Appendix A

Data sets description

A.1 Kennedy space center, Florida, USA (KSC)

KSC data set[1] shown in Fig. A-1 is an HSI acquired on March 23, 1996 at the Kennedy Space Center, Merritt Island, Florida, USA by AVIRIS sensor. This image consists of 512 x 614 pixels and 224 bands with a spatial resolution of 18 m. The number of bands is reduced to 176 by removing water absorption and low signal-to-noise bands. The labeled data were collected using land-cover maps derived from color infrared photography provided by KSC and Landsat thematic mapper imagery. The class name and corresponding numbers of ground truth observations used in the experiments are listed in Table A.1.

[1]Available online through the Grupo de Inteligencia Computacional from the Basque University (EPV/EHU): http://www.ehu.eus/ccwintco/index.php?title=Hyperspectral_Remote_Sensing_Scenes

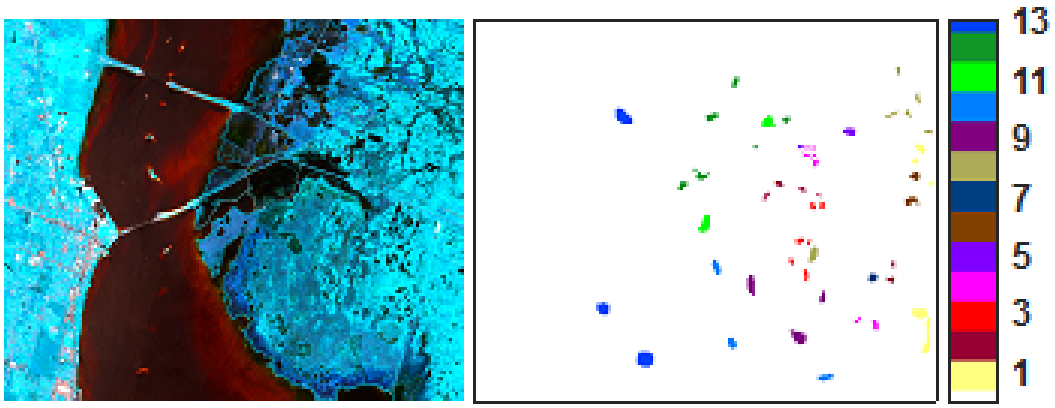

Figure A-1: Hyperspectral KSC image and its reference map.

Table A.1: Land-cover classes and the numbers of available labeled pixels on the KSC data set

Class No.	Class Name	No. of Labeled Samples
1	Scrub	761
2	Willow swamp	243
3	Cabbage palm hammock	256
4	Cabbage palm/Oak hammock	252
5	Slash pine	161
6	Oak/Broadleaaf hammock	229
7	Hardwood swamp	105
8	Graminoid marsh	431
9	Spartina marsh	520
10	Cattaial marsh	404
11	Salt marsh	419
12	Mud flats	503
13	Water	927
Total		**5211**

A.2 University of Pavia, Pavia, Italy

University of Pavia data set[1] is an HSI acquired by the ROSIS-03 (Reflective Optics System Imaging Spectrometer) optical sensor over the urban area of the University of Pavia, Italy. The flight was operated by the Deutsches Zentrum für Luft-und Raumfahrt (DLR, the German Aerospace Center) in the framework of the HySens project, managed and sponsored by the European Union. The size of the image in pixels is 610 x 340, with very high spatial resolution of 1.3 m/pixel. According to specifications, the number of bands of the ROSIS-03 sensor is 115 with a spectral coverage ranging from 0.43 to 0.86 μm. Some channels (twelve) have been removed due to noise. The remaining 103 spectral bands are processed. Fig. A-2 shows a false color composite of the image. The class name and corresponding numbers of ground truth observations used in the experiments are listed in Table A.2.

A.3 Indian Pines, Indiana

The Indian Pines data set[2] is another HSI acquired by the AVIRIS (Airborne Visible/Infrared Imaging Spectrometer) sensor over the agricultural land of Indian

[2]Available online: http://engineering.purdue.edu/ biehl/MultiSpec

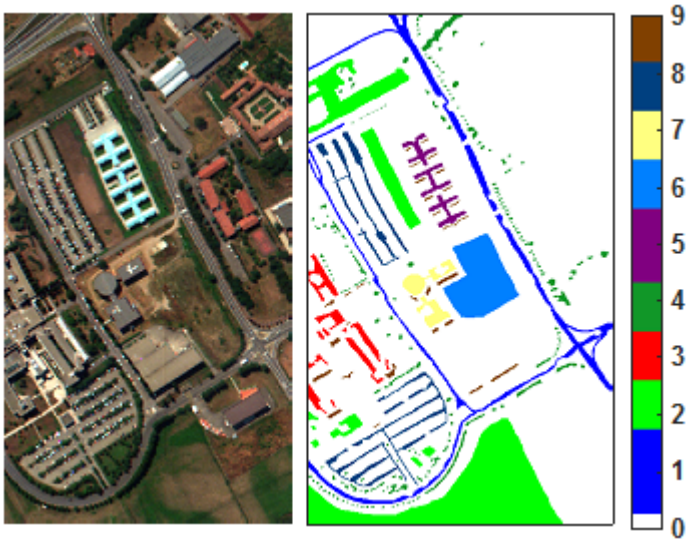

Figure A-2: Hyperspectral University of Pavia image and its reference map.

Table A.2: Land-cover classes and the numbers of available labeled pixels on the University of Pavia data set

Class No.	**Class Name**	**No. of Labeled Samples**
1	Asphalt	6631
2	Meadows	18649
3	Gravel	2099
4	Trees	3064
5	Metal Sheets	1345
6	Bare Soil	5029
7	Bitumen	1330
8	Self-Blocking Bricks	3682
9	Shadows	947
Total		**42776**

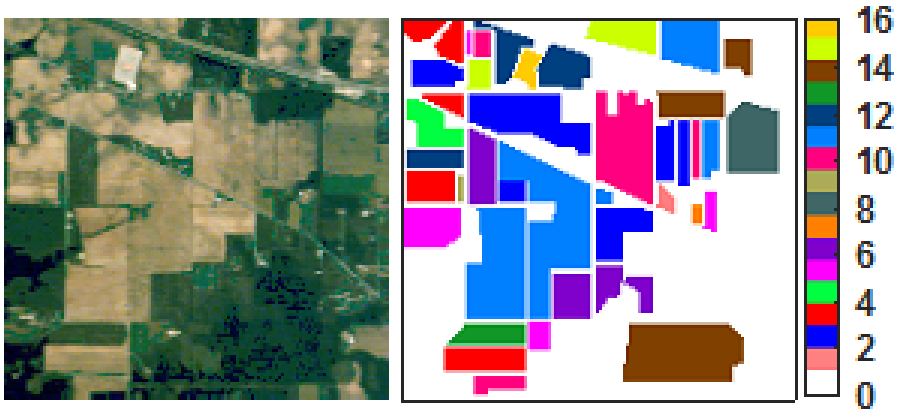

Figure A-3: Hyperspectral Indian Pines image and its reference map.

Pines, Indiana, in the early growing season of 1992. These data were acquired in the spectral range 400-2500 nm with spectral resolution of about 10 nm. The image consists of 145 x 145 pixels and 220 spectral bands with a spatial resolution of 20 m. Twenty water absorption and fifteen noisy bands were removed and the remaining 185 bands were included as candidate features. Fig. A-3 shows a false color composition of the AVIRIS Indian Pines scene. The class name and corresponding numbers of ground truth observations used in the experiments are listed in Table A.3.

A.4 University of Houston, Texas, US

The University of Houston data set[3] is an HSI acquired over the campus of University of Houston, Texas, United States and its neighboring urban area by the Compact Airborne Spectro-graphic Imager (CASI). The size of the image is 349×1905 pixels with a spatial resolution of 2.5 m. The image has 144 spectral bands covering a range from 380 to 1050 nm. Fig. A-4 shows a false composition of the considered image and a map of the available reference samples. The class name and corresponding numbers of ground truth observations used in the experiments are listed in Table A.4.

[3]Provided by Dr. S. Prasad from Dept. of Electrical and Computer Engineering, University of Houston, Texas US through:http://hyperspectral.ee.uh.edu

Table A.3: Land-cover classes and the numbers of available labeled pixels on the Indian Pines data set

Class No.	Class Name	No. of Labeled Samples
1	Alfalfa	46
2	Corn-notill	1428
3	Corn-min	830
4	Corn	237
5	Grass/Pasture	483
6	Grass/Trees	730
7	Grass/Pasture-mowed	28
8	Way-windrowed	478
9	Oats	20
10	Soybeans-notill	972
11	Soybeans-min	2455
12	Soybean-clean	593
13	Wheat	205
14	Woods	1265
15	Bldg-Grass-Tree-Drives	386
16	Stone-steel towers	93
Total		**10249**

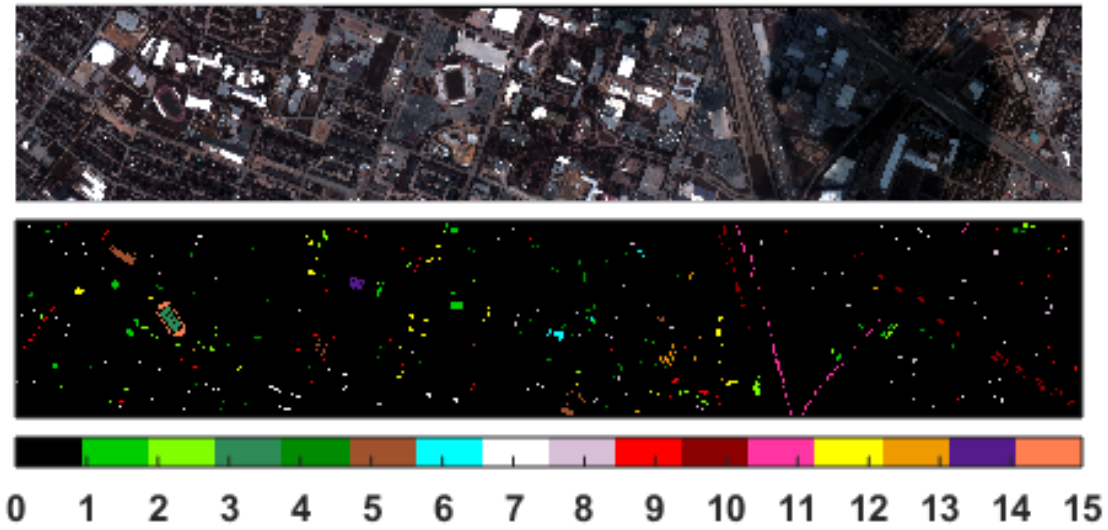

Figure A-4: Three band color image of the CASI University of Houston data set and its related map of available reference samples.

Table A.4: Land-cover classes and the numbers of available labeled pixels on the University of Houston data set

Class No.	**Class Name**	**No. of Labeled Samples**
1	Grass-Healthy	1251
2	Grass-Stressed	1254
3	Grass-Synthetic	697
4	Tree	1244
5	Soil	1242
6	Water	325
7	Residential	1268
8	Commercial	1244
9	Road	1252
10	Highway	1227
11	Railway	1235
12	Parking Lot 1	1233
13	Parking Lot 2	469
14	Tennis Court	428
15	Running Track	660
Total		**15029**

Appendix B

Publication list

The thesis contributions led to the following publications.

Journals

1. Patra, S., Bhardwaj, K., and Bruzzone, L. A spectral-spatial multicriteria active learning technique for hyperspectral image classification. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, 10(12):5213–5227, 2017.

2. Bhardwaj, K. and Patra, S. An unsupervised technique for optimal feature selection in attribute profiles for spectral-spatial classification of hyperspectral images. *ISPRS Journal of Photogrammetry and Remote Sensing*, 138:139–150, 2018.

3. Bhardwaj, K., Patra, S., and Bruzzone, L. Threshold-free attribute profilefor classification of hyperspectral images. *IEEE Transactions on Geoscience and Remote Sensing*, 57(10):7731–7742, 2019.

Conference

1. Bhardwaj, K., Das, A., and Patra, S. Spectral-spatial active learning with attribute profile for hyperspectral image classification, In *International conference on Intelligent Computing and Smart Communication (ICSC'19)*, Springer, 2019.

2. Bhardwaj, K., Das, A., and Patra, S. Spectral-spatial active learning in hyperspectral image classification using threshold-free attribute profile, In *International Conference on Frontiers in Computing and Systems (COMSYS'20)*, Springer, 2020.

3. Bhardwaj, K., Das, A., and Patra, S. Spectral-spatial active learning with superpixel profile for classification of hyperspectral images, In *International Conference on Signal Processing and Communication (ICSC'20)*, IEEE, 2020.