Scientific Journals
Maritime University of Szczecin

Zeszyty Naukowe
Akademia Morska w Szczecinie

2010, 22(94) pp. 59–62

2010, 22(94) s. 59–62

The conception of automatic control system of the camera–filter set in imagery intelligence hyperspectral system

Koncepcja systemu automatycznego sterowania układem kamera–filtr w hiperspektralnym systemie rozpoznania obrazowego

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Key words: remote sensing, hyperspectral system, imagery intelligence

Abstract
The topic of the publication is the presentation of the detection method and identification of every kind of environmental threats such as: pollutants or environmental contamination, causing changes of reflection property of ground, water, atmosphere surface, their locating and the monitoring of changes. This method is based on remote sensing measuring techniques as well as on using Geographic Information System (GIS) tools. It is based on the application of a monochromatic digital camera working in the 300–1100 nm range and equipped in a tunable filter. The point is to work out the automatic control system of the camera-filter set. Imageries gained in a few hundred spectral ranges were preliminary process depending on choosing few ranges with optimum image parameters. These data are transmitting to the automatic control system of camera-filter set.

Słowa kluczowe: teledetekcja, system hiperspektralny, rozpoznanie obrazowe

Abstrakt
Przedmiotem artykułu jest zaprezentowanie metody rozpoznania i identyfikacji wszelkiego rodzaju zagrożeń środowiskowych takich jak: zanieczyszczenia czy skażenia powodujące zmiany własności odbiciowych powierzchni ziemi, wody, atmosfery, ich lokalizowanie i monitoring zmian. Metoda ta bazuje na wykorzystaniu techniki pomiarów teledetekcyjnych oraz wykorzystaniu narzędzi z zakresu systemów informacji przestrzennej. Opiera się na zastosowaniu cyfrowej kamery monochromatycznej pracującej w zakresie 350–1100 nm wyposażonej w filtr przestrajalny. Istota problemu polega na opracowaniu systemu automatycznego sterowania układem kamera–filtr. Pozyskane obrazy w kilkuset zakresach widmowych poddane były wstępnej obróbce polegającej na wybraniu kilku zakresów o optymalnych parametrach obrazowych. Dane te przekazywane są do systemu automatycznego sterowania układem kamera–filtr.

Introduction

The fundamental aims of realized researches were:

1. The work out of the control module of the camera–tunable filter set permitting on work parameters selection in dependence on results of preliminary analysis of images in narrow spectral ranges.
2. The work out of program procedures enabling marking and locating environmental contamination or polluted areas as well as monitoring their changes.

The executed researches had aim at determination of optimum spectral ranges for concrete pollutions (the width of range maximally 20 nm), in which the observation should be conducted and work out the methodology of selection of these ranges to concrete kind of pollution. Researches putting into practice have aim at evolve functioning algorithms of the control of hyperspectral filter.

The proposed technique bases on using a broad--band monochromatic camera equipped in tunable filter. It is the hyperspectral system. Gaining images in narrow spectral ranges makes possible following very subtle changes of observed surfaces. It is possible to choose several such ranges, in which contamination of specific substances is the most visible. Not less essential like camera with filter are suitable software and the control systems. It should meet following functions:

- control of camera and filter work,
- making operation on images,
- locating specific objects or areas.

For reason of complex range of function, the system has to have module structure, with possibility of extension. The computer system consists of several main subsystems:

1. The subsystem of work control of camera optics is tasked to control lens of the camera i.e. the adjustment of focal length and diaphragm in connection with observation distance (at the moment) as well as brightness of reflected or emissioned radiation.
2. The subsystem of work control of tunable filter has two main tasks. The first one is setting spectral parameters of the filter and the second is synchronization filter with the camera. Because the tunable filter is characterized by different transmission in different spectral sub-ranges it requires different time of exposure in individual bands. The time exposure adjustment to chosen range will be hold automatically.
3. The subsystem of images processing is tasked to do operation on gained images in such a way to receive maximum contrast between polluted and non polluted area.
4. The subsystem of pollutants location is the subsystem basing on software of GIS, supplied both data created especially for aims of this project and come from governmental reference databases such as: TBD, Vmap L2, or numeric principal map in peculiarity. The subsystem has the possibility of cyclic updating of data to carried out the contaminations monitoring process in support with newest spatial data. The system is tasked to putting processed images on digital map. Such an operation makes possible precise location of polluted areas. The applied software of GIS makes possible interaction among layers of data (also for relation: vector–raster, raster–raster) permitting on executing spatial queries such as: intersect / intersect + buffer or containing.

All mentioned subsystems co-operate together in control phase and also in transferring data. Data come from one subsystem are indispensable to functioning another subsystems. Therefore such a system requires specialist software basing on modern computer standards.

The final effect of realization of researched problem is the prototype (the model) of remote sensing system to detecting contaminations, consisting of digital monochromatic camera equipped in tunable filter as well as units (computers) processing gained images.

The state of knowledge

The conducted analysis relating the bases of physical phenomena using gained hyperspectral images, researches of reflectance property of surfaces show unambiguously, that the theoretical assumptions as well as the laboratory researches made by authors are correct. Used in researches equipment of advanced technologies range as well as the present numeric methods relating image signals processing permit with very large probability to affirm, that the prototype is possible to realizing. In worked out researches it is showed unambiguously, that the narrow spectral ranges exist (in a dozen or so nanometers), in which it is possible to distinguish the surfaces with different reflectance properties, and such are the contaminated or polluted surfaces. The problem makes till now effective mechanisms of processing of such quantity of imagery data as well as the indication of connections among reflectance characteristic (curve) of concrete objects and the characteristic of the brightness of images. The one of the essential scientific aspects of study is working out the methodology of measurements of reflectance characteristic across hyperspectral measurements of brightness characteristic on gained images in a few hundred narrow spectral channels.

The characteristic of laboratory system

The remote sensing depends on researching of objects from some distance, without physical contact. Remote sensing research is executed from cosmic space, airspace or from surface of the ground. We can distinguish active as well as

passive methods. The passive methods base on analysis of signal sent from observed object, e.g. the photographic picture. In case of active methods signal is sent from instrument, and after reflection from object, received and analysed. The different kind of radars (sending microwaves), lidars (sending light) or sonars (sending acoustic waves) are used in this method.

The basic to conducting researches was set consisting of monochromatic camera working in range 350–1100 nm and tunable filter.

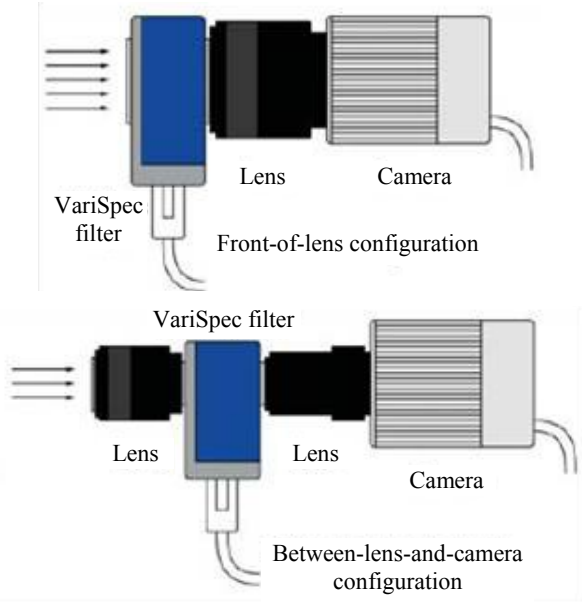

Fig. 1. Monochromatic camera with tunable filter
Rys. 1. Kamera monochromatyczna z filtrem zestrojonym

Such set was tested by our authors' group in various aspects at the Geoinformation Chair of Maritime University in Szczecin. There is also possibility of gaining filters working in different spectral ranges in order to carry out researches in domain of study beyond given range. The control system is tasked to set up parameters of tunable filter on chosen spectral subranges. Images from these subranges become again processed to several ranges, where image parameters are optimum and are again sent to control system. Operation is repeating until receive at the most several spectral subranges where parameters of outcome image are the most suitable from the point of view of scene identification and detecting concrete substance.

The gain of images in narrow spectral ranges lets on qualification with high accuracy changes of reflectance property of observed surfaces. Next, the quantity of gained hyperspectral images makes possible with high accuracy reproducing in chosen spectral range reflectance characteristic on the basics of gained brightness characteristic of objects. This type of methodology makes possible detecting areas with different properties and the dynamic observation appearing changes.

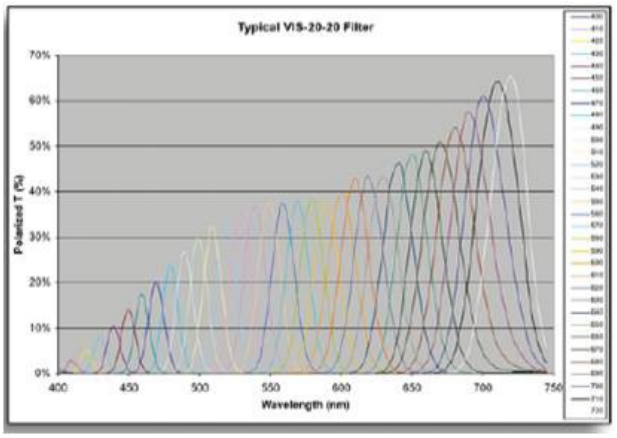

Fig. 2. Characteristics of tunable filter
Rys. 2. Charakterystyka filtra zestrojonego

Results of spectral measurements of reflection coefficients for chosen materials were introduced in table 1, as well as in figure 4.

Table 1. The setting-up – range from 339.77 nm to 341.55 nm (ultraviolet)
Tabela 1. Ustawienie – zakres od 339,77 nm do 341,55 nm (UV)

Wawe-lenght	Sun	White	Sand	Sand in oil	Gravel	Gravel in oil
339.77	6200.3	851.53	1263.20	827.40	1283.00	814.07
340.07	6200.3	851.53	1263.20	827.04	1283.00	814.07
340.36	6254.7	890.20	1334.40	865.47	1334.93	876.33
340.66	6459.4	1049.67	1444.73	1102.80	1559.53	923.27
340.96	6188.4	856.00	1284.20	849.13	1271.73	837.07
341.25	6206.4	832.00	1294.47	826.47	1263.80	804.73
341.55	6217.9	837.93	1294.20	813.87	1267.67	835.60

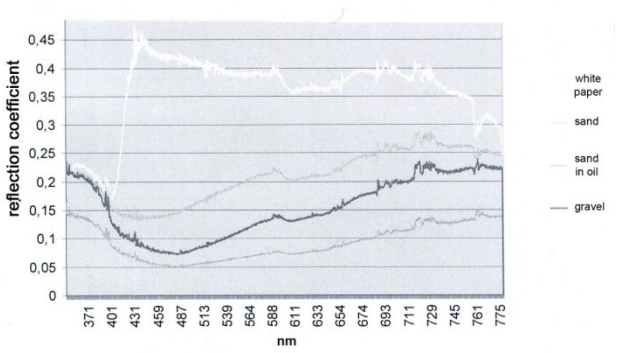

Fig. 4. The chart of reflection coefficients – range from 371 nm to 775 nm (visable range, photographic infrared)
Rys. 4. Wykres współczynników odbicia – zakres od 371 nm do 775 nm (zakres widoczny, podczerwień fotograficzna)

The remote observation of surface or areas lets on not only the contaminations' detection, but also on its precise location and monitoring of spreading.

Images gained using such system are undergoing digital processing, which has at aim the distinction of areas with different reflectance characteristic, and then distinction contaminated or polluted areas.

To conducted analysis ArcGIS software, which is good working in environment of spatial information systems, was used. The program modules assuring the raster-vector conversion, modules of defining the surface of polluted areas, their spreading and monitoring concern just this environment.

Summary

The main researches task was to work out the automatic module control system of tunable filter working in such a way to make possible to characterizing optimum spectral ranges for environmental pollution by different chemicals, which are danger to environment, detecting (e.g. derived from oil), and also to work out of quick images processing procedures and automation of pollution detection process.

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