

A PRELIMINARY STUDY ON SEPARABILITY OF PAVING MATERIALS IN SHADOWED HYPERSPECTRAL PIXELS FROM A CENTRAL URBAN AREA.

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Key words: high resolution, hyperspectral data, paving materials, shadow pixels, urban areas.

ABSTRACT:

Building and tall object shadowing results in a relevant number of pixels in HR hyperspectral urban data to be insufficiently illuminated to get a reliable estimate of the local reflectance and thus to be correctly classified. Masking away shadowed pixels is one of the simplest approaches to this issue. In this paper we instead attempt to investigate the features of these pixels in order to exploit their possible information content. Tests are conducted on an hyperspectral dataset acquired in July 2002 by the DLR over the town of Pavia using the DAIS and ROSIS sensors. We show how a careful selection of the classes may attain significant increases in the classification accuracy. Although the data set is limited and thus the results not to be made general, we are satisfied that those pixel have an exploitable information content.

1. INTRODUCTION

Shadowed areas in hyperspectral images over urban areas for ancient European cities such as Pavia (northern Italy) where large, short buildings are dominant, mostly lay on urban streets. This may not be a problem for lower resolution data and classification can be successful [1], but in very high resolution data (1 m) such as the one used in our experiments, many pixels happen to fall completely into a shadow area. A relevant part of the street paving materials cannot be classified due to the exceedingly low signal-to-noise ratio in such pixels. Training on illuminated pixels does not allow to build a capacity to discriminate shadowed pixel materials.

In this work we make an attempt to recover a part of the information contained in the shadowed pixels using a different strategy.

2. THE DATASET

2.1 The hyperspectral data

The ROSIS (Reflective Optics System Imaging Spectrometer) [2][3] sensor was developed prior to 1992 by Dornier Satellite Systems (DSS formerly MBB) in cooperation with the GKSS Research Centre (Institute of Hydrophysics) and with the DLR. It was originally designed to observe the coastal waters, which determined the choice of the spectral features and the possibility of off-nadir pointing to avoid sunglint. Its 103 bands range from 430 to 850 nm. Both ROSIS and DAIS [3], another hyperspectral instrument, were onboard the Dornier 228 which flew around noon on the 8th of July, 2002, over the town of Pavia in Northern Italy, one of the sites chosen for the 2002 HysenS campaign. 4 flight lines were flown resulting in 4 data stripes from each of the two sensors, 512 pixel wide. The flight height of about 1890 meters resulted in a ground resolution of 1.5 m for the DAIS and 1 m for the ROSIS sensor. The stripes produced by DAIS were partly overlapping, while the narrower field of view of ROSIS resulted in significant gaps between adjacent stripes. In this work ROSIS sensor was chosen for its finer spatial resolution, and its line 2 was used, which ensures the best covering of the urban centre. Preprocessing of the ROSIS data, including system corrections and radiometric calibration, was carried out by the DLR [5].

2.2 The ground truth

Pavia is a small city (about 80,000 inhabitants) in north-western Italy. It was born as a Roman military campsite, of which it preserves the traditional “row-and-column” block organisation. Most of the current buildings in the city centre date back to the middle age and consist of extended, short buildings. A natural consequence of such pattern and features is the formation of a large number of shadowed pixels in the acquired hyperspectral image. A simple 5-class k-means classification of a 512×1000 subsample of the ROSIS acquisition line 2, over the city centre, has showed that the class visually coincident with the shadowed pixels accounts for 105,160 pixels, about 20.5% of the total. Alternatively we could have used thresholding, although an experiment with a threshold 400 over the 550 nm band has shown that there is an 89% overlap between the two results, and tree canopies account for most of the 11% difference.

Extensive surveying and inquiring local administrative authorities allowed us to list the different pavement covers present in the shadowed portions of the scene. The following materials were found:

1. cobbled paving, mostly white or clear cobblestones extracted from the river embedded in battered sand, possibly mixed with concrete.
2. granite plaster of two different sorts, one clearer from national pits, one darker probably from Portuguese pits.
3. slate plaster, mostly used for sidewalks and curbs, not on carriageways; this implied a very limited amount of available pixels at the sensor resolution, and thus exclusion of this class from further analysis.
4. porphyry in small cubes.
5. Asphalt.

A ground truth was then laid down for all of the above classes on both enlightened and shadowed pixels. Care was taken in order to consider, for each class, pixels from both sides of the image in order to account for the different acquisition angles with respect to the sun angle. We stress that the main problem was to find pixels far enough from enlightened areas to be sufficiently clear of disturbance due to atmospheric diffusion: as visible in Figure 1, it is very difficult to find “pure” shadow pixels, due to the geometric features of the scene. A total of about 16,000 shadow pixels and 8,000 enlightened pixel were assigned, each class evenly distributed between training and test sets.



Figure 1: shadowed areas in the urban centre consist mostly of long, narrow stripes (top), and so are forced to be the ground truth sets (bottom).

3. THE EXPERIMENTS

3.1 Starting point

Standard classifiers were used for our experiments: Mahalanobis Distance (MHD), Maximum Likelihood (ML), Minimum Distance (MD) and Spectral Angle Mapper (SAM). The first attempt was obviously to obtain a reference point by directly attempting to classify the shadow pixels, whose results were *expectedly poor*: the best accuracy was the producer's obtained for porphyry of about 77% simply due to its abusive assignment; it has reported indeed an extremely high commission error rate (over 200%). For sake of comparison, the enlightened pixels have obtained overall accuracies of about 85% with $k=0.804$ for MHD, 88% with $k=0.841$ for ML, 76% with $k=0.686$ for MD, 39% with $k=0.304$ for SAM. The poor results for MD and SAM suggest a non-trivial shape of the clusters.

3.2 Curve analysis

The next step was to analyse spectral curves for shadowed pixels to visually decide which classes could have been merged by similarity in an attempt to trade accuracy for precision in classification.

Four representative curves in Figure 2 show a large number of apparent absorption peaks, but their most distinct features seem to be their trends in the visible and in the near IR range. Cobble paving and granite share a high apparent reflectivity in shorter visible wavelengths, while porphyry and asphalt display a tallest peak at the left end of the spectral range but lower values around 500 nm. Moreover, for the former two

materials the trend of reflectivity for increasing wavelengths is definitely towards higher values, while for the latter two such trend is much softer.

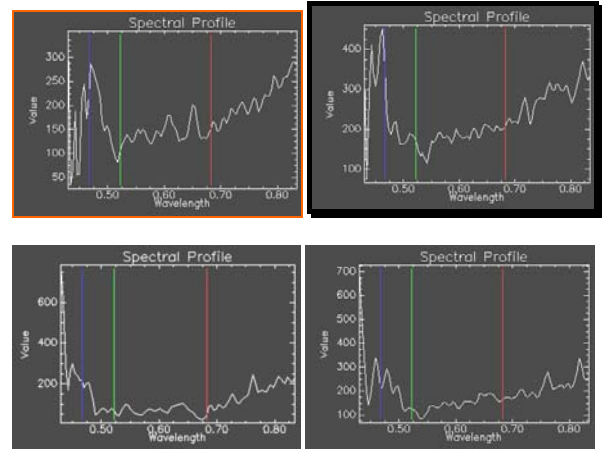


Figure 2: representative spectral curves for classes (from top left,): cobble paving, granite, porphyry, asphalt.

It seemed thus natural to try and merge together the former two classes into a class “higher DN’s” or HDN as well as the latter two classes into a new class “lower DN’s” or LDN. The ground truth was naturally changed accordingly, cutting into half the number of classes but roughly doubling the number of ground truth pixels per each class.

3.3 New classifications

Once established the new class set, we proceeded to reclassifying the dataset with the same set of standard classifiers. This time the accuracy results were 75% with $k=0.621$ for MHD, 73% with $k=0.598$ for ML, 73% with $k=0.599$ for MD, and 38% with 0.26 for SAM.

MHD has allowed a good detection of HDN class, including compactness of pixel blobs. LDN classification is likely to be improved by some sort of spatial classification. Moreover, by zooming on the classification maps we realised that the zone boundaries were detected very accurately.

In contrast, with ML, the accuracy of HDN was as low as 38%, due to extensive misclassification of its pixels into the LDN class.

MD has reported good classification of cobble paving in ample places and poor classification of the same in narrow streets. Its overall accuracy level is comparable with ML.

SAM has reported almost no improvement with respect to the old classes.

4. CONCLUSIONS

In this paper an attempt to investigate the features of the shadowed pixels in order to exploit their possible information content for their classification was described. After collecting ground truth by surveying and inquiring authorities, two attempts were made to classify separately enlightened and shadowed pixels, obviously obtaining poor results in the latter case. Subsequently, an analysis of the spectral curves of the shadowed land covers has highlighted similarities between some of the classes at least in terms of the trends. The similar classes were merged together and the classification performed again with the new class set. A

substantial improvement in both overall accuracy and k coefficient for all of the considered classifiers except SAM was reported.

Results seem to indicate that it is possible to trade some of the class precision for accuracy, i.e. giving up some of the class discrimination capability it is possible to move from useless classifications to sensible ones, exploiting the limited amount of information still available in the low SNR, shadowed pixels. Future work will be aimed at cleaning out the shadowed pixels of the bias from the contribution of diffusion from neighbouring, illuminated pixels. This is believed to be one of the major causes of corruption of the classification results: narrow stripes following the building contours are by far the most frequent shape for groups of shadowed pixels, none of which is sufficiently far from the boundary to assume a negligible influence from the enlightened pixels.

ACKNOWLEDGEMENTS

The authors wish to thank the German Aerospace Center (DLR) for providing the hyperspectral data over Pavia in the framework of the HysenS project, and Marco Pasturezzi for performing the programming work.

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