

GIS AND CONTEXT BASED IMAGE ENHANCEMENT

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ABSTRACT:

Various applications require an optimized (and rapid) display of remote sensing imagery. Multisensor and multiband remote sensing data have to be enhanced for optimal band combination and image contrast. Problems that exist are that contrast stretches are usually optimized for the whole image and might not prove appropriate for selected features. For example, an image that contains land, water and beach classes will be stretched in a way that would produce a compromise for the different classes. Water is usually dark (especially in CIR display), beach will be very bright with little discernible structure (similar for urban classes), and other land classes (e.g. vegetation) will not make use of the full possible range of digital numbers. Also, different features might require different band combinations for optimum display. Selected stretching especially for regions of low contrast is nothing new in the analysis of remotely sensed data. Usually, this is done interactively by the analyst either by selecting a box or digitizing a certain area of interest in the image. This area is then enhanced using standard image processing techniques. The subset is then displayed separately to highlight certain features that would have been impossible to discern in a global enhancement mode.

The goal of this study was to develop automated procedures for feature based image enhancement techniques. Feature based enhancement means that different feature classes in the image require different procedures for optimum display. The procedures do not only encompass locally varying enhancement techniques such as histogram equalization or contrast stretch but also the selection of different spectral bands. There are two main sources for this kind of information: (a) storage of a priori knowledge in a GIS, and (b) context based image information that can be extracted through a segmentation process. Both techniques can also be applied for optimum feature class selection. In this paper, we develop a five-step automated procedure for selective image enhancement and compare the results to those achieved by standard methods. The test area is a coastal region in the US which covers land, water and beach areas. Datasets are multispectral IKONOS and Quickbird satellite data. It is shown that the new methods produces superior results.

1. INTRODUCTION

Image enhancement techniques are usually applied to remote sensing data to improve the appearance of an image for human visual analysis. Enhancement methods range from simple contrast stretch techniques to filtering and image transforms (see, for example, Jensen 1996 or Gonzales and Woods 2002). Image enhancement techniques, although normally not required for automated analysis techniques, have regained a significant interest in recent years. Applications such as virtual environments or battlefield simulations require specific enhancement techniques to create 'real life' environments or to process images in near real time.

This paper deals with the development of automated techniques for the rapid enhancement of high resolution imagery from different sources. We will present the results for multisensor and multiband remote sensing data that have to be optimized for band combination and image contrast using standard point operation functions such as linear contrast stretch or histogram equalization techniques. Problems with these rapid enhancement techniques are that they are usually optimized for whole images and might not prove appropriate for selected features. This affects especially coastal areas that contain land,

water and beach classes. Using global image enhancement techniques, the image will be transformed in a way that would produce a compromise for the different classes. Water is usually dark (especially in CIR display), beach will be very bright with little discernible structure (similar for urban classes), and other land classes (e.g. vegetation) will not make use of the full possible range of spectral values. Also, different features might require different band combinations for optimum display. This cannot be done using conventional enhancement and display strategies. Water, for example, may reveal more information in RGB display whereas vegetation requires a CIR approach. The indicated problems will only get worse with the availability of hyperspectral data where possible combinations of narrow bandwidth spectral channels can differ for land and water features.

The proposed methods make use of existing GIS information, if available, and/or image preprocessing such as NDVI calculations. Using this approach, it is possible to design a procedure for completely automated image enhancement that works in an optimized way for the selected features.

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2. STUDY SITE AND DATA SETS

The study site is located southeast of Jacksonville, North Carolina, USA. It presents one of the largest US Marines sites for which an extensive amount of ground truth, GIS, and remote sensing data is available (fig. 1)

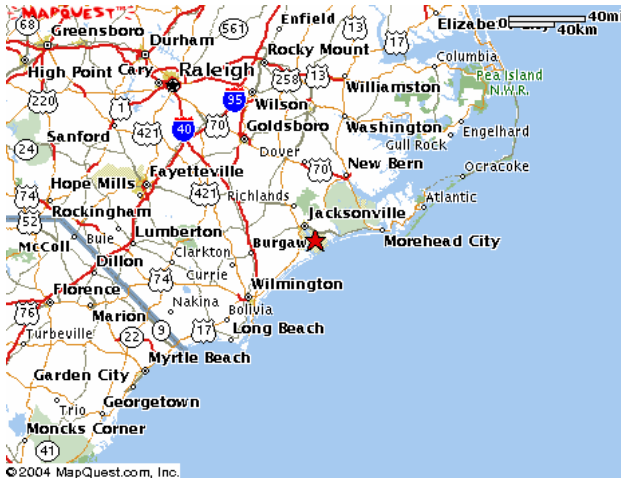


Figure 1. Camp Lejeune study site indicated by a red star

The study was conducted at the Center for Remote Sensing and Mapping Science where the corresponding author stayed for his sabbatical in 2003. The datasets consisted of Landsat, SPOT, IKONOS and Quickbird images as well as GIS landuse/landcover data in shape format (figure 2).



Figure 2. IKONOS multispectral image (2048 x 2048 subset) of the Camp Lejeune study site overlaid with vector GIS information

3. METHODOLOGY

Selected stretching especially for regions of low contrast is nothing new in the analysis of remotely sensed data (see, for example, Jensen, 1996). Usually, this is done interactively by the analyst either by selecting a box or digitizing a certain area

of interest in the image. This area is then enhanced using standard image processing techniques (e.g., histogram equalization or linear contrast stretch). The subset is then displayed separately to highlight certain features that would have been impossible to discern in a global enhancement mode.

The goal of this study was to develop automated procedures for feature based image enhancement techniques for rapid display purposes, especially of high resolution remote sensing images (Ehlers, 2004). Feature based enhancement means that different feature classes in the image require different procedures for optimum display. The procedures do not only encompass locally varying enhancement techniques such as histogram equalization or contrast stretch but also the selection of different spectral bands. The image class water, for example, may be best displayed in a true color mode whereas for the feature class vegetation a false color infrared display is more appropriate. It is envisioned that this technique could be implemented in a near-realtime environment making use of a priori information.

There are two main sources for this kind of information: (a) storage of a priori knowledge in a GIS, and (b) context based image information that can be extracted through a segmentation process. Both techniques can also be applied for optimum feature class selection.

For many areas in the world, there exists a wealth of a priori information in existing spatial databases, digital maps or previous analyses of remotely sensed data. Usually, this type of information is stored in a raster or vector based GIS. With the progress in the integration of remote sensing and GIS software, many commercial systems allow the simultaneous display and use of GIS and image layers. For a joint analysis, however, usually GIS vector layers have to be converted to raster data.

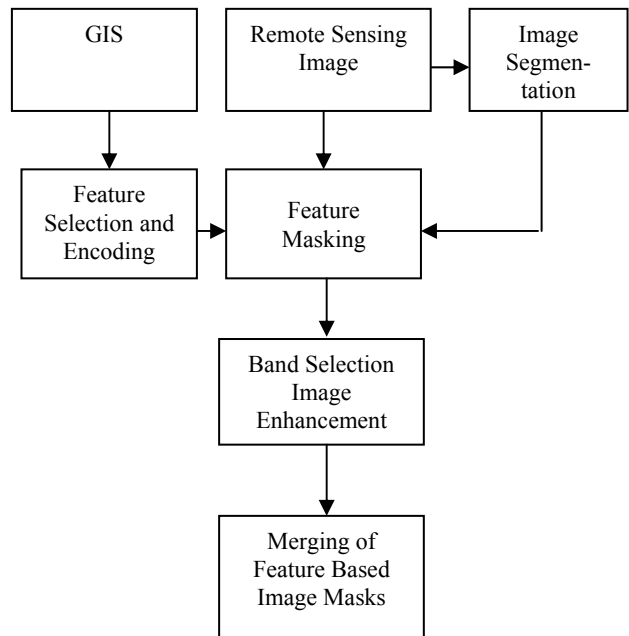


Figure 3. Concept for GIS and context based image enhancement

The case study for our research was conducted in an integrated ArcGIS/ERDAS environment. The developed procedure, however, is system independent and can work in any integrated

GIS/remote sensing environment. The procedure consist of five steps involving either GIS based or image context based masking (Figure 3).

3.1 GIS Based Enhancement

First, all image and GIS layers have to be registered to a common coordinate system, e.g., UTM. GIS layers should be displayed as polygons or raster boundaries overlaid on the remotely sensed image to check for inaccuracies or geometrical and semantical inconsistencies of the data sources (see Figure 2).

In a second step, GIS information to be used as feature masks for local enhancement is analyzed and merged into meaningful classes. If, for example, vegetation classes are to be evaluated, all non-vegetation classes can be recoded into one mask. Other GIS masks that can be used for local image enhancement may separate water from land or built-up areas from open fields. The GIS layers can be overlaid on the image data for visual inspection. With this, editing can be performed if required (Figure 4).



Figure 4: Selected and recoded GIS classes for 'Water/Ocean', 'Water/River', 'Beach', and 'Open Field/Roads/Built-Up' overlaid on multispectral Ikonos data

The third step is the creation of separate image layers that are based on the selected feature classes. After recoding, the GIS layers form 0/1 input masks (0 = area outside the feature class, 1 = area inside the feature class) to segment the image into independent layers (Figure 5). Each spectral band of the image is multiplied with the individual GIS masks to form separate multispectral image layers with have the original nonzero pixel values only inside the selected GIS masks. The last image to be created contains the complement mask to all selected feature classes. Using this procedure, it is assured that for each pixel location only one of the image layers contains the original image value. All the others will have a zero value at this location. Using the 'union' operator, a simple overlay of all image separates recreates the original image. Figure 5 shows the separate image layers for 5 different feature classes.

In a fourth step, each layer is processed separately. This step does include the selection of an appropriate enhancement algorithm and the choice of suitable bands for display or printing purposes. In our study, we worked with 4-band remote sensing data. This step, however, will become more important if it involves hyperspectral images. For example, water information is usually displayed with a higher lever of detail if the blue band is included. Narrow band widths will make it possible to select spectral bands that depict physical phenomena such as turbidity or sediment content. Vegetation, on the other hand, is displayed best in standard false color infrared band combination due to the high reflectance in the near infrared domain.

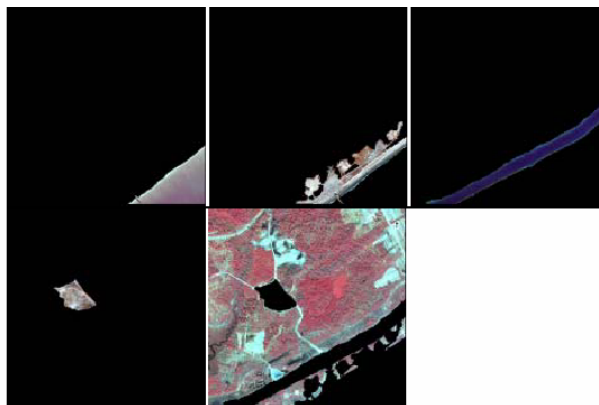


Figure 5. Separate image layers for the selected GIS classes 'Water/Ocean', 'Beach', 'Water/River', 'Open Field' and the complementary class (mostly vegetation)

The user can interactively be involved in this process or can leave the display and contrast enhancement to the default options. The default display options are established based on user experience and standard image processing literature. For water classes, the standard bands to be displayed are near infrared, green and blue (or for Ikonos and Quickbird bands 4, 2, 1). For all other areas, the standard display is near infrared, red, green (or bands 4, 3, 2, respectively). For image enhancement, we selected a contrast stretch based on $\pm 2.5\sigma$. This means that the digital numbers (DNs) for each band are stretched so that the values $[\mu - 2.5\sigma, \mu + 2.5\sigma]$ are mapped to $[0, 255]$ (μ being the mean value of the input image). Values outside the selected range are mapped to 0 and 255, respectively. This contrast stretch usually produces better visual results than the histogram equalization process with often too saturated areas of less discernible level of detail.

The last step involves merging of the separate image layers into a single image file using standard GIS overlay procedures. As the image masks do not overlap, the procedure is based on a simple union process. Figure 6 shows the result of the GIS based local image enhancement process compared to the standard full image enhancement option. The GIS layers selected from the database were 'Water/Ocean', 'Water/River', 'Beach', 'Open Field/Roads/Built-Up', and 'Vegetation'. The GIS based enhanced image shows more detail in all parts of the study area. There are almost no areas that are too bright or too dark to convey any information as is the case in the globally enhanced image which represents a compromise over the different spectral reflectance distribution for the image (Figure 7).

The process can be modeled in a flow chart or script language environment and thus be applied to other images and geographic regions. It has to be noted that the choice of suitable feature classes is still an interactive process and has to be performed by the user.



Figure 6. GIS based enhancement of the Ikonos image (for comparison see Figure 2)



Figure 7. The subset of the GIS enhanced image (left) shows a higher level of detail compared to the globally enhanced image (right) (contrast stretch with $\pm 2\sigma$)

This process can be augmented using image segmentation algorithms. Image segmentation for feature selection can also be used if a priori information is not available, outdated, or inaccurate.

3.2 Context Based Image Enhancement

Often, there is not enough a priori information for a GIS based feature selection process or the information is not accurate and/or outdated. In this case, the information contained in the image itself is the most reliable source for feature based enhancement. The image has to be segmented into meaningful features classes which are again mutually exclusive and can be used as masks to create independent image layers. The process should have the potential of being formalized and automated so that it can run as a preprocessing step. There has been significant progress in the generation of meaningful segments for image classification, most notably the Fractal Net Evolution Approach in the software package eCognition (Blaschke and Strobl 2001). This procedure, however, involves a rather

intuitive and iterative approach which does not facilitate automated processing (Schiewe and Ehlers 2004).

Image indices, on the other hand, can be generated by simple procedures and are easily implemented. To a large degree, they can also be automated. They permit the generation of a number of meaningful feature classes if they represent a normalized process. Consequently, we chose the standard normalized difference vegetation index (NDVI) because it allows the easy separation of vegetated, non-vegetated, and water areas. The NDVI is calculated as the ratio of the difference between the near infrared and the red band and the sum of the two bands:

$$NDVI = (nir-red)/(nir+red)$$

Using this index, the difference between vegetation and non-vegetation is emphasized. Reflectance values for vegetation have their maximum in the near infrared and a minimum in the red spectral domain. High values of the NDVI indicate lush vegetation, values around 0 non-vegetated land areas and negative values are usually associated with water. Figures 8 and 9 show the NDVI as gray value display and its histogram for the study site. For this investigation, we used a Quickbird image of the same area.

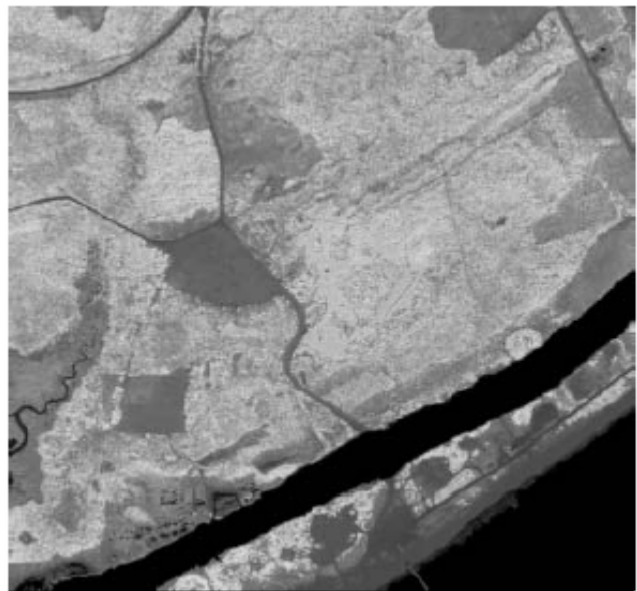


Figure 8. NDVI for the Quickbird image of the study site. Bright values indicate high level of vegetation, intermediate values open fields, and dark values water

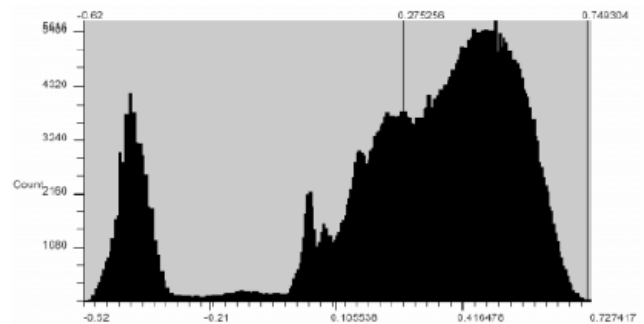


Figure 9. Histogram of the NDVI image. The separations between potential classes (local minima) are clearly visible.

The only interaction that is still required is the NDVI threshold selection for the required feature classes. Although some procedures exist to develop automated threshold selection based on local minima detection, we decided to use an interactive process so that the user can immediately see the selected classes on top of the image data. Mistakes and erroneous thresholds can be interactively corrected. Once the selected NDVI classes have been verified by visual analysis, the image is separated into independent layers and processed similar to the previous process based on the GIS input.

Table 1 presents the NDVI thresholds and the respected feature classes. Figure 9 shows the NDVI masks and Figure 10 the result of the feature based enhancement process. The steps are the same as those of chapter 3.1. It should be noted that for the water areas, another band combination (3, 2, 1) was employed for better feature separation.

Class	NDVI Value
Water	$NDVI \leq -0.12$
Open/Beach	$-0.12 < NDVI \leq 0.00$
Open/Inland/Built-up	$0.00 < NDVI \leq 0.19$
Vegetation	$0.19 < NDVI$

Table 1. Selected enhancement classes with NDVI values

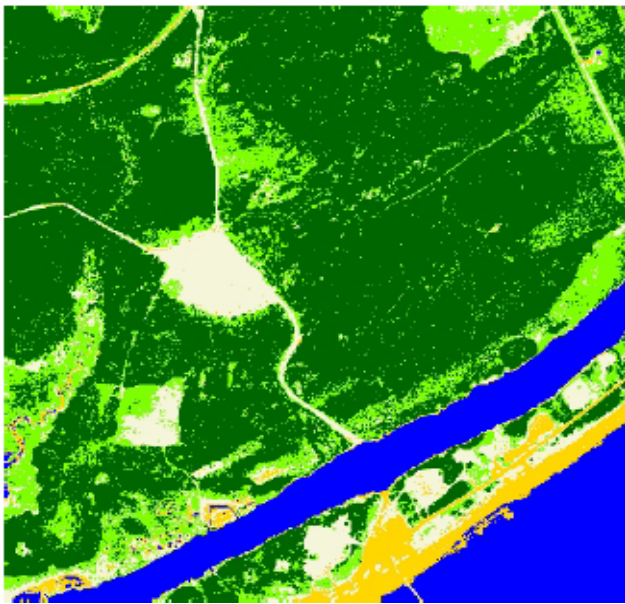


Figure 9. Selected NDVI classes (pseudo color coded)

For a better comparison, Figure 11 presents the same subset as shown in Figure 7. Again, the level of detail demonstrates the superiority of the local enhancement procedure.



Figure 10. NDVI enhanced Quickbird image

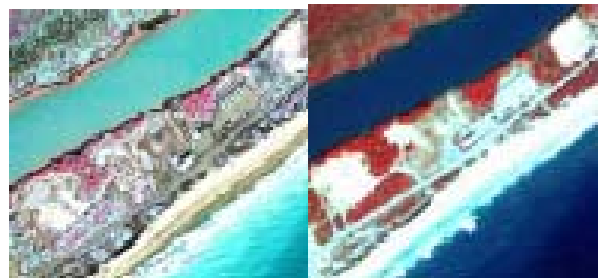


Figure 11. The subset of the NDVI enhanced image (left) shows a higher level of detail compared to the globally enhanced image (right) (contrast stretch with $\pm 2\sigma$)

4. CONCLUSIONS

The result of the NDVI based enhancement seems almost better than the one that is based on GIS information. The reason is that the selected contrast enhancement is based on the underlying image information. At large magnifications, however, discontinuities in the selected classes become visible. In contrast to GIS feature classes, NDVI classes are not contiguous and may contain single pixels and small pixel groups that are differently enhanced than their neighbors. This can result in image noise in certain areas. Image processing such as filtering or blow and shrink operations may be employed to create more contiguous image masks. At standard resolutions, however, this method shows results that prove the validity of the presented approach.

Both procedures work well for the display of multispectral images. As individual band selection can be incorporated in this enhancement process, the extension to rapid hyperspectral image display is possible. Known optimum band selection can be combined with spectral enhancement in this procedure. The method can also be automated to a large degree using a flow chart environment or scripting language. With more investigations in the future, some of the interactive steps will be replaced by default values.

5. REFERENCES

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