Enhancing Haptic Distinguishability of Surface Materials with Boosting Technique

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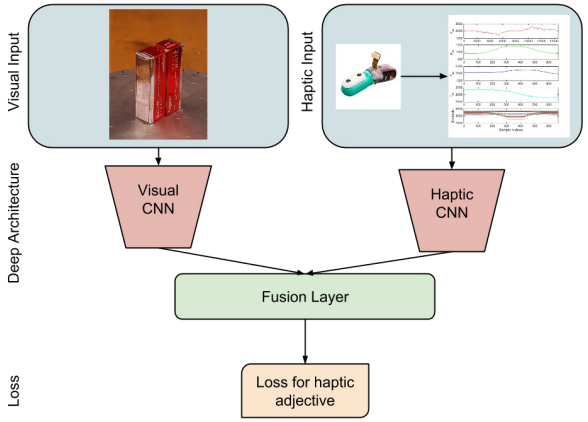
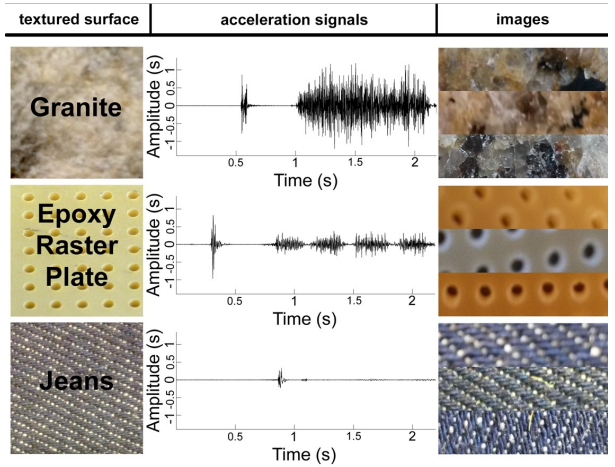
Discriminative Haptic Feature

Use multimodal data – haptic and visual



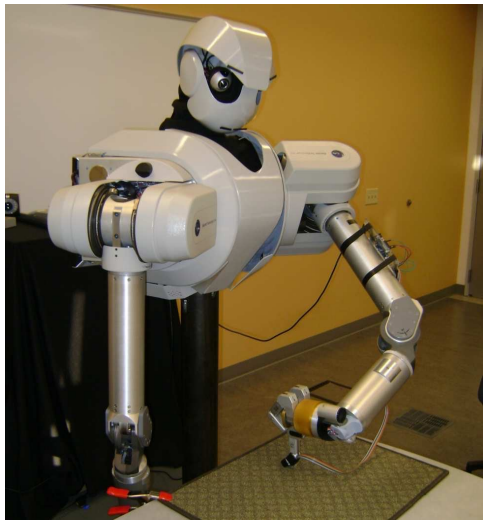
Gao et al. ICRA 2016



Strese et al. ToH 2016

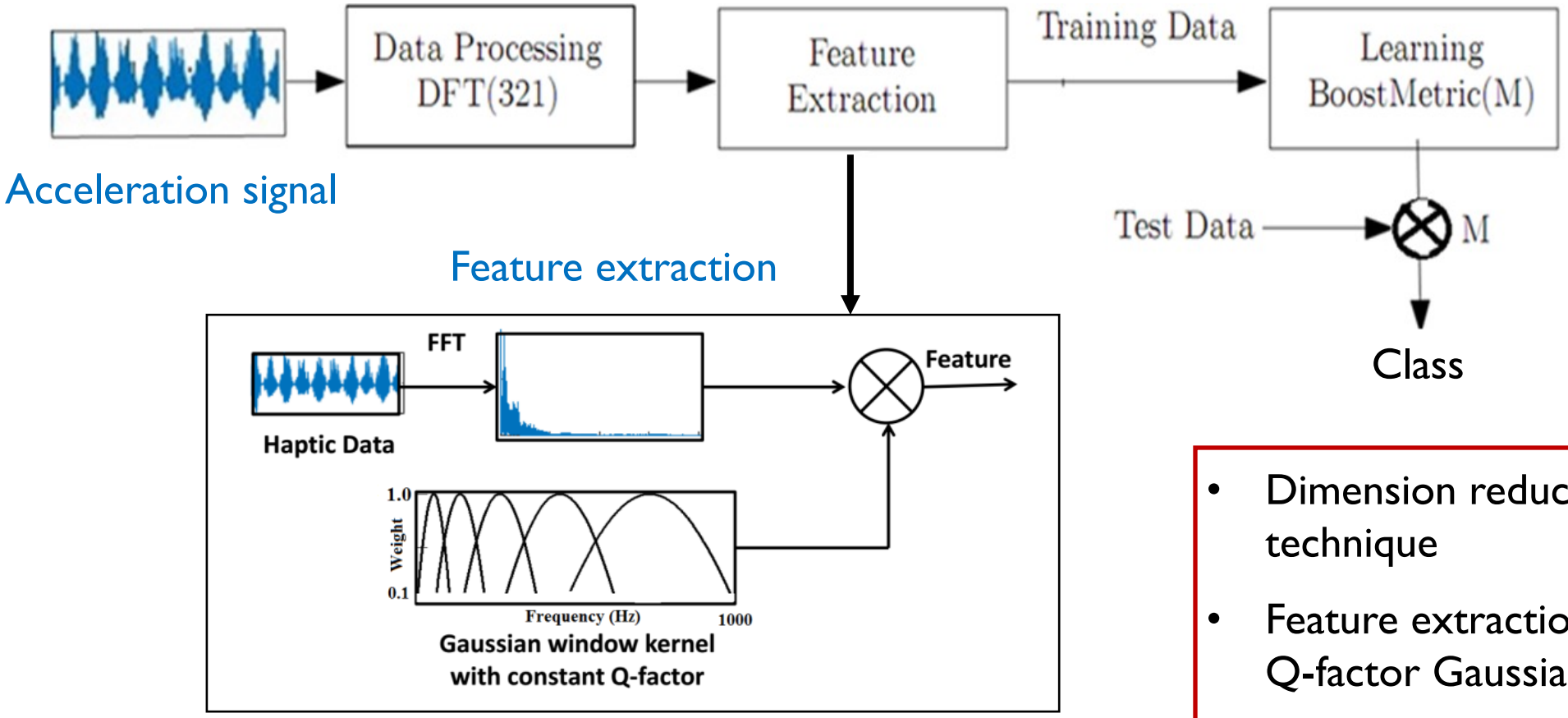
Need high-end devices to record data

Joseph et al. Haptics Symposium 2014



Sinapov et al. ToR 2011

Our Framework



Overview of our algorithm

- Dimension reduction using DFT321 technique
- Feature extraction using Constant Q-factor Gaussian filter bank
- Enhancing distinguishability b/w haptic textures using BoostMetric

Metric-Based Feature Transformation

Problem statement – Given a set of signals $\{x_i\}_{i=1}^{m} \in R^d$ and their class labels, our goal is to learn a feature transformation matrix $M \in R^{\{D \times D\}}$ such that in the projected space, signals from the same class form a compact cluster

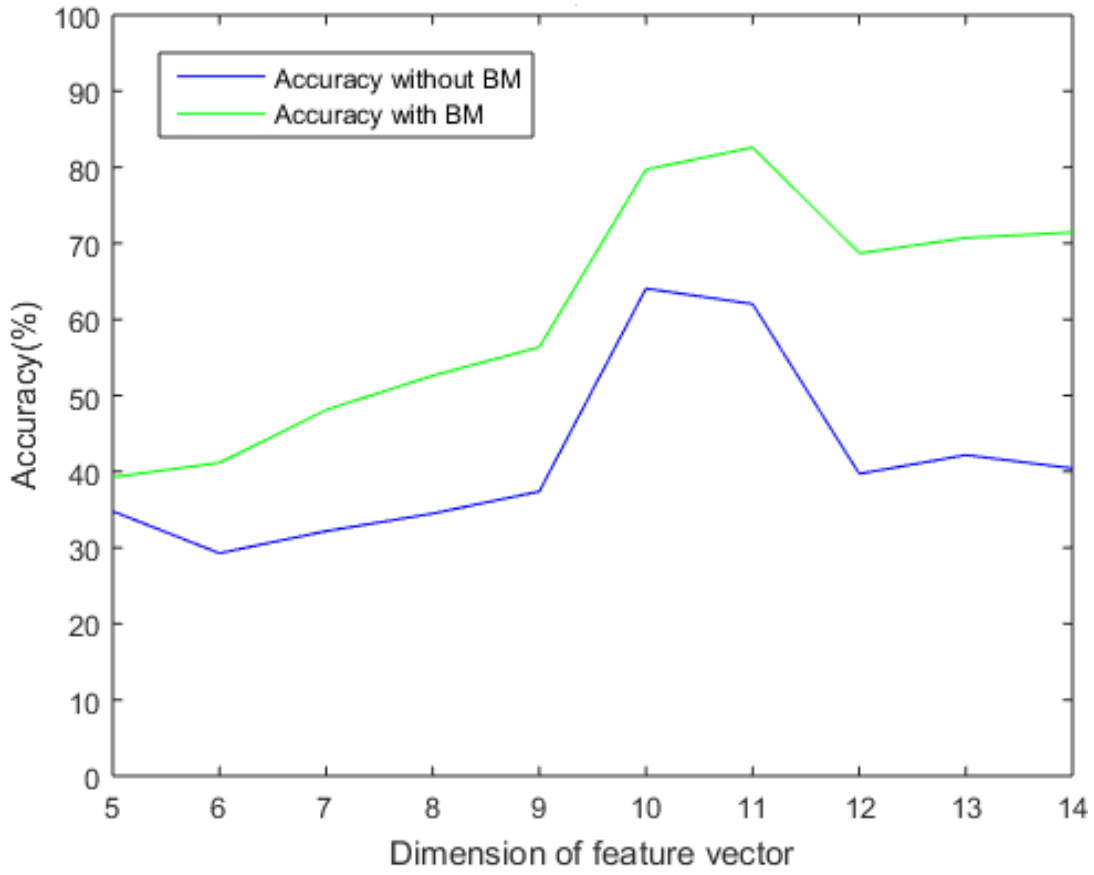
Optimization problem

$$\min_{M} \sum_{r=1}^{|C|} \exp(-(d_M^2(x_i, x_k) - d_M^2(x_i, x_j))) + vTr(M)$$

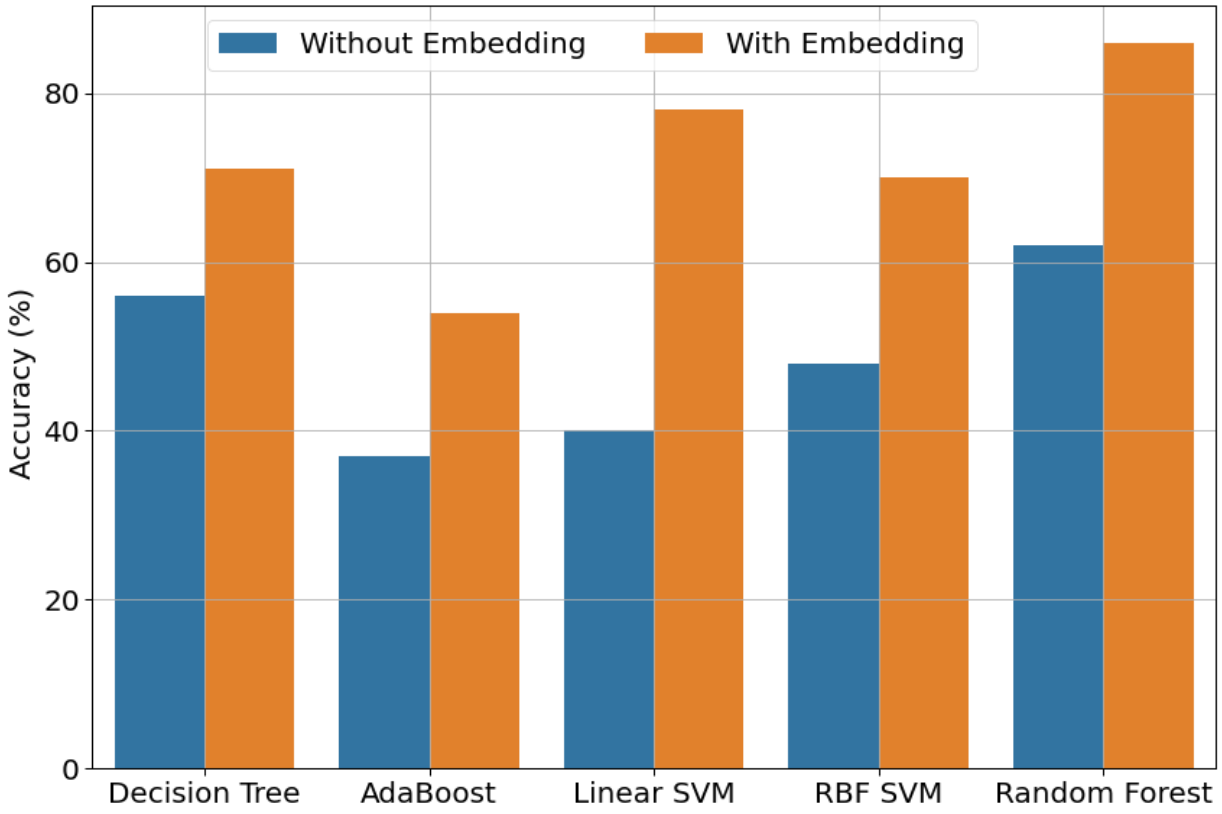
The learned matrix rescales input features to form well-separated compact clusters of different classes.

C. Shen et.al. NIPS -2009

Results - Classification



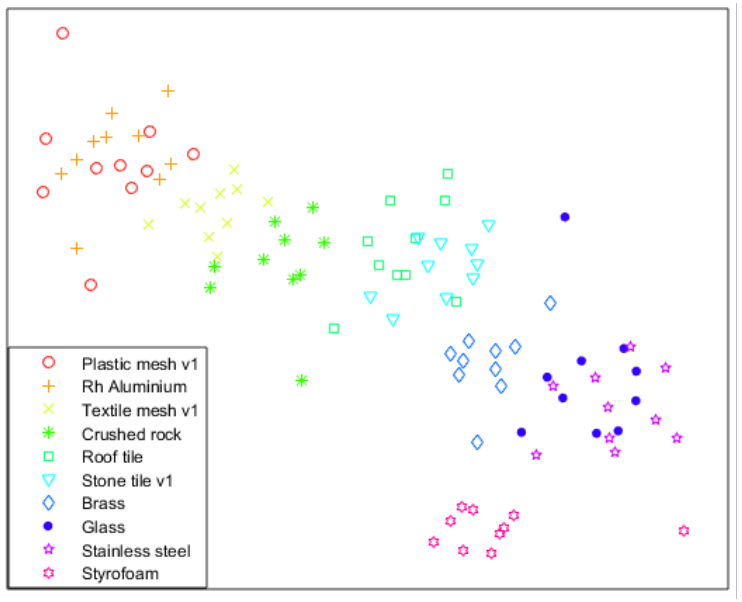
Performance of K-NN classifier in Euclidean (blue) and BoostMetric (green) space as a function of the feature dimension.



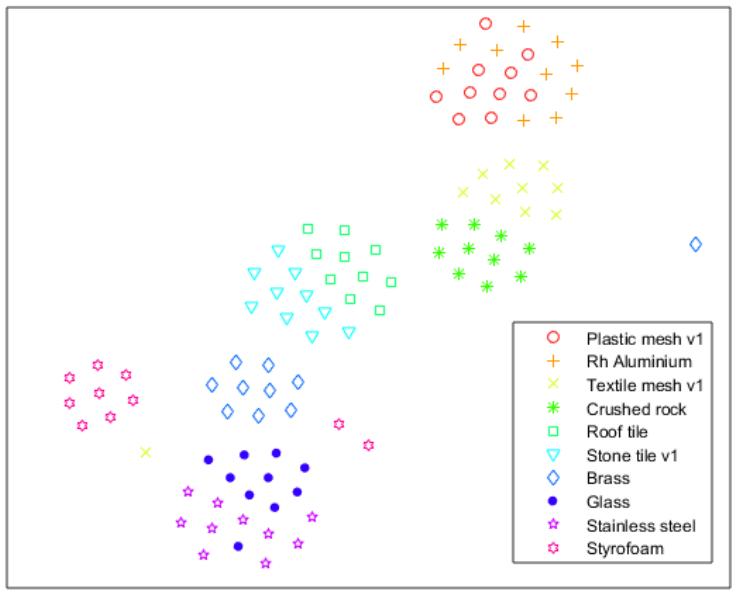
performance gain in classification accuracy in embedded space (orange) over Euclidean space (blue) for different classifiers.

Results – Clustering

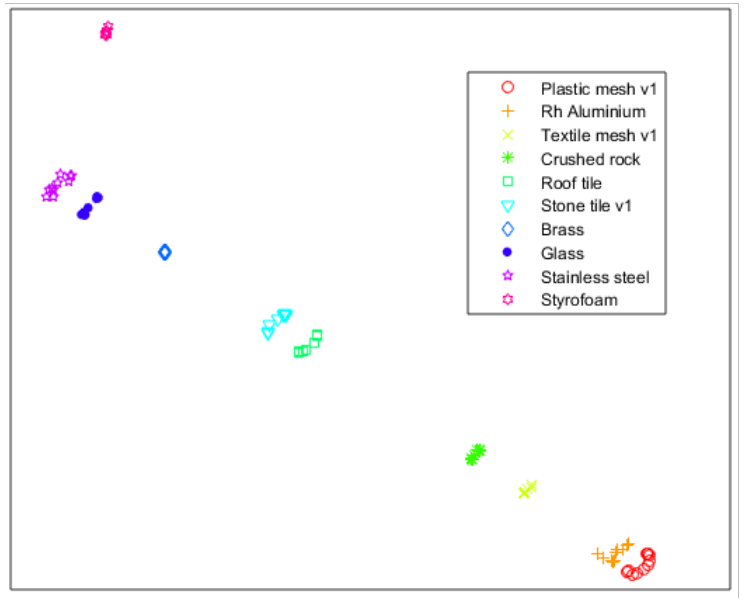
Features are projected onto 2D space using t-SNE plot



Original signals in Euclidean space



CQFB features in Euclidean space



CQFB features projected in the learned space

Conclusions

- Hand-crafted spectral features (CQFB) enables better discrimination of real-world surface textures as compared to raw acceleration signals.
- The boosting-based linear transformation of the CQFB features improves separability between haptic signals.
- Limitation – The linear metric-based feature transformation learned on class-label supervision does not capture the human-perceived dissimilarity well.