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Abhishake Rastogi, Sivananthan Sampath

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Multi-task learning via linear functional strategy

Abhishake Rastogi*, Sivananthan Sampath†
Department of Mathematics
Indian Institute of Technology Delhi
New Delhi 110016, India

Abstract

In machine learning, the multi-task learning is a natural approach that exploits the relations among different tasks to improve the performance. We develop a theoretical analysis of multi-penalty least-square regularization scheme on the reproducing kernel Hilbert space in vector-valued setting. The results hold for general framework of vector-valued functions; therefore they can be applied to multi-task learning problems. We study an approach for multi-penalty regularization scheme which is based on the idea of linear combination of different regularized solutions. We estimate the coefficients of the linear combination by means of the so-called linear functional strategy. We discuss a theoretical justification of the linear functional strategy which particularly provides the optimal convergence rates for multi-penalty regularization scheme. Finally, we provide an empirical analysis of the multi-view manifold regularization scheme based on the linear functional strategy for the challenging multi-class image classification and species recognition with attributes.

Keywords: Multi-task learning; Manifold learning; Multi-penalty regularization; Linear functional strategy; Vector-valued RKHS; Error estimate.
Mathematics Subject Classification 2010: 68T05, 68Q32.

1 Introduction

In computer vision and image processing, we have to solve various problems simultaneously such as object detection, classification, image denoising, inpainting, tracking of multiple agents. Several approaches are proposed in learning to handle this challenges. We need enough resources to solve each of these problems separately. The procedure of obtaining solutions one-by-one is computationally costly. Even if we tackle the problems separately then also we might ignore the relatedness of various tasks. This motivates us to develop the new field of multi-task learning [3, 22, 23, 26, 31, 58] which simultaneously solves several distinct problems as well as incorporate the structure of the relations of different tasks. In order to tackle T-tasks simultaneously we consider the vector-valued functions $f : X \to \mathbb{R}^T$ in multi-task learning where the components of function $f = (f_1, \ldots, f_T)$ describe the individual tasks. Micchelli and Pontil [48] introduced the vector-valued reproducing kernel Hilbert spaces to facilitate theory of multi-task learning. Every vector-valued RKHS is corresponding to some operator-valued positive definite kernel [48]. Here we consider the general framework of vector-valued functions $f : X \to Y$ which includes the multi-task learning setting as a special case when $Y = \mathbb{R}^T$.

*Corresponding Author, Email address: abhishekrastogi2012@gmail.com
†Email address: siva@maths.iitd.ac.in