Accepted Manuscript

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PII: S0047-259X(18)30057-5
DOI: https://doi.org/10.1016/j.jmva.2018.09.009
Reference: YJMVA 4419

To appear in: *Journal of Multivariate Analysis*

Received date : 28 January 2018

Please cite this article as: X. Chen, et al., Functional response regression analysis, *Journal of Multivariate Analysis* (2018), https://doi.org/10.1016/j.jmva.2018.09.009

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Abstract

In this paper, we study functional regression with a random response curve and vector covariates. We propose a supervised least squares estimation procedure after utilizing B-spline functions to approximate the unknown functions and establish the asymptotic normality of the proposed estimators. The method has an analytic form and is easily implemented. Compared to existing methods, it does not rely on a normality assumption and can be broadly applied to sparse or non-sparse, equally or non-equally spaced, and balanced or unbalanced observations. We assess the numerical performance of the proposed procedure through simulation experiments and illustrate its performance on a real example.

Keywords: B-spline approximation, Functional linear models, Functional principal component analysis (FPCA), Principal component curve, Supervised least squares

1. Introduction

Functional data analysis (FDA) has drawn considerable attention in recent decades. Various approaches for the analysis of functional data have been developed and proposed in the literature [7, 12, 28, 30], offering a comprehensive overview. Advances in technology enable us to collect more functional data in areas such as medical studies, speech recognition, biological growth, climatology, and online auctions. Concurrent with this development, functional regression techniques have been widely studied and applied [11, 18, 19, 21, 36–40].

For the FDA approach, we usually consider different characteristics of covariates and responses. The analysis typically addresses one of three scenarios: (i) both the response and covariates are random curves/functions; (ii) the covariates are random functions, but the response is scalar; and (iii) the response is a random function, while covariates are scalars or vectors. For scenario (i), a functional regression model of the form

$$\mathrm{E}\{Y(t) \mid X(\cdot)\} = \mu(t) + \int X(s)\beta(s,t)ds, \tag{1}$$

has been proposed [29], where $Y(t)$ is the response function, $X(t)$ is the covariates function, $\mu(t)$ is a mean response function, and $\beta(s,t)$ is a regression function. Estimation of the regression function $\beta(s,t)$ has been widely studied [8, 9, 14, 38].

The functional linear model for scenario (ii) is defined as

$$\mathrm{E}\{Y \mid X(\cdot)\} = \mu + \int X(s)\beta(s)ds, \tag{2}$$

where μ is the unknown mean, and $\beta(s)$ is the unknown regression function [2, 3, 15, 17]. Nie et al. [24] consider supervised functional principal component analysis under model (2). Essentially, both models (1) and (2) provide

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