

# Model Selection Experiment

In this document, we displayed the results of the cluster-to-class assignments for  $K=10$  and  $K=13$  k-means model which were selected as candidates based on the peaks of the curvature in the range  $[9, 18]$  where the expected number of classes ( $C_{exp}$ ) is 9.

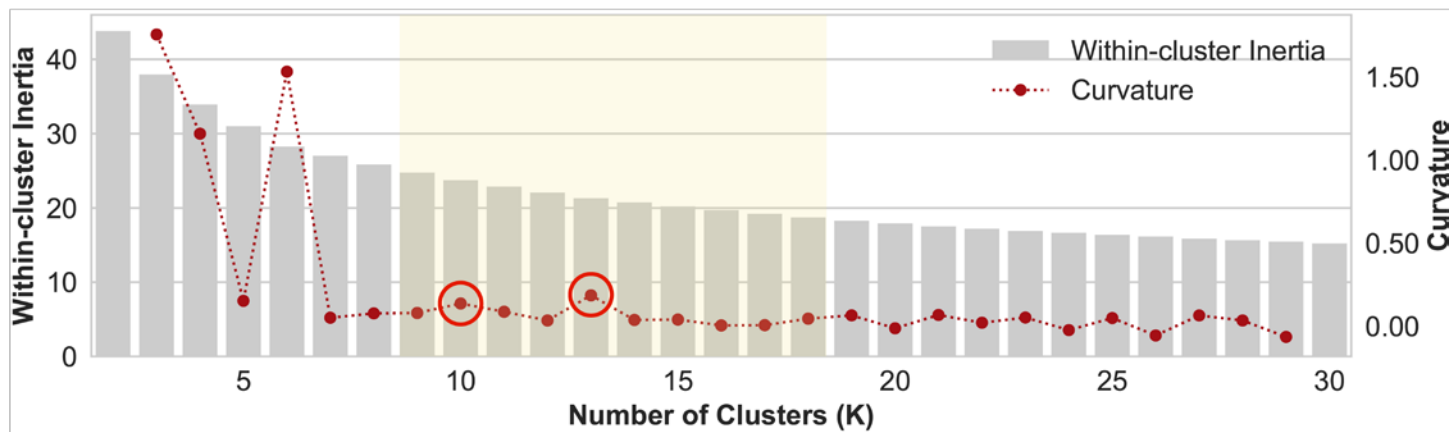


Figure 1 Within-cluster inertias and respective curvature calculated for  $K$  between  $[2, 30]$  on the training set of eight participants..

Measure	Number of Clusters (K)	
	K=10	K=13
Silhouette Scores	0.40	0.42
AIC	-13079.44	-12891.60
BIC	-13560.20	-13515.64

Table 1 Result of clustering evaluations for the two candidate models. The highlighted cell shows the maximum value for AIC based on  $K$  between  $[2, 30]$ .

Images of the training feature vectors, which were five of the 20 closest members ( $N_{top}=20$ ) to each centroid of the six K=10 k-means model clusters.

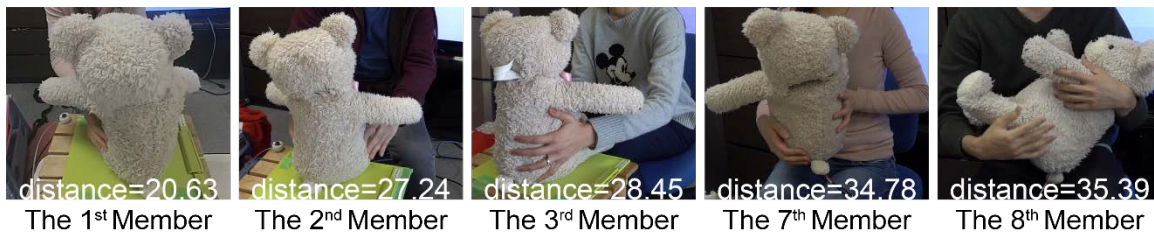


Figure 2 The 9<sup>th</sup> Cluster - Touch

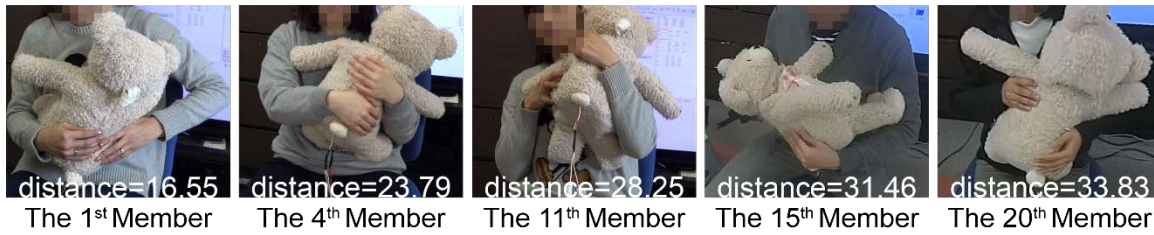


Figure 3 The 3<sup>rd</sup> Cluster - Transition to and from Snuggle and Cradle

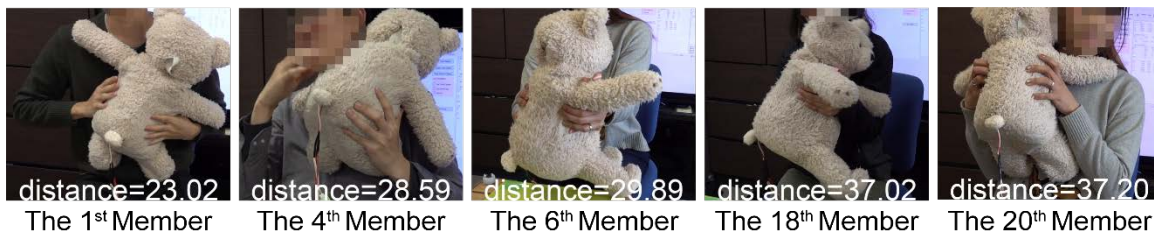


Figure 4 The 8<sup>th</sup> Cluster - Transition to and from Snuggle and Hello-world

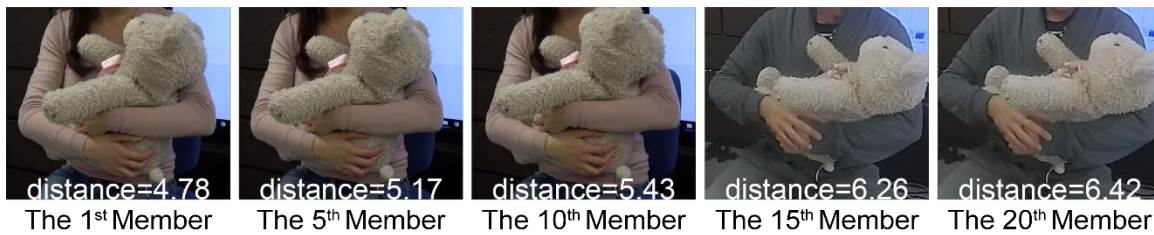


Figure 5 The 0<sup>th</sup> Cluster - Left-cradle

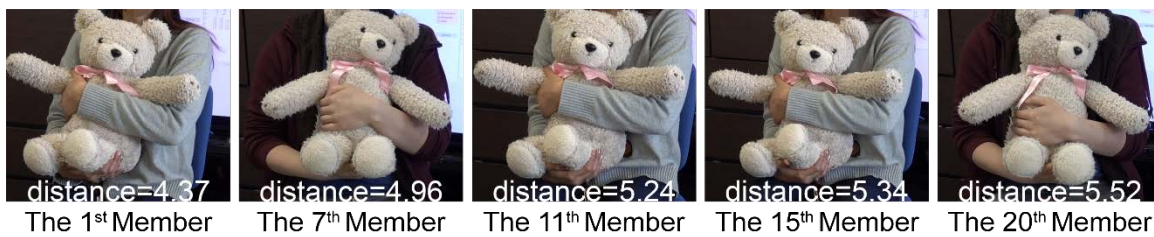


Figure 6 The 7<sup>th</sup> Cluster - Hello-world

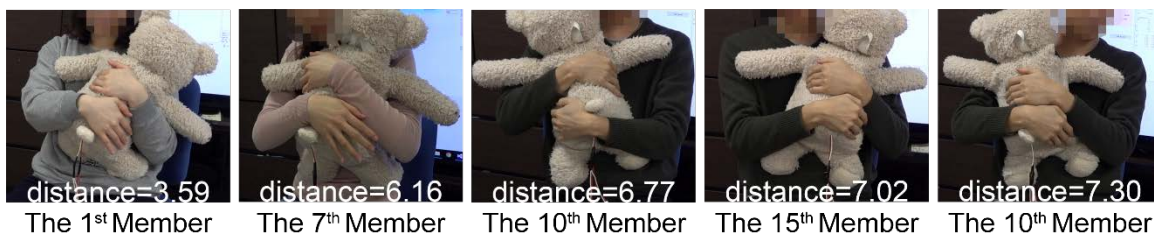


Figure 7 The 6<sup>th</sup> Cluster - Snuggle

Images of the training feature vectors, which were five of the 20 closest members ( $N_{top}=20$ ) to each centroid of the six K=13 k-means model clusters.

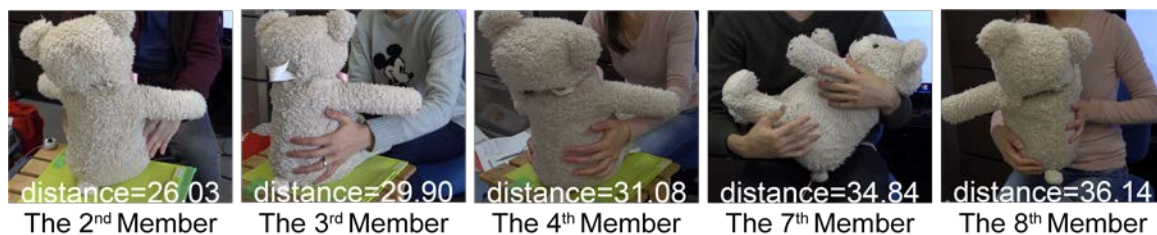


Figure 8 The 9<sup>th</sup> Cluster – Touch



Figure 9 The 2<sup>nd</sup> Cluster – Transition to and from Snuggle and Cradle

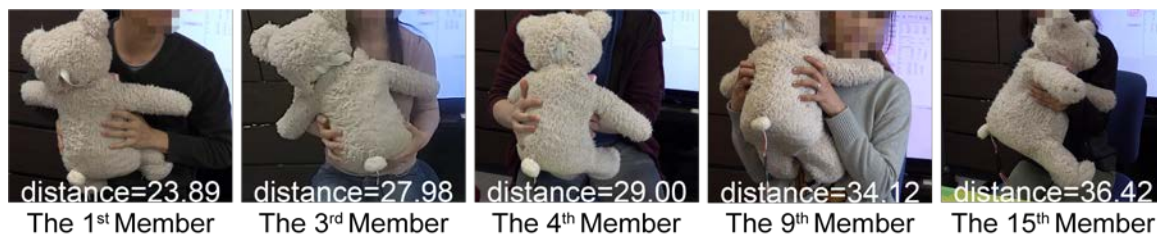


Figure 10 The 12<sup>th</sup> Cluster – Transition to and from Snuggle and Hello-world

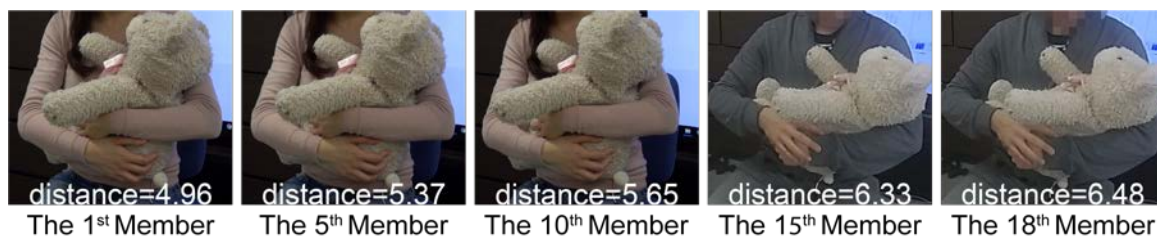


Figure 11 The 0<sup>th</sup> Cluster – Left-cradle

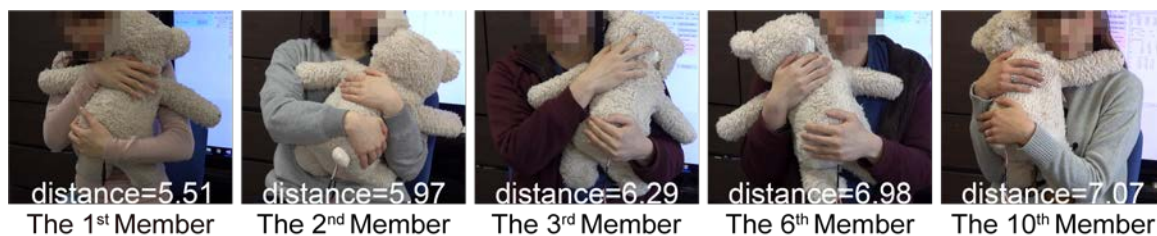


Figure 12 The 4<sup>th</sup> Cluster – Left-snuggle and Right-Snuggle

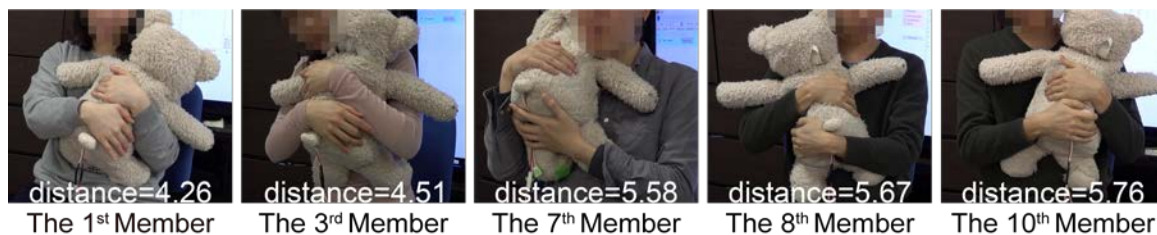


Figure 13 The 5<sup>th</sup> Cluster – Left-snuggle and Right-snuggle

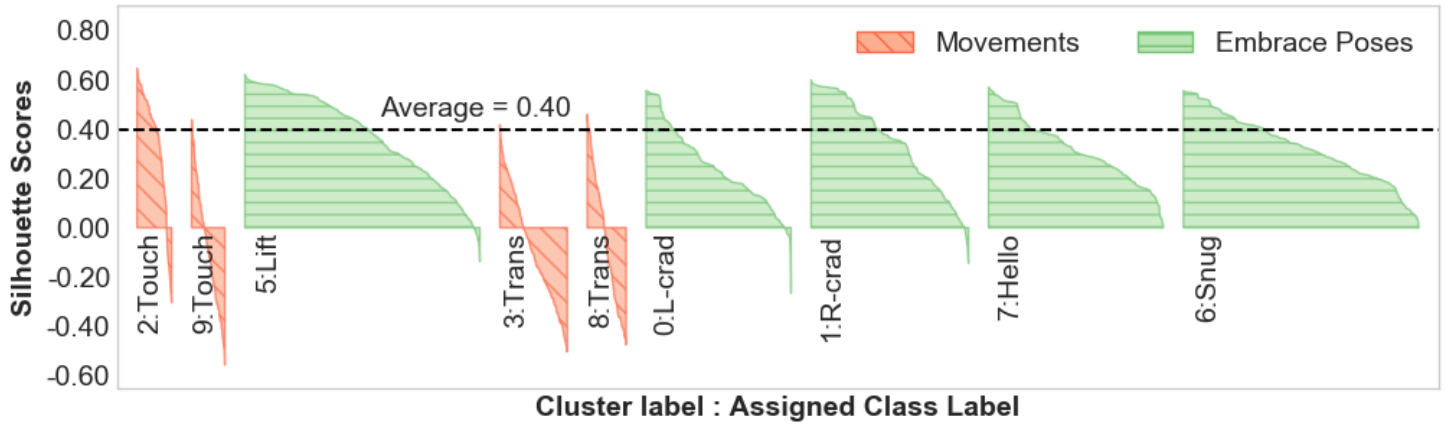


Figure 14 Silhouette Plot for the selected  $K=10$   $k$ -means model. Y-axis represents the silhouette scores. X-axis displays the cluster label and assigned class label using the proposed assignment approach for each group of silhouette scores corresponding to the feature vectors belonging to the cluster. The dashed line shows the average silhouette score. The silhouette scores for the 4<sup>th</sup> cluster assigned as Idle were omitted.

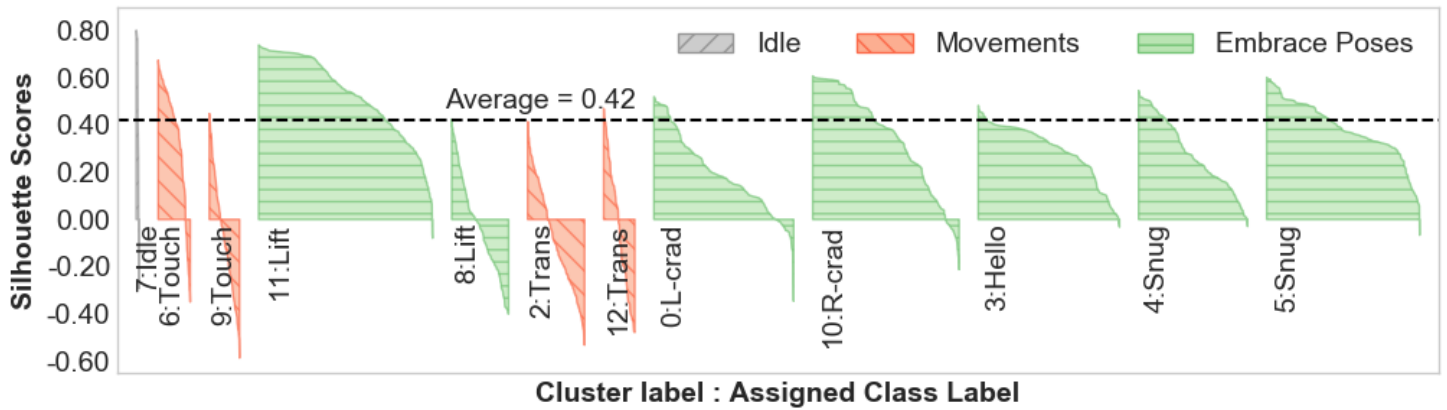


Figure 15 Silhouette Plot for the selected  $K=13$   $k$ -means model. Y-axis represents the silhouette scores. X-axis displays the cluster label and assigned class label using the proposed assignment approach for each group of silhouette scores corresponding to the feature vectors belonging to the cluster. The dashed line shows the average silhouette score. The silhouette scores for the 1<sup>st</sup> cluster assigned as Idle were omitted.

Model	Accuracy by Assignment Method	
	Cluster-to-Class by Kaboli et al.[1]	Proposed Cluster-to-Class
K=10 model	71.89%	81.73%
K=13 model	73.25%	81.67%

Table 2 Validation accuracy for the two candidate models.

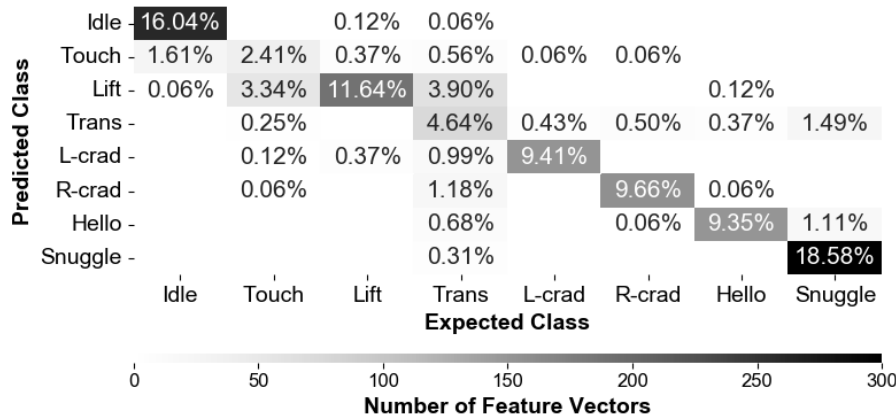


Figure 16 Confusion Matrix for K=10 k-means model on the validation set, using the cluster-to-class assignment in Figure 14.

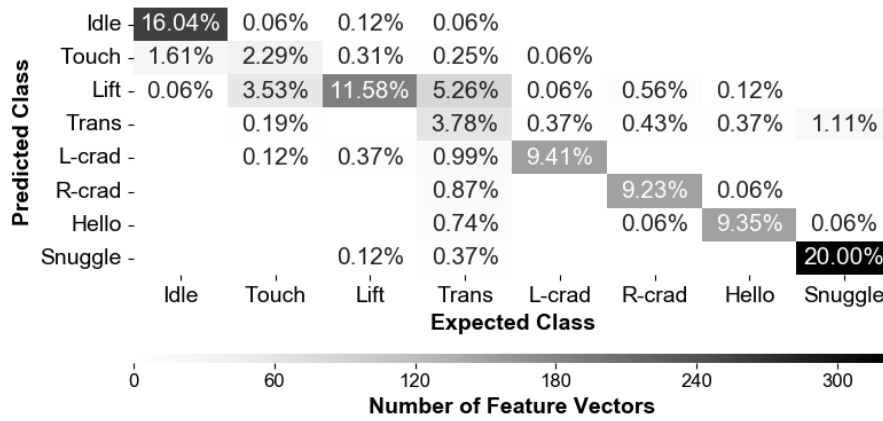


Figure 17 Confusion Matrix for K=13 k-means model on the validation set, using the cluster-to-class assignment in Figure 15.

## Which model to select?

Depending on the context of each embrace action and the choice of your application, users can select the candidate model that best fit their requirements. In this example, if users would like a simpler model, they can select K=10 model. On the other hands, if they would like the models with more specific patterns, K=13 model would be a better choice. In this case, users can merge many specific clusters showing the same context to a touch action. In the manuscript, the K=13 model was shown as example to show the possibility of grouping variations of an embrace pose, e.g. the 4<sup>th</sup> cluster (Figure 12) and the 6<sup>th</sup> cluster (Figure 13) which were merged into the same class by assigning both to Snuggle.

## References

- [1] Kaboli M, Long A, Cheng G. Humanoids learn touch modalities identification via multi-modal robotic skin and robust tactile descriptors. Adv Robot. 2015;29(21):1411—1425.