Cafcam: Crisp And Fuzzy Classification Accuracy Measurement Software

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Introduction

Classification is a fundamental image processing operation to extract information from remote sensing data. Both crisp and fuzzy classifications may be performed. In a crisp classification, each image pixel is assumed to be pure and is classified to one class. Often, particularly in coarse spatial resolution images, the pixels may be mixed containing two or more classes. Fuzzy classifications may be beneficial where a mixed pixel may be assigned multiple class memberships. Both supervised and unsupervised classification approaches may be followed. Generally, supervised classification is adopted involving three distinct stages; training, allocation and testing.

Whether the goal is to produce a crisp or a fuzzy classification, the assessment of classification accuracy is a critical step as it allows a degree of confidence to be attached to the classifications for their effective end use. The accuracy of crisp classifications may be assessed in a number of ways. The error matrix based measures such as the percent correct, user's and producer's accuracy, and the kappa coefficient of agreement are probably the most widely used ones. A number of other measures, for example, Tau coefficient and classification success index have also been proposed, though used sparingly. To evaluate the accuracy of fuzzy classifications, the outputs are often hardened so that the error-matrix based measures are used. This hampers the proper evaluation of fuzzy classifications, as it results in loss of information while degrading these to crisp classifications. Therefore, other accuracy measures that may appropriately include the fuzziness in the classification outputs and/or reference (ground) data are proposed. These include entropy, cross-entropy, Euclidean and L1 distances, fuzzy set operators, and fuzzy error matrix based measure.

The development of a number of measures clearly indicates that there are many problems in the accuracy assessment of image classifications and therefore no single measure may be appropriate for a particular image classification. Despite much of the research being conducted on classification accuracy assessment and its importance, the current image processing software are limited in providing sufficient accuracy information to the user. For example, the well known and the most widely used software namely Erdas Imagine,

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ENVI and IDRISI, contain an accuracy assessment module that can report only a few crisp accuracy measures namely overall, producer's and user's accuracy and kappa coefficient. No other competitive accuracy measures have been included. Also, there is no provision for assessing the accuracy of fuzzy classifications, which are getting useful day by day. To evaluate the accuracy of fuzzy classifications, the users either have to depend on other statistical and mathematical software, where import/export of the data from one package to another may be a tedious task, or write their own codes. Further, to evaluate the performance of a particular accuracy measure vis a vis other measures to identify the most appropriate measure a dedicated software needs to be developed.

The objective of this paper is to introduce software specifically written for the accuracy assessment of both crisp and fuzzy classifications of remote sensing data. The implementation of the software will be demonstrated through a fuzzy land cover classification of IRS 1C LISS imagery, the results of which have recently been accepted for publication in IJRS Letters (Shalan *et al*., 2003).

Software Details

The software, abbreviated as CAFCAM (**C**risp **A**nd **F**uzzy **C**lassification **A**ccuracy **M**easurement), has been developed in Matlab environment. A number of Matlab functions and tools have been used to write the software. The basic graphical user interface resource of the MATLAB has been used to produce a user-friendly and interactive package. The minimum requirement to run this software are Windows '95' OS or later versions. It consists of five basic modules:

i) Display Module

ii) Training Data Module

iii) Classification Module

iv) Testing Data Module

v) Accuracy Assessment Module

Display module

This module is essentially written to display input and output images stored as ASCII or text files. The format corresponds to the ASCII file format of Erdas Imagine consisting of pixels in each row with columns indicating pixel locations (X and Y coordinates) and their Digital Numbers (DN) in various bands respectively. Each single band image may be displayed as grayscale. The multi-spectral image may be viewed as False Color Composite (FCC) where the user has the option of selecting any three bands at a time. Similarly, classified outputs generated from crisp and fuzzy classifications may also be displayed. To display a crisp classification, the user has the option of assigning a particular colour to each class from the color pallet. The fuzzy classified outputs are represented in the form of fraction images for each class. Fraction images portray the spatial distribution of classes to be mapped. In these images, the bright areas denote higher proportion of a class and vice versa. The images can also be saved in a graphics format for their easy export to other image processing software.

Training data module

Training is the first stage of a supervised classification. This module will allow the user to define training areas for each class interactively on the displayed image. The areas may be selected both on polygon and per pixel basis. A plot of training areas may also be generated to indicate their spatial location. The training data are stored in an ASCII file, consisting of information of each training pixel of various classes with columns indicating the location of pixels, their DN values in different bands and the associated class value respectively. Alternatively, a training data file created in this format from other software may also be imported. The user is required to give the number of classes and the number of training pixels in each class. Sometimes and particularly for statistical classifiers, it is necessary to examine the quality of training areas of a class by examining the histogram. A uni-modal histogram is an indication of the homogeneity of training data for a class. The module also has an option to display the histogram of the training data selected for a class.

Classification module

Since the focus of the current software is on accuracy assessment, for demonstration purposes only, two markedly different classifiers namely Maximum Likelihood Classifier (MLC) and Fuzzy c-Means Algorithm (FCM) have been incorporated in this software to produce both crisp and fuzzy classifications. MLC is the most widely used classifier. In majority of studies, this classifier has generally been used as a crisp classifier. However, the output of an MLC in the form of *a posteriori* class probabilities may be related to the actual class proportions for each pixel thereby providing fuzzy classification. The FCM is based on an iterative clustering algorithm that may be employed to partition pixels of remote sensing image into class proportions. It is essentially an unsupervised classifier, however, here it has also been implemented in supervised mode. In the formulation of FCM, the module has the provision of selecting a set of parameters pertinent to the classifier.

Testing data module

For classification accuracy assessment, a set of testing data is mandatory. In this module, the testing pixels are generated randomly and stored in an ASCII file. The number of testing pixels is to be provided by the user. To create testing pixels for fuzzy classifications, the actual proportions of classes within each pixel must be known from the reference data such as existing maps, GPS surveys, aerial photographs and any other remote sensing data at finer resolution than that used for classification. This module has the provision of determining proportions for each testing pixel of the classified image so as to create fuzzy reference data.

Accuracy assessment module

The accuracy of classification, whether crisp or fuzzy, is determined in this module. A number of crisp and fuzzy accuracy measures have been incorporated. For crisp classification accuracy assessment, first an error matrix is generated from the testing data set. However, the user can also input an existing error matrix generated from other sources. All crisp accuracy measures have been divided into three categories,

i) Percent correct measures

ii) Kappa coefficients

iii) Tau coefficients

In percent correct category, five accuracy measures namely overall accuracy, user's and producer's accuracy, and average and combined accuracy have been incorporated. There are four accuracy measures namely kappa, weighted kappa, conditional kappa (user's and producer's perspective) under the second category. To obtain weighted kappa, the user may also provide a weight matrix. In the third category, the Tau with equal and unequal probabilities and the conditional Tau (user's and producer's perspective) can be computed. The user may supply the unequal probabilities. User also has the option of computing all the measures in one go.

For evaluation of fuzzy classification, three sets of accuracy measures have been considered,

i) Entropy measures

ii) Measures of closeness

iii) Correlation coefficients.

The first category includes entropy and cross entropy. In the second category, measures of distance and information closeness are incorporated. The correlation coefficients are used to determine the accuracy of each individual class. The user also has the choice of selecting all the accuracy measures in one go. The outputs in the form of error matrix, crisp and fuzzy accuracy measures may be stored in a text file for subsequent analysis.

Conclusions

CAFCAM is an interactive and user-friendly stand alone Windows based software specifically designed for determining accuracy of crisp and fuzzy classifications from remote sensing data. A number of accuracy measures have been incorporated. Data format adopted in the software is simple and allows portability between other commercial image processing software.

References

Shalan, M. A., Arora, M. K., and Ghosh, S. K. (2003) Evaluation of fuzzy classifications from IRS 1C LISS III data, *International Journal of Remote Sensing Letters* (In Press).