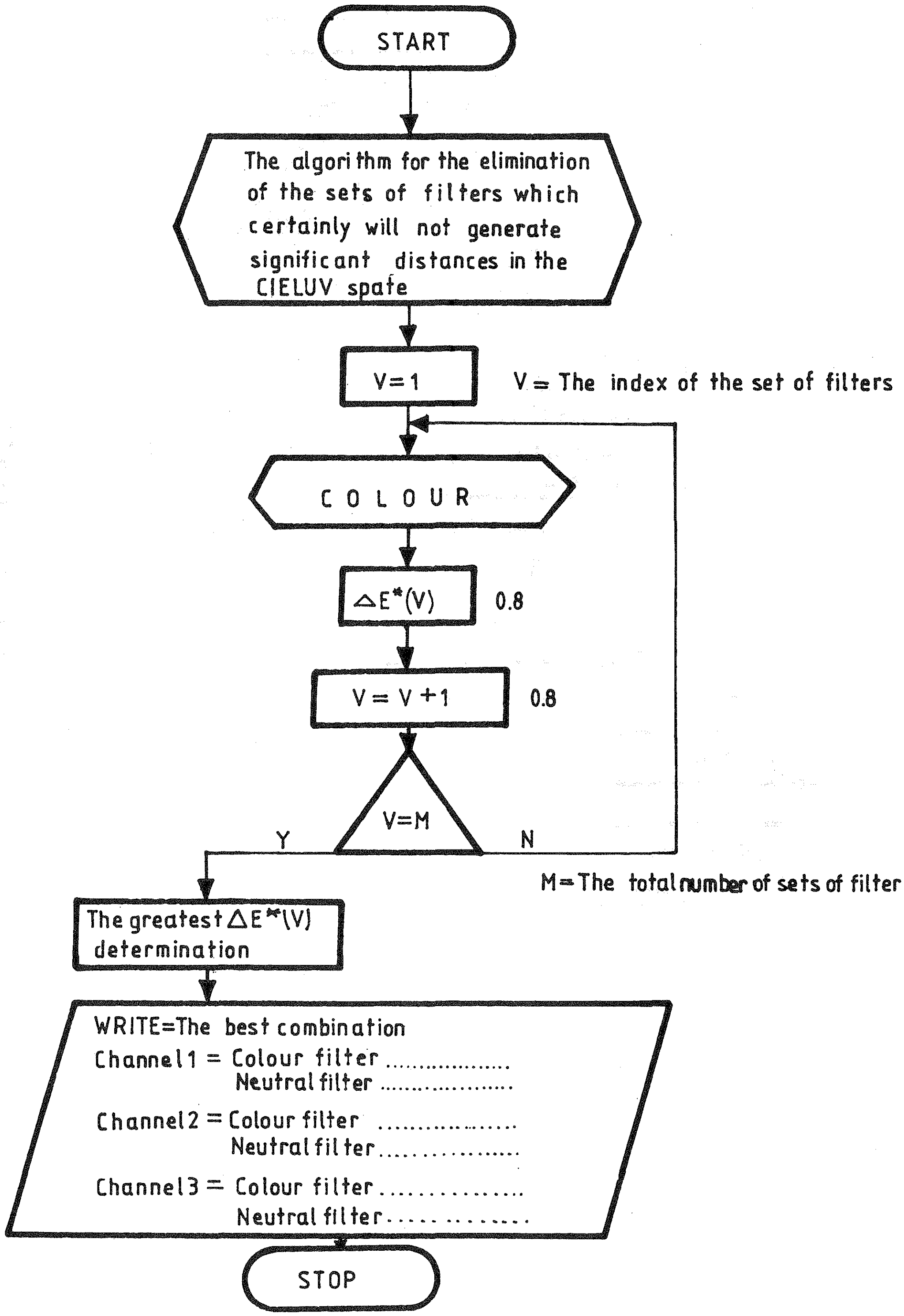

Fig.4

AN COMPUTATIONEL ALGORITHM FOR THE MEAN DISTANCE BETWEEN THE CLASS OF INTEREST AND THE OTHERS CLASSES, IN THE CIELUV SPACE (THE COLOR SUBROUTINE)

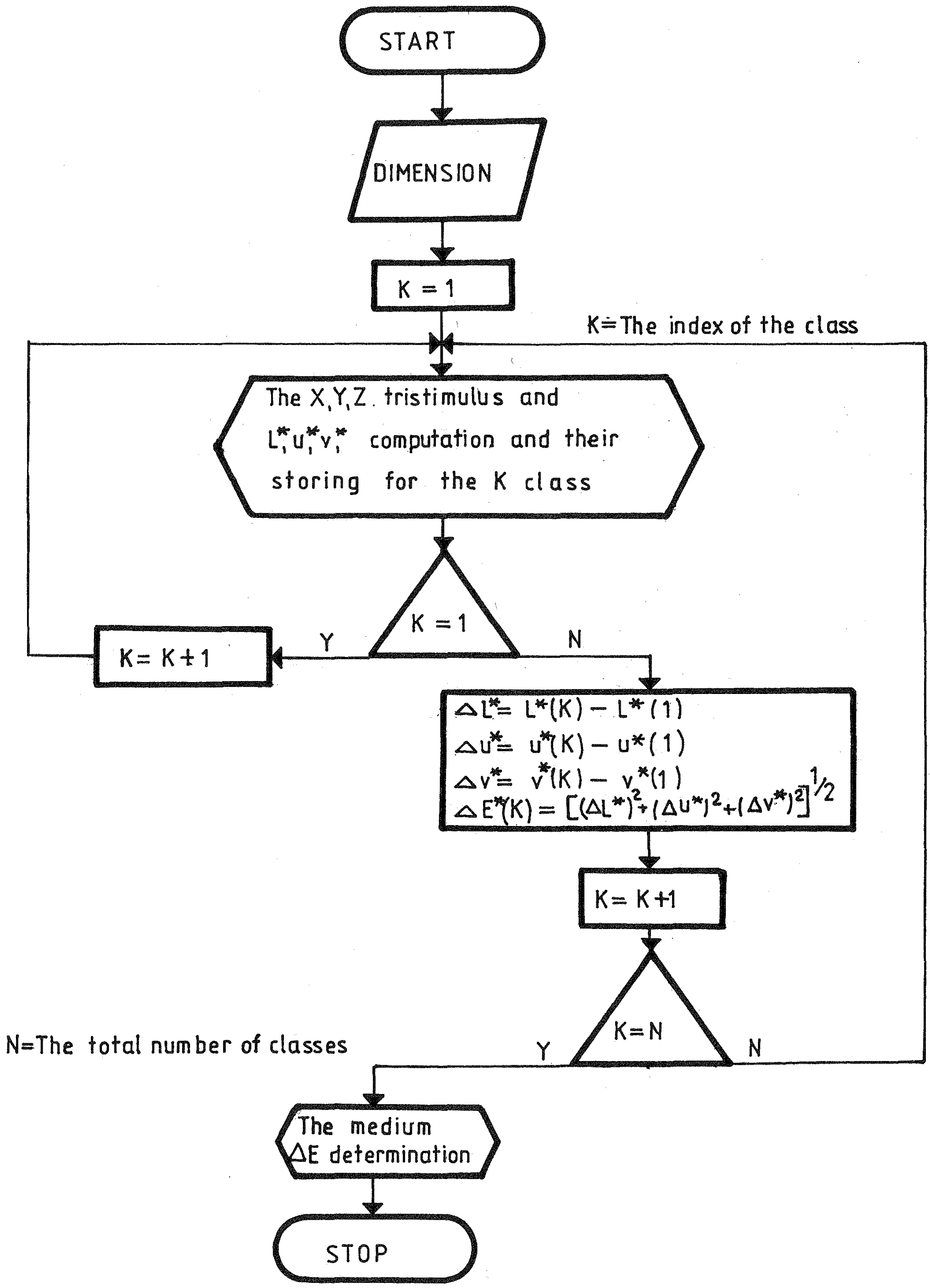

Fig.5