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# The digital method for presentation of the classification results in specified colours

A b s t r a c t. A classification file is characterized by different values for each class. Such a file can be registered on the data-base of the computer system and printed on a line printer or exposed on photographic film or paper by means of a graphic-to-digital converter. This paper presents a new method of obtaining colourful images resulting from the digital image analysis also characterized by the possibility of specifying colours for each class. This method allows to acquire an image in colours which are in agreement with obligatory instructions. This method also allows to obtain the final image in various forms, for example as a diapositive, colour print, black and white colour extraction or colour composite on the additive colour viewer.

This paper also presents the method of digital image rasterring enabling the acquisition of classification imageries which can be printed, without special optical processing.

## 1. Introduction

The digital image analysis usually aims at obtaining a classification file in which each distinguished class has a different meaning. One of the possibilities of registering such a file is to expose it on photo-sensitive material — black and white or colour. This paper presents a method, which allows to transform the classification file in such a way as to specify colours for particular classes of objects and then to insert them into specially prepared for this purpose legend of colours. Thus it is possible to obtain a classification image where particular classes are marked by various, chosen by the user colours.

## 2. Operations performed by a graphic-to-digital converter

One of the devices of the digital image analysis system is the graphic-to-digital converter. It is used to change the image exposed on photo-sensitive material to an image registered on a magnetic tape in the digital form and vice versa, to change the image from the digital

form to an image exposed on a photo-sensitive material. The American Optronics graphic-to-digital converter installed at the Polish Remote Sensing Centre — Institute of Geodesy and Cartography enables the convertion of black and white as well as colour images, exposed on photographic films and papers.

The graphic-to-digital converter can, among others, be used for exposing classification images, registered on magnetic tape, onto photo-sensitive material. In case of exposing black and white images there is no need to use colour filters, while exposing colour images appropriate colour filters are placed on the way of the light rays. The converter works line by line, processing successive elements of the image from one form into another (from graphical to digital or from the digital form of the image to the graphical one). The maximum format of the image which can be obtained on this converter is 22.5×22.5 cm.

### 3. The essence of the digital image analysis

The digital image analysis consists of two fundamental stages. The first one is connected with the transmission into the computer of data concerning spectral characteristics of distinguished classes while the second stage is connected with the implementation by the computer of the classification of this data. During the first stage the operator marks in the image specified test fields, the cover of which is known to him. These can be, for example, arable land on which there are particular types of crops. The information concerning the location of these fields and their meaning, stated usually in the form of corner coordinates and short description are used for the so-called „training of the computer system" in the range of class recognition. Such a training aims at enabling the classification implemented by the computer. During the training of determined test fields the computer calculates characteristic values, for example, mean values of the electromagnetic radiation in various spectral bands, correlation coefficients, standard deviations and other values, which are necessary to perform the digital image analysis. During this stage the operator also specifies the number values, which on the resulting image should characterize the distinguished classes.

The second stage of the digital image analysis is almost performed without the participation of the user. It mainly concerns data classification, according to the stated and computed characteristics, which are the effect of the first stage. The participation of the user at the second stage is limited to specifying the classification type and determining the device which would be used as the output for the final classification image. It can be a screen monitor or a magnetic disk. In case of utilizing the screen monitor the classification image can be displayed as a black and

white or colour image. In case of choosing the magnetic disk the classification image is registered into the data-base. Such an image can be utilized in the future, rewritten on a magnetic tape, which in turn can be visualized on the graphic-to-digital converter, exposed on photographic material, etc.

The acquired classification image, which is the result of the digital image analysis, possesses elements of particular interval of values and can be directly exposed on photo-sensitive material as a black and white image. When it becomes necessary to obtain a colour image exposed on photo-sensitive material by means of digital analysis the matter becomes more complex. This is connected first of all with the character of obtaining colour images on photo-sensitive materials.

## 4. The method of acquiring the classification images in selected colours

As it is known, the principles of colour photography are based on the fact, that each colour obtained on the final image is a combination of three basic colours. The colour image on the printing paper is obtained thanks to the overlapping of basic colours.

This principle, in a slightly changed version is also applied to obtain colour images on the graphic-to-digital converter. The algorithm of the method applied to obtain colour classification images in selected colours is presented in diagram 1.

As it was mentioned above, an image resulting from the digital analysis of satellite or aerial images can be compared with black and white photograph image, where optical density levels correspond to various classes of distinguished objects. In order to obtain a colour image from such an image, two processes ought to be carried out:

1) select the required colours for particular classes,

2) change in an appropriate way the elements of the imput file as to obtain the required colours after exposing the data on the graphic-to-digital converter.

The first process is carried out in order to create the so called „legend of colours", that is a universal colour set, which would be used to mark the classes of objects occurring in the final image. The implementation of this process was carried out on the basis of images of optical wedges, exposed on the colour printing paper, and which were acquired with the application of various colour filters. These optical wedges were generated on the graphic-to-digital converter, and then they were overlayed by the colour filters and exposed on a photographic enlarger applying various filter combinations. In this way colour sets for the combinations of blue-green, blue-red and red-green were obtained. From

the acquired colours, 20 of them were selected which formed the discussed legend of colours.

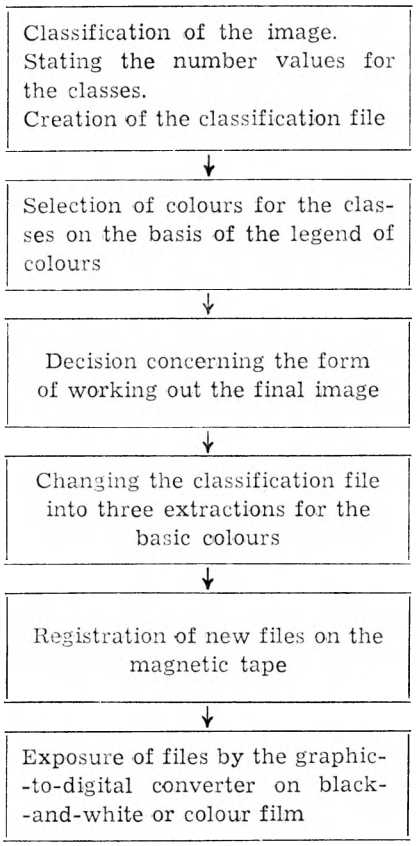


Diagram 1: Implementation algorithm of the method for obtaining results of the digital classification in selected colours

On the basis of the known density values of the optical wedges, also known were the quota of the basic colours in every created colour of the legend. After forming the legend of colours, the second stage of the process could be started — to exchange the final image according to selected colours for particular classes. It should be stressed, that the legend of colours is common for all the elaborated images, and the second stage is implemented separately for each image.

The necessity of implementing the second stage of the elaborated method results from the character of work of the graphic-to-digital converter. This device is equipped with three colour filters, which can be used during the exposure of the image on a colour film. In such a case, the appropriate image is exposed through subsequent colour filters. Instead of a colour film, a black-and-white one can also be used. On it, images prepared for particular basic colours are separately exposed

while the final colour image is acquired in the process of photographic copying by means of an enlarger.

The implementation of the discussed process is based on digital colour filtering of the final image, on which the classification results are registered. It aims at creating colour extractions for basic colours which in turn enable the creation of a colour image by exposing subsequently obtained extractions through photographic filters.

Each element of the classification file has its determined value (optical density), which is the effect of its belonging to a class, possessing the value endowed by the operator. Apart from that, the user also states the number of the colour on the basis of the legend of colours, which is to be given to this class on the colour image. From the legend of colours we get to know the quota of basic colours which form the colour specified by the user. Due to this, the value of the element of the final image can be changed into three values, which subsequently correspond to the quota of basic colours in the created colour. Such a change is done for every element of the classification file. Instead of one file, three files are created in this way, being digital extractions for basic colours. These three files are exposed on the graphic-to-digital converter, and then the colour image is obtained. It can be acquired by one of the four methods, which will be described below and presented in diagram 2.

In all cases three colour extractions digitally registered on magnetic tape are used as the input data.

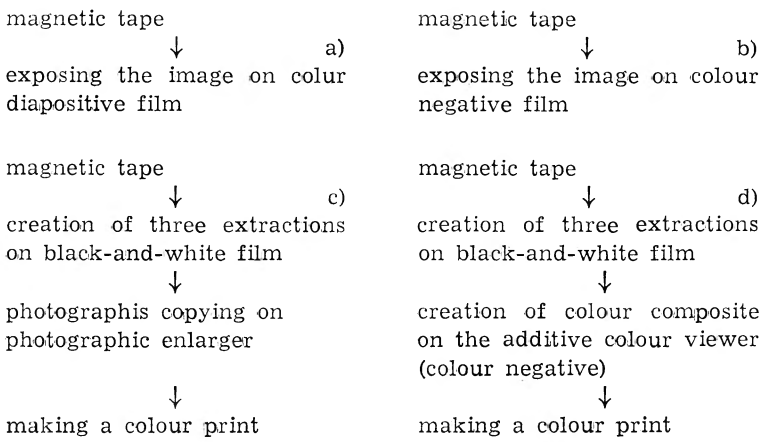


Diagram 2: Four methods of obtaining colour images containing classifications results

The first metod (diagram 2a) is based on the exposure of three colour extractions, registered on magnetic tape, onto a colour diapositive film, subsequently utilizing three colour filters with which the graphic-to-

digital converter is equipped. Three images are exposed exactly in the same place of the film which causes the summing up of colours in particular points and further leads to the acquisition of appropriate colours. This method allows to immediately obtain on the film positive image. However only one copy of the image can be obtained. In order to obtain further copies, the entire process should be repeated.

The second method (diagram 2b) is very similar to the first one. The only difference is the use of a colour negative film instead of the colour diapositive one from the first method. In this way a colour negative image is obtained which enables to acquire a multiple copying of the image, without the necessity of using the graphic-to-digital converter each time, as in the case of the first method.

The third method (diagram 2c) is more complicated than the two previous ones. Three extractions for particular basic colours are separately exposed on black-and-white film. In this way, three images are obtained, which later are copied on photographic enlarger, using appropriate colour filters for each of them. Since three separate images are used for the exposure, it is extremely important to fit them correctly in order not to obtain any image blurring. Special marks are used for this purpose, which should be exposed around colour extractions during their preparation on the graphic-to-digital converter. This method allows to obtain many copies out of one image, without the necessity of using a converter for obtaining successive copies. Apart from that, the method allows to enter colour corrections into the image which are caused for example by the characteristics of the printing paper. This is also essential due to the future usage of the images. During the implementation of this method it is also possible to obtain unrestricted scales of the image by using various settings of the enlarger.

The fourth method (diagram 2d) combines the application of the digital image analysis system and the optical additive colour viewer. This method is similar to the third one, where the only difference being the use of an additive colour viewer instead of the photographic enlarger. Three colour extractions exposed on black-and-white film on the graphic-to-digital converter are placed in the additive colour viewer and a colour negative composite is formed on its screen. Depending on the settings various scales of the image can be obtained. The colour print is acquired on printing paper by the method elaborated by Zbigniew Goljaszewski, M. Sc. at the Polish Remote Sensing Centre (OPOLiS). In this method successive photographs making up the colour composite are exposed on printing paper through appropriate colour filters and during a determined period of time. The exposure time depends on the colour of the filter and on the scale of the image. After exposing all of the three images on colour printing paper a colour positive image, of a very high quality is obtained. This method of obtaining a colour image with

the classification results, not only applies the additive colour viewer but also allows to enter, just like in the third method, colour corrections and allows to change the scale of the received image.

After performing series of experiments concerning the acquisition in the photographic form of the classification results in the selected colours, it turns out, that two legends of colours should be prepared: one for obtaining images on colour diapositive or negative films and the second for obtaining results on colour prints received by copying black-and-white extractions on the photographic enlarger or on the additive colour viewer.

Of crucial importance is the fact that the same colours can be obtained from the photographic enlarger and the additive colour viewer.

## 5. Method of rasterring digital images to obtain recurrence of results

The above described methods of obtaining classification results in required colours allow to obtain recurrent images, but it either demands a repeated use of a graphic-to-digital converter in order to expose the consecutive copy or the use of a photographic enlarger or an additive colour viewer in order to make colour composites, which are then copied by means of photographic methods. To eliminate these disadvantages, and also to increase the efficiency of work and to decrease the amount of time necessary for receiving many copies of one image, the Polish Remote Sensing Centre undertook attempts at acquiring images directly ready to be used for printing being the results of the digital image analysis. Such images must have the form of raster images, they can only contain black and white dots, arranged according to a determined way and characterized by various sizes [3].

It was decided that works in this field should be implemented in two directions:

1) application of the digital rasterring of images,
2) application of the optical rasterring.

The method of the digital rasterring of images was described earlier in the Proceedings of the Institute of Geodesy and Cartography [1]. In this method every element of the image is changed into a combination of black and white dots arranged in a determined way and exposed on the graphic-to-digital converter. In this way, directly from the digital image analysis, the raster image is obtained, which can be copied in the printing process. In order to receive colour images, digital matrices are used, which are characterized by different arrangement of black and white dots and thus being similar to the rotation of rasters, applied in conventional printing techniques.

In the second method the image being the result of the digital classification as well as the image containing colour extractions for obtaining classification results in the specified colours, are photographed on a photographic raster. Within this process, an image which also consists of black and white dots is obtained. It can be used in preparing printing matrices [2].

Both the first and the second methods give similar results, though the second one is simpler and cheaper, since it does not require the work of a computer during the creation of a raster image.

## 6. Conclusions

The described method of obtaining classification results in specified colours is undoubtedly a very important supplement of the presently used digital image analysis methods implemented with the utilization of the computer system installed at the Polish Remote Sensing Centre (OPOLiS) the 2PAAC system made by the OVAAC8, Intl., Canada. This method expands the possibilities of obtaining results of the classification and digital image analysis, since it is very comprehensible, uncomplicated and also communicative for the user. Various types of classification and thematic maps obtained and elaborated in this way can be at the spot utilized by the users. The classification map of the Warsaw area, to the scale of 1 : 100 000, which is the very first elaboration of this type, fully confirms this conclusion.

Undoubtedly this method requires some improvements and detailed research works, concerning mainly the choice of colours as well as digital and optical rasters, particularly in receiving colour images. Works in this field will be continued.

The author of this paper would like to thank the specialists of the photographic laboratory of the Polish Remote Sensing Centre (OPOLiS), particularly Zbigniew Goljaszewski and Maciej Szafran, for their assistance and consultation concerning the preparation of the legend of colours as well as for the help in working on subsequent experiments on the graphic-to-digital converter, the photographic enlarger, and the additive colour viewer in order to expose black-and-white as well as colour images.

Translation: Jacek Domański

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ЯЦЕК ДОМАНЬСКИ

## ЦИФРОВОЙ МЕТОД ПРЕДСТАВЛЕНИЯ РЕЗУЛЬТАТОВ КЛАССИФИКАЦИИ В ИЗБРАННЫХ ЦВЕТАХ

Резюме

Результатом цифрового анализа изображений является обычно классификационный файл, в котором каждому из выделенных классов приписаны разные значения. Такой файл может быть записан несколькими способами. Одним из них является экспонирование файла на светочувствительном материале, черно-белом или цветном.

Для такой записи файла используется графо-цифровая преобразователь, который заменяет изображение, зарегистрированное на магнитной ленте, в изображение, зарегистрированное на фотографической бумаге или пленке.

Специфика получения цветных фотоизображений и способ работы преобразователя диктуют необходимость подготовки данных, содержащихся в преобразуемом соответствующим способом файле.

В статье представлен метод, который разрешает заменить изображение, являющееся результатом цифровой классификации на три цифровые изображения, соответствующие трём составным цветам — красному, зеленому и синему. Благодаря этому, после применения графо-цифрового преобразователя для экспонирования файла на фотографическом материале получается цветное классификационное изображение, причем отдельным классам соответствуют цвета, выбранные потребителем. Реализация этого метода совершается в двух этапах:

— выбор требуемых цветов для отдельных классов,

— замена значения элементов файла таким образом, чтобы после экспонирования на преобразователе получить нужные цвета.

Выбор требуемых цветов осуществляется с помощью интерактивного экранного монитора, входящего в состав цифровой системы анализа изображений.

Первый этап реализуемого метода опирается на изображении оптических клинов, которые получаются после их экспонирования на цветной фотографической бумаге с применением разных фультров. Оптические клины были созданы на графо-цифровом преобразователе, а затем накладывались на них цветные фильтры и экспонировано их на увеличителе. Таким образом, были получены

наборы цветов для зелёно-красной, красно-синей и зелёно-синей комбинации. Из всех цветов, полученных таким образом, выбрано 20 цветов, которые составили легенду цветов. На основе легенды была известна доля каждого основного цвета в созданном цвете.

Необходимость реализации второго этапа вытекает из характеристики работы графо-цифрового преобразователя, который имеет три цветных фильтра, через которые экспонируются изображения составляющие синтезированные изображения с целью получения цветного изображения. При рассматриваемом методе через фильтры экспонируются цифровые изображения для основных цветов, которые после накладки на себя составляют окончательное изображение в требуемых цветах.

Рассматриваемый метод разрешает получать результаты классификации в следующих формах:

— как цветное диапозитивное изображение экспонированное на обратимой плёнке,

— как цветное негативное изображение экспонированное на негативной цветной плёнке,

— как три чёрно-белых изображения для основных цветов, в виде негатива или позитива.

Третья форма экспонирования классификационных изображений дает возможность применения аддитивного проектора или фотографического увеличителя с целью получения синтезированного изображения на фотобумаге. Следует подчеркнуть, что применяя рассматриваемый метод, в каждом из трех случаев, на окончательном изображении получаем те же самые цвета, соответствующие тем же самым классам. Эти цвета такие же, как цвета данные классам потребителем на интерактивном мониторе. В этом большое достоинство данного метода.

Описываемый метод разрешает получать повторимые изображения — результаты классификации данных. Чтобы получить очередную копию изображения следует осуществлять каждый раз излагаемый метод, что влечёт за собой необходимость использования компьютера и графо-цифрового преобразователя. Чтобы этого избежать, был разработан метод цифрового растрирования изображений, который разрешает исключить оптическое растрирование изображений в ходе подготовки изображений к печати. Этот метод разрешает выводить изображения, растрированные компьютером, которые могут печататься без дополнительной оптической обработки.

В статье рассмотрены основы картографической репродукции и принципы составления цифровых растровых изображений. В зависимости от того, какие будут составляться растровые изображения чёрно-белые или цветные, применяются соответствующие растровые системы. Пробы, касающиеся печати растрированных таким способом изображений, указывают на большую пригодность излагаемого метода.

Оба представленных в статье метода расширяют возможности системы цифрового анализа изображений и разрешают получать результаты классификации в удобной для потребителя форме.

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# CYFROWA METODA PRZEDSTAWIANIA WYNIKÓW KLASYFIKACJI W WYBRANYCH KOLORACH

Streszczenie

Wynikiem cyfrowej analizy obrazów jest zwykle zbiór klasyfikacyjny, w którym każdej z wyodrębnionych klas przypisywane są różne znaczenia. Zbiór taki może być zapisany kilkoma sposobami. Jednym z nich jest naświetlenie zbioru na materiale światłoczułym czarno-białym lub barwnym.

Do takiego zapisu zbioru wykorzystuje się przetwornik graficzno-cyfrowy, który zamienia obraz zarejestrowany na taśmie magnetycznej na obraz zarejestrowany na papierze lub filmie fotograficznym.

Specyfika otrzymywania barwnych obrazów fotograficznych oraz sposób pracy przetwornika narzucają konieczność przygotowania danych zawartych w przetwarzanym zbiorze w odpowiedni sposób.

W artykule przedstawiono metodę, która pozwala zamienić obraz będący wynikiem klasyfikacji cyfrowej na trzy wyciągi cyfrowe odpowiadające trzem barwom składowym — czerwonej, zielonej i niebieskiej. Dzięki temu, po zastosowaniu przetwornika graficzno-cyfrowego do naświetlenia zbioru na materiale fotograficznym otrzymuje się barwny obraz klasyfikacyjny, przy czym poszczególnym klasom odpowiadają kolory wybrane przez użytkownika. Realizacja tej metody przebiega w dwóch etapach:

— wybór żądanych kolorów dla poszczególnych klas,

— zmiana wartości elementów zbioru w taki sposób, aby po naświetleniu na przetworniku otrzymać żądane kolory.

Wybór żądanych kolorów jest realizowany z wykorzystaniem interaktywnego monitora ekranowego, wchodzącego w skład systemu cyfrowej analizy obrazów.

Etap pierwszy realizowanej metody przebiega w oparciu o obrazy klinów optycznych, które uzyskano po ich naświetleniu na barwnym papierze fotograficznym, przy zastosowaniu różnych filtrów. Kliny optyczne były wygenerowane na przetworniku graficzno-cyfrowym, a następnie nakładano na nie filtry barwne i naświetlano na powiększalniku. W ten sposób otrzymano zestawy barw dla kombinacji zielono-czerwonej, czerwono-niebieskiej i zielono-niebieskiej. Ze wszystkich kolorów uzyskanych w ten sposób wybrano 20 barw, które utworzyły legendę barw. Na podstawie legendy znany był udział każdej z barw podstawowych w utworzonym kolorze.

Konieczność realizacji etapu drugiego wynika z charakterystyki pracy przetwornika graficzno-cyfrowego, który posiada trzy filtry barwne, przez które naświetla się obrazy tworzące kompozycję kolorową w celu uzyskania obrazu barwnego. W przypadku omawianej metody przez filtry naświetla się cyfrowe wyciągi dla barw podstawowych, które po nałożeniu na siebie tworzą obraz wynikowy w żądanych barwach.

Omawiana metoda pozwala otrzymywać wyniki klasyfikacji w następujących formach:

— jako obraz barwny diapozytywowy naświetlony na filmie odwracalnym,

— jako obraz barwny negatywowy naświetlony na negatywowym filmie barwnym,

— jako trzy czarno-białe wyciągi dla barw podstawowych, w postaci negatywu lub pozytywu.

Trzecia forma naświetlenia obrazów klasyfikacyjnych pozwala na zastosowanie przeglądarki addytywnej lub powiększalnika fotograficznego w celu uzyskania

kompozycji kolorowej na papierze fotograficznym. Należy zaznaczyć, że stosując omawianą metodę, w każdym z trzech przypadków, na obrazie wynikowym otrzymuje się takie same kolory odpowiadające tym samym klasom. Kolory te są takie same, jak barwy nadane klasom przez użytkownika na monitorze interaktywnym. Jest to duża zaleta opisywnej metody.

Opisywana metoda pozwala na otrzymywanie powtarzalnych obrazów — wyników klasyfikacji danych. Aby otrzymać kolejną kopię obrazu należy zrealizować za każdym razem omawianą metodę, co pociąga za sobą konieczność wykorzystania komputera i przetwornika graficzno-cyfrowego. Aby tego uniknąć opracowano metodę cyfrowego rastrowania obrazów, która pozwala wyeliminować optyczne rastrowanie obrazów w trakcie przygotowania obrazów do druku. Metoda ta pozwala wyprowadzać obrazy rastrowane przez komputer, które mogą być drukowane bez dodatkowej obróbki optycznej.

W artykule zostały omówione podstawy reprodukcji kartograficznej oraz zasady tworzenia cyfrowych obrazów rastrowych. W zależności od tego, czy mają być tworzone rastrowe obrazy czarno-białe, czy barwne, stosuje się odpowiednie układy rastrów. Próby dotyczące druku obrazów rastrowanych w ten sposób wskazują na dużą przydatność omawianej metody.

Obie prezentowane w artykule metody rozszerzają możliwości systemu cyfrowej analizy obrazów i pozwalają otrzymywać wyniki klasyfikacji w formie dogodnej dla użytkowników.