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8th Seminar on
Copula Theory and its Applications

Faculty of Technology and Engineering, Velayat University, 5 - 6 Feb, 2025

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In the Name of Allah

Abstracts of

8th Seminar on
Copula Theory and its Applications

Department of Statistics Velayat University of Iranshahr

and

Ordered Data, Reliability and Dependency Center of Excellence

Ferdowsi University of Mashhad,

Feb 5-6, 2025

Disclaimer

This book contains the abstracts booklet of the 8th Seminar on "Copula Theory and its Applications". Authors are responsible for the contents and accuracy. Opinions expressed may not necessarily reflect the position of the scientic and organizing committees.

Preface

The series of biennial workshops on copula theory which took place in Ferdowsi University of Mashhad (2011 and 2013), Shahid Bahonar University of Kerman (2015), Yazd University (2017), Ferdowsi University of Mashhad (2019), Alzahra University (2021) and Ferdowsi University of Mashhad (2023), with an emphasis on application in engineering sciences, agricultural sciences, actuarial science, finance, reliability, survival analysis, economics and etc.is the result for the decision of the scientific committee of the Ordered and Spatial Data Center of Excellence (OSDCE) of Ferdowsi University of Mashhad (FUM) to organize workshops and seminars every two years. This seminar is sponsored by the department of statistics, OSDCE of FUM, Islamic world Science Citation database (ISC), Iranian Statistical Society and Research Institute of Meteorology and Atmospheric Science (RIMAS) of Mashhad to provide suitable facilities for academics to have efficient research cooperation and will be held at Velayat University of Iranshahr at 5 and 6 Feb. 2025. We hope all of the seminar committees provide a suitable satisfactory atmosphere for the participants. After the first call of the seminar, 26 papers were accepted as oral presentations by the referees and scientific committee. The attendants and participants in the seminar are in summary 40 people which are professors, students and researchers of different institutes around Iran. Finally, we would like to extend our sincere gratitude to the Research Council of Velayat University, the OSDCE, the Islamic world Science Citation center, the Iranian Statistical Society, the (RIMAS), the scientific committee, the organizing committee, the referees, and the students and staff of the department of statistics of velayat University for their kind cooperation.

Mojtaba Esfahani (Chair)

Feb. 2025

Topics

The aim of the seminar is to provide a forum for presentation and discussion of scientific works covering theories and methods such as:

- **Methods of copula construction**
- **Copula functions and dependence concepts**
- **Dependence modelling using copula function**
- **Inference based on copula**
- **Application of copula in spatial, survival, reliability, engineering, hydrological, meteorological, agricultural, _nance, economic data and etc.**

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Contents

COPULA LOGISTIC GENERALIZED ADDITIVE MODEL

AHMADI ANGALI, K

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Abstract

This study utilized a Bivariate Copula Logistic Generalized Additive Model to assess the effectiveness of carbohydrate consumption on two cardiovascular diseases: CVD1 (Hypertension) and CVD2 (Cardiac Vascular Disease). Both response variables, CVD1 and CVD2, are binary, taking values of 0 (absent) or 1 (present) for the respective diseases. The model was adjusted for several variables, including age, BMI, smoking status, energy intake, waist circumference, and hip circumference. The Generalized Additive Model (GAM) technique was employed to capture the complex relationships between carbohydrate consumption and both CVD1 and CVD2. Additionally, a Gaussian Copula was used to combine the two logistic regression models.

STOCHASTIC COMPARISON OF PARALLEL SYSTEMS FORMED BY HETEROGENEOUS DEPENDENT EXPONENTIAL COMPONENTS

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Abstract

In this paper, we consider the parallel systems with dependent components from exponential model linked with common Archimedean copula with generator function ϕ. We prove that under some sufficient conditions on the generator function ϕ, the parallel systems from two sets of dependent exponential components are compared with respect to the usual stochastic ordering.

Keywords: Usual stochastic order, Archimedean copula, Majorization order.

FEATURE SELECTION USING EXTROPY-COPULA

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Abstract

This paper presents an innovative feature selection method that leverages extropy and copula. Feature selection is a dimensionality reduction technique aimed at identifying and selecting the most relevant variables from a large dataset. exntropy serves as a measure of order and randomness in the data, helping to identify more relevant features. On the other hand, copulas provide a more accurate framework for modeling the dependencies between features. This combination results in higher-quality feature selection and demonstrates better performance compared to traditional methods. Simulation results emphasize the improved e_ectiveness of this approach in feature selection.

Keywords: Feature Selection, Extropy, Copula Function.

FGM-Copula based Analysis of Physical Layer Security in Wireless Wiretap Channels with UAV Transmitter

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Abstract

Physical layer security, as an important practical concept, in unmanned aerial vehicle (UAV) assisted channels has been studied in the literature, where, correlation impact of wireless channel coefficients has not been considered. In this paper, having briefly reviewed (the discrete memoryless channel, physical secure rate and copula function theory), a continuous alphabet wiretap channel with UAV transmitter is considered. For this channel, we obtain closed form expressions for secrecy capacities in two cases: (i) Gaussian channel with constant channel coefficients; (ii) Gaussian wireless channel with correlated coefficients by using FGM copula function to describe the correlations. Through obtained secrecy rates, we analyze the impacts of (a) UAV situation for transmitter (b) correlation between channel coefficients on the achievable rates. Then, analytical results are numerically assessed across various correlation structures. The findings demonstrate that correlated fading adversely impacts security performance.

 Keywords: based wiretap channel, secrecy capacity, wireless channel correlated coefficients.

SOME NEW RESULTS ON STOCHASTIC COMPARISONS OF THE SMALLEST ORDER STATISTICS FROM DEPENDENT RANDOM VARIABLES UNDER ARCHIMEDEAN COPULA DEPENDENCE

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Abstract

In this paper, we consider two series systems comprising heterogeneous dependent components, with an Archimedean survival copula. We then provide sufficient conditions on the distributions of components' lifetimes and the generator of the Archimedean copula and on the vector of parameters for comparing the lifetimes of two systems with respect to the usual stochastic order.

Keywords: Usual stochastic order, Archimedean survival copula, Majorization, Order statistics.

A SYMMETRIC FAMILY EXTENSION FGM COPULA AND ITS PROPERTIES

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Abstract

In this study, we propose a new class of symmetric FGM copula. This class includes some known extensions of FGM copulas. Some general formulas for well-known measures of dependence of this class are obtained, and various properties of the proposed model are studied.

Keywords: FGM copula, Measures of Dependence, admissible range.

RECENT ADVANCES IN THE MEASURING AND TESTING OF

BIVARIATE ASYMMETRY

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Abstract

The assumption of symmetry, which suggests that a random variable's distribution is symmetric, is essential in numerous probability and statistics issues. In this talk, we will examine recent research on measuring and ordering the asymmetry of random variables and testing for symmetry using copulas.

Keywords: Conditional symmetry, Copula, Dependence, Permutation symmetry, Radial symmetry.

NEW CLASS OF JOINT DISTRIBUTION BASED DISTORTED INVERS LORENZ CURVE

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Abstract

Distortion function is one of the useful tools for generating a distribution function. Distributions generated by the distortion function are called distorted distributions. In this article, by using the Sklar's theorem and distorted marginal distribution functions a joint distribution is introduced. Then, its properties are examined and finally, a special case of it is presented.

Keywords: Copula function, Tau Kendall, Lorenz Curve, Distortion function.

FGM COPULA BASED ANALYSIS OF OUTAGE PROBABILITY FOR RATE SPLITTING AIDED WIRELESS MULTIPLE ACCESS CHANNEL WITH CORRELATED CHANNEL COEFFICIENTS

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Abstract

The wireless channel coefficients are practically correlated necessitating the study of wireless networks with correlated channel gains. On the other hand, rate splitting multiple access (RSMA) is a promising strategy to avoid interference in future wireless networks. In this paper, we study the impact of rate splitting multiple access strategy on the outage probability of two-user multiple access channel with correlated coefficients, by utilizing the Farlie-Gumbel-Morgenstern (FGM) copula as a well-known copula function, and show that the performance of RSMA is dependent on rate splitting parameter, and to achieve the best performance, the rate splitting parameter should be on a specific range depending on the information rate thresholds. Numerical results are presented to confirm the theoretical findings.

Keywords: rate splitting, multiple access, copula function, Rayleigh distribution.

ON USING COPULA FOR DIRECTIONAL DATA

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Abstract

The intrinsic feature of directional data is periodicity which forces one to utilize particular statistical methods that are relatively di_erent from the usual (classical) statistics. Fortunately, many univariate models to treat the directional data are available in the literature. However, rare activities were done to propose the multivariate counterparts. One of the main challenges to doing so is related to various ways of de_ning dependency between directional variables. This paper reviews those resources related to constructing bivariate toroidal densities using the concept of copula.

Keywords: Directional statistics, Periodicity, Copular, Von Mises distribution.

ON THE RATES OF CONVERGENCE FOR WEIGHTED SUMS OF RANDOM VARIABLES AND ITS APPLICATION IN CHANGE POINT DETECTION

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Abstract

In this paper, convergence rates for the maximal of weighted sums of random variables without any restriction on the dependence structure and under the condition of stochasically dominated are investigated. As an application, rates of convergence for the cumulative sum (CUSUM) estimator of the mean change point models regardless of any dependence structure of errors are obtained. Simulation studies based on copula function are also provided to support the theoretical results.

Keywords: Convergence rate, Change point detection, Copula function, Cumulative sum.

EXPLORING CHERRY JUNCTION TREES: STRUCTURE, SPECIAL CASES AND APPLICATIONS

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1 Department of Statistics, Faculty of Mathematics and Computer, Shahid Bahonar University of Kerman, Kerman, Iran

Abstract

Cherry Junction Trees are powerful graphical models used to capture dependencies in high-dimensional data. This article explores the structure and special cases of Cherry Junction Trees, including C-Vine and D-Vine models. By organizing variables into hierarchical tree structures, these models offer a flexible approach to represent complex relationships and dependencies. We discuss how Cherry Junction Trees are constructed, their unique features, and their ability to model non-linear, asymmetric dependencies through copula functions. Finally, we examine their practical applications in fields such as statistics and data science.
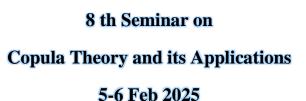
On the Weighted Copula Extropy

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Absrtact

In this paper, we propose a novel uncertainty measure, termed weighted copula extropy, which generalizes the concept of copula extropy by integrating a weighting scheme into the density copula framework. This measure offers enhanced flexibility in quantifying uncertainty, particularly in scenarios where specific dependencies within multivariate distributions necessitate prioritized analysis. We derive closed-form expressions for the weighted copula extropy for several widely used copula functions, including the product copula, iterated Farlie-Gumbel-Morgenstern (FGM) copula, and Nelsen's polynomial copula. These analytical results provide a theoretical foundation for applying the proposed measure in various statistical and probabilistic contexts, enabling more precise and tailored uncertainty assessment in complex systems.

COPULA-BASED TOTAL VARIATION DISTANCE AS A ROBUST DEPENDENCY MEASURE

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Abstract

Total variation distance (TVD) measures the discrepancy between two probability distributions. This paper proposes a copula-based approach to measure dependency using TVD. The proposed method leverages the copula density to estimate TVD, providing a robust dependency measure. Asimulation study is conducted to evaluate the performance of the proposed estimator. The results demonstrate that the suggested method outperforms existing approaches regarding accuracy and efficiency.

Keywords: Total variation distance, Copula density, Dependency measure.

Modeling of Spatial Survival Function with Archimedean Copula

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Abstract

One of the critical issues in survival data analysis is the investigation of risk factors affecting the survival time of subjects. Conventional survival analysis methods are based on the independence of survival times. However, survival times are somehow interdependent in some practical problems, such as investigating infectious diseases in an area. Suppose this dependence is a function of the position of the subjects in the spatial region under study. In that case, such data are called spatial survival times, and it is necessary to identify the structure of data dependence and consider it in data analysis. In addition, survival data usually include types of censoring, and their distribution is skewed. The Cox model is the most common for fitting survival data in survival analysis methods. The use of this model requires the independence of survival data. Using the Cox model for correlated survival data can cause incorrect analysis and misleading decision-making if it is incorrectly recognized or ignored.

Usually, fragility models are used to introduce unknown risk factors into the survival model, in which a random variable with positive support is introduced into the Cox model. One unknown factor affecting survival data is the spatial location of the observations. A spatial hazard function accounts for the spatial correlation of data by assuming a random field. Since observations are usually unavailable for this random field and its distribution is skewed, this article presents the survival function modeling of survival data using the spatial pairwise Archimedean copula function and the analysis of spatial survival data. For this purpose, the parameters of the spatial survival model are estimated using a two-stage method. Then, the performance of the proposed model is numerically evaluated in a simulation study. Then, the application of the proposed model to analyze data on olive trees will be shown.

Keywords: Spatial survival function, Archimedean copula function, Two-stage maximum likelihood estimation method.

TIME SERIES CLUSTERING BASED ON COPULA FUNCTION

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Abstract

Clustering time series based on dependence structures has emerged as a critical tool in finance, risk management, and biology. Clustering aims to group financial time series with similar behavior. Traditional methods may not work well when the focus is on extreme events, as they primarily rely on correlations that fail to capture tail dependencies. Copula-based clustering, which isolates multivariate dependencies from marginal distributions, offers signi_cant advantages when analyzing extreme events or nonlinear relationships. In finance, extreme events often involve strong co-movements between different assets. This co-movement is termed tail dependence. This clustering procedure uses the time series' tail dependence behaviour, measured via a suitable copula function, and the dissimilarity matrix is based on tail dependence coefficients estimated by the copula function. This article synthesizes methodologies, insights, and applications from three key studies to present a cohesive narrative on advancements in copula-based time series clustering. A simulation study shows the properties of the dissimilarity based on tail dependence coefficients, and an application to financial data is presented.

Keywords: Cluster analysis, Copula function, Dissimilarity, Tail dependence.

THE ROLE OF COPULA FUNCTIONS IN MEDICAL DATA ANALYSIS AND HEALTHCARE STUDIES

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Abstract

Copulas are widely applied in medical and healthcare studies to model complex dependence structures in multivariate health data, such as correlated outcomes among patients or multiple health events. They enable flexible modeling by separating the marginal distributions from their dependence structure, capturing indices like tail dependence or asymmetry. In this talk, we review some applications of copulas and dependence measures in medical and healthcare studies, such as their applications in modeling joint survival times, handling censored data in clinical trials, improving accuracy prediction models by capturing non linear relationships, Frailty models, etc. These applications highlight the vast application of copulas in addressing complex dependencies and improving the analysis of multivariate health data.

Keywords: Copula, healthcare data, Cox model, Survival analysis.

STOCHASTIC COMPARISON OF PARALLEL SYSTEMS WITH HETEROGENEOUS DEPENDENT GOMPERTZ-G COMPONENTS

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Abstract

This manuscript investigates the stochastic comparisons of the largest order statistics from dependent and heterogeneous Gompertz-G family of distributions observations. We obtain the usual stochastic order for the largest order statistic of samples having Gompertz-G model and Archimedean copulas.

Keywords: Gompertz-G distribution, Majorization, Usual stochastic order, extreme order statistics, Archimedean copula.

USUAL STOCHASTIC ORDER OF SERIES SYSTEMS WITH DEPENDENT AND HETEROGENEOUS WEIBULL COMPONENTS

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Abstract

This paper studies series systems composed of m dependent subsystems consisting of dependent and heterogeneous Weibull components. The components dependence is modelled by Archimedean copulas. The paper provides sufficient conditions for comparing two series systems stochastically, when the vector of the scale parameters of the first system majorizes the vector of the scale parameters of the second one. In addition, the systems are compared when the vectors of the number of components in each subsystem of the systems are different. The paper also provides a numerical example to illustrate the theoretical results.

Keywords: Mixture models, Usual stochastic order, Proportional odds model.