Median Hetero-Associative Memories Applied to the Categorization of True-Color Patterns

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Abstract. Median associative memories (MED-AMs) are a special type of associative memory based on the median operator. This type of associative model has been applied to the restoration of gray scale images and provides better performance than other models, such as morphological associative memories, when the patterns are altered with mixed noise. Despite of his power, MED-AMs have not been applied in problems involving true-color patterns. In this paper we describe how a median hetero-associative memory (MED-HAM) could be applied in problems that involve true-color patterns. A complete study of the behavior of this associative model in the restoration of true-color images is performed using a benchmark of 14400 images altered by different type of noises. Furthermore, we describe how this model can be applied to an image categorization problem.

1 Introduction

The concept of associative memory (AM) emerges from psychological theories of human and animals learning. These memories store information by learning correlations among different stimuli. When a stimulus is presented as a memory cue, the other is retrieval as a consequence; this means that the two stimuli have become associated each other in the memory.

An AM can be seen as a particular type of neural network designed to recall output patterns in terms of input patterns that can appear altered by some kind of noise. Several AMs have been proposed in the last 50 years (refer for example [1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11] and [12]). Some of these AMs have several constraints that limit their applicability in complex problems. Most of these constraints are related to storage capacity, the type of patterns (only binary, bipolar), see for example [4], and robustness to noise (additive, subtractive, mixed, Gaussian noise, deformations, etc), see for example [8] and [12].

In 1998, Ritter et al. [8] proposed the concept of morphological associative memories (MAMs) which exhibit optimal absolute storage capacity and one-step convergence. Basically, the authors substituted the outer product by **max** and **min**

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operations. This type of associative model has been applied to different pattern recognition problems including face localization and reconstruction of gray scale [9] and true-color images [17], but they are not robust to mixed noise. However, the morphological associative model alone is incapable to deal with patterns distorted with additive and subtractive noise at the same time. A solution to this problem was proposed in [6].

There are other approaches based on fuzzy theory and lattice theory, see for example [7], [13], [14] and [16]. Kosko's model [7] describes an associative memory in terms of a nonlinear matrix vector product called max-min composition, and the synaptic weight matrix is given by fuzzy Hebbian learning; however, it exhibits a low storage capacity (one rule per FAM matrix). Later in 1996, Chung and Lee [13] presented a generalization of this model and demonstrated that a perfect recall of multiple rules per FAM matrix is possible if the input fuzzy sets are normal and max-t composition orthogonal. Recently, Sussner and Valle [14], generalized the implicative learning rules to include any max-t composition based on a continuous *t*-norm. On the other hand, the associative memory based on a dendritic single layer morphological perceptron is robust under different type of noises [16]. Despite of the robustness of these models under noisy patterns, they do not present one-step convergence as morphological associative memories.

Another interesting one-step approach was introduced by Sossa, *et al.* [12]. In this model, the authors substituted the **max-min** operator by the **med** operator. By using this new operator the median associative model (MED-AM) was capable to deal with patterns which include additive and subtractive noise at the same time.

Despite of the power of recent models, they have not been applied in problems that involve true-color patterns neither a deep study of this associative model under true-color image pattern has been performed.

In this paper it is described how a MED-AM could be applied in problems that involve true-color patterns. Furthermore, a complete study of the behavior of this associative model in the reconstruction of true-color images is performed using a benchmark of 14400 images altered by different type of noises. In addition, we describe how this model could be applied to an image categorization problem.

2 Basics on Median Associative Memories

An associative memory is a device designed to recall patterns. These patterns might appear altered by noise. An associative memory **M** can be viewed as an input-output system as follows: $\mathbf{x} \rightarrow \mathbf{M} \rightarrow \mathbf{y}$, with **x** and **y**, respectively the input and output patterns vectors. Each input vector forms an association with a corresponding output vector. The associative memory **M** is represented by a matrix whose *ij*-th component is m_{ij}. **M** is generated from a finite a priori set of known associations, known as the *fundamental set of associations*, or simply the *fundamental set* (FS). If ξ is an index, the fundamental set is represented as: $\{(\mathbf{x}^{\xi}, \mathbf{y}^{\xi}) \mid \xi = 1,2,\ldots,p\}$ with *p* the cardinality of the set. The patterns that form the fundamental set are called *fundamental patterns*. If it holds that $\mathbf{x}^{\xi} = \mathbf{y}^{\xi}\ \forall\, \xi \in \{1,2,\ldots p\}$, then **M** is auto-associative,