RESOLUTION MERGE OF 1:35.000 SCALE AERIAL PHOTOGRAPHS WITH LANDSAT 7 ETM IMAGERY

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ABSTRACT:

Merging of different data sets is often used in digital image processing to improve the visual and analytical quality of the data. The analyst may need to merge different types of data. In this process, different data such as satellite imagery from the same sensor but with different resolution, satellite imagery from different sensors with varying resolution, digitized aerial photography and satellite imagery or satellite imagery with ancillary information can be merged. In this paper, the efficiency of three different merging techniques (Principal Component, IHS, and Brovey Transform) is examined, in order to improve the spatial resolution of very high resolution aerial photographs (1:35.000 scale panchromatic) with the Landsat 7 ETM imagery. The aim was to get best enhanced merged aerial imagery for the visual interpretation. Because of the very big difference between the resolutions of sources, the techniques give very different results. The general conclusion is that when the original source imagery is used, Principal Component and Brovey Transform merging techniques should be preferred for such kind of imagery. Other methods were also tested to enhance the merge imagery, such as, merging the multispectral Landsat 7 ETM imagery with Landsat 7 ETM panchromatic imagery at first and merging this imagery with aerial photographs again with three different merging techniques afterwards. In another method, multispectral Landsat 7 ETM imagery was resampled to higher resolution imageries and then panchromatic aerial imagery was merged with this resampled image with three different merging techniques. In all approaches, Brovey Transform and Principal Component techniques serve well the purpose of increasing resolution of the low resolution images with the high resolution images. However, all methods should be tested in different areas by using multispectral and panchromatic images which were taken in different time frames to define the overall performances of these methods and merging techniques.

1. INTRODUCTION

1.1 Resolution Merge

Digital images taken by airborne or spaceborne sensors are very frequently used in earth sciences and applications. The increasing applications are due to the availability of high quality images for a reasonable price and improved computation power. Nowadays there is a wide range of systems that provide images in digital format, and their interpretation into terrestrial attributes is very dependent on their spatial and spectral resolution. As a result of the demand for higher classification accuracy and the need in enhanced positioning precision there is always a need to improve the spectral and spatial resolution of remotely sensed imagery. For most of the systems, panchromatic images typically have higher resolution, while multispectral images offer information in several spectral channels. Resolution merge (also called pan-sharpening) allows us to combine advantages of both kinds of images by merging them into one.

A variety of resolution merging techniques is available and described by several authors. The most common techniques are implemented in standard image processing software packages (IHS , PCA, Multiplicative and Brovey transforms) It is hard to categorise the techniques into a limited number of main types (Pohl, C.,1999, Hill et al.,1999, Bretschneider et al.,2004). In another study conducted by Carvalho et al.,(2006), a geostatistical merging methodology based on direct sequential cosimulation with reference images of LandsatTM and SPOT-P is tested. With the stochastic simulation one generates a high spatial resolution image with the characteristics of the of the higher spectral resolution image. It is an iterative inverse optimization procedure that tends to reach the matching of an objective function by preserving the spectral characteristics and spatial pattern, as revealed by the variograms, of the higher-spectral resolution images both in terms of descriptive statistics and band correlation coefficients.

Digital image-merging procedures are techniques that aim at integrating the multispectral characteristics in a high spatial resolution image, thus producing synthetic images that combine the advantages of both types of images. The main constraint is to preserve the spectral information for tasks like classification of ground cover. Ideally, the method used to merge datasets with high-spatial resolution and high-spectral resolution should not distort the spectral characteristics of the high spectral resolution data. Not distorting the spectral characteristics is important for calibrating purposes and to ensure that targets that are spectrally separable in the original data are still separable in the merged dataset (Chavez et al.,1991). Several methods for spatial enhancement of low-resolution imagery combining high and low resolution data can be used. Some widely used ones are: Intensity-Hue Saturation, Principal Component, Multiplicative, Color Normalized, and Brovey Transform. Before the resolution merge, the source imagery need to be processed to have the same reference system. The images have to be accurately registered to the same reference system and to one another.

In this paper, the efficiency of three different merging techniques (Principal Component, IHS, and Brovey Transform) is examined, in order to improve the spatial resolution of very high resolution aerial photographs (1:35.000 scale panchromatic) with the Landsat 7 ETM imagery. The aim was to get best enhanced merged aerial imagery for the visual interpretation.

Principal Component method, which is the first method used in the study, calculates principal components, remaps the high resolution image into the data range of first principal component and substitutes it for first principal component, then applies an inverse principal components transformation. The Principal Component method is best used in applications that require the original scene radiometry (color balance) of the input multispectral image to be maintained as closely as possible in the output file. As this method scales the high resolution data set to the same data range as Principal Component 1, before the Inverse Principal Component calculation is applied, the band histograms of the output file closely resemble those of the input multispectral image. Unfortunately, this radiometric accuracy comes at the price of a large computational overhead. The Principal component method is consequently the slowest of the three methods offered and requires the most system resources. Another result of this methodology is that the output file tends to have the same data range as the input multispectral file (Erdas Field Guide,2006).

Second merging method (IHS) works by assessing the spectral overlap between each multispectral band and the high resolution panchromatic band and weighting the merge based on these relative wavelengths. Therefore, it works best when merging images (and bands) where there is significant overlap of the wavelengths. As such, it may not produce good results when merging SAR imagery with optical imagery, for example. Normally, the biggest limitation of a method based on IHS processing is that it can only process three bands at a time (because of using the RGB to IHS method). However, the color consistency is so good that this implementation of the approach enables images with more than three bands to be merged by running multiple passes of the algorithm and merging the resulting layers. The technique can be used to merge different sensors (such as merging SPOT 4 data with Landsat5) (Erdas Field Guide,2006).

Lastly used merging method (Brovey Transform) uses a ratio algorithm to combine the images. The Brovey Transform was developed to visually increase contrast in the low and high ends of an images histogram (i.e. to provide contrast in shadows, water and high reflectance areas such as urban features). Consequently, the Brovey Transform should not be used if preserving the original scene radiometry is important. However, it is good for producing RGB images with a higher degree of contrast in the low and high ends of the image histogram and for producing visually appealing images 8 Erdas Field Guide,2006).

Since the very high difference at the resolution of source data, the techniques give very different results. The general conclusion is that if the original source imagery is used, Principal Component, and Brovey Transform merging techniques is preferable for such kind of imagery.

In addition to previous ones, some other methods were also tested to enhance the merge imagery. In another method, firstly the multispectral Landsat 7 ETM imagery was merged with Landsat 7 ETM panchromatic imagery and finaly this imagery was merged with aerial photographs again with three different merging techniques. The results showed that this method creates better merged imagery.

In the other method, at the first step multispectral Landsat 7 ETM imagery was resample to higher resolution imageries (20, 10, 5 meters resolutions) step by step. At the second step, these three images were enhanced with filtering. Finally, panchromatic aerial imagery was merged with these this resampled Landsat imagery again with three different merging techniques.

In all approaches, Brovey Transform and Principal Component techniques serve well the purpose of increasing resolution of the low resolution images with the high resolution images. However, all methods should be tested in different areas by using multispectral and panchromatic images which were taken in different time frames to define the overall performances of these methods and merging techniques.

1.2 Study Area and Data

The study area is situated in the west of Izmir, which is the third biggest city of Turkey. The area shows the characteristic of much of the Aegean region, with agriculture and urban lands dominating valley bottoms and deciduous forests covering steeper areas. The area is generally rural. In the East of the study area there is a small village having some small farmlands. Izmir- Çeşme motorway and national road extend from west to northeast of the study area.

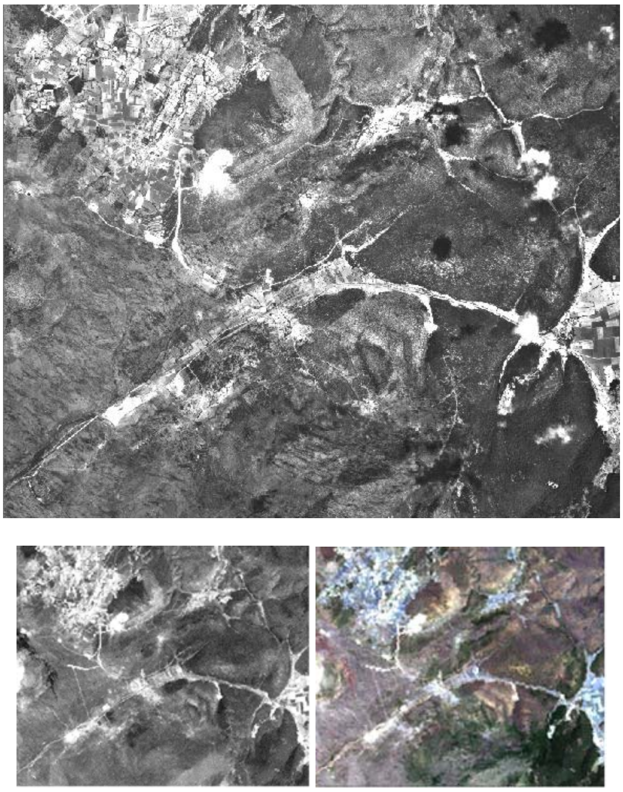

Figure 1. Study area and data (a: Aerial photographs, b: Landsat panchromatic, c: Landsat multispectral)

Image data for the study are eight 1:35.000 scale black and white aerial photographs and Landsat-7 ETM imagery. Aerial photographs were taken in 1996 by Zeiss RMK TOP15 camera (focal length: 153 mm) with 1:35 000 scale. They are black and white photographs and were scanned in 21 microns and orthorectified with 1 meter resolution. Landsat imagery is dated 2000. 28.5 meter resolution 1st, 2nd, 3rd and 14.25 meter resolution panchromatic bands of the imagery are used for study. Study area and data are shown in Figure 1.

2. RESOLUTION MERGE OF 1:35.000 SCALE AERIAL PHOTOGRAPHS WITH LANDSAT 7 ETM IMAGERY

2.1 Direct Merge

In this method, aerial orthophoto is directly merged with Landsat multispectral imagery. The efficiency of three different merging techniques (Principal Component, IHS, and Brovey Transform) is examined. The merged images are shown in Figure 2 and also a part of imagery is zoomed in and shown in Figure 3.

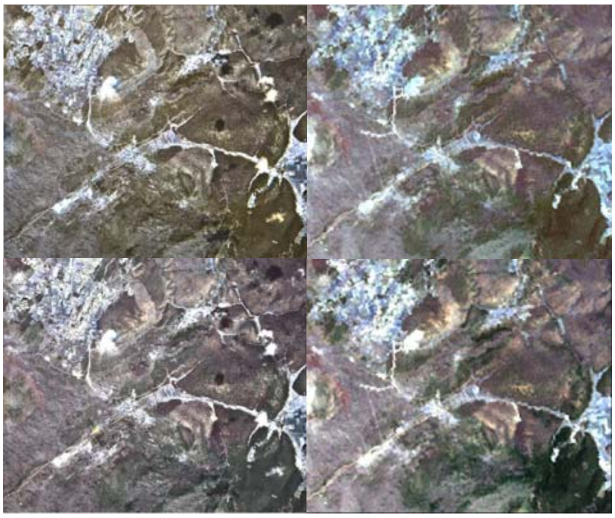

Figure 2. Merged imageries (a: Brovey Transform, b: IHS, c: Principal Component, d: Landsat multispectral)

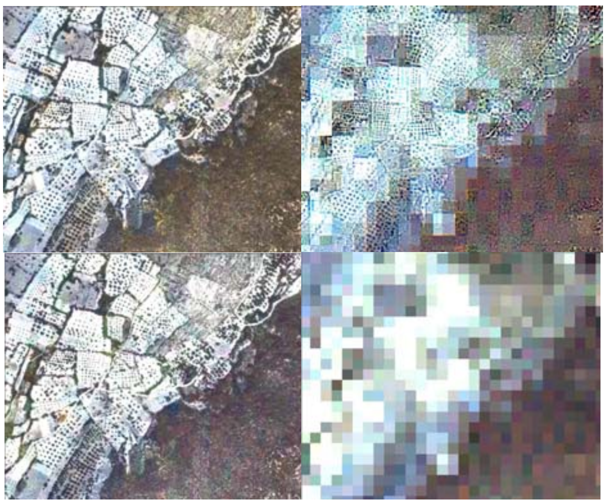

Figure 3. Merged imageries (a: Brovey Transform, b: IHS, c: Principal Component, d: Landsat multispectral)

When the imageries examined, it can be easily seen that Principal Component and Brovey Transform techniques gives better results. Especially there is a big degradation at the imagery generated with the IHS technique. Brovey Transform method creates a more sharpened imagery but with some color spot areas. Sharpness is less at Principal Component method if compared with Brovey Transform but no color spots happens in this method. If the pan-sharpening results from Brovey Transform, IHS (Intensity-Hue-Saturation) and PC (Principal Component) are compared, respectively consistent, weak and superior spectral recovery was achieved with the methods.

2.2 Merge with Resolution Merged Landsat Imagery

In this method, firstly the multispectral Landsat 7 ETM imagery was merged with Landsat 7 ETM panchromatic imagery and finaly this imagery was merged with aerial photographs again with three different merging techniques. The results showed that this method creates better merged imagery. The merged images are shown in Figure 4 and also a part of imagery is zoomed in and shown in Figure 5.

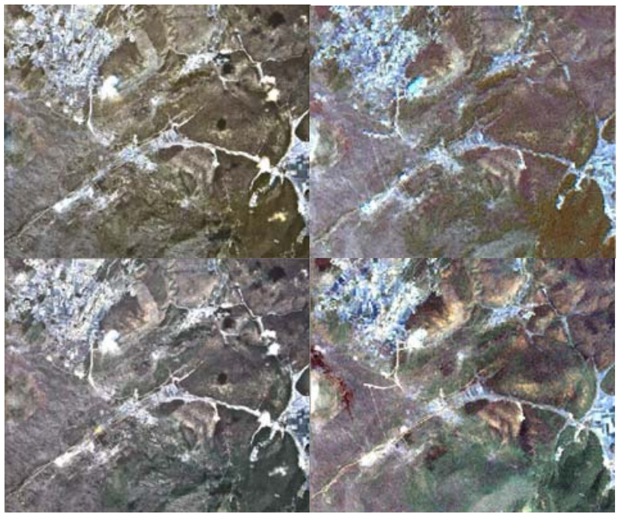

Figure 4. Merged imageries (a: Brovey Transform, b: IHS, c: Principal Component, d: Resolution merged Landsat multispectral)

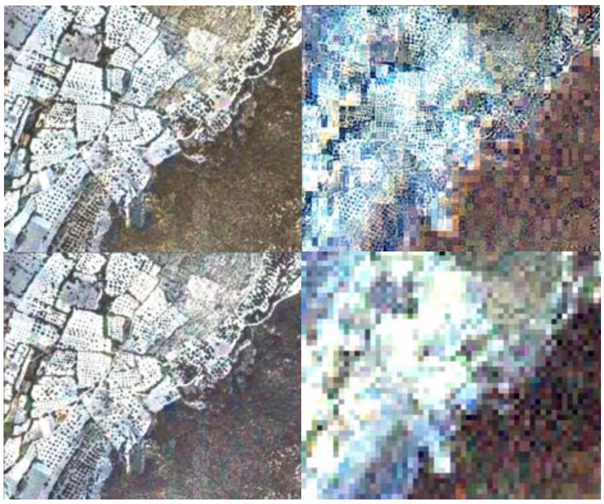

Figure 5. Merged imageries (a: Brovey Transform, b: IHS, c: Principal Component, d: Resolution merged Landsat multispectral)

In this method, The Principal Component method serves well the purpose of spatial resolution enhancement of the low resolution images with the high resolution images if in a step-by-step approach the input files and their spectral structures are controlled and prepared for the final merging. In this way, the results are much more satisfactory than the ones obtained through the Direct Merge method. For example, several linear and point features (wood fences, trees, etc.) that are difficult to distinguish in the Landsat images are visible in these merged images.

2.3 Merge with Resampled Landsat Imagery

In this method, at the first step multispectral Landsat 7 ETM imagery was resample to higher resolution imageries (20, 10, 5 meters resolutions) step by step. At the second step, these three images were enhanced with filtering. Finally, panchromatic aerial imagery was merged with these this resampled Landsat imagery again with three different merging techniques. The merged images are shown in Figure 6 and also a part of imagery is zoomed in and shown in Figure 7.

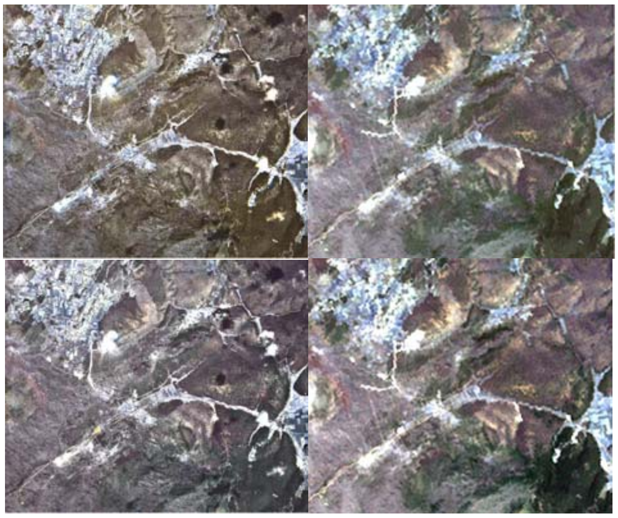

Figure 6. Merged imageries (a: Brovey Transform, b: IHS, c: Principal Component, d: Resampled Landsat multispectral)

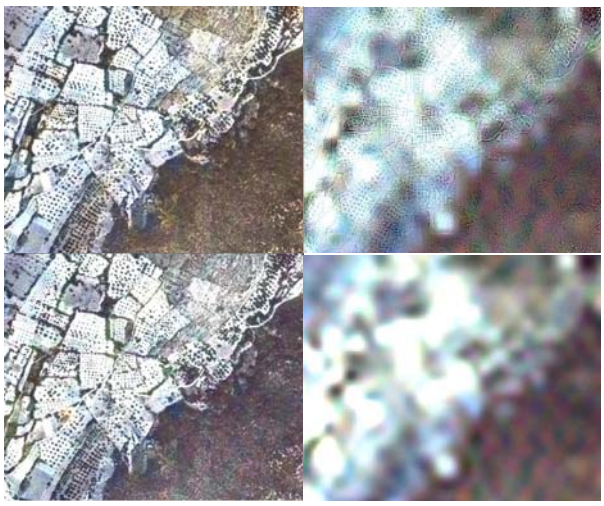

Figure 7. Merged imageries (a: Brovey Transform, b: IHS, c: Principal Component, d: Resampled Landsat multispectral)

In this method, Brovey Transform gives the more satisfactory result by creating a good spectral reflectance. This method decreases the color spot effect in the direct merge method and creates a more homogenous merged imagery.

3. CONCLUSIONS

Merging methods for utilising both the high resolution panchromatic and the multispectral images in a combined manner is one way of improving the methods for many remote sensing applications such as change detection, classification, etc. The aim of the resolution merge is to achieve a maximal spatial detail augmentation and a minimal color distortion.

The results of this study demonstrate that for the merge of aerial photographs and Landsat ETM imagery, Principal Component and Brovey Transform techniques achieve significantly better results than IHS. The main advantage of the images generated by the Principal Component and Brovey Transform techniques is that they have a close spatial characteristics with the aerial photograph. This could make the photo interpretation easier. Furthermore, these images have an aspect of softly colored aerial images, in which the color tones have been obtained from the Landsat ETM ones. The merged images are more similar to the Landsat ETM multispectral images, but with better spatial feature details derived from aerial photographs.

Another conclusion is that merge with resampled Landsat imagery generates a better spectral merged imagery compared with the other methods.

IHS technique doesn’t work well for imageries having such a big difference of spatial resolution. For this technique, merge with resolution merged Landsat imagery gives the best results. A lack of this technique is that since this technique creates only three spectral bands, it is not preferred for some remote sensing applications such as classification.

Brovey Transform technique creates very sharp merged images but with some spectral problems. In direct merging, some color spots happen in the merged imagery. Merge with resampled Landsat imagery decreases this effect.

In all of these techniques, Principal Component seems to work best for such imageries. It creates imagery with low spectral problems. Only the sharpness is less if compared with the Brovey transform. But this problem can be decreased by merging with resolution merged Landsat imagery.

As a result of this study, it is advised that for the applications needing good spectral reflectancy; Principal Component technique and Merge with Resolution Merged Landsat Imagery method should be used and for the applications needing good spatial information; Brovey Transform technique and Merge with Resampled Landsat Imagery method should be used.

REFERENCES

Bretschneider, T., Kao, Odej.2004, Image fusion in remote sensing, Technical University of Clausthal, Germany, http://www.ntu.edu.sg/home/astimo/Publications/Documents/OSEE2000.pdf

Carvalho, J., Delgado-Garcia J., Soares, A., Caetano, H.,2006, Stochastic simulation with reference images for merging

Landsat TM and SPOT-P images. Int. Journal of Remote Sensing (submitted).

Chavez, P.S., Sides, S.C., Anderson, J.A.,1991, Comparison of three different methods to merge multiresolution and multispectral data: Landsat TM and SPOT Panchromatic. *Photogrammetic Engineering and Remote Sensing*, 57 (3), pp. 295-303.

Erdas Field Guide, 2006, ERDAS Inc., Atlanta, USA

Hill, J., Diemer, C., Stöver, O., Udelhoven, Th., 1999. A local correlation approach for the fusion of remote sensing data with different spatial resolutions in forestry applications, *International Archives of Photogrammetry and Remote Sensing*, (32) 7-4-3

Pohl, C.,1999, Tools and methods for fusion of images of different spatial resolution, International Archives of Photogrammetry and Remote Sensing, Vol. 32, Part 7-4-3 W6, Valladolid, Spain.