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Transforming Region-Detection, a One-Dimensional (1D) Problem to Point Detection, a Zero-Dimensional (0D) Problem

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Introduction

Kernel regression is a nonparametric method in which the underlying signal can be estimated at any given point using the local noisy observations. In this method, the signal Y (dependent variable) is defined as a random variable and the goal is to estimate the conditional expectation value of Y given the independent variable X. A bandwidth controls the degree of smoothness by defining the maximum distance of the observations form the center of the kernel (located at x) to be considered local. Thus, observations which are contained inside the kernel (local observations) will be used for estimating the conditional expectation E (Y|X).

Region detection in the proposed approach is performed using a multiscale kernel regression combined with statistical multiple testing. The key idea of this approach is to apply kernel regression for transforming the region detection problem to a peak detection problem [1]. A detected peak is a zero dimensional representative of a one-dimensional region because convolution of a non-zero constant region or a unimodal non-zero region with a symmetric unimodal kernel produces a unimodal peak at the center of the region. Moreover, if the kernel bandwidth matches the size of the region, the signal-to-noise ratio (SNR) of the peak will be maximized. In this way, regions will be represented by peaks, i.e. for detection purposes a nonzero region can be identified by its representative detected peak. The goal is achieved by matched filtering via multiscale kernel regression summarized here.

Multiscale Kernel Regression

A set of kernels with the same shape and different bandwidths is applied to the noisy observations. This step generates a bank of smoothed signals each of which provides a deferent estimate for conditional expectation E (Y|X).

Locating Candidate Peaks

A peak is detected by locating high local maximum that indicates close match between a specific bandwidth and the underlying signal at the given location. A set of candidate peaks is then obtained with collecting the peaks detected by all bandwidths. Each located peak is represented with its location, its height, and its associated bandwidth and is a potential candidate to represent an underlying signal region.

Bandwidth Matching

A true underlying non-zero region might be represented by several peaks if the bandwidth is smaller than the best matching bandwidth. To avoid this redundancy, the peak that maximizes the SNR in a local neighborhood will be selected. Therefore, a selected subset of candidate set is chosen by pruning the redundant peaks in the candidate set such that a selected peak is the best single representative of a potential underlying region.

Region Identification

Finally, a *p*-value is computed and assigned to each selected peak. Significant *p*-values are identified by statistical multiple testing and are collected in the identified set. This is achieved by controlling the FDR (False Discovery Rate) using the Benjamini and Hochberg (BH) algorithm [2]. Each peak in the identified set represents a non-zero region where its location marks the center of the underlying non-zero region and its associated bandwidth determines the length of that region.

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