Identification of Prototypes for Handwritten Digits using Manifold Learning

Nitish Srivastava Pradeep Karuturi

SE 367: Introduction to Cognitive Science Department of Computer Science and Engineering, IIT Kanpur

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- Sensory perception received by humans is extremely high dimensional in terms of attributes.
- One possible way in which the brain could extract meaningful information from this multitude of data is by mapping objects to categories.
- This mapping is governed by a *regularity* in the features of objects belonging to the same category.

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- We aim to find the *regularity* that can be used to map all instances of a digit to the same category and also find out the central instances of that category.
- ► Tangent distance as a distance metric between digit images.
- ► ISOMAP algorithm to generate a low dimensional embedding.
- find the manifolds for the entire dataset and also for each digit separately.
- find the prototypical image of each digit using the manifold for that digit
- validate the results of prototype selection from the visualization of the manifold.
- identify peripheral images in the visualization and validate that these are indeed far from prototypical.

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- Tangent distance [1] is invariant to certain transformation in the images, such as translation, rotation, scaling, shearing, squeezing etc.
- The tangent distance computes the distance shortest distance between two manifolds generated by the two corresponding input images.

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Tangent distance

The manifolds are approximated as tangents to the manifold at the original image point. The distance between the two images is the smallest distance between the two tangents.



Tangent distance example



Figure: Adapted from [1]. Left: Original image. Middle: 5 tangent vectors corresponding to: scaling, rotation, expansion of the X axis while compressing the Y axis, expansion of the first diagonal while compressing the second diagonal and thickening. Right: 32 points in the tangent space generated by adding or subtracting each of the 5 tangent vectors.

- ISOMAP estimates the intrinsic geometry of a data manifold based on a rough estimate of each data points neighbors on the manifold.
- Uses geodesic distance(i.e., shortest path on the kNN-graph) as the distance measure between two datapoints.
- It then embedds the pair-wise distances into a low-dimensional space using Multi-dimensional scaling(MDS).



Separation of '4' and '9' using tangent distance



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Separation of '4' and '9' using tangent distance



Separation of '4' and '9' using tangent distance



Separation of '4' and '9' using L_2 distance



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Separation of '1', '2' and '7' using tangent distance



Separation of '1', '2' and '7' using tangent distance



Separation of '1' , '2' and '7' using L_2 distance



Embedding of '2'





Embedding of '1'





Embedding of '4'





Embedding of '7'





 Patrice Y. Simard, Yann A. Le Cun, John S. Denker, and Bernard Victorri.
Transformation invariance in pattern recognition - tangent distance and tangent propagation.
In *Lecture Notes in Computer Science*, pages 239–274.

Springer, 1998.

J. B. Tenenbaum, V. de Silva, and J. C. Langford.

A global geometric framework for nonlinear dimensionality reduction.

Science, 290(5500):2319-2323, December 2000.

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