Online Nonnegative Matrix Factorization with Temporal Affinity

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Introduction

Online nonnegative matrix factorization (ONMF) attempts to explain the sequential data with nonnegative learning. Existing methods focus on the independent optimization of each time slice.

- In this work, online learning of NMF is handled via optimization of ***temporal learning***, while affinity of temporal patterns are brought into objective function.
- As a consequence, the proposed method is able to exploit the sequential factorizations with online nonnegative learning, while enhancement can be achieved with ***smooth affinity***. Particularly, the ***memorized patterns*** can be obtained via ***temporal fusion*** of sequential factorizations, and stable performance is able to be presented.
- Experiments on several data sets demonstrate that, the proposed method is able to give better performance compared with the state-of-the-art methods.

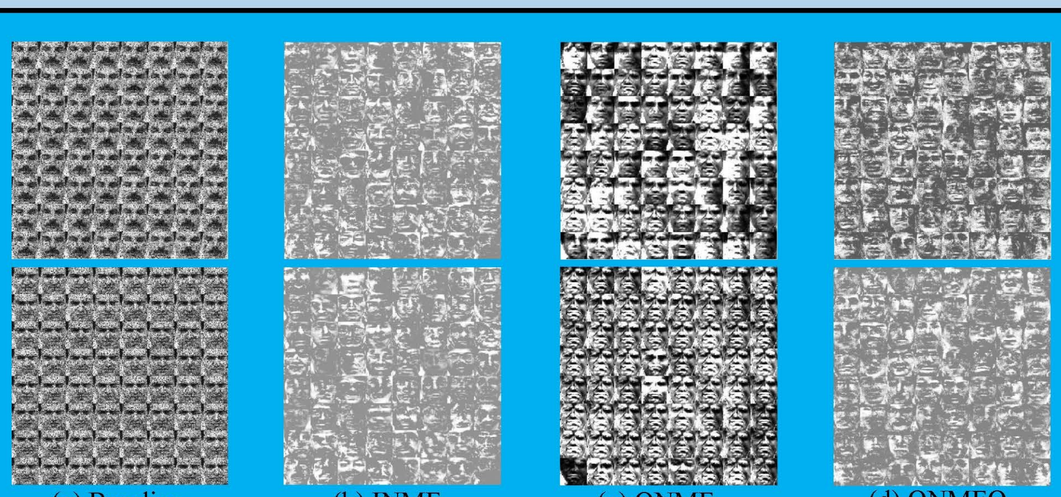
Online Nonnegative Matrix Factorization

- The well-known Nonnegative Matrix Factorization (NMF) method aims to unfold the nonnegative data X into the multiplication of two separated factorizations.

$$X \approx AU$$
$$s.t.\ A \geq 0,\ U \geq 0$$

- **Related Works:**
  - ⇒ INMF [S. S. Bucak, et. al., 2007]
  - ⇒ Wang's ONMF [F. Wang, et. al., 2011]
  - ⇒ Itakura-Saito divergence based ONMF [A. Lef´ evre, et. al., 2011]
  - ⇒ Zhao's ONMF [R. Zhao et. al., 2016]

Temporal Nonnegative Patterns



(a) Baseline (b) INMF (c) ONMF (d) ONMFO

The obtained first 64 factorizations of different algorithms on the Yale database in the 10th (above) and 90th (bottom) time slices.

- **The obtained factorizations *changed* as more sequential data involved, and memorized patterns are lost during temporal learning.**

Contributions

- The proposed ONMF method optimizes the objectives of *reconstruction* and *temporal* learning simultaneously.
- The *smooth* affinity of nonnegative patterns is adopted as well as the sequential fusion of temporal factorizations.
- As a consequence, the robustness can be achieved by the proposed method.

Temporal Learning

- Temporal learning aims to exploit the intrinsic patterns of series of data
- Normally, the optimization of accumulated objectives are referred

$$J_t = \operatorname{argmin} \sum_{i=1}^{t-1} a_i \cdot J_i(x_i) + a_t \cdot J_t'(x_t)$$

Temporal Learning of TANMF

- With triangle inequation, it is clear that the traditional learning methods actually aim to minimize the *temporally sequential objective* of data stream.
- The temporal learning of proposed method adopts reconstruction and temporal learning into objective function simultaneously.

TANMF with Memorized Fusion

- **Existing Issues:**

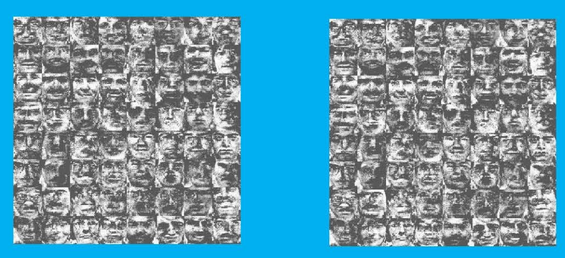
⇒ Learning stability
⇒ Disadjusted learning

- **Enhancement:**

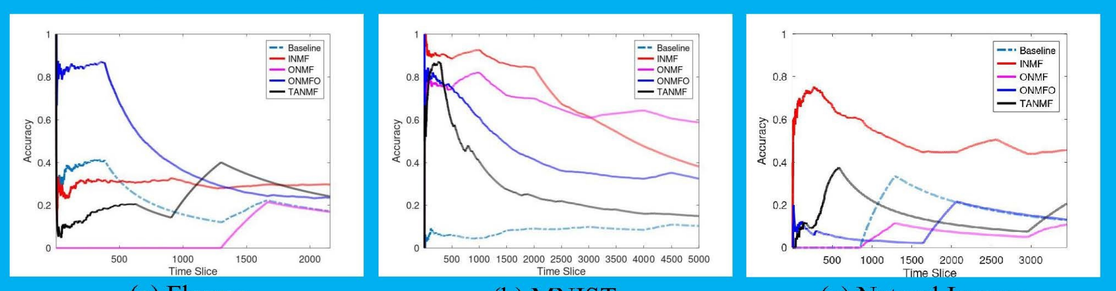
⇒ The *smooth affinity* is brought into online learning
⇒ The memorized patterns rely on *temporal fusion* of factorization

Experimental Results

- The memorized patterns can be obtained during temporal nonnegative learning



- The results on three visual data sets



(a) Flower (b) MNIST (c) Natural Images