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DIMENSIONALITY REDUCTION FOR HANDWRITTEN DIGIT RECOGNITION

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Problem Statement

~~The Curse of Dimensionality~~

The exponential growth in data causes **high sparsity** in the data set and unnecessarily increases **storage space** and **processing time** for the particular modelling algorithm.

As the number of features considered increases, the number of dimensions increases. This may lead to a better classification accuracy, but this may be because of **over-fitting**, which means our classifier will not work well with real-world data.



FRAME WORK:

DIMENSIONALITY REDUCTION

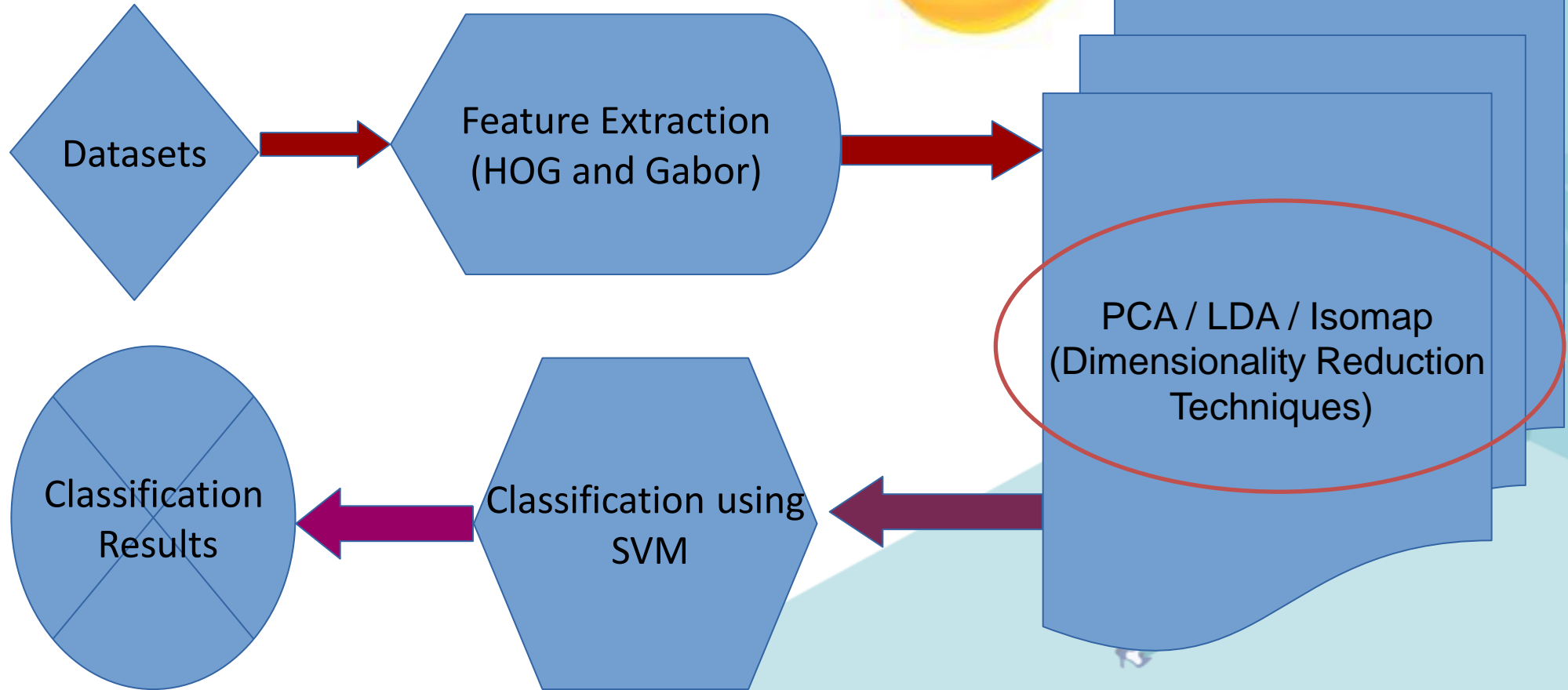
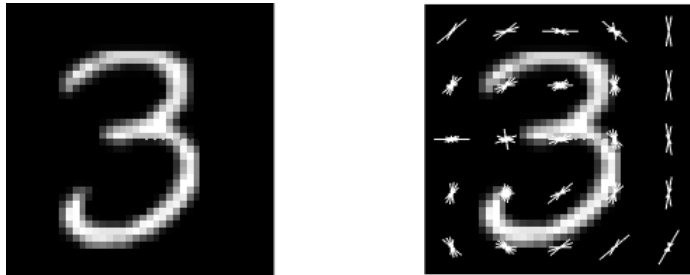


Image Filters applied to extract the features:

Histogram of Oriented Gradients (HOG)[1]

- Distribution (histograms) of directions of gradients (oriented gradients) are used as features.
- Gradients (x and y derivatives) of an image are useful because the magnitude of gradients is large around edges and corners (regions of abrupt intensity changes).
- We know that edges and corners pack in a lot more information about object shape than flat regions.



MNIST sample image with superimposition of HOG direction gradient after resizing to 40×40 pixels. (Images taken from our paper)

[1] N. Dalal and B. Triggs, “Histograms of oriented gradients for human detection,” in Computer Vision and Pattern Recognition, 2005. CVPR 2005. IEEE Computer Society Conference on, vol. 1. IEEE, 2005, pp. 886–893.

Image Filters applied to extract the features:

Gabor descriptor [II]

- Gabor descriptor for an image is computed by passing the image through a filter bank of Gabor filters.
- Gabor filter is a linear band-pass filter whose impulse response is defined as a Gaussian function modulated with a complex sinusoid.
- Gabor filters successfully extract orientation dependent frequency features from every possible pixel of an image.
- It has been widely used by researchers for problems relating to face recognition and texture analysis.

[II]D. Gabor, "Theory of communication. part 1: The analysis of information," Journal of the Institution of Electrical Engineers-Part III: Radio and Communication Engineering, vol. 93, no. 26, pp. 429–441, 1946.

The Dimensionality Reduction Techniques:

1.Linear Techniques:

PCA

LDA

2.Non-Linear Techniques:

Isomap

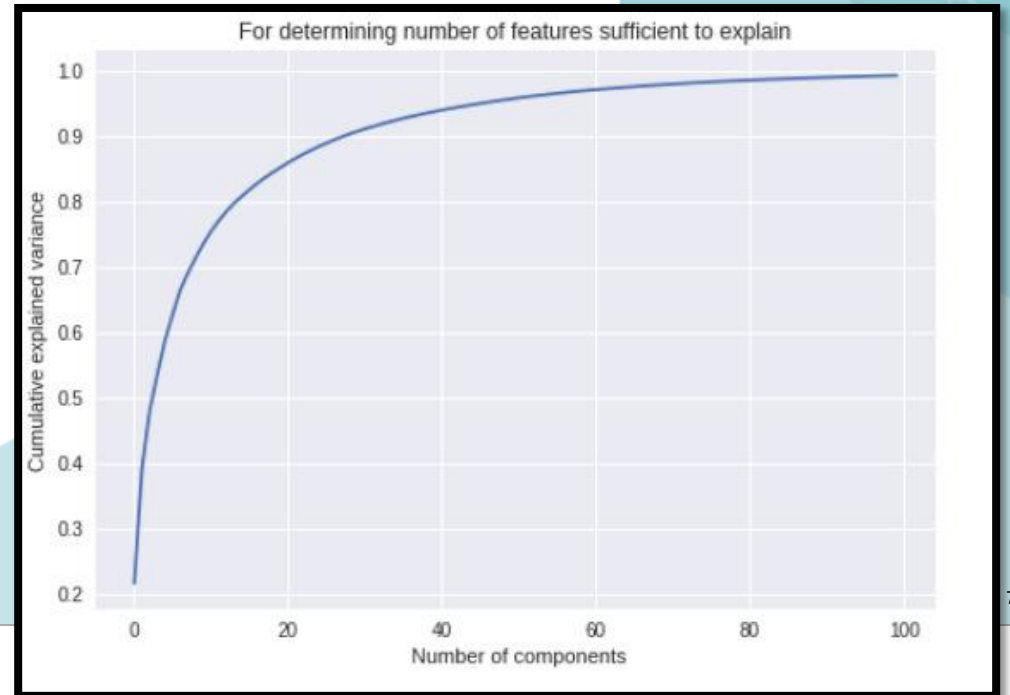


PCA[1][2]

- Linear and unsupervised dimensionality reduction technique
- PCA constructs a low dimensional representation of data that describes as much variance as possible.

Drawbacks:

- Size of the covariance matrix is proportional to the dimensionality of the datapoints. As a result, the computation of eigenvectors becomes infeasible.



LDA[3]

- Linear, unsupervised dimensionality reduction technique.
- Maximizes the separability between **known** categories or classes.
- Once the data is projected on the new axis LDA tries to
 1. Maximize the distance between mean of the known categories.
 2. Minimize the variation between each category.



Isomap[4]

- > Non-linear, unsupervised dimensionality reduction technique.
- > The Multidimensional Scaling(MDS) algorithm is applied to the pairwise geodesic distance matrix.

Drawbacks:

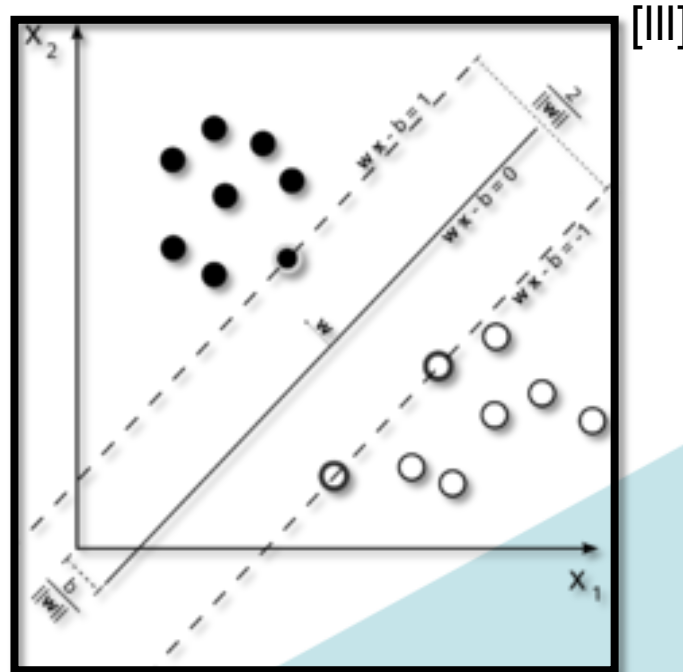
- > Topological Instability(Erroneous connections maybe formed)
- > Suffers from holes in the manifold.
- > May fail if manifold is “Non-convex”.



Classification Algorithm used:

Support Vector Machines(SVM)

A classifier method that performs classification tasks by constructing hyperplanes in a multidimensional space that separates cases of different class labels.



[III] https://en.wikipedia.org/wiki/Support_vector_machine

Experimental Results

ACCURACY RESULTS WITH FEATURE SETS GENERATED USING HOG

Dataset	Image size (in pixel)	PCA		LDA	
		Reduced features	Accuracy	Reduced features	Accuracy
MNIST	24x24	46	98.74	9	97.79
	32x32	89	99.29	9	98.29
	40x40	151	99.12	9	98.34
CVL SD	24x24	50	83.79	9	82.63
	32x32	97	85.14	9	84.2
	40x40	160	85.32	9	84.17

Experimental Results

ACCURACY RESULTS WITH FEATURE SETS GENERATED USING GABOR FILTER

Dataset	Down sampling factor	PCA		LDA	
		Reduced features	Accuracy	Reduced features	Accuracy
MNIST	14	75	96.76	9	90.9
	7	176	98.96	9	97.71
CVL SD	14	64	81.56	9	78.21
	7	164	84.72	9	83.81



Experimental Results

ACCURACY RESULTS WITH ISOMAP AS THE DIMENSIONALITY REDUCTION TECHNIQUE

Feature descriptor	Dataset	Image size (in pixel)	Down sampling factor	Isomap	
				Reduced features	Accuracy
HOG	MNIST	24x24	No down sampling	46	95.95
		32x32		89	97.95
		40x40		151	97.85
	CVL SD	24x24		50	93.36
		32x32		97	96.14
		40x40		160	96.57
Gabor filters	MNIST	28x28	14	75	88.45
			7	176	86.85
	CVL SD		14	64	85.36
			7	160	83.56

FINAL RESULTS

For MNIST Images

Image size:32X32

Classification Algorithm :SVM

Feature Descriptor : HOG

DIMENSIONALITY REDUCTION

PCA

LDA

CNN

ACCURACY

99.29%

98.29%

99.16%

PROCESSING TIME(in seconds)

140.631

28.248

142.60

Conclusions

- **HOG-PCA Model for MNIST dataset performs with the higher accuracy than even CNN , taking time lower than that required by CNN.**
- **HOG-LDA is however considered better because although it gives a slightly lower accuracy ,the time required is almost 1/4th.**



References

- [1] K. Pearson, "On lines and planes of closest fit to systems of points in space," *Philosophical Magazine*, vol. 2, pp. 559–572, 1901.
- [2] H. Hotelling, "Analysis of a complex of statistical variables into principal components." *Journal of educational psychology*, vol. 24, no. 6, p. 417, 1933.
- [3] R. A. Fisher, "The statistical utilization of multiple measurements," *Annals of eugenics*, vol. 8, no. 4, pp. 376–386, 1938.
- [4] Schölkopf, Bernhard, Alexander Smola, and Klaus-Robert Müller. "Nonlinear component analysis as a kernel eigenvalue problem." *Neural computation* 10, no. 5 (1998): 1299-1319.
- [5] Risojević, Vladimir, Snježana Momić, and Zdenka Babić. "Gabor descriptors for aerial image classification." In *International Conference on Adaptive and Natural Computing Algorithms*, pp. 51-60. Springer, Berlin, Heidelberg, 2011.

Thank You

