Article
Journal of Technology and Innovation
December 2019 Vol.6 No.19 8-14

Interface design for water, vegetation and city segmentation in multispectral images using SVM (TOLTECA)

Diseño de una interfaz para la segmentación de agua, vegetación y ciudad en imágenes multiespectrales utilizando SVM (TOLTECA)

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DOI: 10.35429/JTI.2019.19.6.8.14 Received July 22, 2019; Accepted September 26, 2019

Abstract

Floodings in Mexico generated economic and human losses in recent years, so it is necessary to use all possible tools that can help the government to reduce all these disasters, especially human losses. Therefore, a Graphical User Interface (GUI) was developed in Matlab for the segmentation and classification of vegetation, water and city in multispectral images obtained from the Landsat 8 satellite with the intention of detecting floods and vulnerable zones of flooding. The interface performs a feature extraction, segmentation, classification, validation and visualization of the final results obtained through basic segmentation algorithms such as the Normalized Difference Water Index (NDWI), Normalized Difference Vegetation Index (NDVI), in addition to performing the segmentation with one of the artificial intelligence methodologies most used in the state of the art: support vector machine (SVM) and the proposal of SVM with the k-nearest neighbors as an improvement to the algorithm.

Support Vector Machine, Flooding, Multispectral Image

Resumen

Las inundaciones en México han generado perdidas económicas y humanas en los últimos años, por eso es necesario utilizar todas las herramientas posibles que puedan ayudar al gobierno a reducir todos estos desastres, en especial la perdida humana. Por lo tanto se desarrolló una interfaz gráfica para el usuario, conocida también como GUI (del inglés Graphical User Interface) en Matlab para la segmentación y clasificación de vegetación, agua y ciudad en imágenes multiespectrales obtenidas del satélite Landsat 8 con la intención de detectar inundaciones y zonas vulnerables a inundaciones, el diseño de la interfaz realiza una extracción de características, segmentación, clasificación, validación y visualización de los resultados finales obtenidos a través de algoritmos de segmentación básicos como lo son Índice Diferencial de Agua Normalizado (NDWI), Índice de vegetación de Diferencia Normalizada (NDVI), además de realizar la segmentación con una de las metodologías de inteligencia artificial más utilizadas en el estado del arte: máquinas de vectores de soporte (SVM) y la propuesta de SVM con k-vecinos cercanos como una mejora al algoritmo.

Máquinas de Vectores de Soporte, Inundaciones, Imágenes Multiespectrales

Citation: GONZÁLEZ-RAMÍREZ, Andrea, YAÑEZ-VARGAS, Israel, SANTIAGO-PAZ, Jayro, TORRES-ROMÁN, Deni and PARRA-MICHEL, Ramón. Interface design for water, vegetation and city segmentation in multispectral images using SVM (TOLTECA). Journal of Technology and Innovation. 2019, 6-19: 8-14.

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Introduction

Torrential rains have become one of the most common natural phenomena in Mexico. Practically every year, the increase in rains has caused severe flooding which exceeds the capacities of dams, especially in southern Mexico. In addition, they cause the increase of the riverbeds and consequently their overflow, together with the constant hurricanes in areas of the country already affected year after year.

The United States Geological Survey (USGS) facilitates the extraction and visualization of multispectral images acquired from different satellites, this tool is essential for obtaining reference data, elevation, land use, coverage data of the ground and data obtained from the satellite. From the data obtained it is possible to detect: droughts, earthquakes, changes in temperature, floods, fires and displacements in soils or rocks, pollution, etc. Also, the images of some areas of the country were obtained from this source.

For the monitoring of flooded areas any tool that can help analyze the state of the land, population and environment is necessary, so technology becomes a fundamental part of the study of the land. A typical example is the use of multispectral images obtained through remote sensing systems (RS), in which there is a great knowledge of vast areas of land, since it is possible to obtain characteristics and information of the observed scenes. This will help to classify, segment and analyze the images, which will be of utmost importance in trying to determine flood prone areas.

For the determination of flood prone areas, an extensive analysis is required in multispectral images where the first thing is to know the areas of water, vegetation, flat land and cities. For this, information that can help classify and separate/segment the classes mentioned above is required, so the use of spectral indices such as the normalized difference vegetation index (NDVI) and the normalized differential water index (NDWI) are used to segment classes in multispectral images and were described by Gao, B. (1996) and Butler (sf), but it is still not enough to have a better classification. Therefore, it is necessary to add elements used in artificial intelligence such as the use of support vector machines (SVM).

The concept of segmentation and classification of vegetation, floods and city in multispectral images has been approached from different perspectives, where it is possible to use spectral indexes, genetic algorithms, neural networks and even support vector machines. It is worth mentioning that morphological operators are also used to segment elements into images.

Among the most common algorithms it is possible to mention Sarp and Ozcelik (2017) who carry out a study for the extraction of characteristics and detection of changes in multispectral images through an evaluation of NDVI standardized indexes and the modified NDVI to subsequently use SVM. Likewise, (Elsahabi, Negm & Hamid MH El Tahan, 2016) perform a comparison of 8 different techniques for the extraction of water areas and their subsequent evaluation through algorithms of supervision and non-supervision.

Verpoorter (2012) proposes obtaining information for the classification and segmentation of water bodies for the extraction of characteristics thresholding, contrast improvement and transformations by principal component analysis (PCA).

However, all the previous algorithms fail to locate flooded areas with a large percentage, in addition to not having information that can allow a continuous analysis of multispectral images and that they do not possess an interface that allows the user to change images for later analysis or modify parameters to perform different classifications.

For this reason, this project has the design of an interface in Matlab for the detection, classification and visualization of flooded areas through multispectral images and the use of algorithms such as NDVI, NDWI, SVM and the fusion of SVM with k-nearest nighbors, which makes a great contribution to the state of the art.

Methodological Base

Remote Sensing (RS) can be defined as the science and art of obtaining information about an object by analyzing the data acquired through a device that is not in physical contact with that object.

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RS provides a temporary overview in large areas; this allows us to observe changes over time that could range from minutes to years. This can be used to study changes in the state of the earth's surface and atmosphere as mentioned by Curlander, J., & McDonough, R. (1991).

For years, remote sensing systems have been working under multispectral sensors, creating the so-called multispectral images, which are defined as a collection of several monochromatic images of the same scene, each taken with a different sensor and each image is known as a band as mentioned by Flores, B. (sf). A well-known multispectral (or multiband) image is an RGB color image, consisting of a red, a green and a blue image, each taken with a sensor sensitive to a different wavelength, as shown in the Figure 1.

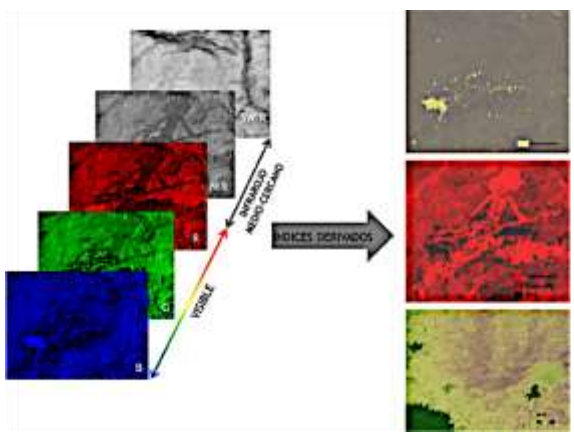

Figure 1 Example of multispectral image

It is known that multispectral images from RS systems can have linear and non-linear combinations of *m* bands that form physically significant spectral indices in the spectral space, so that during the project, 3 combinations of bands were made as Lira, J. (2010) also did.

1. Normalized Vegetation Difference Index (NDVI)

The NDVI allows identifying the presence of green vegetation on the surface and characterizing its spatial distribution. It is known from the normalized difference between the red R band and the near infrared NIR band and is calculated through NDVI equation 1, Das, K. (2017):

$$NDVI = \frac{NIR-R}{NIR+R} \tag{1}$$

2. Normalized Water Difference Index (NDWI)

The water body has a high absorption capacity and low radiation in the range of visible wavelengths to infrared, equation 2 performs the calculation of the NDWI Gao, B. (1996) and Das, K. (2017):

$$NDWI = \frac{G-NIR}{G+NIR} \tag{2}$$

Where G is the green band and NIR is the infrared band

3. Population

Butler, K. proposes that the best bands to find population segmentation are 2 and 4 of the images used, since they contain the characteristics to be able to highlight it by applying equation 3, where A is the blue band and R is the red band

$$Population = \frac{A-R}{A+R} \tag{3}$$

4. Support Vector Machines

Support Vector Machines (SVM) were developed by Vapnik in the year of 1979, together with some co-workers. SVM is considered as a supervised classification technique, which allows separating only two classes at a time, this way of classifying it is called binary type as mentioned by Zylshal et al. (2016).

The objective of SVM is to make a classification looking for the best separation hyperplane that can exist between two classes. The hyperplane is obtained from maximizing the distance that exists between one class and another; in this way, SVM finds the largest margin that exists between two classes without intermediate points within this margin and thus, is considered as the maximum distance of the points that run parallel to the hyperplane; these points are called support vectors. Figure 2 shows a small explanation of SVM, for a more detailed explanation see Santiago, J. (2016).

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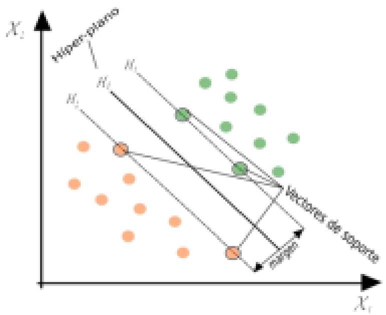

Figure 2 Explanation of SVM

5. k-Nearby Neighbors

In (Gonzalez, 2007), nearby neighbors is defined as a simple algorithm that stores all available cases and classifies new ones based on a measure of similarity. A case is classified by the majority vote of its neighbors, the case being assigned to the most common class among its neighbors. Figure 3 shows an example.

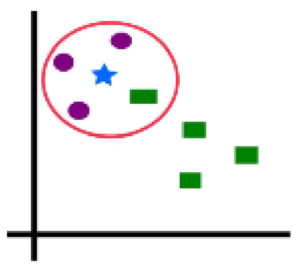

Figure 3 Example of nearby neighbors

Methodology and Development

Figure 4 shows the general block diagram to obtain the classification through SVM, where we will make a description of each of the blocks:

- Step 1: The original image is loaded with the extension .jpg, this in order to display the RGB image, as well as the bands of each image.

- Step 2: The multispectral image is pre-processed so that it has the appropriate properties for further processing.

- Step 3: The acquisition of the characteristics for its SVM training is carried out.

- Step 4: The multispectral image classification is performed.

- Step 5: The final result is projected on the RGB image.

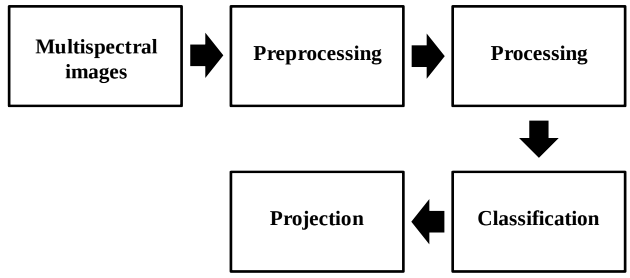

Figure 4 General block diagram

Each of the processes described above were used to perform a GUI interface in MATLAB, which will be described in the next section.

Interface

Figure 5 shows the main screen, which shows the title of the project, and at the top there is a menu bar that contains the options: Menu and Exit. In the menu option two options will be displayed: Classifier by indexes and Classifier by SVM.

Figure 5 Main interface of the TOLTECA project

Figure 6 shows the classifier screen by spectral indexes, its function is to be able to classify: water, vegetation and city. The classification by spectral indexes was made after applying a preprocessing to the multispectral images and the use of equations (1), (2) and (3).

Figure 6 Spectral index interface

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The number one shows the menu bar that has the functions:

- **File**: Open the original image and the image is displayed in box number two.

- **Metrics**: Quantitative comparisons of the classification by classes, this result will be reflected in box 6.

- **Exit**: Returns to the main screen.

The four buttons in section 3 have the function of obtaining the area of interest, the results are shown in box number 5 and described below:

- **Water**: Its function is to obtain the body of water using the NDWI spectral index, loading bands 3 and 5 of the multispectral image.

- **Vegetation**: Its function is to obtain the vegetation of the multispectral image, using the NDVI spectral index, performing the mathematical operation with bands 4 and 5.

- **City**: Obtains the population of the multispectral image, through bands 2 and 4.

The GT button loads an image classified pixel by pixel in a supervised manner and is displayed in box number 4. An example of the results obtained is shown in Figure 7.

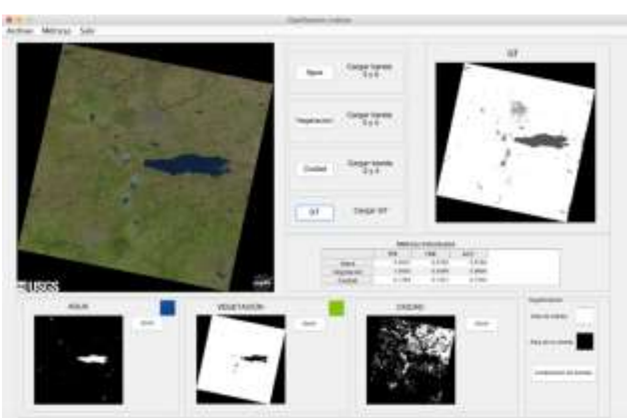

Figure 7 Example in spectral indexes

Box 7 of Figure 6 shows a button that has the function of making a projection of the final result, which will show the classification represented by colors: water-blue, vegetation-green and city-yellow as shown in Figure 8.

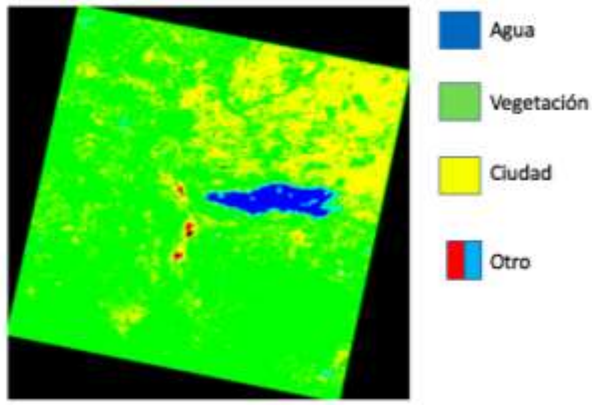

Figure 8 Result of the classification

The classification screen with SVM is shown in Figure 9, which will be described by means of numbered red boxes.

Figure 9 SVM interface

Number one contains the menu bar, which shows the following options:

- **File**: Open the original image which will be shown in box number two.

- **Metrics**: Quantitative comparison of class classification, this result will be reflected in box 6.

- **Prediction**: Makes an estimate of areas vulnerable to flooding.

- **Exit**: Returns to the main screen.

In number three, the classes defined as: water, vegetation and city, described below are shown:

- **Water**: This section contains two buttons, its function is to select in the image shown in table 2 the area that is water and the one that is not water.

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The next step is to select the best parameters to evaluate them, so the model was created and obtained the metrics True Positive Rate (TPR) and True Negative Rate (TNR); if the numbers approach 1 is a good model, otherwise the parameters will have to be moved.

- **Vegetation**: This section contains two buttons, its function is to select in the image shown in table 2 the area that is vegetation and the one that is not vegetation, the same steps described in the water section are performed.

- **City**: This section contains two buttons, its function is to select in the image shown in table 2 the area that is city and the one that is not city, as in the water section.

By having the characteristic matrices, we click on the button called Testing, located in box 4, its function is to perform the training of the matrices and thus perform their subsequent classification, which will reflect the results in box number 8.

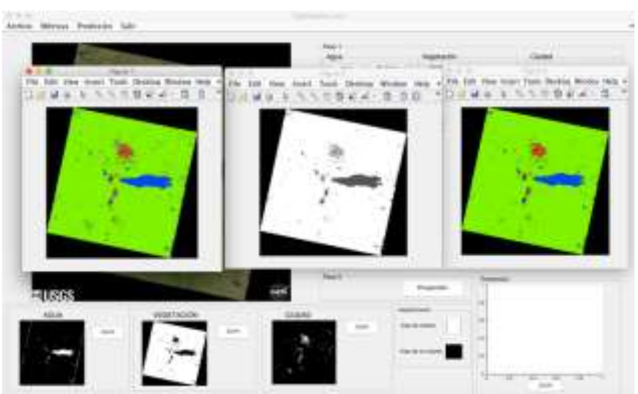

Figure 10 Example with SVM and k-nearby neighbors

Table 7 shows a button called projection, which has the function of opening a new window by displaying the first SVM result, and also opens a new window displaying the SVM result with nearby neighbors, as shown in Figure 10.

The prediction option located in the menu bar, estimates the areas vulnerable to flooding, this by means of two options: synthetic images and temporary images, in addition to the help of morphological operators, displaying the result in box 9 of Figure 11.

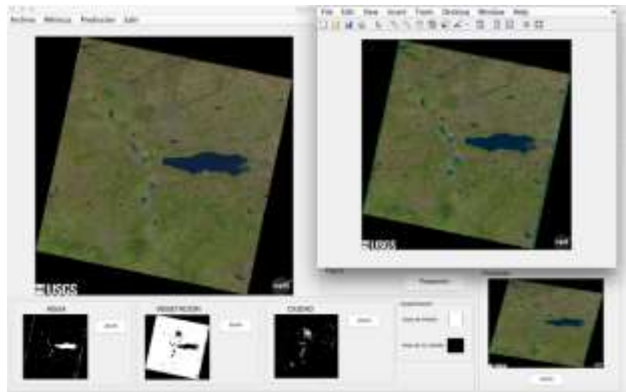

Figure 11 Areas likely to be flooded

Conclusions

This work shows that the spectral indexes perform a simple unsupervised classification of pixels, taking into account that in order to achieve it, it is necessary to have prior knowledge of each of the spectra for the election of the appropriate bands that highlight some areas of interest.

Likewise, the classification with SVM and k- nearby neighbors was proposed since by being a supervised classification better results can be obtained. As it was visually demonstrated, training is required to be able to classify in the best way, for this matrices are generated with the characteristics of the classes, in this case: water, vegetation and city.

By having two methods for processing multispectral images, it is important to incorporate an interface, as it allows for user-computer communication through a set of instructions (algorithms) of images, buttons and texts. The interfaces simplify the operation of a computer, allowing the user who is not familiar with programming to be able to use it. Likewise, they are designed to be intuitive when used, as they allow the user to gain experience and knowledge.

Thus, it helps to have a tool for manipulating these multispectral images, in order to observe the classification in a friendly way, so that the user can graphically observe each of the results and have the ability to choose freely either one of them. Also, with the use of these algorithms, better results are obtained, which will be better described in another paper, including comparative metrics between the methods and the ground trouth image, in addition to having the matrices of confusion of classification.

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Acknowledgments

This research project was supported by the TOLTECA ANR-CONACYT T No. 273562 project and project 253955 / CB-2015-01.

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