SHARE 2012: Subpixel detection and unmixing experiments

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ABSTRACT

The quantitative evaluation of algorithms applied to remotely sensed hyperspectral imagery require data sets with known ground truth. A recent data collection known as SHARE 2012, conducted by scientists in the Digital Imaging and Remote Sensing Laboratory at the Rochester Institute of Technology together with several outside collaborators, acquired hyperspectral data with this goal in mind. Several experiments were designed, deployed, and ground truth collected to support algorithm evaluation. In this paper, we describe two experiments that addressed the particular needs for the evaluation of subpixel detection and unmixing algorithms. The subpixel detection experiment involved the deployment of dozens of nearly identical subpixel targets in a random spatial array. The subpixel targets were pieces of wood painted either green or yellow. They were sized to occupy about 5% to 20% of the 1 m pixels. The unmixing experiment used novel targets with prescribed fractions of different materials based on a geometric arrangement of subpixel patterns. These targets were made up of different fabrics with various colors. Whole pixel swatches of the same materials were also deployed in the scene to provide in-scene endmembers. Alternatively, researchers can use the unmixing targets alone to derive endmembers from the mixed pixels. Field reflectance spectra were collected for all targets and adjacent background areas. While efforts are just now underway to evaluate the detection performance using the subpixel targets, initial results for the unmixing targets have demonstrated retrieved fractions that are close approximations to the geometric fractions. These data, together with the ground truth, are planned to be made available to the remote sensing research community for evaluation and development of detection and unmixing algorithms.

Keywords: hyperspectral imaging, spectral unmixing, subpixel detection

1. INTRODUCTION

The quantitative evaluation of algorithms applied to remotely sensed hyperspectral imagery require data sets with known ground truth. Accurate ground truth is often only available as part of dedicated experimental collections. A recent data collection known as SHARE 2012, conducted by scientists in the Digital Imaging and Remote Sensing (DIRS) Laboratory at the Rochester Institute of Technology (RIT) together with several outside collaborators, acquired hyperspectral data with this goal in mind[1]. As part of this data collection, two experiments were designed in particular to acquire well ground-truthed data for the quantitative evaluation of subpixel detection and unmixing performance. This paper provides a description of the ground targets, their deployment, and preliminary analysis of the data. These data will be made available to the remote sensing research community as part of the overall SHARE 2012 data distribution through a link at http://dirs.cis.rit.edu/resources/.

2. SUBPIXEL DETECTION EXPERIMENT

One of the relatively unique capabilities of hyperspectral imaging in remote sensing is the ability to detect targets that are not spatially resolved[2]. Algorithms to accomplish this subpixel detection have been an active area of research among the signal processing community for over two decades. However, there have been very few data sets of empirical imagery with known ground truth available to the research community. One of the best known data sets for hyperspectral object detection was the Forest Radiance I data collection[3]. Another more recent data set that has become popular is the RIT Blindtest[4,5]. However, while multiple targets were deployed in these data collections, the number of instances of a particular target was limited; most commonly just a single instance. Accurate estimation of detection performance through Receiver Operating Characteristic (ROC) curves requires large sample sizes[6].

Thus, as part of SHARE 2012 an experiment was included where a large number of painted wooden blocks (48 of each color) were deployed as targets. The targets were approximately 20" x 12" in size, and given the approximate 1 m

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ground resolution of the ProSpecTIR-VS airborne hyperspectral imager, the targets subtended an area subpixel fraction ranging from 5% to 20%, depending on how the pixels were aligned on the targets. Figure 1 shows ground level views of the green and yellow blocks deployed in a grass area and the adjacent asphalt basketball court. Figure 2 shows an aerial view of the target deployment collected by RIT's WASP airborne imaging sensor. The targets were deployed in a semi-random arrangement, spaced a minimum of 2 meters apart with a goal of ensuring just a single instance per HSI pixel.

Figure 1. Subpixel targets. The green wooden blocks are shown in the grass field on the left while the yellow wooden blocks are on the right.

Figure 2. Subpixel target detection experiment deployment. The green wood blocks are seen in the grass in the upper left area of the image while the yellow wood blocks are seen on the basketball court in the lower left area of the image. The image is extracted from RIT WASP imagery collected at 1551Z with approximately 6" resolution.

Figure 3 shows example spectral reflectance ground truth measurements that were made of the two painted targets. Additionally, field spectral reflectance measurements were made of the adjacent background areas.
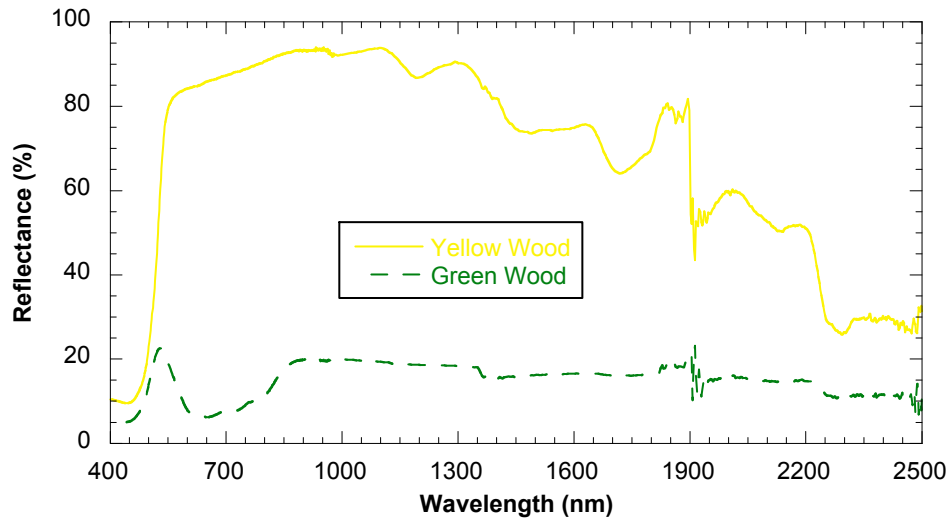

Figure 3. Reflectance spectra of subpixel detection targets. Data collected with SpectraVista SVC-1024 field spectrometer.

3.   UNMIXING EXPERIMENT

Unmixing has also been an active area of research in the analysis of hyperspectral imagery[7]. Similar to subpixel object detection, there have been few data sets with quantitative truth by which to estimate accuracy of unmixing algorithms. One of the most common data sets used in the evaluation of unmixing algorithms has been the AVIRIS Cuprite image[8]. However per-pixel knowledge of the area fractions of the minerals present in the imagery is not generally available and most researchers resort to showing good qualitative comparisons to the results of previous work. Recent efforts have developed simulated data for which quantitative evaluation is possible[9], but these data even with random noise added do not replicate real-world effects present in empirical data. A recent data collection with thermal hyperspectral imagery included targets deployed in precise arrangement with good estimates of subpixel fractions possible through comparison with the resulting airborne imager pixel arrangement[10]. However, in real remote sensing imagery the precise ground resolution is not always known. Also due to optical and atmospheric point spread function effects, the radiance collected in a single pixel is not restricted to simple circle or square projected on the ground. Rather, due to these optical and atmospheric effects, it is a weighted summation over an area often extending beyond the pixel-sampling interval.

Thus for this experiment a set of unique checkerboard targets were designed for which precise knowledge of the materials and their area fractions can be known, independent of how the HSI pixels align with the targets. Targets were constructed out of 12"x12" squares of six different fabrics arranged in a repeating pattern. One target was 24' x 24' and made up of alternating blue cotton and blue felt squares, arranged as in a checkerboard fashion. Given the approximate 1 m ground resolution of the ProSpecTIR-VS airborne hyperspectral imager, no matter how the pixels were aligned with the target pattern this arrangement ensured each material occupied 50% area fraction of a pixel. An adjacent 16' x 16' panel was made with a 2x2 repeating pattern comprised of 3 yellow felt squares and 1 yellow cotton square, thus achieving a 75%/25% area fraction per pixel. A second 16' x 16' panel was fabricated using a combination of squares in a repeating pattern, but with the exact materials and proportions not included in the ground truth with the goal of serving as a blind test target for unmixing algorithm assessment. The yellow felt/yellow cotton target was deployed during the morning airborne collections and then was replaced for the afternoon collections by the unknown target panel, while the large blue 50/50 target was deployed throughout the day. To allow for in-scene endmember extraction, additional 10' x 10' solid panels of all six fabrics used in the unmixing targets were also fabricated and deployed adjacent to the unmixing targets. All panels were made large enough to ensure a good number of sample pixels would image the center of the targets while avoiding edge effects, recognizing the ground area contributing to the radiance in a pixel is larger than the nominal 1 m due to the point spread function effects. Figure 4 shows a ground-level image of the unmixing targets and a few of the whole pixel targets. Figure 5 presents are aerial view of the morning deployment showing both unmixing targets and the solid panels.

Figure 4. Image of the unmixing targets. The yellow/yellow unmixing target is in the upper left while the blue unmixing target is in the upper right. Four of the whole pixel targets are shown in the foreground.

Figure 5. Unmixing target detection experiment deployment in the morning configuration. The large (24' x 24') 50/50 blue target is visible in the upper right area of the asphalt court while the smaller (16' x 16') 75/25 yellow/yellow target is in the upper left. The six 10' x 10' whole panels of the fabrics are seen clearly just below the unmixing targets. The two small panels just below and to the left of the blue target are pink felt (on the left) and yellow cotton (on the right). The four small panels across the lower part of the asphalt area are (from left to right): yellow felt, blue cotton, gold felt, and blue felt. The image is extracted from RIT WASP imagery collected at 1551Z with approximately 6" resolution.

Figure 6 presents field reflectance spectra measured for the six different materials used in the unmixing targets.
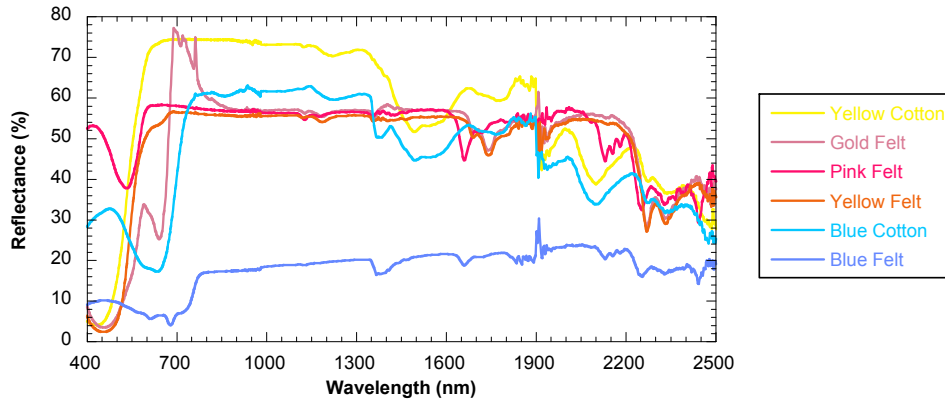

Figure 6. Reflectance spectra of unmixing fabrics. Data collected with SpectraVista SVC-1024 field spectrometer.

As an initial test of the unmixing experiment, a preliminary analysis has been performed on the Yellow/Yellow and Blue/Blue targets[11]. Figure 7 shows a natural color image extracted from the airborne hyperspectral imagery along with a retrieved fraction plane for the yellow felt endmember. The analysis used unconstrained linear unmixing using single pixels extracted from the image for the six fabric materials and three backgrounds: asphalt, grass, and sand. All 360 spectral bands in the calibrated spectral radiance imagery were used for this analysis.
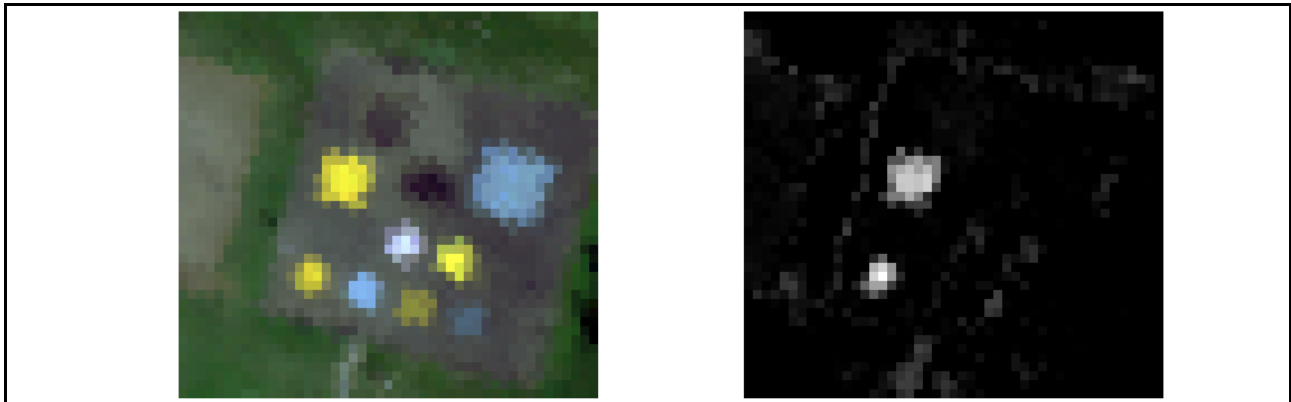

Figure 7. Natural color representation of the scene captured by the ProSpecTIR-VS instrument (left) showing the asphalt court with targets, sand court (on the left), and grass surrounding the courts. The fractional abundances for each pixel of the unmixing results for the yellow felt endmember are shown as a grey level intensity (right).

Table 1 presents quantitative results of this unconstrained unmixing for the two target panels. The retrieved mean and standard deviation for each panel were calculated for four subsets of pixels on the targets. The subsets included the full visible area of the target in the hyperspectral imagery along with three smaller subsets using only pixels with one, two, or three guard pixels on all sides. As can be seen in the table the mean retrieved fraction was found to be close to the truth with a low standard deviation only when considering the HSI pixels which were clearly inside the edges of the targets. This demonstrates that the radiance measured by a given pixel extends beyond the simple geometric projection of its instantaneous field of view (IFOV). In addition, the use of a repeating pattern is demonstrated to be a useful target configuration for unmixing analysis even with the unknown alignment between the ground targets and the pixels in real remote sensing imagery. A more sophisticated unmixing algorithm might be able to obtain even better results than the 1 to 2% errors seen with the simple unconstrained linear unmixing algorithm considered here.

Table 1. Retrieved fractions of materials found using unconstrained spectral unmixing applied to the Yellow/Yellow and Blue/Blue unmixing targets. The mean and standard deviations are from the set of unmixed fractions from pixels in the target area. The full area includes every pixel the target touched.

	Yellow Felt		Yellow Cotton		Blue Cotton		Blue Felt	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
True Fractions	0.75		0.25		0.50		0.50	
Full Area	0.33	0.30	0.12	0.18	0.26	0.25	0.27	0.29
1 guard pixel	0.56	0.21	0.21	0.17	0.41	0.19	0.43	0.22
2 guard pixels	0.76	0.057	0.24	0.087	0.51	0.011	0.53	0.026
3 guard pixels	0.77	0.016	0.26	0.005	0.52	0.007	0.53	0.021

4. SUMMARY

This paper presents a description of two experiments included as part of the SHARE 2012 data collection along with a few preliminary analysis results of the data. A large number of painted wooden blocks were deployed as subpixel targets with the goal of providing empirical ROC curve estimates for detection algorithms using hyperspectral imagery based on sample sizes not generally available. Unique repeating-pattern unmixing targets were deployed to provide data with known area fractions for endmembers, independent of how the pixels in the airborne hyperspectral imagery sampled the scene. While analysis of the subpixel detection targets remains to be done, preliminary analysis of the unmixing targets has confirmed their use in the quantitative evaluation of unmixing accuracy. These data, along with the corresponding ground truth, will be distributed as part of the SHARE 2012 data distribution.

ACKNOWLEDGEMENTS

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