A SPECTRAL FEATURE BASED CLASSIFICATION ALGORITHM FOR CHARACTERISATION OF URBAN SURFACES IN MUNICH

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ABSTRACT:
Urban areas are characterised by a high heterogeneity of surfaces. In this context hyperspectral imagery, which has a high spectral and spatial resolution, has proven itself to be a valuable data source.
The aim of this study is the development of an (semi-)automatic surface mapping algorithm for urban areas. The approach is tested on an exemplary urban area of Munich, Germany, where a HyMap dataset with a spatial resolution of 4 m and a spectral resolution of 128 bands are available. Next to the hypespectral dataset, a building mask is used to reduce the confusion between roof and ground materials
The successful identification of surface materials in hyperspectral images requires a detailed knowledge about the spectral characteristics of urban surfaces. Based on a number of spectroscopic laboratory studies and field investigations material-specific spectral features were selected. Finally, the parameterized features are used for a knowledge-based classification.
An accuracy assessment with in-situ reference data shows an overall accuracy of 85.1 % and a kappa-coefficient of 0.82. Even a differentiated identification of spectrally similar surfaces was successful. The results from this study indicate that spectral features are widely independent of spectral variations caused by illumination and degradation effects. Furthermore the proposed methodology is expected to reduce the need for test site specific training data.

KEY WORDS: urban mapping, spectral features, knowledge-based classification, HyMap

1. INTRODUCTION

Urban areas are one of the most challenging applications areas for remote sensing analysis. Approximately 50-60% of the world’s population lives in urban areas, as reported by the United Nations (2005), and generates almost 80% of the world’s economic output. The effective planning and management of urban areas requires up to date data in different spatial resolutions. Characterised by an extreme heterogeneity of surfaces, the differentiating of urban areas is ambitious. In this context hyperspectral imagery, which is characterised by a high spectral and spatial resolution, has proven itself to be a valuable data source. Hyperspectral remote sensing has shown the potential to directly identify and parameterize absorption features and form parameters of spectral signatures, which use the bio- and geophysical properties of the urban surfaces.

1.1 Research Objective

In this research, the development of an (semi-) automatic surface mapping algorithm is presented in order to reveal urban structures using hyperspectral data. The approach is tested on an exemplary urban area of Munich, Germany. The classification scheme that is used, aims at the identification of urban materials. The algorithm is implemented into a software tool written in IDL.

2. DATA AND PREPROCESSING

The study area is located in the city of Munich, Germany. The area is approximately 2.8 km x 5km (Figure 1a) and is characterised by a mixture of urban surface materials including various roof materials of different age and condition. The urban region Munich is by her typical settlement development representative for a huge number of German cities, for example Berlin, Köln or Leipzig (Blaschke, 2001). The main materials are roofing tiles, concrete, copper, aluminium, bitumen and asphalt. In addition to the roof surfaces water bodies, vegetation and bare soil are represented in the investigation area. Furthermore there are different land use types, like residential areas with different densities and socioeconomic structures, as well as commercial and industrial areas with different surfaces. For the classification of the urban surfaces, a hyperspectral dataset and a building mask were used in combination. The building mask was generated from HRSC-AX imagery and a vector data set provided by the municipality of Munich (Figure 1b).

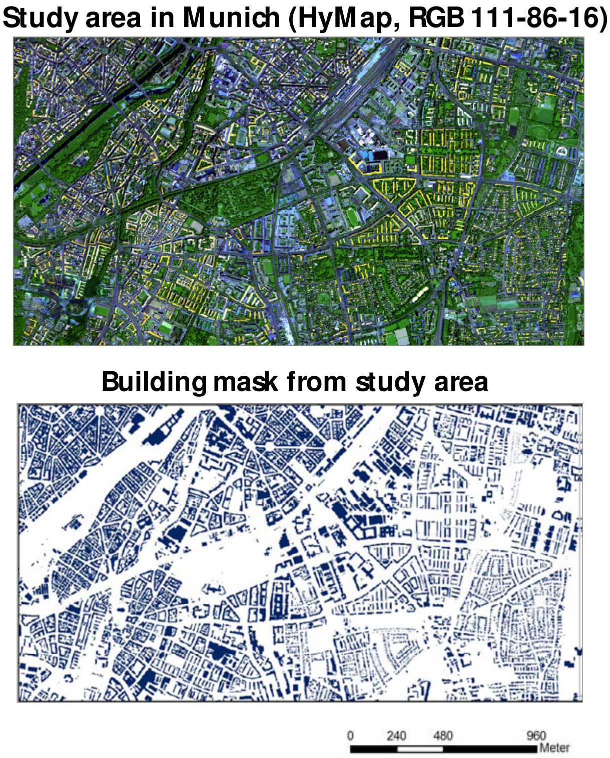


Figure 1: The selected study area in Munich: (a) HyMap, r-band 111 (2.27 µm), g-band 86 (1.72 µm), b-band 16 (0.68 µm); (b) Building mask.

The hyperspectral HyMap data were acquired on 17th of June 2007 during the HyEurope 2007 campaign with a spatial resolution of 4 x 4 m and 128 spectral bands. After radiometric correction the data was corrected for atmospheric influences and converted to reflectance with ATCOR 4 (Richter, 2007). Geo-referencing was done using ORTHO into the UTM WGS 84 coordinate system (Müller et al., 2005).

3. METHODOLOGY

Previous investigations with hyperspectral data show the high spectral variability of urban surfaces (Figure 2). The HyMap sensor used in this study offers a high spectral resolution and good signal to noise ratio (SNR) of the bands, which allows the identification of less pronounced spectral features. For the successful identification of surface materials a detailed knowledge about the spectral characteristics of urban surfaces is required. In order to gain this detailed knowledge a number of spectroscopic laboratory studies and field investigations were analysed (Ben-Dor et al., 2001, Heiden et al., 2001, Herold et al., 2004). Based on these studies, material-specific spectral features were selected for each surface material.

3.1 The identification of the spectral features

The identification of the material-specific features includes: the location of absorption bands and reflectance peaks, the relative increase or decrease of reflectance, the overall brightness and the continuity of a spectral curve. The identified spectral features are parameterized and thus transformed into numerical values (Table 1). The identification of the spectral features is between specific wavelength ranges. Materials with a typical brightness and flat curve progression are identified using mean and standard deviation values.

A comparable distinct feature is the reflectance peak described by its wavelength position and height.

Table 1: Selected spectral features and the corresponding feature functions

Spectral feature	Feature function
Absorption band	Absorption position and depth; Calculation of the area
Reflectance peak	Reflectance peak position and height
Brigthness	Mean, Standard deviation
Increase	Ratio
Decrease	

This is of high importance for the discrimination of materials with low spectral reflectance properties (e.g. for dark materials such as Bitumen). The ratio is sensitive to the decrease or increase of reflectance between two wavelength positions. Broad absorption bands such as shown in the spectral characteristics of Zinc (Figure 2) can be expressed by the area, which is enclosed by the reflectance curve and continuum function (Van Der Meer, 2004) in a specific wavelength range. In case of narrow absorption bands the absorption depth and position are suitable features.

Both, absorption and reflection features are derived from the difference between the reflectance curve and the continuum function within a defined wavelength range (Clark et al., 2002, Heiden et al., 2007).

3.2 Knowledge-based classification algorithm

The parameterized features are used for a knowledge-based classification of the urban surface areas. All together 27 spectral features were selected for the classification algorithm. The spectral features are represented in the whole wavelength range from 0.4-2.5 µm.

The selected features were divided into reuired, optional and excluding features, which are included in a decision process. If the pixels match one of the required (identification) features they will be assigned to their respective class. The second step classifies unknown pixels according to a (weighted) score scale, which operates with diagnostic and optional criteria.

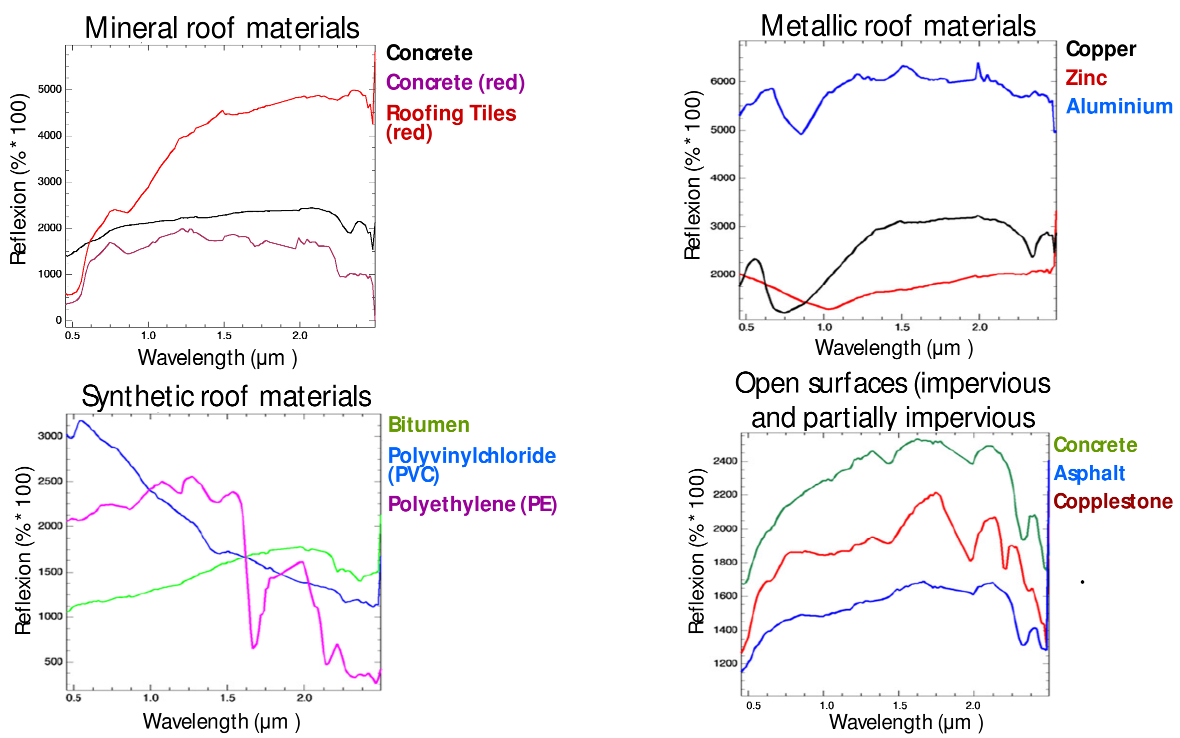


Figure 2: Spectral variations of urban materials from the HyMap Sensor

4. RESULTS AND DISCUSSION

The result is a classification scheme with 13 classes, which aims at the identification and classification of urban surfaces with material-specific reflectance characteristics.

In Figure 3 the classified urban surfaces are presented for the study area.

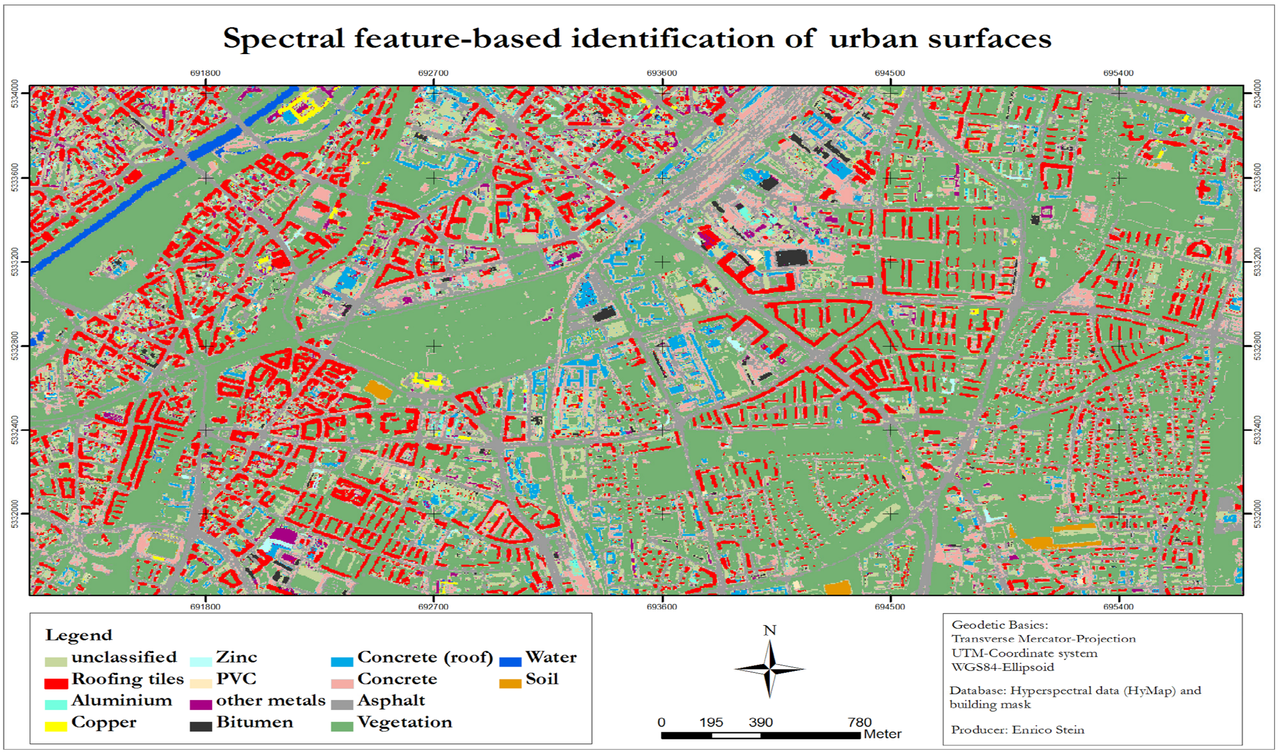
An accuracy assessment with in-situ reference data shows an overall accuracy of 85.1 % and a kappa-coefficient of 0.82. Even a differentiated identification of spectrally similar surfaces was successful. Next to the hypespectral dataset, a building mask is used as an additional data to reduce the confusion between roof and ground materials. The usage of the buidling mask within the classifiaction algorithm improves the quality of the result. A classification without a building mask shows only an overall accuracy of 68 % and a kappa-coefficient of 0.71. Especially the confusion between spectral similar materials (e.g. concrete as roof mateial and open spaces) is reduced when using a building mask. However, an important requirement is the correct co-registration with the HyMap-Data.

5. CONCLUSION AND OUTLOOK

The presented feature-based methodology can be used for a (semi-) automated differentiation and identification of known urban surfaces. The accuracy assessment with reference data shows a very good agreement. Even a differentiated identification of spectrally similar surfaces was successful. The results from this study indicate that spectral features are widely independent of spectral variations caused by illumination and degradation effects. Furthermore the proposed methodology is expected to reduce the need for test site specific training data. Further research on the transferability of the algorithm is needed to confirm this.

The identification of small objects is expected to be improved by using hyperspectral data with a higher spatial resolution. Furthermore the usage of thermal data allows identification of additional features (e.g. the sensor ARES with 30 bands in thermal region).

Figure 3: Result of the spectral feature-based classification of urban surfaces for the study area in Munich (Database:



HyMap-Data and building mask)

As an outlook, these material maps can be used to derive indicators, such as building density or imperviousness. Based on the surface material it will be possible to characterise and categorise urban objects such as buildings, roads and vegetated areas, which can afterwards be combined into urban structures. These material maps can be used for several applications, like vulnerability and risk management, urban climate analysis, management of transport infrastructure, or fire danger assessment.

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7. ACKNOWLEDGEMENTS

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