

POWERFUL SPATIAL MULTIPLE TESTING VIA BORROWING NEIGHBORING INFORMATION

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Abstract: Clustered effects are often encountered in multiple hypothesis testing of spatial signals. In this paper, we propose a new method, termed *two-dimensional spatial multiple testing* (2D-SMT) procedure, to control the false discovery rate (FDR) and improve the detection power by exploiting the spatial information encoded in neighboring observations. The proposed method provides a novel perspective of utilizing spatial information by gathering signal patterns and spatial dependence into an auxiliary statistic. 2D-SMT rejects the null when a primary statistic at the location of interest and the auxiliary statistic constructed based on nearby observations are greater than their corresponding cutoffs. 2D-SMT can also be combined with different variants of the weighted BH procedures to improve the detection power further. A fast algorithm is developed to accelerate the search for optimal cutoffs in 2D-SMT. In theory, we establish the asymptotic FDR control of 2D-SMT under weak spatial dependence. Extensive numerical experiments demonstrate that the 2D-SMT method combined with various weighted BH procedures achieves the most competitive performance in FDR and power trade-off.

Key words and phrases: Empirical Bayes, false discovery rate, near epoch dependence, side information.

1. Introduction

Large-scale multiple testing with spatial structure has become increasingly important in various areas, e.g., Functional Magnetic Resonance Imaging research, genome-wide association studies, environmental studies, and astronomical surveys. The essential task is identifying locations that exhibit significant deviations from the background to build scientific interpretations. Since thousands or even millions of spatially correlated hypotheses tests are often conducted simultaneously, incorporating informative spatial patterns to provide a powerful multiplicity adjustment for dependent multiple testing is becoming a significant challenge.

There has been a growing literature on spatial signal detection with false discovery rate control (FDR, Benjamini and Hochberg, 1995). Heller et al. (2006) and Sun et al. (2015) proposed to perform multiple testing on cluster-wise hypotheses by aggregating location-wise hypotheses to increase the signal-to-noise

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