Lectures on Count Time Series Analysis

Syllabus

Department of Economics & Finance

University Tor-Vergata

Fall Semester 2025-2026

Konstantinos Fokianos

fokianos@ucy.ac.cy

University of Cyprus

Course Description: This series of research lectures introduces students to the problem of statistical analysis for count time series with a particular focus on network time series. A first attempt towards the analysis of count time series was introduced by Alzaid and Al-Osh (1988) based on the concept of integer autoregressive process. We review this type of processes but our point of view is based mostly on the theory of generalized linear models as outlined in McCullagh and Nelder (1989) and extended by Kedem and Fokianos (2002). Recent references include the edited volume by Davis et al. (2016) and the text by Weiß (2018).

I will introduce univariate and multivariate models for count time series. We will be studying basic properties (mean and autocovariance function) and develop estimation methodology. These topics provide solid foundations for progressing the main theme of network models for both continuous and count data. Besides basic properties, estimation and inference, students will see a case study related to tourist industry. In addition I will present, as time allows, current research topics like space-time data, non-stationary processes and high-dimensional data.

Most of the results that will be presented have been obtained in a series of papers by Fokianos et al. (2009), Fokianos and Fried (2010, 2012), Fokianos (2012), Fokianos and Tjøstheim (2012), Christou and Fokianos (2014), Christou and Fokianos (2015), Liboschik et al. (2017), Fokianos et al. (2020), Jia et al. (2021), Davis et al. (2021), Armillotta and Fokianos (2023, 2024), Armillotta et al. (2024) and Maletz et al. (2024).

More precisely, I will cover the following topics accompanied with the use of `R` software using the packages `tscount`–see Liboschik et al. (2017) and `PNAR`-see Armillotta et al. (2023):

Lecture 1: Introduction to regression models for time series of counts. Basic properties, Integer autoregressive processes, estimation, GLM based models, simple properties and inference. Integer GARCH models: examples, estimation and inference, inclusion of covariates intervention analysis.

Lecture 2: Multivariate models for integer valued time series, examples stochastic properties, inference. Network models for time series for both continuous and cont time series.

Lecture 3: Network models for count time series: non-linear models, case study in Advanced Topics: Space-Time data, High-dimensional data–non-stationary processes: examples, inference, open problems.

Prerequisites: It is helpful to have some background on time series analysis at the level of Shumway and Stoffer (2011). More advanced time series theory has been given by Brockwell and Davis (1991). See also Tsay (2010) for financial time series analysis. The book by Francq and Zakoïan (2010) provides an excellent introduction to GARCH models. Finally some exposure on multivariate data will be useful when dealing with models for network time series and multivariate discrete distributions; see Cameron and Trivedi (2013), for instance. We will be using the software `R` and `Rstudio`. The main packages that we will be applying to data analysis are `tscount` and `PNAR`.

Timeline: The lectures will run as follows (classroom will be announced later):

Lecture 1	September 22	11.00–13.00
Lecture 2	September 23	11.00–13.00
Lecture 3	September 29	11.00-13.00

References

Alzaid, A. and M. Al-Osh (1988). First-order integer-valued autoregressive (INAR (1)) process: distributional and regression properties. *Statistica Neerlandica 42*, 53–61.

Armillotta, M. and K. Fokianos (2023). Nonlinear network autoregression. *The Annals of Statistics 51*, 2526–2552.

Armillotta, M. and K. Fokianos (2024). Count network autoregression. *Journal of Time Series Analysis 45*, 584–612.

Armillotta, M., K. Fokianos, and A. Guizzardi (2024). Unveiling Venice's hotels competition networks from dynamic pricing digital market. *Journal of the Royal Statistical Society Series A 187*, 132–159.

Armillotta, M., M. Tsagris, and K. Fokianos (2023). Inference for network count time series with the R package PNAR. *The R Journal 15*, 255–269.

Brockwell, P. J. and R. A. Davis (1991). *Time Series: Data Analysis and Theory* (2nd ed.). New York: Springer.

Cameron, A. C. and P. K. Trivedi (2013). *Regression analysis of count data* (Second ed.), Volume 53 of *Econometric Society Monographs*. Cambridge University Press, Cambridge.

Christou, V. and K. Fokianos (2014). Quasi-likelihood inference for negative binomial time series models. *Journal of Time Series Analysis 35*, 55–78.

Christou, V. and K. Fokianos (2015). Estimation and testing linearity for mixed Poisson autoregerssions. *Electronic Journal of Statistic*, 1357–1377.

Davis, R. A., K. Fokianos, S. H. Holan, H. Joe, J. Livsey, R. Lund, V. Pipiras, and N. Ravishanker (2021). Count time series: A methodological review. *Journal of the American Statistical Association 116*, 1533–1547.

Davis, R. A., S. H. Holan, R. Lund, and N. Ravishanker (Eds.) (2016). *Handbook of Discrete-Valued Time Series*. Handbooks of Modern Statistical Methods. London: Chapman & Hall/CRC.

Fokianos, K. (2012). Count time series models. In T. S. Rao, S. S. Rao, and C. R. Rao (Eds.), *Handbook of Statistics: Time Series Analysis–Methods and Applications*, Volume 30, pp. 315–347. Amsterdam: Elsevier B. V.

Fokianos, K. and R. Fried (2010). Interventions in INGARCH processess. *Journal of Time Series Analysis 31*, 210–225.

Fokianos, K. and R. Fried (2012). Interventions in log-linear Poisson autoregression. *Statistical Modelling 12*, 299–322.

Fokianos, K., A. Rahbek, and D. Tjøstheim (2009). Poisson autoregression. *Journal of the American Statistical Association 104*, 1430–1439.

Fokianos, K., B. Støve, D. Tjøstheim, and P. Doukhan (2020). Multivariate count autoregression. *Bernoulli 26*, 471–499.

Fokianos, K. and D. Tjøstheim (2012). Nonlinear Poisson autoregression. *Annals of the Institute of Statistical Mathematics 64*, 1205–1225.

Francq, C. and J.-M. Zakoïan (2010). *GARCH models: Stracture, Statistical Inference and Financial Applications*. United Kingdom: Wiley.

Jia, Y., S. Kechagias, J. Livsey, R. Lund, and V. Pipiras (2021). Latent Gaussian count time series. *Journal of the American Statistical Association 118*, 596–606.

Kedem, B. and K. Fokianos (2002). *Regression Models for Time Series Analysis*. Hoboken, NJ: Wiley.

Liboschik, T., K. Fokianos, and R. Fried (2017). tscount: An R package for analysis of count time series following generalized linear models. *Journal of Statistical Software 82*, 1–51.

Maletz, S., K. Fokianos, and R. Fried (2024). Spatio-temporal count autoregression. *Data Science in Science 3*, 2425171.

McCullagh, P. and J. A. Nelder (1989). *Generalized Linear Models* (2nd ed.). London: Chapman & Hall.

Shumway, R. H. and D. S. Stoffer (2011). *Time Series Analysis and its Applications* (Third ed.). New York: Springer. With R examples.

Tsay, R. (2010). *Analysis of Financial Time Series* (3rd ed.). Hoboken, NJ: John Wiley.

Weiß, C. H. (2018). *An Introduction to Discrete-Valued Time Series*. Hoboken, NJ: Jonh Wiley.