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Plenary Sessions : Reggio Calabria, September 13-14, 2021
"Distributed" Parallel Session: September 15-18, 2021

Parallel Session:

NETWORKS, BIG DATA, AND ARTIFICIAL INTELLIGENCE IN ECONOMICS, FINANCE, AND SOCIAL SCIENCES

Organizers: Fabrizio Lillo, Michele Tumminello, Piero Mazzarisi

Wednesday, September 15, 2021

9:00 - 13:00 (4 hours - 25 minutes speech)

Abstracts ara attached below.

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Fine-tuned AlBERTo for Stock Price Prediction: a Gibbs Sampling Approach

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Extended abstract [1]

BERT (Bidirectional Encoder Representations from Transformers) [1] is one of the most popular techniques in Natural Language Processing (NLP) for Sentiment Analysis. The main goal is to classify sentences (or entire texts) and to obtain a score in relation to their polarity: positive, negative or neutral. Recently, a Transformer-based architecture, the fine-tuned AlBERTo [2], has been introduced in order to determine a sentiment score in the financial sector, through a specialized corpus of phrases. In this paper we use the sentiment (polarity) score to improve the forecast of stocks. We apply the BERT model to determine the score associated to various events

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(both positive and negative) that have affected some stocks in the market. The phrases used to determine the scores are newspaper articles published on MilanoFinanza. We compute both the average sentiment score and the polarity, and we use a Monte Carlo method to generate (starting from the day the article was released) a series of possible paths for the next 5 trading days (45 trading hours), exploiting the Bayesian inference to determine a new series of bounded drift and volatility values on the basis of the score; returning an exact “directed" price as results [3], [4], [5].

Keywords
BERT; Gibbs Sampling; Price forecast; Sentiment analysis.

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Moving average options: Machine Learning and Gauss-Hermite quadrature for a double non-Markovian problem

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Extended abstract [1]

Evaluating moving average options is a tough computational challenge for the energy and commodity market as the payoff of the option depends on the prices of a certain underlying observed on a moving window so, when a long window is considered, the pricing problem becomes high dimensional. We present an efficient method for pricing Bermudan style moving average options, based on Gaussian Process Regression and Gauss-Hermite quadrature, thus named GPR-GHQ. Specifically, the proposed algorithm proceeds backward in time and, at each time-step, the continuation value is computed only in a few points by using Gauss-Hermite quadrature, and then it is learned through Gaussian Process Regression. We test the proposed approach in the Black-Scholes model, where the GPR-GHQ method is made even more efficient by exploiting the positive homogeneity of the continuation value, which allows one to reduce the problem size. Positive homogeneity is also exploited to develop a binomial Markov chain, which is able to deal efficiently

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with medium-long windows. Secondly, we test GPR-GHQ in the Clewlow-Strickland model, the reference framework for modeling prices of energy commodities. Finally, we consider a challenging problem which involves double non-Markovian feature, that is the rough-Bergomi model. In this case, the pricing problem is even harder since the whole history of the volatility process impacts the future distribution of the process. The manuscript includes a numerical investigation, which displays that GPR-GHQ is very accurate and it is able to handle options with a very long window, thus overcoming the problem of high dimensionality.

Keywords
Option princing; moving average options; Gaussian Process Regression; Gauss-Hermite quadrature; Binomial tree.

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Optimal data collection design in machine learning: the case of the fixed effects generalized least squares panel data model

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Abstract
This work belongs to the strand of literature that combines machine learning, optimization, and econometrics. The aim is to optimize the data collection process in a specific statistical model, commonly used in econometrics, employing an optimization criterion inspired by machine learning, namely, the generalization error conditioned on the training input data. More specifically, the paper is focused on the analysis of the conditional generalization error of the Fixed Effects Generalized Least Squares (FEGLS) panel data model, i.e., a linear regression model with applications in several fields, able to represent unobserved heterogeneity in the data associated with different units, for which distinct observations related to the same unit are corrupted by correlated measurement errors. The framework considered in this work differs from the classical FEGLS model for the additional possibility of controlling the conditional variance of the output variable given the associated unit and input variables, by changing the cost per supervision of each training example. Assuming an upper bound on the total supervision cost, i.e., the cost associated with the whole training set, the trade-off between the training set size and the precision of supervision (i.e., the reciprocal of the conditional variance of the output variable) is analyzed and optimized. This is achieved by formulating and solving in closed form suitable optimization problems, based on large-sample approximations of the generalization error associated with the FEGLS estimates of the model parameters, conditioned on the training input data. The results of the analysis extend to the FEGLS case and to various large-sample approximations of its conditional generalization error the ones obtained by the authors in recent works for simpler linear regression models. They highlight the importance of how the precision of supervision scales with respect to the cost per training example in determining the optimal trade-off between training set size and precision. Numerical results confirm the validity of the theoretical findings.

Keywords Fixed effects generalized least squares panel data model · First-order serial covariance · Conditional generalization error · Large-sample approximations · Optimal training set size

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Reinforcement Learning algorithms in financial trading systems: A comparison

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Extended abstract [1]

In this paper we present and implement different Reinforcement Learning (RL) algorithms in financial trading systems (FTSs). RL is a self-adaptive machine learning approach [1] which aims to find an optimal policy, that is an optimal mapping between the variables describing an environment state and the actions available to an agent through the interaction with the environment itself, all this in order to maximize a cumulative return. In our case, the agent is a FTS and the environment is a financial market. The FTS, once perceived the state of the market, decides to sell/buy an asset or to stay out of the market; in response, the market provides a loss or a gain to the FTS. This permits the online detection of a trading strategy for the maximization over time of a cumulative performance measure; the two cumulative performance measures considered here are based on the Sharpe Ratio and on the Calmar Ratio, respectively. Our aim is to improve the results obtained in [2] while keeping a similar simple structure of both the state space representation and of the trading actions available. In particular, we compare the results obtained considering on-policy and off-policy RL algorithms – namely, SARSA [1], QLearning [1], and Greedy-GQ [3] – applied to the daily trading of some major Italian stocks (Enel, Generali, Intesa, Tim, and Unicredit, from January 2000 to October 2018). We both consider computational issues and investigate practical matters, in an effort to improve previous results while keeping a simple and understandable structure

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of the used models. Generally, all the implemented RL-based FTSs perform satisfactorily.

Keywords
Reinforcement Learning (RL); SARSA; Q-Learning; Greedy-GQ; financial trading system.

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A novel differential evolution algorithm for solving a class of portfolio optimization problems with risk-budgeting constraints

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Extended abstract [1]

The financial crisis and the market uncertainty of the last decades, merged with the outburst of the COVID-19 pandemic, have pointed out the weaknesses of the traditional portfolio theory, making necessary for the investors to develop new portfolio designs that are able to adequately manage the different sources of risk of the investment process.
In this work, we propose a novel portfolio optimization problem where we maximize a modified formulation of the Sharpe ratio [1], which takes into account the possibility of negative expected excess returns [2]. A set of risk-budgeting constraints is introduced to adequately control the portfolio risk. Furthermore, we introduce a variant of the differential evolution (DE) algorithm to solve the resulting fractional programming problem with non-convex constraints [3]. Our procedure integrates in the standard DE a new hybrid constraint-handling strategy in which reflection and normalization operators manage the budget and box constraints, and a variant of the ε-constrained feasibility rule deals with the risk-budgeting constraints.

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Finally, we assess robustness and profitability of our portfolio design compared to other strategies from literature. The numerical experiments are based on a set of European country and industry indices with monthly data covering the period from January 2005 to March 2021.
This abstract is submitted for the special session on "Networks, Big Data, and Artificial Intelligence in Economics, Finance, and Social Sciences" organized by F. Lillo, M. Tumminello and P. Mazzarisi.

Keywords
Portfolio optimization; Risk-budgeting; European equity market; Differential evolution algorithm; Constraint-handling techniques.

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A NETWORK PERSPECTIVE ON CO-BRANDING CAMPAIGNS: EVIDENCE FROM THE FASHION INDUSTRY

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Extended abstract [1]

Over the last decades, the co-branding phenomenon has proved of greater interest to academics in marketing research. Co-branding occurs when two brands create a new product together that will carry the specificities and names of both brands in the partnership [3]. Previous research privileged the analysis of co-branding campaigns by studying dyadic relationships between brands. Here, we take a network view to highlight the influence of companies' co-branding portfolios on partnership formation and the logics underlying these partnerships. Indeed, an interesting topic in branding research is the brand-leveraging process that identifies how consumers react to a brand strategy when a brand is related to other entities, e.g., other brands [1] that, in this study, compose the portfolio of previous partnerships of a given brand. From a theoretical perspective, co-branding studies analyze the

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process by which partner brands send a "signal" to consumers. Here, we propose looking at partner selection as a process in which a signal, namely, the portfolio of previous co-branding campaigns, is transmitted from one brand to others. In particular, we focus on the network of co-branding campaigns in the fashion industry. We look at the system through the lens of Signaling Theory [2] to inquire if i) the portfolio of partnerships a brand has constructed in time, and ii) its direct and indirect connections in the network influence the creation of new co-branding partnerships. Indeed, the position of a brand in the overall co-branding network is not only descriptive of such a portfolio but also accounts for indirect brand relationships that result from alliances between brands from different portfolios. Thus, we develop a probabilistic model that only exploits network information, and evaluate its ability to predict partnerships iteratively removed from the network of co-branding campaigns.

Keywords
co-brand; signaling theory; co-branding network; partner selection; complex systems.

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REALIZED EXPONENTIAL RANDOM GRAPHS

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Abstract

Given a sequence of random graphs generated by an exponential family distribution, known as *exponential random graphs* (ERG), we define a *realized* ERG (RERG) as a single snapshot maximum-likelihood estimate of the ERG parameters. RERG's are noisy observations of the latent state variables driving the evolution of the graph over time. They allow us to: *i)* map a nonlinear state-space graph model into a linear time-series model; *ii)* describe a wide variety of dynamic network structures under several sparsity regimes; *iii)* develop an asymptotic inferential theory for ERG models with dynamic common factors. To this end, in the same spirit of [1], we introduce a two-step estimator based on PCA and Kalman smoothing: first, the parameters of the ERG model are estimated from an OLS on principal components, then the factors are estimated via the Kalman smoother. Under mild conditions on the observation error of RERG, we prove the asymptotic consistency of the two-step estimator of the ERG models with latent dynamic factors. In particular, we show that the ERG parameters and the common factors can be estimated at a super-consistent rate of convergence for large cross-sections provided that the random graph sequence is *dense*.

We highlight the merits of our novel framework by using it to infer and forecast the dynamic of the Italian electronic Market for Interbank Deposit (e-MID). We consider two ERG models, the so-called β-model [2] and p_1-model [3], and show in both cases a strong evidence in favor of the average lending rate as the largest factor driving the evolution of the market's structure. We corroborate our findings by using the novel method to forecast the future trades in the e-MID interbank network.

Parallel Session: *Networks, Big Data, and Artificial Intelligence in Economics, Finance, and Social Sciences*. Organizers : Fabrizio Lillo , Michele Tumminello , Piero Mazzarisi.

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Key words and phrases. Exponential Random Graphs, Dynamic networks, State-space models, Kalman filter, Interbank market.

High-frequency trading and networked markets

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Extended abstract [1]

Financial markets have undergone a deep reorganization during the last 20 years. A mixture of technological innovation and regulatory constraints has promoted the diffusion of market fragmentation and high-frequency trading. The new stock market has changed the traditional ecology of market participants and market professionals, and financial markets have evolved into complex sociotechnical institutions characterized by a great heterogeneity in the time scales of market members' interactions that cover more than eight orders of magnitude. We analyze three different datasets for two highly studied market venues recorded in 2004 to 2006, 2010 to 2011, and 2018. Using methods of complex network theory, we show that transactions between specific couples of market members are systematically and persistently overexpressed or underexpressed. Contemporary stock markets are therefore networked markets where liquidity provision of market members has statistically detectable preferences or avoidances with respect to some market members over time with a degree of persistence that can cover several months. We show a sizable increase in both the number and persistence of

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networked relationships between market members in most recent years and how technological and regulatory innovations affect the networked nature of the markets. Our study also shows that the portfolio of strategic trading decisions of high-frequency traders has evolved over the years, adding to the liquidity provision other market activities that consume market liquidity.

Keywords
high-frequency trading; statistically validated networks; networked markets.