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Empirical evaluation of general-purpose image features for pathology-oriented image retrieval of Alzheimer Disease cases

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Purpose

To evaluate the applicability of general-purpose image feature algorithms as effective and efficient descriptors for pathology-based image retrieval of Magnetic Resonance Imaging (MRI) brain volumes under the hypothesis that localized quantitative visual similarity associates consistently with the pathological state in Alzheimer Disease (AD).

Methods

In order to evaluate general-purpose image feature algorithms in the task of retrieving similar subjects according to their demented state, 174 MRI T1 previously pre-processed brain volumes were selected from OASIS dataset (<http://www.oasis-brains.org/>), comprising 87 controls and 87 AD subjects. Pre-processing steps included: gain-field normalization, skull removal, an atlas-based registration to the Talairach and Tournoux atlas, and removal of background information.

For evaluation purposes, the criteria used to label a case as healthy was a Clinical Dementia Rating (CDR) value of zero (CDR=0), and greater than zero for demented AD subjects (CDR > 0). CDR values were also included as part of OASIS data. The CDR is a dementia-staging rating considering six domains for cognition impairment: memory, orientation, problem solving, function in community, home, and personal care.

The distribution of selected subjects, according to their CDR was: 87 subjects with CDR = 0, 60 subjects with CDR = 0.5 (very mild AD), and 27 subjects with CDR \geq 1.0

(mild to severe AD). Subjects age spanned between 18 and 96 years old, with 44 subjects in the range between 18 and 35 years old, 44 subjects between 35 and 70 years old, 43 subjects between 71 and 79 years old, and 43 subjects between 80 and 96 years old.

We selected for evaluation 24 general-purpose image features descriptors' algorithms (see Figure 1). Four different functions were used to measure the similarity between image features of the same kind: L1 distance, L2 distance, Jansen-Shannon Divergence (JSD), and Tanimoto coefficient.

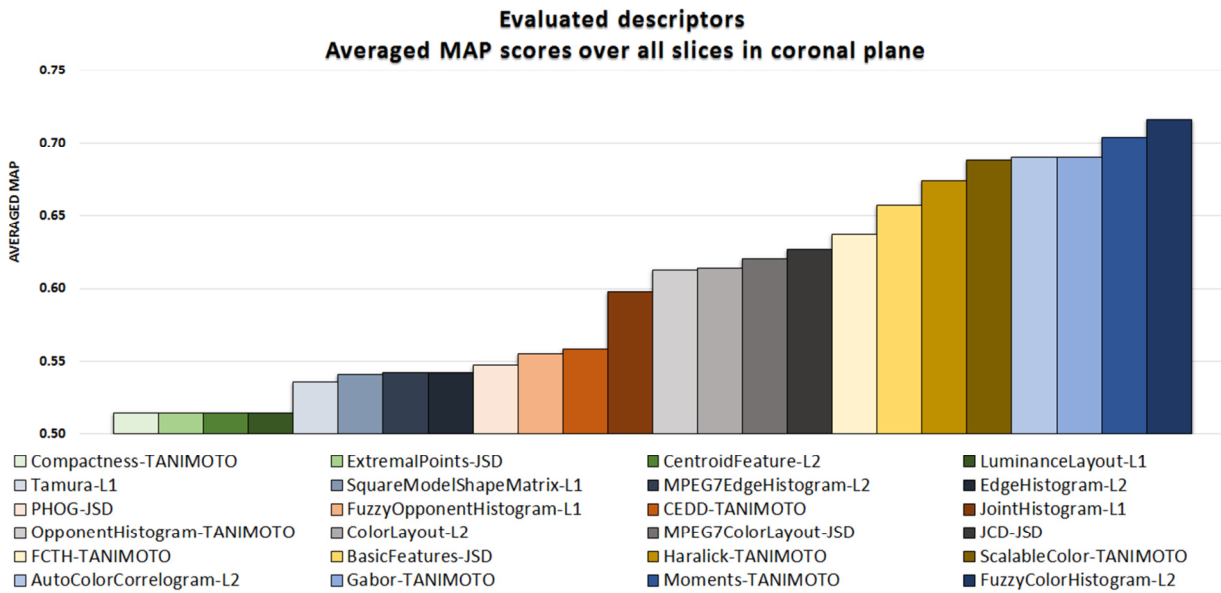


Figure 1. Averaged MAP performance along the slices on the coronal plane for the 24 evaluated features. Each bar represents a descriptor-similarity function pair. Only the result for the best similarity function on each descriptor is shown.

Image groups corresponding to axial, coronal, and sagittal anatomical planes were extracted from the selected volumes and further divided into sets corresponding to the same slice position in all 174 subjects (155 sets for the axial plane, 171 sets in the coronal plane, and 147 sets in the sagittal plane). Then, retrieval performance was evaluated at each set using the Mean Average Precision (MAP) measure independently for each feature and metric combination, totaling 96 MAP evaluations for each set (24 features by 4 similarity measures).

The MAP value is the mean of the Average Precision (AP) of query results, obtained by picking each image in the set as query and ranking the remaining images (examples) following a decreasing query-example feature pair similarity (score) order. Accumulative precision and recall values required to evaluate AP are computed based on ranking order and labels (healthy or demented) assigned to each slice according to the case to which the slice belongs.

Results

In order to identify outperforming descriptions, individual MAP values at each slice in a given anatomical plane were averaged. Figure 1, shows the results of the averaged MAP along the coronal plane for the 24 descriptions evaluated. Feature performance was diverse, ranging from cases with almost random-like MAP behavior (expected random MAP is 0.51), as in the case of the Compactness, Extremal Points, Centroid Feature, and Luminance Layout descriptors, up to averaged MAP values above 0.7 in the case of the Moments and Fuzzy Color Histogram descriptions.

Furthermore, three outperforming features were detected in all anatomical planes when analyzed in a slice-by-slice fashion: Auto Color Correlogram, Fuzzy Color Histogram, and Moments. The best MAP values were located at: the 106th axial slice, the 134th coronal slice, and the 129th sagittal slice, being the Fuzzy Color Histogram feature with Tanimoto coefficient the best at all locations (MAP values of 0.763, 0.770, and 0.783, respectively). Additionally, even though the MAP was evaluated independently at each slice set, we also noted a highly similar and continuous pattern of MAP behavior for outperforming descriptors along each anatomical plane. An example of this behavior can be seen in Figure 2, where also near symmetric pattern is observed along the sagittal plane, with a noticeable decrease of MAP for slices at the medial line (the plane that separates both brain hemispheres, between slices 81 and 94, approximately), which is very consistent with brain morphology and symmetry.

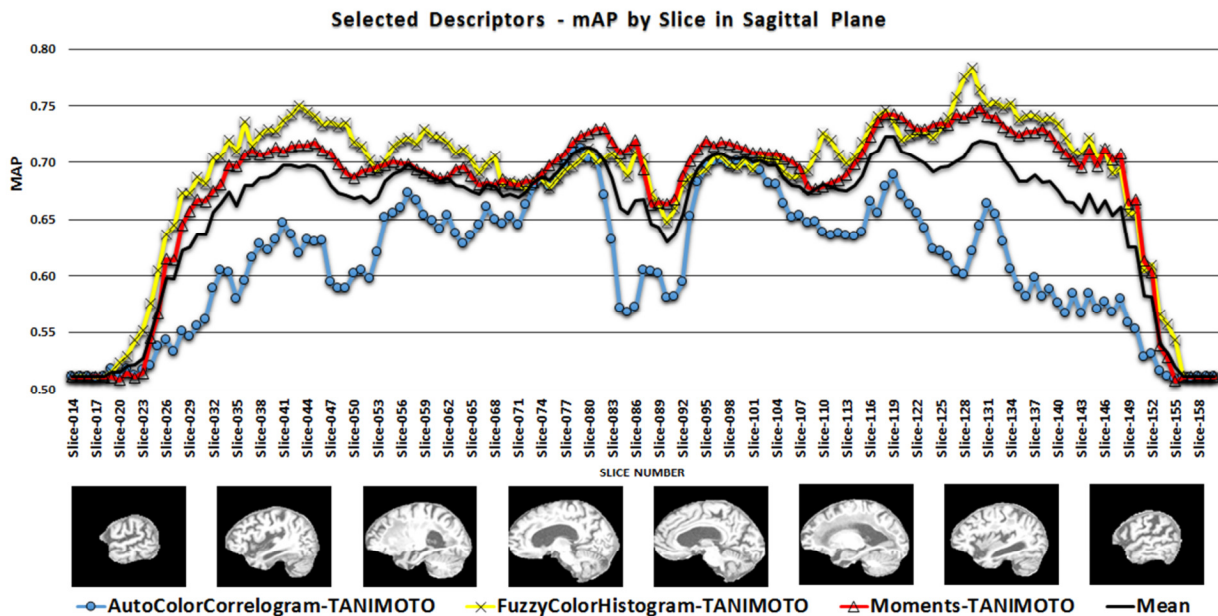


Figure 2. MAP performance and mean value (in black) along slices on the sagittal plane for three outperforming features. Only the result for the best metric on each descriptor is shown.

Conclusions:

Obtained results strongly suggest that quantitative visual similarity, at certain anatomical locations, appears to associate consistently with the pathological state. Specifically, when analyzing the different anatomical planes, some specific locations of the brain MRI volumes seemed to contain visual aspects more closely related with healthy and demented cases than others. Additionally, based on the results of this extensive evaluation of general-purpose image features, this work also suggests that despite their simplicity and general-purpose nature, quantitative features may allow to retrieve pathologically similar MRI images. Interpretation of the results may also be complemented with the ordered relevance rankings that are returned, which may provide further clinically-meaningful information during AD identification in new subjects. Finally, retrieval performance results illustrate that general-purpose image features may also be useful for other pathology-oriented retrieval tasks in brain images, with the added benefit of being simple and efficient (evaluation of one 2D slice is only needed), and thus probably suitable for large scale systems.

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