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ARTMAP neural networks for information fusion and data mining: map production and target recognition methodologies

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Abstract

The Sensor Exploitation Group of MIT Lincoln Laboratory incorporated an early version of the ARTMAP neural network as the recognition engine of a hierarchical system for fusion and data mining of registered geospatial images. The Lincoln Lab system has been successfully fielded, but is limited to *target* / *non-target* identifications and does not produce whole maps. Procedures defined here extend these capabilities by means of a mapping method that learns to identify and distribute arbitrarily many target classes. This new spatial data mining system is designed particularly to cope with the highly skewed class distributions of typical mapping problems. Specification of canonical algorithms and a benchmark testbed has enabled the evaluation of candidate recognition networks as well as pre- and post-processing and feature selection options. The resulting mapping methodology sets a standard for a variety of spatial data mining tasks. In particular, training pixels are drawn from a region that is spatially distinct from the mapped region, which could feature an output class mix that is substantially different from that of the training set. The system recognition component, *default ARTMAP*, with its fully specified set of canonical parameter values, has become the *a priori* system of choice among this family of neural networks for a wide variety of applications.

Keywords: ARTMAP; Adaptive Resonance Theory (ART); Information fusion; Data mining; Remote sensing; Mapping; Image analysis; Pattern recognition

1. Introduction

Neural network models for vision, learning, and recognition form the foundation of a system for multisensor image fusion and data mining developed by Allen Waxman and colleagues, first in the Sensor Exploitation Group at MIT Lincoln Laboratory (Ross et al., 2000; Streilein et al., 2000; Waxman et al., 2001) and recently in the Boston University CNS Technology Lab (Waxman et al., 2002). While the primary domain of the Lincoln Lab (LL) system is geospatial image analysis, it has also been tested for other spatially defined applications, including medical imaging (Aguilar & Garrett, 2001).

Fuzzy ARTMAP was chosen to perform category recognition and output class prediction in the LL fusion system because of its computational capabilities for incremental training, fast stable learning, and visualization. ARTMAP networks learn to predict specified output classes from critical patterns of input features, with the system creating as many of these internally defined categories as needed to meet accuracy criteria. The interpretability of the learned category structure with respect to input features suggests straightforward feature selection methods, which are often important for efficient on-line image processing and search of large images.

Despite extensive development of other functions, the LL system still relies on the originally implemented simplified ARTMAP algorithm (Kasuba, 1993). Meanwhile, new ARTMAP systems that have been developed over the past decade include ART-EMAP (Carpenter & Ross, 1995), ARTMAP-IC (Carpenter & Markuzon, 1998), and distributed ARTMAP (Carpenter, Milenova, & Noeske, 1998). Network capabilities and design options have been tested, and system performance has been compared with that of other neural and statistical algorithms, on many application domains, including remote sensing, data mining, and visualization (e.g., Carpenter et al., 1997, 1999; …
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