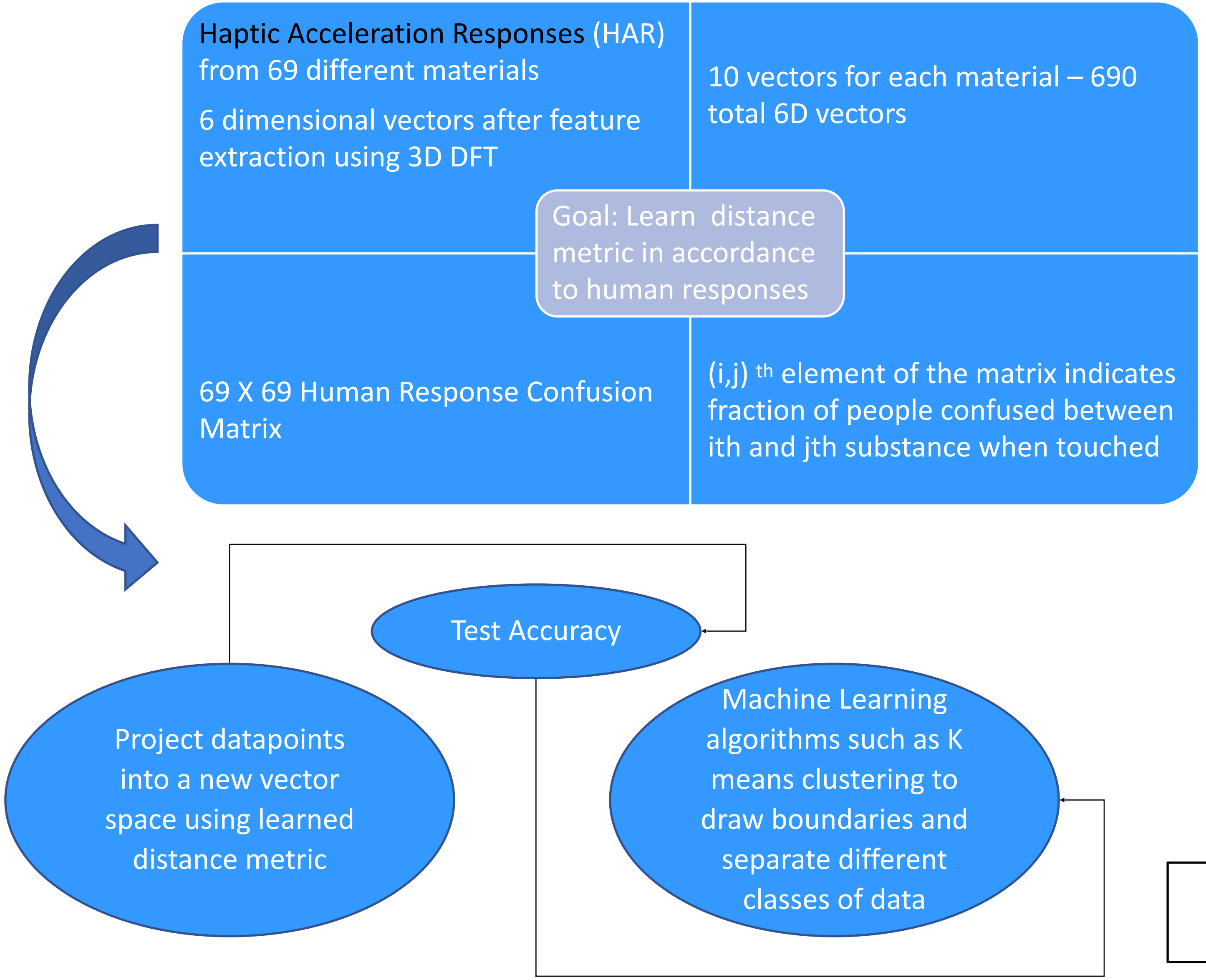
# Distance Metric Learning for Haptic Data Classification

Megh Bhalerao

3rd Year B.Tech., Electrical & Electronics Engineering

National Institute of Technology Karnataka, Surathkal, Mangalore, India

# HAR Solution using Constrained Convex Optimization




- All Possible Triplets (i, j, k) generated using the confusion matrix such that C(i, j) > C(j, k)
- Constrained optimization problem formulated with such constrains – distance calculated between feature vectors using distance metric must be in compliance with the triplets obtained

$$\begin{aligned} \underset{M}{\operatorname{argmin}} \quad & \operatorname{trace}(M) + \sum_{ijk} \varepsilon_{ijk} \\ \text{subject to} \quad & (Ar, M) < 1 - \varepsilon_{ijk} \; \forall \, (i, j, k) \in T, \\ & M \succeq 0. \end{aligned}$$

where

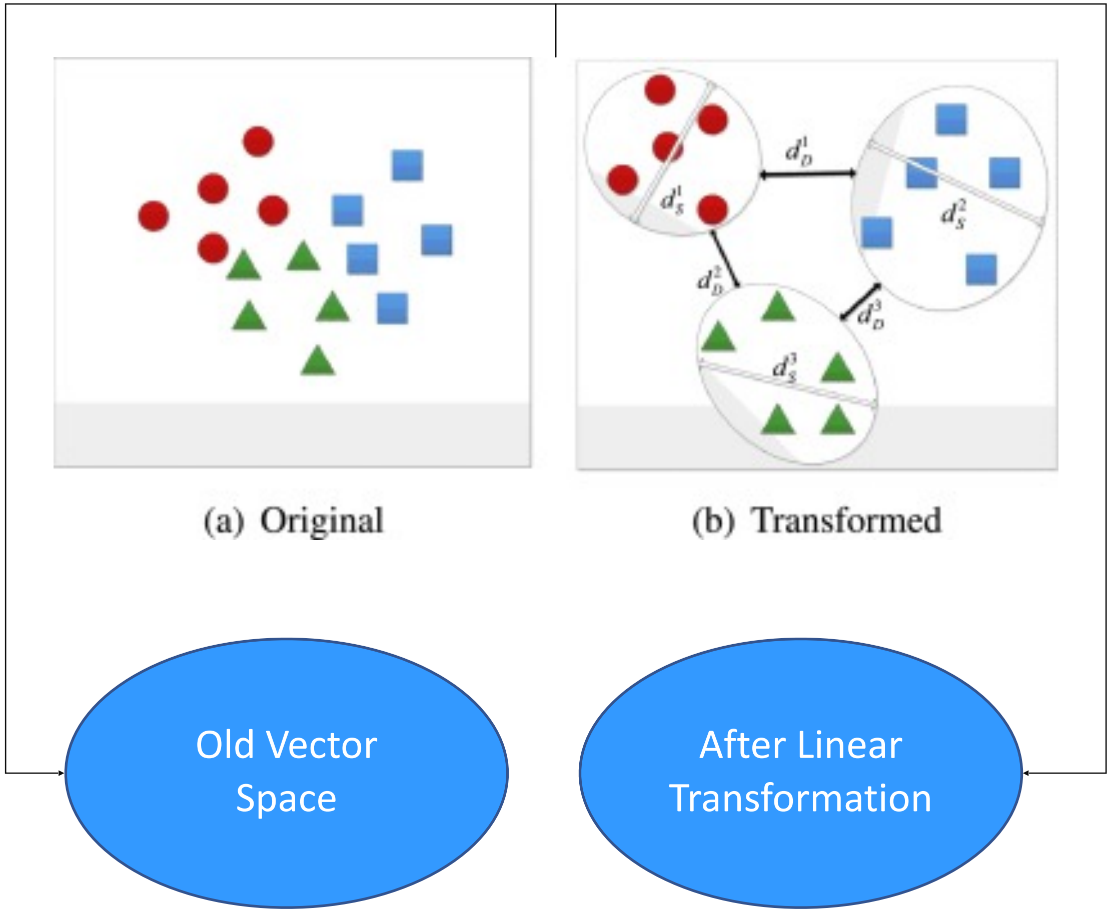
$$Ar = (x_i - x_j)(x_i - x_j)^T - (x_i - x_k)(x_i - x_k)^T$$

and $x_i, x_j$ & $x_k$ are the $i^{th}, j^{th}$ & $k^{th}$ row of the matrix $X$.

- Solution obtained using gradient descent algorithm

*Metric Learning when applied prior to ML / DL drastically increases the accuracy*

# HAR Solution Accuracy Measurement



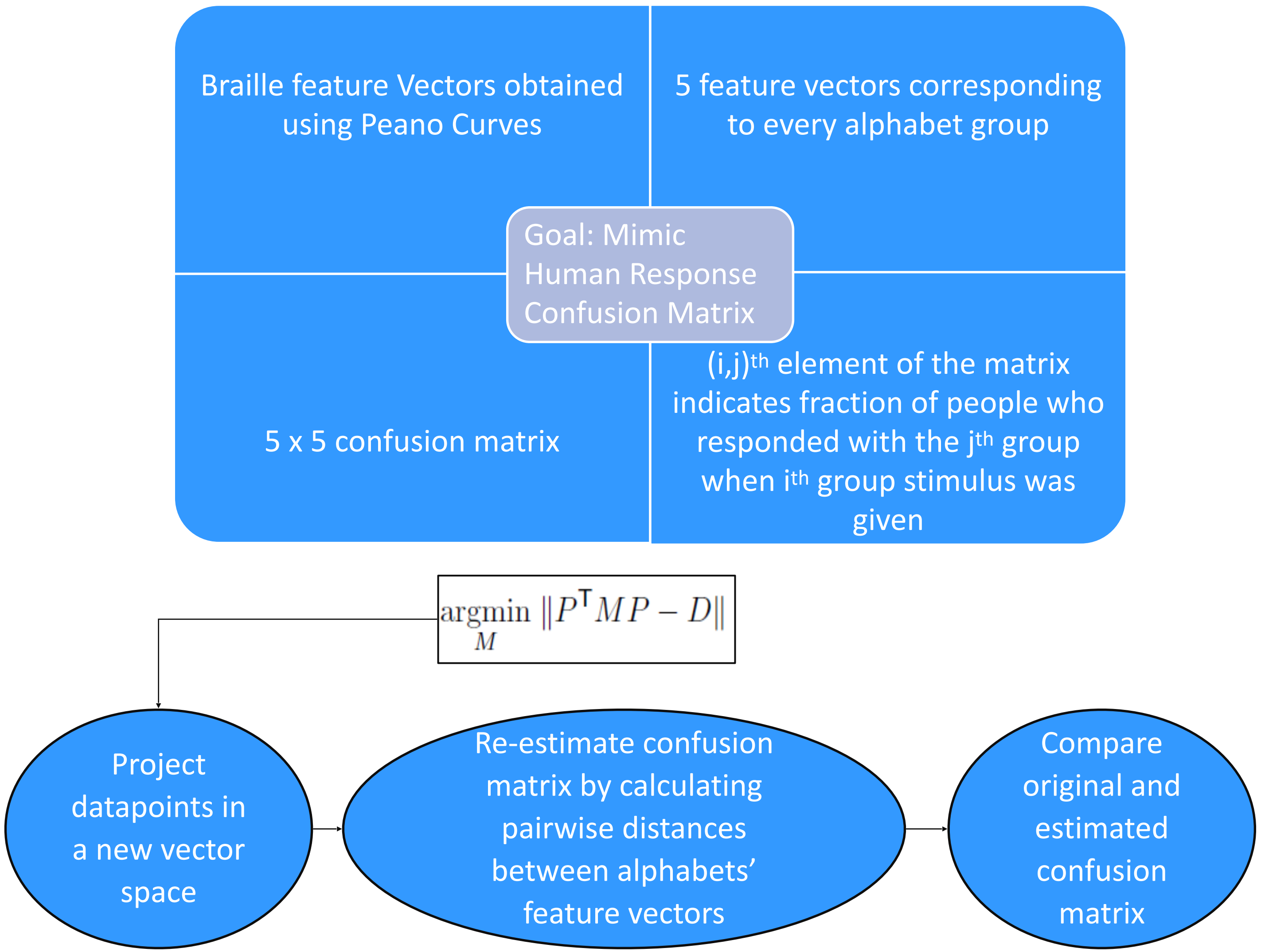
(a) Original (b) Transformed

- Distance metric accuracy is measured by number of triplet conditions satisfied when the set of feature vectors is projected into a new vector space using our learned distance metric
- Accuracies for various numerical error shown :

| Accuracies versus the Numerical Error | | |
|---|---|---|
| Numerical Error | Training Accuracy | Testing Accuracy |
| $10^{-17}$ | 50.5% | 47.5% |
| $10^{-16}$ | 69.0% | 63.2% |
| $10^{-15}$ | 99.0% | 98.5% |
| $10^{-14}$ | 83.1% | 80.8% |
| $10^{-13}$ | 100% | 100% |
| $10^{-12}$ | 100% | 100% |

*As the numerical error constrain gets more relaxed the accuracy is seen to increase*

# Braille Character Dataset Application




Given Distance Matrix – Entries according to Human response

| # of dots raised | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| 1 | 0.0040 | 0.9919 | 0.9993 | 0.9996 | 1.0000 |
| 2 | 0.9919 | 0.0953 | 0.9021 | 0.9789 | 0.9899 |
| 3 | 0.9993 | 0.9021 | 0.2893 | 0.7901 | 0.9156 |
| 4 | 0.9996 | 0.9789 | 0.7901 | 0.3416 | 0.5676 |
| 5 | 1.0000 | 0.9899 | 0.9156 | 0.5676 | 1.0000 |

Estimated Distance Matrix – Entries as calculated by braille feature vectors and learnt distance Metric

| # of dots raised | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| 1 | 0 | 0.1541 | 0.9632 | 1.0169 | 1.1209 |
| 2 | 0.1541 | 0.4821 | 0.7339 | 0.8043 | 0.9567 |
| 3 | 0.9632 | 0.7339 | 0.3967 | 0.7911 | 0.9834 |
| 4 | 1.0169 | 0.8043 | 0.7911 | 0.3295 | 0.8694 |
| 5 | 1.1209 | 0.9567 | 0.9834 | 0.8694 | 0.5357 |

*Classical optimization doesn't work up to the mark (as seen from entries of given and estimated distance matrices). Neural Network approaches could give better results.*

# Thank You!