Image Processing of Petrographic and SEM Images

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By

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Abstract

Image processing software is used in many ways but as far as I have seen, it has not been used to analyze SEM or petrographic thin sections. This use will be very beneficial at the very least as a compliment to current mineral and lithologic studies but the potential is limitless with the right programming.

The goal of my thesis was to test for the potential of using standard image processing software, IDL and ENVI, to analyze these thin sections. I have found it to be very feasible to use software packages already available for topographic and satellite image analysis. Isolating pixels and adjusting the display colors have proven to be a relatively simple tasks that can be put to use by someone with very little experience using this software. Though, more work will need to be done to put this to greater use, these programs have demonstrated a great deal of potential for this use in the field.
Introduction

Petrographers can obtain a wealth of information simply by looking at SEM and petrographic images but using computer software to process images may improve upon these observations significantly. For example, the potential to isolate a color range or shape in the image that corresponds to a specific mineral, get an accurate pixel percentage estimate with respect to the rest of the image, and accurately define the type of rock. In addition, stained images can quickly be analyzed for porosity with standard image processing. By isolating a specific mineral or color stain in a computer display, we may make it easier for the observer to recognize patterns, orientation, or crystallization and then may better be able to place constraints on the location and depth of cooling.

Image processing is commonly used to analyze satellite and topographic data for many remote sensing applications, but to my knowledge it has not been used for analyzing two dimensional petrographic and SEM images. My Senior Thesis hypothesizes standard digital image processing software that is not initially intended for petrographic and SEM images can be utilized for just that purpose and this is a cost effective way to perform rapid analysis of geologic thin sections.

I worked with two software packages. The first is called IDL, Interactive Data Language. This program is meant for scientific
programming and data analysis. It has a number of programming tools, graphical functions and device drivers. IDL is available for multiple operating systems including Microsoft Windows, Unix, Linux, and Mac OS X (Bowman, 2006).

IDL is capable of many user defined computations and has been used in the field of satellite imagery and medical imaging for many years. An experienced programmer can appreciate the freedom offered by IDL (Bowman, 2006). It would be beneficial for me to write a program that is specifically addressing my needs but this also requires a great deal of knowledge about the program language.

The other software package is called ENVI, Environment for Visualizing Images. ENVI is a commercial image processing package written in the IDL programming language immediately useable and beneficial to test for the goals of this project. This program has many tools available such as spectral tools, geometric correction, and terrain analysis, to name a few (ENVI, 2007). The menu commands in ENVI are easier to interpret and quickly helped me reach my goals but the limitations of using pre-defined commands also results in limited flexibility of processing capability.

It is also possible to use ENVI + IDL. This feature allows the user to utilize both programs at once, combining the strengths of each. ENVI uses IDL language so these could complement each other well (ENVI, 2007).
Objectives

The primary objective of this thesis is to test the feasibility of using standard image processing for petrographic and SEM image analysis. The tasks needed to accomplish this goal include:

1. Create a pixel count. Doing this sets the groundwork for calculating percentages of pixels allowing mineral and pore space calculations. The ENVI software package is a good product to start with because it helps visualize images, as the name implies.

2. In order to make use of the pixel count, I must isolate colors or objects. Isolating one color or objects will be very useful as long as there is also a way to count the number of pixels of that specific color or object so it is crucial to obtain that pixel count as well. This is accomplished by generating a histogram of the colors in the image. A pixel count is associated with each color beneath the histogram.

3. I must estimate mineral quantities, pore space, and other rock features. Upon obtaining the total pixel count and the pixel count of an isolated feature of the image, estimating mineral quantities and pore space is done by counting the pixels over a simple range of colors as defined by the histogram.

4. ENVI is also capable of producing a shaded relief surface image. This image will show surface relief based on color values which depend on the format of the image and this view will help
determine patterns and anomalies that would be difficult to see in
a 2D image.

5. Utilize the software to obtain a trend analysis that helps recognize
alignment of individual, crystallized minerals.

Methods

I began my thesis an IDL program meant to open a TIFF image
from a scanning electron microscope. The goals of this program were to
be capable of opening an image of a thin section, generating a histogram,
generating a 3 dimensional surface relief image, and potentially isolating
colors allowing for porosity estimates and trend analysis.

I used ENVI as well, especially to mask individual color values but
also to compare the results of both programs. The commands were
straight forward but I would also benefit by defining my commands using
IDL. Being capable to use both programs would certainly be most
beneficial.

Discussion

Using ENVI, it is possible to examine many aspects of an image
with little trouble. With IDL, I could generate a histogram and a 3-
dimensional surface profile of an image but had trouble deciphering the
information from each. The histogram I generated with IDL was the
same as one I generated using ENVI and the surface relief image I generated with ENVI was much clearer than IDL.

Figures 1a-1d; IDL images vs. ENVI images

You can see from the examples above that the surface image from ENVI maintains the shading so we can easily recognize the 3D surface image as a representation of the original image. With additional time I could perfect the programs in order to properly analyze images using IDL but this proved more difficult than anticipated so I used the remaining time to focus on the tasks I can perform with ENVI.

With ENVI opening an image is very easy and described under the ‘Demonstrations and Examples’ section below. Three windows will appear when you open an image file. One is the entire image and it is labeled ‘#1 Scroll’. This has a red square within which can be moved throughout the image, hence the name, ‘Scroll’. The largest image is labeled ‘#1 Band “image name.format”’ and it is a blown up image of the small red square within the Scroll window. The last image is labeled ‘#1 Zoom[4x]’ with the magnification within the brackets. The last image is a zoomed in view of a red square within the Band image. You can zoom in
or out with the ‘Zoom’ window using the controls on the bottom left corner of the window. All three of these windows are numbered because ENVI does not limit the number of windows you can open.

Based on the image display, Figure 3, you will see that ENVI is designed for convenience. The image display makes it easy to focus and zoom in on a specific feature of the image. I found that this program has many convenient options that are easy to find and allow for a comprehensive analysis.

Masks can be applied for isolating specific pixel values or you can stretch the histogram values, removing outlier color values. Other options include the capability to load different color tables and stretch the top range or the bottom range of the color display. I did not investigate the possible applications of the latter but it would be useful for enhancing the color display.

These commands are easy to find by opening the program and selecting the available tabs. Many options are available under the ‘Basic Tools’ or ‘Tools’ tabs in the main ENVI window or one of the image display windows. Options such as computing statistics, where you can generate a histogram, can be easily reached through a few commands. Depending upon what you are looking for, these options adjust the display to enhance the desired features.

It is important to recognize the format of the image you plan to work with but, luckily, this is not of greatest concern because ENVI does
recognize different image formats, such as a TIFF or JPEG, and can write an image in a new one simply by saving the image in the new format.

ENVI uses the same color systems as IDL, one of which is called RGB, for red, green and blue. The combination of differing intensities, ranging from 0 to 255, of these three colors will yield a very large selection of colors. Others, such as HSV, which is for hue-saturation-value, are available (Bowman 2006). There are a number of color systems that can be used but my focus will be on an image with a single, gray scale band. Ideally, if you know the parameters that define the colors of your image and it is recognized by ENVI, then you should be able to perform the same tasks when analyzing your image with any color scheme.

The most important capability of ENVI is to block or ‘mask’ specific color values in one or each of the color bands in an image. This option allows us to isolate pixels of a specific band value. With a total pixel count for the image, we can quickly approximate the percentage of the pixels with that specific range thus obtaining a mineral quantity or pore space estimation. When a mask is applied, the image is switched to a black and white image with the masked pixels given a value of 1 and the others given a value of zero. The histogram of this image will be a straight line connecting the quantity of pixel values that are equal to zero, to the number of values that equal one. I have isolated pixels using
a gray scale image of a thin section obtained from a Scanning Electron Microscope.

You can apply a mask to three bands but ENVI automatically converts this image into a single band. If you mask the bands individually, you can load all three into their respective color bands and save the new image as an image file. This new image has a combination of the three masks loaded into each band and will display colors other than black and white because the pixels have three different values that define a specific color. In this case, you will only see bright colors or black since one is the maximum value instead of 255.

You are better able to obtain color values you need isolated by clicking on the Tools tab in the Band window and select ‘Cursor Location/Value’. A window with the same label will appear with the location of the cursor in brackets, the first number representing the column and the second number represents the row of pixels the cursor is located. At each location, the R, G, and B value is also listed allowing you to see what values of each band are so you are more likely to correctly isolate that color.
Many minerals share the same color as well as vary in color individually. You have to recognize the minerals in the image so you can properly isolate the band range you would like displayed. If more than one mineral shares the same color in your image, it will be difficult to obtain an accurate estimate of one mineral quantity in the rock. Also, when attempting to estimate the porosity, you must know the values of the background color. Given a thin section image, you can confidently estimate porosity by isolating the background color, obtaining the number of pixels with a value of one, retrieved from the statistics that are given when you take the steps to generate a histogram, and dividing by the total number of pixels, which are also given in the statistics.

This is an estimate because we cannot guarantee the minerals in the thin section are not somehow yielding the same value as the background. However, it is unlikely to show the exact color value as the background since any manipulation of the light at all will change the value of at least one of the three bands. Also, the background color will manipulate the colors of the rest of the image since it will show through a thin section. A mineral with the same color as the background will have a different color value when combined with the background color so I am confident about this aspect obtaining pore space estimates.

Segmenting an image also prove to be helpful for isolating a range of values. With this command, I was capable of maintaining differing values within the image. It breaks the image into segments that are
assigned a specific value based on the value of the pixels within each segment. In order to fall within a group of pixels, the color or shade value must have the minimum number of neighbors, which is user defined, that fall in the range of pixel values, also defined by the user.

Segmenting an image appears to provide a better way to estimate a mineral quantity since it is difficult to mask a range for values without including values of an undesired mineral. When seeking a porosity estimate, it is most beneficial to apply a mask to a single color value and find the quotient of the quantity of pixels with the selected value and the total number of pixels in the image.

Generating a histogram is a simple task with ENVI. I describe the process in detail below. It involves computing statistics which actually allows you to generate more than just the histogram. After generating a histogram for an image, you can build a mask and load the new image for which, you can generate another histogram. Under each of the histograms is a list of ‘Stats’. Both have the same number of total points so if you mask the correct band range, you simply need to find the number of pixel values that that are equal to one and divide by the total number of pixels in the image.

ENVI automatically generates a surface relief profile of an image using a linear range for differing color values to correspond with height. This is done simply by selecting the ‘Tools’ tab in the Band window and selecting the 3D Surface option. With ENVI, you must be aware of the
color system with which the image was loaded. The values of one band are loaded so your relief image will be dependent upon which band you choose if you are using the RGB color scheme.

**Results and Examples**

All examples are from ENVI, 2007. Select ENVI from the programs list under the START menu.

- **To Open an Image File:**
  - Select File, Open Image File, and search for the image you would like opened through ENVI.
  - Once you find and select your image, a window will appear that will prompt you to select a band or file from a list and click on the 'Load Band' button on the bottom left.
• To Build a Mask

- Select ‘Tools’ in the Band window and select ‘Build Mask’.
- A window labeled ‘#1 Mask Definition’ appears, select options at the top.
- Select ‘Input Data Range’ at the top of the collapsible list
- Select the image file you would like to edit from the ‘Select Input for Mask Data Range’ window that appears
- Selecting the ‘Spectral Subset’ button opens another window labeled ‘File Spectral Subset’ which allows you to specify what bands to apply the mask to. Otherwise it will be applied to all three bands. Select ‘OK’ on the bottom left corner.
- Input the minimum and maximum values in their respective boxes. You can also decide whether to mask the pixel if all bands match that range or to mask it if any band matches that range. Select ‘OK’.
- Enter the name and location you would like your mask file to be saved and select ‘Apply’. You can also output the result to memory.
- Once you have applied the mask, you must select it from the list of available bands and load it using the button on the bottom left corner.

Figures 4a through 4g illustrate the display after applying a mask. I masked the grayscale value 215 in the original image, figure image and the images. There are only 93 out of 903,168 pixels with a value of 215 so it is difficult to see those pixels with a value of one. Both of these values can be seen in the statistics window. You can see the red square on Fig. 4d has some white pixels and the image beneath is a zoomed in view of that box. This illustrates the benefit of using the three window display. If the background value of this image is 215, then the porosity estimate is about 0.00103%.
Figures 4a-4g: Building a Mask

- **Figures 4a-4g:** Building a Mask
  - a. Original Image
  - b. Histogram of 4a.
  - c. List of statistics for 4a.
  - d. Mask of a single value
  - e. Histogram of 4d.
  - f. List of Statistics for 4d.
  - 4g. Exploded view of the red square within Figure 4d.

Figures 5a through 5c are attempts at building a mask that has a high range of values in order to isolate the light colored minerals. Comparing these images with the original image, Figure 4a, it is clear that values within the range I selected are also found within other minerals. In Figure 5a, I chose a range from 155 to 255, using the ‘Cursor Location/Value’ window to help define the values. The following two
figures are adjustments. The range in figure 5b was 74 to 255 and in 5c, 110 to 255. The last two attempts appear nearly exactly the same.

- **Segmenting an Image**: See Figure 6.
  - Select ‘Basic Tools’ in the main ENVI window, then ‘Segmentation Image’.
  - Select the Band number beneath your chosen image and select the ‘OK’ on the bottom left corner of the window.
  - Input minimum and maximum threshold values.
  - Input your preferred ‘Population Minimum’.
  - Choose a name and location to save the new file or output the result to memory.
  - Select ‘OK’ on the bottom left corner.
With ENVI, I obtained the statistics for Figure 6. In it you will see that the pixels are broken into bin sizes of 131 excluding those with a value of zero. ENVI automatically partitioned this image in this way.

- Generating a Surface Relief Profile: See Figures 8a through 8c for examples.
  - Click ‘Tools’ tab in the Band window.
  - Click ‘3D SurfaceView...’ at the bottom of the collapsible list.
  - Select the image band that is displayed.
  - Select your preferred resolution.
  - Select ‘OK’ at the bottom left corner of the window.
Figures 8a-8c; Surface Relief Profile Examples

- Figure 8b. The lower the DEM Resolution, the smoother the surface image will appear. If you select ‘Full’, your surface image will display the complete contrast between neighboring color values.

- Figure 8c illustrates the vertical exaggeration using the surface controls obtained from the ‘Options’ tab. The default value of ‘Vertical Exaggeration’ is 5 so the difference between that and 30 is clear when you compare with the image above.

• Generating a Histogram: View example of a histogram in Figure 4b.

  - Make sure the image displayed is the one for which you need a histogram and select ‘Basic Tools’ in the main ENVI window.
  - Select ‘Statistics’, then select ‘Compute Statistics’.
  - A window labeled ‘Compute Statistics Input File’ pops up, select the image.
  - Select ‘OK’ and check ‘Histogram’ at the top of the next window labeled ‘Compute Statistics Parameters.’
  - Select ‘OK’ on the bottom left and a new window appears.
  - Under the ‘Select Plot’ tab, you can select the histogram display.
Interactive Stretch: See Figure 9.

- Select ‘Enhance’ in the Band window.
- Select ‘Interactive Stretch’ at the bottom of the list. A new window labeled ‘#1 Red:Segmentation Image:[image_name]’ will appear.
- If your image has three bands, then you can select which to apply the stretch.
- Input the minimum and maximum values in the boxes labeled ‘Stretch’.

Figure 9; Interactive Stretch

In Figure 9, you can see the stretch takes the minimum and maximum color values you select and it stretches them to the 0 and 255 values respectively.
Conclusions

My preferred program is ENVI for this project. Using IDL will take a much longer time to accomplish the same goals as ENVI due to the limitations of my own experience. The ability to adjust commands in ENVI using IDL would be extremely beneficial. There are multiple applications available in ENVI to allow many forms of analysis. I do not have adequate experience with this software to meet the full potential for image processing but given this, I have proven this is a valuable package that can be picked up by almost anyone and used effectively.

Building a mask and creating histograms of images that include the statistics are very useful tools for calculating pore space estimates. The capability to segment the pixels in an image to help estimate the mineral quantity is also useful. Computing the statistics for the segmented image could yield a mineral quantity estimate with more accuracy than using statistics from a masked image. This only applies to a range of values. For a single color value, like that of a background color, building a mask would yield the best pore space approximation.

Generating a 3D image using the color values is a simple task with ENVI. It does not represent all three bands. If your image does use three color bands for display, you must select one. This must be taken into consideration when making judgments based on the 3D surface.
Future Work

One of my objectives was to perform trend analysis. I was unable to explore the potential for ENVI or IDL to facilitate this objective in great detail but it would be useful for estimating the level of crystallization. There may be a specific command for recognizing shapes that I have not found or the use of the ‘Segmentation Image’ option can be perfected. In either case, a trend analysis would be much easier to perform. In general, a complete investigation of the capabilities of IDL and ENVI will reveal multiple applications for petrographic images.
References

