Consensus Graph and Auto-context Modelling for Feature Fusion

Huan Song, SenSIP Center, School of ECEE, ASU

***Abstract*— In machine learning, the idea of feature fusion is to combine the complementary information from a diverse set of features which characterize different aspects of data. In this paper we present two feature fusion frameworks in the applications of human activity recognition and image classification, respectively. Features from both modalities are fused through consensus graph in the first framework while context information is recursively improved and fused with image appearance model in the second one. Experimental results show that each framework improves the recognition performance in the corresponding task.**

I. Project Description

In many machine learning applications, effective fusion of features which contain diverse information of the data provide improved discriminative power and make the recognition system more robust. We present here two recent research outcomes which successfully use feature fusion to harness the data in the challenging problems of acitivty recognition and image classification.

The objective of mobile phone based human activity recognition is to learn the activity the subject performs. In this case, the feature fusion is particularly significant since the integrated mobile sensors are usually noisy and inaccurate. We propose to extract various features from each sensors and perform a two-stage fusion [1, 3]. An example implementation is shown in Figure 1. In the first stage, the fusion is performed on the sensor level and we adopt a variant of the multi-layer graph consensus algorithm [2]. In the second stage, feature fusion is performed using the reference-based classifier [4] in the ensemble setting. Experimental results on a collected dataset show that the final recognition result improves over any sensor by around 10% in accuracy. This demonstrates the effectiveness of the proposed framework in combining the complementary information from various features.

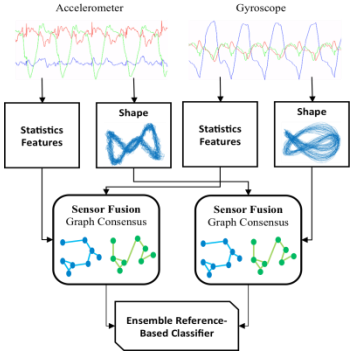

Fig. 1. Two-stage framework for activity recognition.

On the second problem in image classification we focus on exploiting the significant high-level context information [7]. Existing auto-context algorithm [6] targets the posterior probabilities and recursively learns better context feature. We extend this approach by explicitly viewing the combination of image appearance model and context model as a feature fusion problem [5] (illustration in Figure 2). By posing the problem in the Reproducing Kernel Hilbert Space (RKHS), we adopt Multiple Kernel Learning as the fusion strategy. Marginal probabilities of each example data with respect to each class are estimated from the decision functions of the learned classifier. The use of the kernel methods extends the power and flexibility of auto-context modelling. The advantage is demonstrated in the experiments on standard image classification datasets with improved recognition accuracy. Additional work in [8-11].

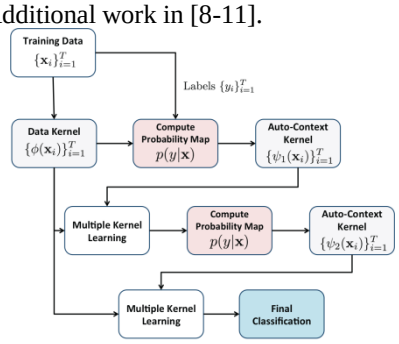

Fig. 2. Framework for integrating context information with image feature under the RKHS setting

References

[1] H. Song, J. J. Thiagarajan, K. N. Ramamurthy, A. Spanias and P. Turaga, "Consensus Inference on Mobile Phone Sensors for Activity Recognition," in *Proceedings of 2016 IEEE ICASSP-2016* , *Mar.* 2016

[2] K. N. Ramamurthy, J. J. Thiagarajan, R. Sridhar, P. Kothandaraman and R. Nachiappan, "Consensus Inference with Multilayer Graphs for Multi-modal Data," in *2014 Asilomar Conference*., p. 1341, Nov 2014.

[3] J. Frank, S. Mannor and D. Precup, "Activity and Gait Recognition with Time-delay Embeddings," in *AAAI, Citeseer*, 2010.

[4] Q. Li, H. G. Zhang, J. Guo, B. Bhanu and L. An, "Reference-based Scheme Combined with K-SVD for Scene Image Categorization," *IEEE Signal Processing Letters*, vol. 20, no. 1, pp. 67-70, 2013.

[5] H. Song, J. J. Thiagarajan, K. N. Ramamurthy and A. Spanias, "Auto-context Modelling Using Multiple Kernel Learning," in *Proceedings of 2016 IEEE ICIP 2016*, Phoenix, Sept. 2016.

[6] Z. Tu, "Auto-context and its application to high-level vision tasks," in *Proceedings of 2008 IEEE CVPR* , pp. 1-8, 2008.

[7] J. J. Thiagarajan, K. N. Ramamurthy, P. Turaga, A. Spanias, "Image Understanding Using Sparse Representation," *Synth. Lectures on Image, Video, Multimedia Processing*, vol. 7, No. 1, pp. 1-118, 2014.

[8] H. Song, J. Thiagarajan, P. Sattigeri, A. Spanias, "Optimizing Kernel Machines using Deep Learning" Accepted *IEEE Tran. on Neural Networks and Learning Systems*, pp. 5528 – 5540, Feb. 2018.

[9] U. Shanthamallu, J. J. Thiagarajan, H. Song, A.s Spanias, "GrAMME: Semi-Supervised Learning using Multi-layered Graph Attention Models," Accepted *IEEE Trans. on Neural Networks*, Oct. 2019.

[10] K. Jaskie and A. Spanias, "Positive and Unlabeled Learning Algorithms and Applications: A Survey," *Proc. IEEE IISA 2019*, Patras, July 2019.

[11] U. Shanthamallu, A. Spanias, C. Tepedelenlioglu, M. Stanley, "A Brief Survey of Machine Learning Methods and their Sensor and IoT Applications," *8th Int. Conference on IISA 2017*, Larnaca, Aug. 2017.