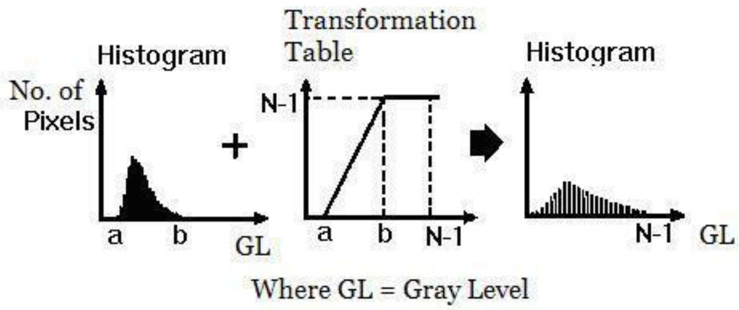
Class 4 – Image Processing

1Image Contrast

The contrast enhancement technique aims at improving the quality of the images from the subjective criteria of human eye. It is normally used as a pre-processing step in the pattern recognition systems.

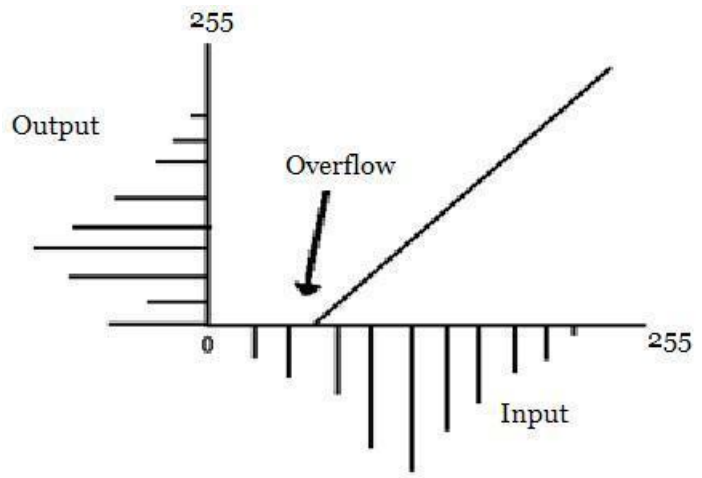
The **contrast manipulation** consists in a radiometric transfer on each pixel in order to enhance the visual discrimination among the objects present in the image. The operation is performed at each point, regardless of the neighborhood.

The image **Histogram** describes the statistical distribution of the gray levels as a function of the number of samples (pixels) at each level.



As a general rule, we can assume that the higher the inclination of the transformation function applied to the histogram the higher the resulting contrast. An inclination of 45o means no enhancement or compression on the gray levels. You should take care in order not o "overflow", unless it is desired.

An "*overflow*" occurs when part of the pixels with different gray levels are transformed into the same level, that is, when the inclination of the transfer line is excessive. Observe the figure below where the arrow points to the "overflow", signifying loss of information, since pixels in neighboring columns of the input histogram that could be originally distinguished from one another based on their gray level are now compressed into one column and will have the same gray level (0 in the case of the figure).



⇒ ***Loading the Database and Project***

*Windows: **#Start – Spring<version><Language><system> – Spring<version> <Language>***

Linux: # Command to be typed on the Console (Shell) – # s_spring

*MAC: #Dock – Launchpad – Spring <version> < **language** >*

SPRING

Load the database* **Course.

Load the project* **Brasilia.

Remember: The directory where the databases are is *C:|Tutor_10classes|springdb*

1.1Contrast of one band image

⇒ ***Image visualization:***

Control Panel

- (Categories | TM_Image)
- (Information Layers | TM3)
- (M) – *for monochromatic (image in gray levels)*

⇒ *Defining an increase in the linear contrast:*

SPRING

- [Image][Contrast...]

Contrast

– [Operation][Linear]

**Select with the cursor (left button) the minimum value in the histogram*

** Select with the cursor (right button) the maximum value in the histogram*

– (Apply)

**The image is enhanced on the active display.*

⇒ *Saving the enhanced image:*

CONTRAST

- {Name: TM3_linear_enhancement}

⇔

- [Execute][Save]

**In case you wish, you could select with the cursor a smaller area to save. It's enough to define a smaller rectangle over the image, as if performing a zoom, but without clicking on Execute – Draw.*

**Repeat the procedure for bands TM4 and TM5.*

– [Execute][Close] or button  *(upper right corner of the dialog box)*

Important: In case you close the Contrast dialog box after applying some contrast enhancement over an image, that enhancement might be saved. Thus, if you load an image that has been enhanced it will be shown enhanced, even though the Contrast dialog box is closed. If you don't want that to occur, you must answer **No** when you close the dialog box.

1.2Contrast on color composite (RGB) images

⇒ *Visualizing a color composite in three bands:*

Control Panel

- (<u>Categories</u> | TM_Image)

- (Information Layer | TM4), (R)
- (Information Layer | TM5), (G)
- (Information Layer | TM3), (B)

⇒ ***Defining a contrast for each band:***

SPRING

– [Image][Contrast…]

Contrast

– [Operation][Linear] *or any other.*

– [Channel][Red]

**Select with the cursor (left button) the minimum value in the histogram*

** Select with the cursor (right button) the maximum value in the histogram*

– (Apply)

**The color composite image on the active display presents the result of the enhancement performed in the histogram. *Repeat for the green and blue channels.*

⇒ ***Creating a Synthetic Image out of the color composite:***

Contrast

- {Save Image – Name: comp_453}

⇔

- [Execute][Save]

The synthetic image will be available on the* **Control Panel *and will be presented automatically on the Auxiliary Display*

– *Analyze other contrast options:* **MinMax**, **SquareRoot**, **Square**, **Logarithm**, **Negative**, **Histogram Equalization**.

– *Analyze the* **Editing** *contrast option. Verify the operations:* **Remove**, **Add**, *and* **Move** *points on the enhancing curve.*

– [Execute][Close] or button  *(upper right corner of the dialog box)*

2Pixel reading

The pixel reading allows us to know what is the gray level of a specific pixel and that of its neighbors. Such analysis is useful for works that involve the study of the spectral response of targets, in the various bands of multispectral images.

⇒ *Reading the gray level of a pixel:*

- *#Start – Programs – Spring<version><Language> – Spring<version><Language>*

SPRING

Load the database* **Course*.*

Load Project* **Brasilia *(or* **DFederal***, in case you have completed the previous lesson).*

Visualize the image* **TM5.

– [Image][Pixel Values...]

Pixel Values

– [View][Cross Cursor] or button  in case it is not yet active.

**Select the pixel on the display with a click*

Verify the pixel values for different targets. Note that for each click the values are presented in the* **Pixel Values *dialog box.*

⇒ *The value of a pixel defined by a coordinate:*

Pixel Values

– (Set Cursor Position...)

Set Cursor Position

– (Coordinates ⇔ Planes)

– {X: 196219.3}, {Y: 8251421.6} – *Note: Jaburu Lake ("Lago Jaburu")*

– (Apply)

Note that a "cross**" is positioned on the indicated coordinate and the report is presented*

⇒ *Save in a file:*

Pixel Values

– (Save...)

Save As

**Select the directory to save the report.*

– (Folder | C:\Tutor_10classes\Reports) *Windows*
~/Tutor_10classes/Reports *Linux*

– {File Name: pixeltm5}

**Simply substitute the * in (*.txt) by the name above.*

– (Save)

Pixel Values
- (Close)

Note: The same procedure for the pixel values can be employed on a three-band color composite image or on a synthetic image.

3IHS transformation

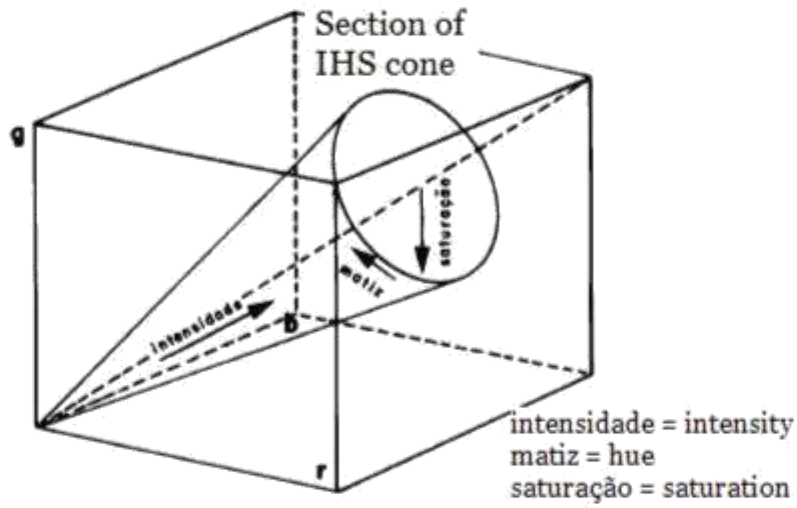
To describe the color properties of an object in an image, the human eye usually does not distinguish the proportions of red, green, and blue, but instead evaluates the intensity (I), the hue (H), and the saturation (S).

The **Intensity** or brightness is a measure of the average energy in all the wavelengths present, being thus responsible for the sensation of brightness of this incident energy on the eye.

The **Hue** or color of an object is a measure of the average wavelength that reflects or originates from the object, thus defining its color.

Saturation or purity expresses the wavelength range round the average wavelength where the energy is reflected or transmitted. A high value of saturation implies in a spectrally pure color, on the other hand a low value indicates a mixture of wavelengths that will produce pastel tones (pale colors).

The IHS space can be graphically depicted as a cone. The spatial relationship between the RGB space and the IHS space is shown in the figure that follows.



The distance from one point to the origin or apex of the cone represents the intensity.

The radial distance from a point to the central axis of the cone represents the saturation.

Hue is represented as a radial sequence around the saturation circles and the intensity axis.

Being independent, those three parameters can be classified and modified separately, for a better color adjustment to the characteristics of the visual system. It is many times used to produce images that are integrated from images of different sensors or geophysical images.

⇒ ***Transformation RGB-IHS:***

*Windows: **#Start – Spring<version><Language><system> – Spring<version> <Language>***

Linux: # Command to be typed on the Console (Shell) – # s_spring

*MAC: #Dock – Launchpad – Spring <version> < **language** >*

SPRING

Load database* **Course*.*

Load project* **Brasilia

Visualize the image* **TM5_Sample

– [Image][IHS ↔RGB Transformation ...]

IHS ↔ RGB Transformation

- (Transformations ⇔ RGB → IHS)
- (Input Images ⇔ R)

  - (Categories | TM_Image)
  - (Infolayer | TM5_sample)
  - (Apply)

  **Repeat for: input layer G –* TM4_sample *and input layer B –* TM3_sample

IHS Transformation

- {Output Layer: Tihs}
- (Output Resolution ⇔ R, G, or B) = {X: 30}, {Y:30}, *for in this case the output resolution will be the same as that of any input IL.*
- (Apply)

**The resulting images will be available on the Control Panel*

Perform the transformation IHS → RGB using the **PAN** band (category: **SPOT_Image**) in the place of I, and the Output Resolution X=10 and Y=10.

⇒ ***Inverse Transformation IHS – RGB:***

- [Image][IHS ↔RGB Transformation...]

IHS ↔ RGB Transformation

- (Transformations ⇔ IHS → RGB)
- (Input Images ⇔ I)

  - (Categories | SPOT_Image)
  - (Infolayer | PAN)
  - (Apply)

- (Input Images ⇔ H)

  Categories and Infolayers

  - (Categories | TM_Image)
  - (Infolayer | Tihs-H)
  - (Apply)

- (Input Images ⇔ S)

  Categories and Infolayers

  - (Categories | TM_Image)

- (Infolayer | Tihs-S)
- (Apply)

IHS ↔ RGB Transformation

- {Output Layer: T_inverse}
- (Output Resolution ⊬) = {X: 10}, {Y: 10} - (Apply)

**Compare the original and the transformed color compositions*

4Arithmetic operations between images

We use one or two bands of a same geographic area, previously georeferenced. The operation is performed pixel to pixel, through a defined mathematical rule, giving as a result a band representing the combination of the original bands, allowing the data compression but normally the results can exceed the 0-255 interval, being these automatically normalized, saturating the values below 0, and above 255 at 0 and 255, respectively, causing the loss of spectral information, thus one must use the **Gain** (multiplier) or **Offset** (additive) factors.

Image Subtraction

Used to enhance the differences in the spectral content (linear operation), provided you know the target spectral response curve and the spectral interval of the sensors' bands.
Application examples:

⇒Identification of different types of vegetation cover;
⇒Identification of minerals formed from iron dioxide;
⇒Detection of cover change, like land use, urban expansion, deforestation.

We recommend the equalization of the average and standard deviation before performing the subtraction.

Image Addition

The addition of images constitute a linear operation, that can be used to obtain the arithmetic mean of the images, thus minimizing noise, or even to integrate images resulting from different processing.

Multiplication

It's a linear operation that consists in the multiplication of a constant by the gray levels of a band.

Division or ratio between bands

It's a non-linear operation used to enhance the spectral differences between a pair of bands, with special care for the noise, that will also be enhanced.

The ratio of bands operation can:

⇒ Remove the effect of gain that might be the resultant of spatial or temporal variations, when they occur in the bands of a same scene;

⇒ Reduce the variations in the image radiances, resultant of topography, declivity and aspect;

⇒ Increase the radiance differences between soil and vegetation.

The reduction of the illumination effect also eliminates the topographic shadowing effect.

To increase the contrast between soil and vegetation, you can use the division between the red and near infrared bands, thus constituting the so-called vegetation indexes.

⇒ ***Performing arithmetic operations with images:***

*Windows: **#Start - Spring<version><Language><system> - Spring<version> <Language>***

Linux: # Command to be typed on the Console (Shell) – # s_spring

*MAC: #Dock – Launchpad – Spring <version> < **language** >*

SPRING

Load database* **Course

Load Project* **Brasilia

Visualize the image* **TM4

- [Image][Arithmetic Operations...]

Arithmetic Operations

- (Operation ⇔C=Gain*(A/B)+Offset)

- (A), (Infolayer: TM4)
- (B), (Infolayer: TM3)
- {Gain: 50}
- {Offset: 100}
- {Output C: division3-4}
- (Apply)
- (Close)

Visualize the resulting "*division3-4-(OP4)***" image*

**Test other operations. Do not forget to analyze the values of Gain and Offset.*

Note: In creating a plan for information can define what type of image (unsigned char, signed char etc). If the plan of information already exists, the output image will be of the type defined in the creation of the same, if the plan of information there is the image output will be the same type of image A.

5Filtering

The filtering techniques are pixel to pixel transformations of the image, that do not depend only on the gray levels of a certain pixel but also on the gray level values of the neighboring pixels, in the original image.

The filters that are implemented are shown in the table below. Besides those, it is also possible to edit a mask.

Filter type	Options	Masks
Linear	Low-Mid Pass	3x3, 5x5, or 7x7
	Edge Directional	NW, W, SW, N, S, NE, E, or SE
	Edge non-Directional	Low, Medium, or High
	TM Enhancement	-
	Masks	Mask Editor
Non-Linear	Edge Detection	Sobel or Roberts
	Morphological-Dilation	Mtot, Mx M+, M-, M|, Md, or Me
	Morphological-Median	

	Morphological-Erosion Masks	Element Editor
Radar	Lee	Define the Type, Size (3x3, 5x5, 7x7, 9x9), Image, and Number of Looks.
	Kuan	Define the Type, Size (3x3, 5x5, 7x7, 9x9), Image, and Number of Looks.
	Frost	Define the Type, Size (3x3, 5x5, 7x7, 9x9), Image, Number of Looks, and Correlation Coefficient.

⇒ ***Performing Image Filtering:***

*Windows: **#Start – Spring<version><Language><system> – Spring<version> <Language>***

Linux: # Command to be typed on the Console (Shell) – # s_spring

*MAC: #Dock – Launchpad – Spring <version> < **language** >*

SPRING

Load database* **Curso

Load Project* **Brasilia

Visualize the image* **TM4_enhanced

– [Image][Filtering...]

Filtering

– (Types ⇔ Linear)

– (Linear Filters ⇔ Low-mid Pass)

– (5x5)

– {Output Infolayer: tm4_average}

– (Bounding Box...) *select the area to filter over the image, if you don't the whole IL area will be used.*

– (Number of Interactions ⇔ 1)

– (Apply)

Visualize the resulting "tm4_average**" image for comparison *Test other filters.*

Note: The filtering is performed directly on disk, creating a new IL or changing the active IL.

⇒ ***Editing User Filters:***

Control Panel

Visualize the image* **PAN *(Category: SPOT_Image)*

Filtering

- (Types ⇔ Linear)
- (Linear Filters ⇔ Masks)
- (Select...)

Filtering

- (Directory...) *select the path C:|Tutor_10aulas|Data.*
- (CR)
- (Create...)

Mask Edition

- {Name: urb}
- (X ⇔ 7), (Y ⇔ 7)

**Fill in the following mask values*

0	0	0	-2	0	0	0
0	0	0	-2	0	0	0
0	0	1	-2	1	0	0
-2	-2	-2	20	-2	-2	-2
0	0	1	-2	1	0	0
0	0	0	-2	0	0	0
0	0	0	-2	0	0	0

- (Offset) {0}
- (Factor Normalize) {1}
- (Save)

- (Apply)

Filtering

- {Image Output: **SPOT_m**}
- (Bounding Box...)

** select the area to filter over the image, if you don't the whole IL area will be used.*

- (Number of Interactions ⇔ 1)

- (Apply)
Visualize the* **SPOT_m *image for comparison*
**Edit other masks and test*

The filtering techniques that employ low-pass filters are useful for non-systematic noise removal, as we can see in the following exercise. Observe that totally black (NC=0) and totally white (NC=255) noises were created.

⇒ ***Low-pass Image Filtering for noise removal:***

SPRING

Load Project* **Rondonia
Visualize the image* **TM5_noiseA
Compare to the images* **TM5_noiseB *and* **TM5_noiseC**

- [Image][Filtering...]

Filtering

- (Types ⇔ Linear)
- (Linear Filters ⇔ Low-mid Pass)
- (3x3)
- {Output Infolayer: **TM5_NoNoiseA**}
- (Number of Interactions ⇔ 1)
- (Apply)

Note: Test the effect of using filters with masks that are bigger and also non-linear filters like the median type one.

6Noise elimination

Noise (totally white or black points) can show up both randomly or systematically distributed (vertical or horizontal stripes). The causes could be detector failure, limitations of the sensor electronic system, etc.

The Threshold values **Upper** and **Lower** should be chosen.

Choosing the lower threshold value

A pixel will be considered as noise if its gray level is lower than the gray level of its neighbors above and below (lines above and below) by a value that is higher than this lower threshold value. In this case, the pixel value will be replaced by the average between those two neighboring pixels.

Choosing the upper threshold value

A pixel will be considered as noise if its gray level is higher than the gray level of its neighbors above and below (lines above and below) by a value that is higher than this upper threshold value. In this case also, the pixel value will be replaced by the average between those two neighboring pixels.

⇒ ***Image noise elimination:***

*Windows: **#Start - Spring<version><Language><system> - Spring<version> <Language>***

Linux: # Command to be typed on the Console (Shell) – # s_spring

*MAC: #Dock – Launchpad – Spring <version> < **language** >*

SPRING

Load database* **Course

Load Project* **Rondonia

Visualize the image* **TM5_noise

– [Image][Noise Elimination...]

Noise Elimination

– (Thresholds – Lower ⇔ 64), (Thresholds – Upper ⇔ 40)

– (Bounding Box...)

Bounding Box

– (Cursor ⇔ Yes)

Select the noisy area on the image using the* **Area cursor *in*

– (Acquire)

– (Apply)

Noise Elimination

– (Output Image: TM5_c)

– (Apply)

Visualize the image* **TM5_c *in* **Main Display** *for comparison*

**Test with other upper and lower threshold values in case noise persists*

7Image statistics

The function Statistics is performed over defined samples on the image, with the objective of calculating and presenting the following statistical parameters from previously selected images: Moments, Median, Mode, Standard Deviation and Variance, Covariance and Correlation Matrix, Autocorrelation Matrix, and Cross-Correlation Matrix.

⇒ ***Performing Statistical Analysis:***

Windows: ***#Start - Spring<version><Language><system> - Spring<version> <Language>***

Linux: *# Command to be typed on the Console (Shell) – # s_spring*

MAC: *#Dock – Launchpad – Spring <version> < **language** >*

Load database* **Course

Load Project* **Brasilia

Visualize the image* **TM5

- [Image][Statistics...]

Sample Statistical Analysis

- {Name: stat1}
- (Infolayers ⇔ TM3, TM4, TM5)
- (Create File...)

⇒ ***Obtaining Samples:***

Obtaining Samples

- {Sample Name: sample1}
- (Acquisition ⇔Cursor)

**Acquire one sample over the image by defining a rectangle as if performing a zoom*

- (Acquire)

⇒ ***Analyzing Samples:***

Obtaining Samples

- (Samples ⇔ sample1) – *observe that a yellow rectangle defines the sample on the drawing area*

⇒ ***Analyzing the moment of the samples:***

Obtaining Samples

- (Calculations ⇔ Moments)
- (Calculate and Show…)

Statistics of the Samples

- (Layer Selection: TM3)

**Analyze the histogram and the statistical values (mean, variance, standard deviation, and moments)*

**Select other infolayers and analyze the statistical values*

⇒ ***Analyzing the moment of the samples:***

Obtaining Samples

- (Calculations ⇔ Covariance and Correlation Matrix)
- (Calculate and Show…)

Statistics of the Samples

**Analyze the calculated matrices*

**Analyze other samples and other calculations*

8Image restoration

Restoration is a technique of radiometric correction whose objective is to correct the distortions introduced by the optical sensor in the process of digital image generation, aiming at the reduction of this blurring effect.

The correction is performed by a linear filter, where the weights are obtained from the sensor characteristics, and not empirically as in the case of the traditional enhancement filters. In this case, the filter is specific for each sensor type and spectral band.

⇒ ***Restoring an image:***

*Windows: **#Start – Spring<version><Language><system> – Spring<version> <Language>***

Linux: # Command to be typed on the Console (Shell) – # s_spring

*MAC: #Dock – Launchpad – Spring <version> < **language** >*

SPRING

Load database* **Course

Load Project* **Brasilia

Visualize the image* **PAN (Category **SPOT_Image**)

- [Image][Restoration...]

  Restoration

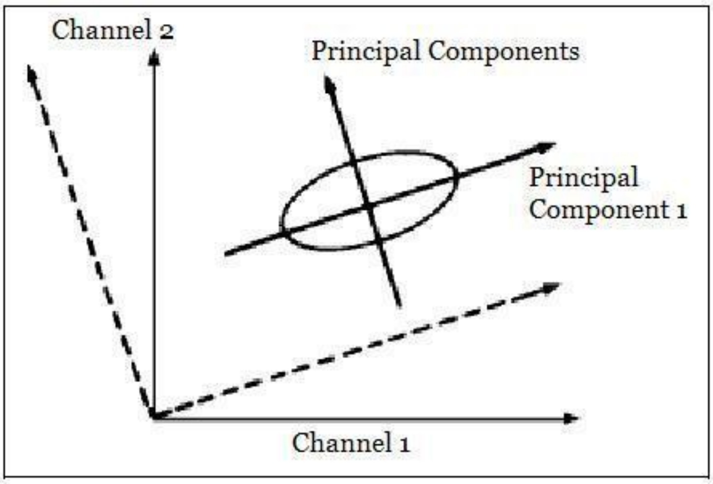
  - (Sensor ⇔SPOT-P)
  - {Name: PAN_R_5}
  - (Pixel ⇔ 5)
  - (Apply)

Visualize the image* **PAN_R_5 *on* **Main Display** *for comparison*

9Analysis of Principal Components

The generation of principal components is an enhancement technique that reduces or removes spectral redundancy, that is, it generates a new set of images whose individual bands present information not available in other bands. Such redundancy is mainly due to the effect of shadows resulting from the topography, from the superposition of spectral windows between adjacent bands, and from the very spectral response of the objects.

The figure below shows that the transformation of the principal component in two dimensions corresponds to the rotation of the original coordinate axis to coincide with the directions of maximum and minimum variances in the data.



The first principal component contains the brightness information associated to the topographic shadows and to the great variations in the general spectral reflectance of the bands. This principal component has the greatest part of the total data variance, concentrating the information formerly diluted, in various dimensions.

The second and subsequent principal components gradually present less contrast between the targets and are devoid of topographic information, due to the absence of shadows.

The third and fourth principal components typically contain less image structure and more noise than the first two, thus indicating the data compression on the first channels.

The last component basically represents the existing noise in the original data.

⇒ ***Performing the Principal Components transformation:***

*Windows: **#Start - Spring<version><Language><system> - Spring<version> <Language>***

Linux: # Command to be typed on the Console (Shell) – # s_spring

*MAC: #Dock – Launchpad – Spring <version> < **language** >*

SPRING

Load database* **Curse

Load Project* **Brasilia

Visualize the image* **TM5

– [Image][Principal Components...]

Principal Components

– (Infolayers | **TM3**, **TM4**, and **TM5**)

– (Sample ⇔Cursor)

**Select an area on the image*

– (Acquire)

**Acquire other samples based on your own interest*

– (Parameters...)

Principal Components Parameters

**Acquire other samples*

Save the parameters in the file* **princol

Principal Components

– {Output Image: tmpc}

– (Enhance ⇔Yes)

– (Apply)

Visualize the resulting* **tmpc *image*

**Test without enhancement*

Visualize the image* **PAN_R_5 *on* **Display 2** *for comparison*

** If the option "Automatic Visualization of infolayer created" is actived in the tool "Environment Configuration", by clicking "Apply" your IF will be automatic drawn on the assistant page.*