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"Spektrale Objektsignaturen"

REPORT OF THE ISP WORKING GROUP VII-9
"Spectral Signatures of Objects"

RAPPORT SUR LES ACTIVITES DU GROUPE DE TRAVAIL VII-9 DE LA SIP
"Signatures spectrales des objets"

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ZUSAMMENFASSUNG

Innerhalb der IGP-Kommission VII ist die Arbeitsgruppe VII-9 "Spektrale Objektsignaturen" gegründet worden. Im Vordergrund des augenblicklichen Arbeitsprogramms stehen terminologische Probleme, vor allem die Festlegung und Definition einer für die Fernerkundung sinnvollen Reflexionsgröße, dem Reflexionsfaktor. Weiterhin werden Fragen zur Reproduzierbarkeit spektraler Signaturen diskutiert.

Für die Zukunft wäre zur Beantwortung dieser Fragen ein Testprogramm wünschenswert, das von mehreren Institutionen unter weitestgehend gleichartigen Bedingungen durchgeführt werden könnte.

ABSTRACT

Within ISP Commission VII, the Working Group VII-9 "Spectral Signatures of Objects" was founded. The principal items of the present working programme are terminological problems, in particular the determination and definition of a reflection quantity adequate for remote sensing, the reflectance factor. In addition, questions of the repeatability of spectral signatures are discussed.

To answer these questions it is suggested to set up a test programme which could be carried out by several institutions under conditions which are as similar as possible.

RESUME

Le groupe de travail VII-9, portant la dénomination de "signatures spectrales des objets", a été fondé au sein de la Commission VII de la S.I.P. Au premier plan du programme actuel de travail figurent des problèmes terminologiques, surtout le problème d'établir et de définir une quantité de réflexion raisonnable pour la télédétection, le facteur de réflexion. On discute en outre des problèmes quant à la réproductibilité de signatures spectrales.

Il serait souhaitable pour l'avenir d'établir un programme de test qui pourrait être exécuté par plusieurs institutions à des conditions aussi identiques que possible.

REPORT OF THE ISP WORKING GROUP VII-9

"Spectral Signatures of Objects"

1. OBJECTIVES OF WORKING GROUP VII-9

On the initiative of the President of ISP Commission VII, Prof. Dr. G. Hildebrandt, Freiburg/Br., Working Group VII-9 "Spectral Signatures of Objects" was founded after the 13th ISP Congress held in Helsinki in 1976. One reason for founding this Working Group was the increased application of spectral signatures for classification tasks in image processing. Another reason was to achieve as early as possible - to a limited extent - a standardization of measuring methods and measures. The latter one seemed particularly important in view of the fact that photogrammetry as well as remote sensing call to an increasing degree for the interdisciplinary cooperation of scientists from disciplines as different as agriculture, forestry, physics, hydrology, geosciences, etc.

2. TERMINOLOGY

One of the first efforts of the Working Group was to determine - with contribution of a large group of interested people and in closest connection with already existing international standards - an adequate reflection quantity and to define the concept "spectral signature".

2.1 Reflectance Factor R

In remote sensing applications, the reflected radiation is generally measured with instruments having a rather small field of view to get more or less directional reflection quantities. Due to the fact that the resulting reflection properties depend on the angle of view of the instrument over which they are averaged, it makes a difference whether the angle of view of the instrument is 1 mrad or 100 mrad. However, usually both measurements are called directional and are compared to each other as if they were made with the same instrument. That is the main reason why we recommend to avoid the directional geometry and to use the conical geometry which will probably be better suited to remind investigators to specify the angle of view of their instruments to make comparisons of results more reliable.

Another reason to do so is the terminology. The directional reflection quantity in use is usually denoted in two different ways. It is either called (reflection) radiance factor (CIE[1], DIN[2], Kondratyev[3]) or directional reflectance factor (Nicodemus[4], IAMAP/RC[5]). Because it is still open whether there will be a compromise, the use of the term reflectance factor, connected to the conical geometry, avoids the discrepancy between the two terminology systems because it is used by both systems in the same way for the conical geometry. Therefore we recommend the term reflectance factor for all real measuring conditions except for the hemispherical measurement for which the term reflectance is reserved, again in accordance with both terminology systems mentioned above.

Usually, there will be hemispherical irradiation because the radiation of sky and clouds cannot be neglected compared to the sun's irradiation. Splitting of the reflection properties for different cones of the irradiation which would result in reflection data independent of the distribution of the irradiation, is mostly too elaborate to be carried out. But because this is possible, a distinction between these two cases should be made and it should be indicated whether it is a reflectance factor for hemispherical incidence or for conical incidence. The latter is the normal situation at laboratory measurements with only one source of irradiation.

As to the symbol we follow the recommendation given by CIE[6] and DIN[2] and propose the "reflectance factor R for hemispherical incidence" as the recommended quantity to characterize hemispherically incident radiation and conically reflected radiation as the usual situation in remote sensing application.

Its definition, as given by CIE[6], is as follows:
Reflectance factor (at a representative element of a surface, for the part of the reflected radiation contained in a given cone with apex at the representative element of the surface, and for incident radiation of given spectral composition and geometrical distribution): Ratio of the radiant (luminous) flux reflected in the directions delimited by the cone to that reflected in the same directions by a perfect reflecting diffuser identically irradiated (illuminated).

Herewith, the defining equation of the reflectance factor is

$$R(\lambda) = \frac{\int_{\Omega_r} L_{\lambda r}(\vartheta_r, \varphi_r)\cos\vartheta_r \, d\Omega_r}{L_{\lambda w}\int_{\Omega_r}\cos\vartheta_r \, d\Omega_r} = \frac{\overline{L}_{\lambda r}(\Omega_r)}{L_{\lambda w}} \qquad (1)$$

where (ϑ_r, φ_r) denote zenith angle and azimuth of reflection, respectively. $\overline{L}_{\lambda r}(\Omega_r)$ is the reflected spectral radiance averaged over the solid angle Ω_r with the mean direction (ϑ_r, φ_r). $L_{\lambda w}$ is the reflected spectral radiance of the perfect reflecting diffuser. If no reflectance standard is used but the incident radiation is measured as the irradiance E_λ, the reflectance factor $R(\lambda)$ is obtained by substituting $L_{\lambda w}$ by $E_\lambda/\pi\,\Omega_o$ because per definition $E_\lambda = \pi \cdot \Omega_o \cdot L_{\lambda w}$ with $\Omega_o = 1$ steradian

This yields

$$R(\lambda) = \frac{\pi \cdot \Omega_o \cdot \overline{L}_{\lambda r}(\Omega_r)}{E_\lambda} \qquad (2)$$

Measurements using equation (1) require a calibrated reflection standard which fills the field of view of the instrument totally. But only the relative response characteristic of the instrument must be known, if the field of view of the instrument (not necessarily the direction of view) is kept constant for both measurements.

Measurements using equation (2), however, require the knowledge of the reflected radiance and of the irradiance in absolute units because they cannot be measured with the same instrument due to the differing fields of view necessary for the two measurements.

We do not recommend any argument or index to the symbol R because the specification of the situation of measurement incorporates too many points to denote them as arguments or indices. In the following, a recommendation of specifications is given to make comparisons of different measurements more reliable.

It should be specified:

a) surface:

type (species), composition, slope and exposition to sun, linear or nonlinear texture and its azimuth difference to sun, period length (the mean distance of the dominant features of a surface, as, e.g. the mean distance of the trees in case of a forest), age, growth height, growing status, time of the seasons,

b) conditions of measurement:

position of sun, direct sun or not, degree of cloudiness, wind, wind speed, relation of direct sun to global radiation, atmospheric turbidity, air temperature and humidity, mean zenith (nadir) angle and azimuth difference to sun of the direction of view, height of the instrument over ground, date and time of measurement, environmental factors affecting the spectral properties,

c) instrument:

field of view, diameter of field of view at the object's distance (compare to period length), center wavelengths and halfwidths or bandwidths of spectral intervals, integration time of the electronics,

d) reflection standard:

type and size, calibration values, time lapse.

2.2 Spectral Signature

In order to obtain a definition of the concept "spectral signature", it was decided at the '78 Freiburg Symposium of Commission VII to send questionnaires to all members of the Working Group. The "mean" result of the answers received showed that the definition of "spectral signature" should contain two properties:

- it shall be a dimensionless relative distribution function and
- it shall be based on spectral radiation quantities and material character-

istics respectively (e.g. reflectance factor).

A quantity meeting these two demands is listed under no. 45-05-195 of the International Lighting Vocabulary published in 1970. It is called relative spectral energy distribution with the symbol S(λ).

45-05-195 répartition spectrale relative d'énergie

Représentation des qualités spectrales d'un rayonnement (description d'un illuminant) par la répartition spectrale relative d'une grandeur énergétique quelconque (flux énergétique, intensité énergétique, etc.).

symb. S(λ)

relative spectral energy distribution

Description of the spectral character of a radiation (description of an illuminant) by the relative spectral distribution of some radiometric quantity (radiant flux [power], radiant intensity, etc.).

symb. S(λ)

Strahlungsfunktion

Kennzeichnung der spektralen Beschaffenheit einer Strahlung (Beschreibung einer Lichtart) durch die relative spektrale Verteilung einer beliebigen Strahlungsgrösse (Strahlungsfluss, Strahlstärke, usw.).

Symb. S(λ)

45-05-190 répartition spectrale (d'une grandeur énergétique: flux énergétique, intensité énergétique, etc.)
Densité spectrale de la grandeur énergétique en fonction de la longueur d'onde.

Note: On utilise généralement la répartition spectrale relative, c'est-à-dire la densité spectrale de la grandeur énergétique mesurée par rapport à une valeur arbitraire de cette grandeur.

spectral distribution (of a radiometric quantity: radiant flux [power], radiant intensity, etc.)
The spectral concentration of the radiometric quantity as a function of wavelength.

Note: Commonly the relative spectral distribution is used, i.e. the spectral concentration of the radiometric quantity measured in terms of an arbitrary value of this quantity.

Spektrale Verteilung (einer Strahlungsgrösse: Strahlungsfluss, Strahlstärke, usw.)
Spektrale Dichte der Strahlungsgrösse in Funktion der Wellenlänge.
Anmerkung: Gewöhnlich wird die relative Verteilung benutzt, d.h. die spektrale Dichte bezogen auf einen beliebigen Wert der Strahlungsgrösse.

Because of the wide circulation and international recognition of the CIE-Vocabulary, these definitions served as basis for the following definition recommended at the last meeting of the WG VII-9 in Frankfurt/Main in April 1978:

> In Remote Sensing "Spectral Signature" is a relative spectral energy distribution S(λ) of the radiation reflected or emitted by an object.
>
> En télédétection, la "Signature spectrale" est la répartition spectrale relative d'énergie S(λ) du rayonnement reflèchi ou émis par un objet.
>
> In der Fernerkundung bedeutet "Spektrale Signatur" die Strahlungsfunktion S(λ) der von einem Objekt reflektierten oder emittierten Strahlung.

3. FUTURE WORKING PROGRAMME

The real goal of spectral signature research should be to assist in the (automated) classification of multi-spectral recordings. Numerous contributions and discussions held at the Freiburg Symposium revealed, however, that this aim has not yet materialized to the desired degree.

One way to reach this goal after all could be the following: first so-called "basic signatures" of the single objects are determined. This could be done either by measurements according to uniformly established measuring rules or by a computational mean formation of different measurements at similar objects and under similar conditions.

Then correction functions for different actual situations (position of the sun, growing season, etc.) are ascertained by means of which the actual signatures could be obtained from the basic signatures.

In order to accomplish this it is, however, necessary to determine what factors to be represented by correction functions are of relevant influence. Although these factors have already been discussed at several occasions (e.g. LARS[7], Guyot[8], Kriebel, Schlüter, Sievers[9]), such investigations have not yet found that degree of consideration that would be desirable for spectral signature research.

> For this reason it may be advantageous to carry out a joint test which is performed in part according to uniform measuring rules but which grants every participant freedom in the selection of the object, the time of measurement, the measuring procedures, and the instrumentation.

Such a test could, e.g. be carried out in such a manner that each participant performs during his investigations the following additional measurements, or parts thereof, provided these measurements do not form part of his measuring programme from the outset:

for measuring the effect of the sun's position,

- measurements at the same object throughout the day,

for demonstrating the homogeneity and/or the variability of the objects,

- measurements under the same conditions but at different locations of a homogeneous object,
- measurements at the same object from different distances,

for determining the repeatability of the measurements,

- repetition measurements at the same object under unchanged conditions,
- measurements with different measuring instruments at the same object.

Maybe such a programme will show how to handle spectral signatures and, above all, what to expect of them.

4. CONCLUSION

Thanks to the very lively and active cooperation of the WG members there have been so many useful and fruitful discussions in all fields that we can bring the discussion on terminological questions to a close and turn entirely to practical work and problems.

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