A comparison of Machine Learning Algorithms: The Effects of Classification Scheme Detail on Map Accuracy

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Abstract
Remote sensing research has benefited from the introduction of machine learning algorithms for specific land-cover and land-use mapping. As research into machine learning tools grows, knowing which algorithm is most appropriate for a given application can be difficult. Previous studies have compared machine learning classifiers to assess land-cover map accuracies, but little is known about the impact of thematic detail on algorithm performance. In this study, Landsat ETM+ and environmental GIS data are used to compare classification speeds and output accuracies between a Classification Tree Algorithm, Fuzzy ARTMAP, Self-Organizing Feature Map, and a Multi-layer Perceptron at aggregated levels of classification scheme detail, over a subset of Massachusetts, USA. The results of this study demonstrate that while the four algorithms produce statistically similar accuracies at three levels of thematic detail, the classification tree algorithm outperforms other classifiers in speed and integration of multi-source data.

Introduction
The usefulness of satellite data for land-cover mapping projects has been well researched and documented in remote sensing literature since the early 1970’s. As the capabilities of remote sensing based mapping and monitoring programs improve, natural resource managers and researchers are taking on more ambitious programs than previously possible. The result are land-cover mapping programs that attempt to characterize large spatial domains (biomes and countries) with medium spatial scale data (e.g., 30 m) (Franklin and Walder 2002). The ideal classification algorithms for such activities are ones that can handle multi-source, voluminous datasets while minimizing user input (Rogan et al., 2003).

To this appeal, machine learning algorithms have commonly outperformed conventional classifiers (e.g., Maximum Likelihood) in their use over the past 15 years (Gopal et al., 1999). Machine learning refers to a variety of algorithms, based on artificial intelligence, that are able to recognize data patterns through repeated learning techniques without prior data distribution assumptions. However, while machine learning classifiers are known to address the shortcomings of traditional, parametric algorithms, comprehensive comparative studies are still required to assess their usefulness when compared with each other since studies, to date, provide no clear evidence that any one algorithm outperforms the others (DeFries and Chan, 2000).

This objective of this study was to compare four machine learning algorithms in their ability to accurately map land-cover at three levels of categorical detail. Additional comparison was performed testing algorithm speed and the usefulness of multi-temporal and environmental GIS variables.

Machine Learning Algorithms

- Multi-Layer Perception (MLP)
- Self-Organizing Map (SOM)
- Classification Tree Algorithm (CTA)
- Fuzzy ARTMAP

Study Area
Encompasses the portion of the state of Massachusetts, USA that falls within WRS-2 Path/Row 12/31

Land-cover Categories

- Level I: Agriculture, Forest Land, Grasslands, Water, Barren
- Level II: Agriculture, Forest Land, Grasslands, Water, Barren, Agriculture, Forest Land, Grasslands, Water, Barren

Sponsors:

Results
Thematic Detail:
No significant difference in kappa accuracies were produced between classifiers as the level of thematic detail increased. Though not significantly lower, SOM produced the lowest accuracy maps in the majority of trials.

Multi-source Data:
In 80% of the trials the inclusion of multi-temporal spectral imagery produced significantly higher accuracies at the 95% confidence level; increasing accuracies an average of 11.3% at Level I, 11.6% at Level II, and 15.5% at Level III. The inclusion of environmental variables had lesser effect on accuracy, averaging increases of 0.2% at Level I, 3.2% at Level II, and 1.7% at Level III.

Detrimental Variables:
The images below highlight how MLP, Fuzzy ARTMAP, and SOM were negatively affected by the inclusion of detrimental variables. The TWI, Southwestern and Texture images proved to be detrimental variables in the case of this study. CTA was not affected by the inclusion of these images in either overall accuracy or visual correctness of classification.

Methodology

- Spectral July 9/27/2000
- Spectral July 7/7/1999

Classification Time:
This graph displays the average time taken by each algorithm to classify the image. CTA performed the fastest in an average of 8 hours, while Fuzzy ARTMAP performed the slowest increasing greater than 10 hours per classification. In all cases increasing the amount of input data or thematic detail required longer classification times.

Conclusion
The number of map categories did not prove to be a distinguishing characteristic in comparing classifiers since the four algorithms produced statistically similar land-cover maps at all three levels of thematic detail. The classification tree proved the best classifier to meet the needs of large-area land-cover mapping programs based on its speed and ability to integrate multi-source data without requiring any pre-classification variable testing to weed out detrimental variables.

References

Gopal, K., I., and D. M. (1999), Classification Accuracy Comparisons for Joint Use of Thematic Mapper and Enhanced Thematic Mapper Plus Imagery.