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Ocena przydatności sieci neuronowych i danych hiperspektralnych do klasyfikacji roślinności Tatr Wysokich

Assessment of neural networks and Imaging Spectroscopy for vegetation classification of the High Tatras

Słowa kluczowe: kartowanie roślinności, sztuczne sieci neuronowe, fuzzy ARTMAP, dane hiptespektralne, TPN, zbiorowiska roślinne
Keywords: plant mapping, ANN, fuzzy ARTMAP, hyperspectral data, Tatra National Park, plant communities

This research aims to discover potential of hyperspectral remote sensing data for mapping high-mountain vegetation ecosystems. First, the importance of mountain ecosystems to global system should be stressed: due to environmental fragility and location of plant species and communities at the upper levels of habitats, mountainous ecosystems form a very sensitive indicator of global climate change. Furthermore, a variety of biotic and abiotic factors that influence spatial distribution of vegetation in the mountains are producing diverse mosaic of habitats leading to high biodiversity. Mountain plants developed specific adaptations to survive at the fringe of life (pigment content, plant tissue structure etc.). These adaptations have direct impact on their reflectance properties which can be acquired and quantified using hyperspectral imagery interpretation techniques. These changes are characterised by a large number of closely spaced spectral channels. Application of remote sensing techniques allows vegetation research and mapping in areas that are otherwise inaccessible. This could be due to low accessibility of terrain, very short vegetative period and unstable weather conditions. Mapping vegetation and its condition is often constrained or even prevented using traditional, field mapping techniques. To protect a delicate balance in mountainous environments vegetation cover (a perfect indicator of all the other components of biosphere) should be researched in detail and mapped with sufficient level of accuracy. This is of particular importance for the proper management as both anthropogenic pressure and local disturbances (avalanches, solifluction after extensive rainfalls) can have significant impact on vegetation, leading to disturbance, and eventually – disintegration of plant cover. It is anticipated, that vegetation mapping and condition analysis can be achieved using hyperspectral, high ground resolution imagery and digital and field remote sensing techniques.

Artificial Neural Network (NN/ANN) algorithms use whole object characteristics (spectral, structural and/or textural properties, where the relationship between pixels are also taken into account). These relationships among the spatial patterns of the image frequently appear over natural biotopes and plant communities with closed coverage. Traditional classification methods that use parametrical approaches do not show satisfying results. The implemented neural network is the fuzzy ARTMAP (FAM) simulator. For training the neural network, particular layers of the covering vegetation classes were used that were identified via field mapping while the aircraft was operating. In the same time separate field data was collected for validation purposes too. For hyperspectral data compression the Minimum Noise Fraction transformation (MNF) was used. This method may be especially useful to separate and classify vegetation or land cover units.

The High Tatras are located within the MAB Biosphere Reserve and encompasses alpine and subalpine zones of the Tatra National Park (TPN). The area extends within: 49°10'30"–49°16'00" N and 19°45'30"–20°07'30" E rectangle, encompassing approximately 110 km^2. However, in this publication only Polish part of the Tatra Mountains (so called "High Tatras") was analysed (Figure 15).

Vegetation in the area has been well researched (since the 1920's), however most of the research has been carried out on transects or glades. Plant species have been well identified and described, however detailed maps of vegetation are available only for selected areas. The most of the research area is covered by natural and seminatural key units: peaty and boggy communities, avalanche meadows, tall herb communities (*Adenostylion*), grassland communities after grazing, subalpine dwarf scrub communities, willow thicket (*Chamaenerion angustifolium-Salix silesiaca* community), mountain-pine scrub on silikat substrate (*Pinetum mugho carpaticum silicicolum*), mountain-pine scrub (*Pinetum mugho carpaticum silicicolum*) in a complex with epilitic lichen communities, mountain-pine scrub on calcareus substrate (*Pinetum mugho carpaticum calcicolum*), montane spruce forest (*Plagiothecio-Piceetum*) and lakes.

In this study a DAIS 7915 hyperspectral data was classified that was acquired on 04 August 2002 by the German Aerospace Center (DLR) in the frame of the HySens PL02_05 project. This instrument is a 79-channel imaging spectrometer operating in the wavelength range 0.4-12.5 µm with 15 bit radiometric resolution. After preprocessing the obtained ground resolution was 3 meters.

The classification procedures (Figure 21) began with a preparation of reference layers of 42 dominant classes for the fuzzy ARTMAP teaching (Figure 22A). This stage based on terrain acquired data. For validation's map Spectral Angle Mapper (SAM) was used; in the first step, basing on field sampled polygons and endmembers obtained from DAIS data (corresponding to the key areas from the ground mapping) a pre-validation map was created. In the second step, basing on terrain mapping validation polygons of each analysed class were reselected (Figure 22B, Table 4).

Parallel to this procedure, an exploration from all 79 bands covering the VIS-TIR regions of the spectrum was made. The first step was a band's information analysis and the reselection of 60 spectral bands was made (Figures 23 and 24). The second step was to reduce the data dimensionality to 40 original and 20 MNF bands.

For the actual classification of the plant communities, a fuzzy ARTMAP simulator was used. In order to obtain the desired results 5000 and 10 000 iterations were used while training the Neural Net. Each set of image bands and reference layer contained a detailed DEM of analysed area.

Classification accuracy was measured using ENVI software's algorithms based on test and training sets. The overall accuracy was measured throughout a pixel by pixel comparison post classification images to ground truth map (prepared from SAM and field' verified mapping). The final results of the High Tatras polygon are shown in Tables 5-24, and the classification images present in Figures 28-35.

Generally, the forty-band set of input data offered higher accuracy (1-2%) than the twenty-MNF-band set (Tables 23 and 24). In the first case, the overall accuracy value achieved was 88.6%, and kappa coefficient was 0.8740.

In the case of 20 MNF bands, the overall accuracy was 82.6%, and kappa coefficient 0.8310.

Two of fourt-two analysed classes weren't classified properly: *Salicetum herbaceae* in a complex with *Empetro-Vaccinietum* (class# 6) and grassland communities after grazing in a complex with ruderal communities (#32). The worst classification results were achieved in the range of 44-80% for *Oreochloo distichae-Juncetum trifidi* scree form with *Juncus trifidus* (#14), *Festuca picta* community (#30), *Vaccinium myrtilus* community in a complex with tall herb communities (#36) and willow thicket – *Chamaenerion angustifolium-Salix silesiaca* community (#37).

The best results were achieved for: *Oreochloo distichae-Juncetum trifidi typicum* (#8); *Oreochloo distichae-Juncetum trifidi sphagnetosum* (#11), *Oreochloo distichae-Juncetum trifidi* subalpine anthropogenic form (#16), *Caricetum fuscae subalpinum* (#21), *Empetro-Vaccinietum* in a complex with *Pinetum mugho* (34), mountain-pine scrub on silikat substrate (38) and waters

Hyperspectral data showed significant potential for discriminating different vegetation types. The use of an artificial neural network is a proper method for mapping plant communities; it should be a supporting tool for traditional vegetation mapping. The increased number of bands while classification is being done (more than 40) does not offer a significantly better overall accuracy, but the worst results are not so low like in the case of twenty-MNF band sets. The processing time of MNF-transformed data was significantly shorter while provides less accurate classification results (3-6% less overall accuracy compared to using forty-band sets). A long training time is the most inconvenient aspect of this kind of classification.