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Cumulant Estimation in Bi-Additive Models: Variance Stabilization

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Authors:

Patrícia ANTUNES¹
Dário FERREIRA^{2,3}
Sandra S. FERREIRA^{2,3}

¹ Polytechnic University of
Castelo Branco, Sport Physical
activity and health Research &
Inovation Center (SPRINT-
IPCB, Castelo Branco, Portugal

² Department of Mathematics,
University of Beira Interior,
Covilhã, Portugal

³ Center of Mathematics and
Applications, University of
Beira Interior, Covilhã,
Portugal

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Abstract

Cumulants offer a fundamental description of probability distributions, capturing shape and tail properties beyond the mean and variance (Kendall & Stuart, 1945; Stuart & Ord, 1999). This presentation develops a unified inferential framework for estimating higher-order cumulants in bi-additive models with fixed location effects and independent random components, building on classical distribution theory and tensor-based representations (McCullagh, 1987). We focus on consistent and asymptotically normal estimation of the fourth-order cumulant, using both a direct approach based on the cumulant-generating function and an indirect least-squares method derived from moment-cumulant relations. Explicit asymptotic variances and finite-sample corrections are obtained under general location-scale families, with justification relying on higher-order asymptotic arguments (Hall, 1992). The main novel contribution is the introduction of a variance-stabilizing transformation for the fourth-order cumulant estimator, improving robustness and finite-sample performance under model deviations (Huber & Ronchetti, 2009).

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