Accepted Manuscript

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PII: S0047-259X(16)30206-8
DOI: https://doi.org/10.1016/j.jmva.2018.08.012
Reference: YJMVA 4407

To appear in: *Journal of Multivariate Analysis*

Received date : 30 November 2016

Please cite this article as: A.E.D. Veraart, Modeling, simulation and inference for multivariate time series of counts using trawl processes, *Journal of Multivariate Analysis* (2018), https://doi.org/10.1016/j.jmva.2018.08.012

Modeling, simulation and inference for multivariate time series of counts using trawl processes

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Abstract

This article presents a new continuous-time modeling framework for multivariate time series of counts which have an infinitely divisible marginal distribution. The model is based on a mixed moving average process driven by Lévy noise, called a trawl process, where the serial correlation and the cross-sectional dependence are modeled independently of each other. Such processes can exhibit short or long memory. We derive a stochastic simulation algorithm and a statistical inference method for such processes. The new methodology is then applied to high frequency financial data, where we investigate the relationship between the number of limit order submissions and deletions in a limit order book.

Keywords: Count data, Continuous time modeling of multivariate time series, Infinitely divisible, Limit order book, Multivariate negative binomial law, Poisson mixtures, Trawl processes

Mathematics Subject Classification: 60G10, 60G55, 60E07, 62M10, 62P05

1. Introduction

Time series of counts can be viewed as realizations of non-negative integer-valued stochastic processes and arise in various applications in the natural, life and social sciences. As such there has been very active research in various fields. Recent textbook treatments can be found in [7, 9, 24, 45] and we refer to [8, 10, 11, 13, 21, 28, 44] for recent surveys and some new developments in the literature.

However, most of these previous works focus on univariate time series of counts. The literature on multivariate extensions is rather sparse and almost exclusively deals with models formulated in discrete time, borrowing ideas from traditional autoregressive time series models. For example, Franke and Rao [15] and Latour [25] introduced the first-order integer-valued autoregression model, which is based on the generalized Steutel and van Harn thinning operator; see [39]. Recently, Boudreault and Charpentier [6] applied such models to earthquake counts. Also, the recent handbook on discrete-valued time series by Davis et al. [9] contains a chapter by Karlis [22], who surveys recent developments in multivariate count time series models.

One challenge in handling multivariate time series is the modeling of the cross-sectional dependence. While for continuous distributions the theory of copulas presents a powerful toolbox, it has been pointed out by Genest and Nešlehová [17] that a problem arises in the discrete context due to the non-uniqueness of the associated copula. From an applied perspective, it is sometimes argued, however, that this might not be a major problem and in some settings the numerical issues arising can be overcome; see, e.g., [41].

Motivated by the reliability literature, Lindskog and McNeil [26] introduced the so-called common Poisson shock model to describe the arrival of insurance claims in multiple locations or losses due to credit defaults of various types of counterparty. Other related developments in the actuarial literature include the work by Pfeifer and Nešlehová [32] which discusses models for dependent risk processes based on Poisson (and related) processes; also, Bäuerle and Grübel [5] study multivariate counting processes where the emphasis is on models constructed via copula methods.

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