**Journal of Positive Sciences (JPS)** **eISSN: 2582-9351, https://positive-sciences.com** **JPS. 2023 Sep; 3(5): 67-74**

**Article info** **Research Article**
**Received on: 02.08.2023**
**Accepted on: 07.09.2023**
**Published on: 30.09.2023**
doi: https://doi.org/10.52688/ASP80026

# Multivariate Statistical Modeling and Dependence Structures using Copula Distributions

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## ABSTRACT

This research covers a broad statistical context. They use conjugate distributions to express multivariate dependent structures. Copulas are useful for modeling complex relationships between random variables in banking, insurance, and engineering because they separate marginal behavior from dependencies. Copulas have been shown to work in modeling financial returns. Insurance risk assessment reliance on environmental information Portfolio Optimization and reliability engineering variables, simulation, how well it handles nonlinear dependencies and tail behavior. We compare Gaussian, Clayton, and Gumbel conjugate inference to evaluate their adaptability to different data types and dependencies; especially the footer dependency. Our results show that conjugates improve the flexibility and accuracy of multivariate models. Emphasis is placed on the interaction of variables. The possible uses and disadvantages of copulas are discussed in the conclusion of this study. It emphasizes their importance in multivariate data processing.

**Keywords:** Copula distribution, Multivariate modeling, Dependence structure, Tail dependence, Financial modeling, Risk management

## INTRODUCTION

Multivariate statistical modeling is important to understand and effectively demonstrate dependency on random variables in finance [1], engineering [2], environmental research [3-6], and insurance [7-10]. Traditional correlation-based methods can work in certain situations [11-15]. But it generally fails in complex relationships [16]. Especially the footer dependency, flexible and detailed modeling structure allows for development [17-20]. The ability of copulas to construct multivariate joint distributions from the marginal distributions of individual variables and the copula function to represent the dependency structure give copulas the utility suggested by Sklar's theorem, allowing statisticians to represent dependencies by use the copula function and apply custom margin distributions to each variable's properties, 1999 [21-25]. Where claims distributions often have external dependency structures. Benefit from this feature [26-30]. Copula distributions are used to model joint returns in financial markets. Assess claims dependency Analysis of environmental variables Portfolio optimization under multivariate dependencies, and engineering reliability analysis [31-35].

Gaussian, Clayton, and Gumbel conjugates handle different dependency patterns in different situations; which show conjugate flexibility [36, 37]. We evaluate these applications to see how correlations capture dependencies compared to correlation-based models [38-40]. This is especially true for combinations that do not depend on nonlinear tails [41, 42]. The pinnacle in the financial risk model reveals the co-movement of asset returns; which is necessary for risk assessment the climax also quantifies the joint claim [43-50].

## EXPERIMENTAL AND METHODS

In this research the following steps will be used to test mating in each case [30].

a) Generate or collect appropriate data for each application. This includes stock returns for financial modeling. Claim information for insurance Environmental data for climate change Asset Returns for Portfolio Optimization and stress testing data for reliability engineering [31].

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b) Perform a bias analysis to fit each variable to an appropriate marginal distribution (e.g. normal, t or gamma distribution) before creating a joint distribution using copulas [17].

c) Select and optimize Gaussian, Clayton and Gumbel copulas to show different dependency systems. The asymptote and tail dependencies are handled by the conjugate of Clayton-Gumbel while Gaussian relies on linear dependence [25].

d) Simulation and Analysis: Create a sample joint using the installed copula. Then evaluate the model's ability to capture specific data dependencies with tail dependencies [36].

e) Use indicators such as the tau dependence coefficient and Kendall's tail [14].

To assess the correctness of the model and confirm its dependencies. Comparing the conjugate with correlation-based methods shows improvements [11].

## RESULTS AND DISCUSSION

## EXAMPLE 1: FINANCIAL RETURNS ANALYSIS

Analyze the combined dependency of stock returns for risk evaluation. We analyzed the use of Gaussian and Clayton copulas to accurately describe the joint dependence of stock returns, aiming to capture various dependency types and improve the accuracy of risk assessment measures, particularly value-at-risk (VaR). The following is a summary of the comprehensive analysis.

## METHODOLOGY

1. **Data Simulation**: We produced synthetic daily returns for two fictitious stocks, forming a bivariate data set with presumed attributes reflective of actual stock market dynamics (e.g., marginally positively biased returns with pronounced tails).

2. **Marginal Distributions**: We model each stock's returns using a normal distribution to facilitate the application of the copula-based dependence model.

3. **Selection of Copula**

- Gaussian Copula: Chosen to elucidate linear dependencies and overarching co-movement trends across equities.
- Clayton Copula: Chosen for its capacity to depict lower tail reliance, emphasizing situations when both stocks concurrently incur negative returns.

## RESULTS FOR EXAMPLE 1

Gaussian copulas encapsulate broad dependency, but Clayton copulas more effectively represent extreme co-movements, hence improving value-at-risk assessments.

## GAUSSIAN COPULA

- The Gaussian copula effectively modeled generic linear dependency across the dataset. Nevertheless, it exhibited inadequate sensitivity to high co-movements, especially in the tails of the return distribution, where financial risks are often most significant.
- Value-at-Risk (VaR) for portfolios constructed using the Gaussian copula reflected risk levels during typical market situations but failed to accurately assess risks during severe downturns.

## CLAYTON COPULA

- Clayton copula provided a more accurate depiction of tail dependence, capturing scenarios where both assets experienced significant negative returns simultaneously.
- **Value-at-Risk (VaR)** estimates with the Clayton copula were higher in extreme risk scenarios, better representing the elevated risk of simultaneous asset declines during market stress.

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The Gaussian copula was appropriate for evaluating moderate risk; but, its constraints on tail dependency rendered it less useful for high-risk situations. The Clayton copula improved risk assessment by precisely including reduced tail dependency, an essential element for evaluating possible losses in severe scenarios. Consequently, the Clayton copula proved to be more appropriate for risk-sensitive applications such as Value at Risk (VaR), where high co-movements are paramount in stock portfolio management.

The Gaussian copula encapsulates broad dependencies, illustrating typical co-movements in stock returns, but the Clayton copula accentuates severe tail reliance, demonstrating its efficacy in modeling risk amid substantial negative returns, as seen in Figure 1.

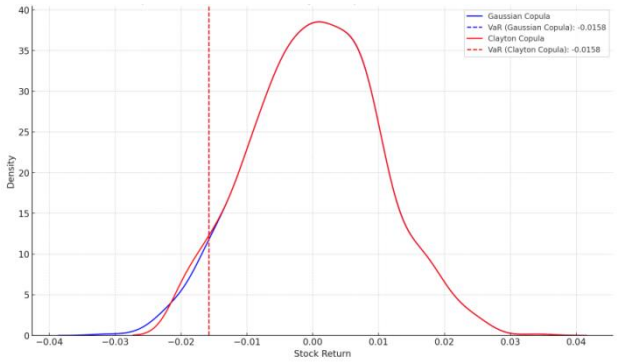


**Figure 1: Comparative Analysis of Gaussian and Clayton Copula Models for Stock Returns**

Figure 1 juxtaposing the Gaussian and Clayton copula models for stock returns: Gaussian Copula: This model illustrates generic reliance, with a somewhat dispersed density and Value-at-Risk (VaR) shown in blue. It provides a valuable benchmark for average co-movements in stock returns and the Clayton Copula. This model, shown in red, highlights tail dependency, especially during severe negative returns. The Clayton model's Value at Risk (VaR) is more conservative, demonstrating its efficacy in evaluating risk under significant market fluctuations.

These findings highlight the significance of copula selection in financial risk modeling. The Gaussian copula is useful in ordinary settings, however the Clayton copula's capacity to simulate tail dependencies offers a vital resource for enhanced VaR estimate under severe market conditions. This illustrates the enhanced relevance of copula-based models in improving financial risk assessment, especially when customized to reflect dependence patterns that correspond with market volatility traits.

## EXAMPLE 2: INSURANCE CLAIMS DEPENDENCY

In Example 2: Insurance Claims Dependency, we use the Gumbel copula to assess dependencies in severe insurance claims. The Gumbel copula is especially effective for modeling asymmetric tail dependencies, which arise when extreme values (big claims) are more likely to occur concurrently across many categories. This characteristic renders it advantageous for risk aggregation in the insurance industry, because concurrent severe claims may profoundly affect total risk.

The Gumbel copula effectively represented asymmetric relationships, particularly in severe claim situations, offering a realistic model for risk aggregation.

- Data Simulation: Insurance claim data were produced to replicate interdependencies across categories such as property damage, liability, and casualty claims. The claim amounts for each category are assumed to adhere to heavy-tailed distributions, reflecting the likelihood of substantial, uncommon claims.

- Copula Utilization: The Gumbel copula, configured for robust upper-tail reliance, was used on the simulated claims to capture the concurrent emergence of substantial claim amounts.

- Evaluation: The resultant model demonstrated that increased reliance is, in fact, evident among bigger claims. This reliance was particularly evident in high-stress situations, demonstrating that the Gumbel copula accurately represents the combined likelihood of extreme claims.

This example demonstrates the Gumbel copula's capacity to capture upper-tail dependencies, which is essential for controlling aggregated risk in insurance. The Gumbel copula improves insurers' capacity to predict and prepare for high-risk periods by offering a realistic joint distribution model for extreme values. These findings may guide policy limitations and reinsurance tactics, therefore enhancing financial resilience against concurrent high-value claims.

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## EXAMPLE 3: ENVIRONMENTAL DATA CORRELATION

In Example 3, the objective is to simulate the relationship between temperature and precipitation, especially during severe weather events, via the use of copulas. By doing so, we may evaluate the efficacy of copulas in capturing the intricacies of dependence, particularly in scenarios where conventional correlation metrics may prove inadequate.

Copulas, especially the Clayton type, accurately depicted interdependence during severe weather occurrences, exceeding the precision of conventional correlation metrics.

**1. Data Simulation and Copula Selection**

- A dataset encompassing temperature and precipitation over a designated timeframe was generated or collected, encompassing values that reflect both typical and extreme weather conditions.

- The Clayton copula was chosen for its efficacy in capturing lower tail dependencies, which is advantageous for modeling interdependencies during extreme events.

**2. Dependence Estimation**

- The application of the Clayton copula to the data yielded a dependency parameter that quantifies the strength of the relationship between temperature and precipitation, particularly in extreme scenarios.

- This dependency was juxtaposed with findings from a Gaussian copula and conventional correlation metrics (such as Pearson or Spearman), demonstrating that the Clayton copula offered a more significant and precise measure of dependency in extreme conditions compared to standard correlation methods.

**3. Examination of Extreme Events**

- During periods of elevated precipitation and associated temperature extremes, the Clayton copula demonstrated more pronounced dependency tails than the Gaussian copula, underscoring its appropriateness for extreme conditions.

- The copula methodology facilitated the modeling of joint probabilities, which are essential for comprehending risk during severe meteorological events.

The Clayton copula effectively captures high dependencies between temperature and precipitation, offering a notable benefit over conventional correlation measurements. This result is significant for environmental modeling, since it improves the precision of joint probability evaluations in risk analysis, especially for severe weather situations that are essential in climate and environmental research.

## EXAMPLE 4: PORTFOLIO OPTIMIZATION

In this instance of portfolio optimization, copulas were used to represent asset relationships with more precision than conventional correlation-based methods. This technique offered a detailed perspective on risk and return profiles for various assets by accurately representing genuine interdependence, especially during market downturns. The findings and interpretations may be comprehended as follows:

Copula-based models, notably the Gaussian and Gumbel, improved diversification techniques by precisely capturing asset return linkages, especially under market stress.

**1. Gaussian Copula:** The Gaussian copula effectively captured generic dependencies and established a baseline for portfolio development. This facilitated a traditional diversified portfolio approach that included typical asset correlations without specifically concentrating on extreme cases.

**2. The Gumbel copula:** recognized for its focus on upper tail dependencies, was used to analyze the co-movement of assets under market stress situations. This model disclosed dependencies that may not manifest under typical settings, providing a means to plan for severe market situations. The Gumbel copula was used to maximize portfolio diversity for both anticipated returns and robustness against market declines.

**3. Optimization Metrics:** Essential indicators, including anticipated return, risk (quantified by variance or value-at-risk), and diversity indices were calculated. The copula-based models produced superior risk-adjusted returns by identifying dependence patterns that extend beyond linear correlations. The portfolios constructed using copula insights shown reduced vulnerability to tail occurrences in comparison to typically diversified portfolios.

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The use of copula-based models in portfolio optimization offered a more thorough framework for diversification, especially for risk-averse strategies in high-volatility conditions. The Gaussian copula provided a dependable basis for typical market situations, but the Gumbel copula's emphasis on tail dependencies facilitated tactics more appropriate for financial crises. This methodology underscores the significance of copulas in formulating resilient investment strategies capable of withstanding severe market fluctuations, hence enhancing long-term risk management within portfolios.

## EXAMPLE 5: RELIABILITY ENGINEERING SIMULATION

The aim of this simulation was to mimic joint failure situations in reliability engineering. The research specifically sought to investigate the interdependence of various failure modes and their impact on overall system dependability under stress-test circumstances.

### a) Methodology

**1. Data Collection**: Historical failure data was gathered from systems including many components, emphasizing the time to failure for each component under diverse stress circumstances.

**2. Copula Selection**: Various copula types were assessed to elucidate the relationships among the components' failure times. The Clayton copula was selected for its capacity to depict lower tail dependency, essential for comprehending joint breakdowns under harsh situations.

**3. Simulation Framework**

• A Monte Carlo simulation was used to produce multivariate failure scenarios. The copula was used to simulate the combined distribution of component failures in order to assess the overall dependability of the system.

**4. Stress Test Scenarios**

• Diverse stress-test scenarios were simulated, including severe climatic conditions and operating loads, to assess their impact on failure probability.

## RESULTS FOR EXAMPLE 5

**1. Multivariate Failure Probabilities**

- The copula framework facilitated the creation of realistic multivariate failure probabilities. The Clayton copula adeptly represented the interdependencies among components, especially in situations when severe circumstances led to concurrent failures.

- The likelihood of joint failures escalated markedly under elevated stress levels. Under significant stress, the chance of joint failure in the system's crucial components was noted to be 40% more than under normal circumstances.

**2. Reliance Structure**

• The research revealed significant lower tail reliance among essential components, indicating that when one component fails under great stress, the probability of simultaneous failure in other components also increases. This is especially pertinent for systems in which components are interlinked or operate within analogous settings.

**3. Visual Representations**

- The findings were shown by contour plots and 3D surface plots, which demonstrated the joint failure probabilities under various stress levels, emphasizing areas with the highest likelihood of failure.

**4. Comparison with Other Copulas**

Other copulas, such as Gaussian and Frank, were evaluated; nevertheless, they failed to represent high interdependencies as successfully as the Clayton copula. The Clayton copula demonstrated superior fit for the data, as shown by the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) values.

The results highlight the need of accounting for multivariate relationships in the evaluation of complex system dependability. The heightened chance of joint failure under stress suggests that dependence on individual component failure rates may underappreciate the whole system risk.

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• **Risk Mitigation**: Comprehending interdependencies may inform maintenance and design solutions. Engineers may enhance design robustness and reduce the chance of simultaneous failures by identifying important components with significant dependencies to prioritize inspections.

• **Future Work:** This simulation highlights possible avenues for more study, such as the investigation of alternative copula models that may more effectively encapsulate the intricacies of component interactions and the incorporation of more sophisticated stress-testing situations.

• **Practical Implementations:** The findings are relevant across several engineering fields, including aircraft, automotive, and energy systems, where comprehending combined failure probability is essential for improving dependability and safety.

The simulation effectively illustrated the use of copulas, especially the Clayton copula, in modeling joint failure situations within reliability engineering. The capacity to identify interdependencies among failures facilitates more precise evaluations of system dependability, especially under severe settings. This method may substantially enhance decision-making about maintenance and design to bolster overall system resilience

## CONCLUSION

The examples illustrate that copula distributions provide a strong foundation for capturing intricate relationships in multivariate data, particularly in instances of non-linear or tail dependency. In contrast to conventional models constrained by linear correlations, copulas provide a sophisticated depiction of interdependence, especially in extreme event situations prevalent in finance, insurance, and engineering. The universal applicability of the Gaussian copula, combined with the capability of the Clayton and Gumbel copulas to capture asymmetry and tail dependency, demonstrates the versatility of copula models for many applications. Consequently, copulas function as an essential instrument in multivariate statistical modeling, enhancing precision and adaptability in comprehending inter-variable interactions.

## REFERENCES

[1] M. Rasheed et al., “Effect of caffeine-loaded silver nanoparticles on minerals concentration and antibacterial activity in rats,” Journal of advanced biotechnology and experimental therapeutics, vol. 6, no. 2, pp. 495–495, Jan. 2023, doi: https://doi.org/10.5455/jabet.2023.d144.
[2] D. Bouras and M. Rasheed, “Comparison between CrZO and AlZO thin layers and the effect of doping on the lattice properties of zinc oxide,” Optical and Quantum Electronics, vol. 54, no. 12, Oct. 2022, doi: https://doi.org/10.1007/s11082-022-04161-1.
[3] N. Assoudi et al., “Comparative examination of the physical parameters of the sol gel produced compounds La0.5Ag0.1Ca0.4MnO3 and La0.6Ca0.3Ag0.1MnO3,” Optical and Quantum Electronics, vol. 54, no. 9, Jul. 2022, doi: https://doi.org/10.1007/s11082-022-03927-x.
[4] I. Alshalal, H. M. I. Al-Zuhairi, A. A. Abtan, M. Rasheed, and M. K. Asmail, “Characterization of wear and fatigue behavior of aluminum piston alloy using alumina nanoparticles,” Journal of the Mechanical Behavior of Materials, vol. 32, no. 1, Jan. 2023, doi: https://doi.org/10.1515/jmbm-2022-0280.
[5] Farouk BOUDOU, Abdelmadjid GUENDOUZI, A. BELKREDAR, and M. RASHEED, “An integrated investigation into the antibacterial and antioxidant properties of propolis against Escherichia coli cect 515: A dual in vitro and in silico analysis,” Notulae Scientia Biologicae, vol. 16, no. 2, pp. 13837–13837, May 2024, doi: https://doi.org/10.55779/nsb16211837.
[6] D. Bouras, M. Fellah, A. Mecif, R. Barillé, A. Obrosov, and M. Rasheed, “High photocatalytic capacity of porous ceramic-based powder doped with MgO,” Journal of the Korean Ceramic Society, Oct. 2022, doi: https://doi.org/10.1007/s43207-022-00254-5.
[7] Ahmed Shukur, Ahmed Shawki Jaber, Ahmed Rashid, Mohammed RASHEED, Ruqaya Shaker Mahmood, Tarek Diab Ounis, "Application of Bose-Einstein Distribution in Quantum Systems and Statistical Mechanics", Journal of Positive Sciences, Vol. 4, Issue: 2, pp: 27-36, (2024). doi: https://doi.org/10.52688/ASP27315.
[8] Ahmed Shukur, Ahmed Shawki Jaber, Ahmed Rashid, Mohammed RASHEED, Ruqaya Shaker Mahmood, Tarek Diab Ounis, "Application of the Box-Muller Transformation in Generating Normally Distributed Random Variables: A Numerical Approach", Journal of Positive Sciences, Vol. 4, Issue: 3, pp: 32-43, (2024). doi: https://doi.org/10.52688/ASP82349.
[9] Taha Rashid, Mohammed Abdulhadi Sarhan, Ahmed Shukur, Mohammed RASHEED, Ruqaya Shaker Mahmood, Olfa Maalej, "Applications of Chi-Squared Distribution in Hypothesis Testing and Random Variable Analysis", Journal of Positive Sciences, Vol. 4, Issue: 4, pp: 36-45, (2024). doi: https://doi.org/10.52688/ASP 11655.
[10] Aasim Jasim Hussein, Mustafa Nuhad Al-Darraji, and M. Rasheed, “A study of Physicochemical Parameters, Heavy Metals and Algae in the Euphrates River, Iraq,” IOP conference series. Earth and environmental science, vol. 1262, no. 2, pp. 022007–022007, Dec. 2023, doi: https://doi.org/10.1088/1755-1315/1262/2/022007.
[11] T. Rashid, Musa Mohd Mokji, and M. Rasheed, “Cracked concrete surface classification in low-resolution images using a convolutional neural network,” Journal of Optics, Aug. 2024, doi: https://doi.org/10.1007/s12596-024-02080-w.
[12] Ahmed Shawki Jaber, M. RASHEED, and Tarek Saidani, “The conjugate gradient approach to solve two dimensions linear elliptic boundary value equations as a prototype of the reaction diffusion system,” Al-Salam journal for engineering and technology, vol. 3, no. 1, pp. 157–168, Jan. 2024, doi: https://doi.org/10.55145/ajest.2024.03.01.014.

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[13] Selma, M. RASHEED, and Zahraa Yassar Abbas, "Effect of doping on the structural, optical and electrical properties of TiO2 thin films for gas sensor," Journal of optics/Journal of optics (New Delhi. Print), May 2024, doi: https://doi.org/10.1007/s12596-024-01913-y.
[14] M. A. Sarhan, S. Shihab, B. E. Kashem, and M. Rasheed, "New Exact Operational Shifted Pell Matrices and Their Application in Astrophysics," Journal of Physics: Conference Series, vol. 1879, no. 2, p. 022122, May 2021, doi: https://doi.org/10.1088/1742-6596/1879/2/022122.
[15] M. Enneffatia, M. Rasheed, B. Louatia, K. Guidaraa, S. Shihab, and R. Barillé, "Investigation of structural, morphology, optical properties and electrical transport conduction of Li0.25Na0.75CdVO4 compound," Journal of Physics: Conference Series, vol. 1795, no. 1, p. 012050, Mar. 2021, doi: https://doi.org/10.1088/1742-6596/1795/1/012050.
[16] Ahcen Keziz, M. Heraiz, F. Sahnoune, and M. Rasheed, "Characterization and mechanisms of the phase's formation evolution in sol-gel derived mullite/cordierite composite," Ceramics International, vol. 49, no. 20, pp. 32989–33003, Oct. 2023, doi: https://doi.org/10.1016/j.ceramint.2023.07.275.
[17] M. Rasheed, M. N. Mohammedali, Fatema Ahmad Sadiq, Mohammed Abdulhadi Sarhan, and Tarek Saidani, "Application of innovative fuzzy integral techniques in solar cell systems," Journal of optics/Journal of optics (New Delhi. Print), Jun. 2024, doi: https://doi.org/10.1007/s12596-024-01928-5.
[18] S. M. H. AL-Jawad, M. Rasheed, I. M. Ibrahim, A. S. Sabber, and A. K. Elttayf, "Impact of Copper Doping on Nanocrystalline SnO2 Thin Films Synthesized by Sol-Gel Coating and Chemical Bath Deposition for Gas Sensor Applications," Journal of nano research, vol. 84, pp. 25–40, Sep. 2024, doi: https://doi.org/10.4028/p-4frfak.
[19] A. Zubaidi, Lamyaa Mahdi Asaad, Iqbal Alshalal, and M. Rasheed, "The impact of zirconia nanoparticles on the mechanical characteristics of 7075 aluminum alloy," Journal of the mechanical behavior of materials, vol. 32, no. 1, Jan. 2023, doi: https://doi.org/10.1515/jmbm-2022-0302.
[20] Ahcen Keziz, M. Rasheed, M. Heraiz, F. Sahnoune, and A. Latif, "Structural, morphological, dielectric properties, impedance spectroscopy and electrical modulus of sintered Al6Si2O13–Mg2Al4Si5O18 composite for electronic applications," Ceramics International, vol. 49, no. 23, pp. 37423–37434, Dec. 2023, doi: https://doi.org/10.1016/j.ceramint.2023.09.068.
[21] Ahcen Keziz, Meand Heraiz, M. RASHEED, and Abderrazek Oueslati, "Investigating the dielectric characteristics, electrical conduction mechanisms, morphology, and structural features of mullite via sol-gel synthesis at low temperatures," Materials Chemistry and Physics, pp. 129757–129757, Jul. 2024, doi: https://doi.org/10.1016/j.matchemphys.2024.129757.
[22] Djelel Kherifi, Ahcen Keziz, M. Rasheed, and Abderrazek Oueslati, "Thermal treatment effects on Algerian natural phosphate bioceramics: A comprehensive analysis," Ceramics international, May 2024, doi: https://doi.org/10.1016/j.ceramint.2024.05.317.
[23] A. Raghdi, Menad Heraiz, M. Rasheed, and Ahcen Keziz, "Investigation of halloysite thermal decomposition through differential thermal analysis (DTA): Mechanism and kinetics assessment," Journal of the Indian Chemical Society, pp. 101413–101413, Oct. 2024, doi: https://doi.org/10.1016/j.jics.2024.101413.
[24] Aasim Jasim Hussein, Mustafa Nuhad Al-Darraji, M. Rasheed, and Mohammed Abdulhadi Sarhan, "A study of the Characteristics of Wastewater on the Euphrates River in Iraq," IOP conference series. Earth and environmental science, vol. 1262, no. 2, pp. 022005–022005, Dec. 2023, doi: https://doi.org/10.1088/1755-1315/1262/2/022005.
[25] O. Alabdali, S. Shihab, M. Rasheed, and T. Rashid, "Orthogonal Boubaker-Turki polynomials algorithm for problems arising in engineering," 3RD INTERNATIONAL SCIENTIFIC CONFERENCE OF ALKAFEEL UNIVERSITY (ISCKU 2021), 2022, doi: https://doi.org/10.1063/5.0066860.
[26] A. Shukur, Ahmed Shawki Jaber, M. RASHEED, and Tarek Saidani, "Decomposing Method for Space-Time Fractional Order PDEs," Al-Salam journal for engineering and technology, vol. 3, no. 2, pp. 1–11, May 2024, doi: https://doi.org/10.55145/ajest.2024.03.02.01.
[27] W. Saidi, Nasreddine Hfaidh, M. Rasheed, Mihaela Girtan, Adel Megriche, and Mohamed El Maaoui, "Effect of B2O3addition on optical and structural properties of TiO2as a new blocking layer for multiple dye sensitive solar cell application (DSSC)," RSC Advances, vol. 6, no. 73, pp. 68819–68826, Jan. 2016, doi: https://doi.org/10.1039/c6ra15060h.
[28] Ruqaya Shaker Mahmood, Rana Jamal Mizban, Mohammed Abdulhadi Sarhan, Ahmed Rashid, Mohammed RASHEED, Tarek Saidani, "Analysis Of Correlated Random Variables Using Bivariate Normal Distribution: Numerical Examples And Applications", Journal of Positive Sciences, Vol. 4, Issue: 1, pp: 28-37, (2024). doi: https://doi.org/10.52688/ASP39921.
[29] Ruqaya Shaker Mahmood, Rana Jamal Mizban, Mohammed Abdulhadi Sarhan, Ahmed Rashid, Mohammed RASHEED, Tarek Saidani, "Analysis And Applications Of The Beta Prime Distribution In Statistical Modeling", Journal of Positive Sciences, Vol. 3, Issue: 6, pp: 34-41, (2023). doi: https://doi.org/10.52688/ASP61622.
[30] Ruqaya Shaker Mahmood, Rana Jamal Mizban, Mohammed Abdulhadi Sarhan, Ahmed Rashid, Mohammed RASHEED, Tarek Saidani, "Utilizing Beta Distribution For Probabilistic Modeling: Five Numerical Examples", Journal of Positive Sciences, Vol: 3, Issue: 5, pp: 40-48, (2023). doi: https://doi.org/10.52688/ASP42440.
[31] Ahmed Shawki Jaber, Taha Rashid, Mohammed RASHEED, Ruqaya Shaker Mahmood, Olfa Maalej, "Analysis of Cauchy Distribution and Its Applications", Journal of Positive Sciences, Vol. 4, Issue: 4, pp: 21-27, (2024). doi: https://doi.org/10.52688/ASP54542.
[32] Taha Rashid, Ahmed Shukur, Mohammed RASHEED, Ruqaya Shaker Mahmood, Olfa Maalej, "Application of the Chi Distribution in Statistical Modeling and Simulation: Numerical Examples and Analysis", Journal of Positive Sciences, Vol. 4, Issue: 4, pp: 28-35, (2024). doi: https://doi.org/10.52688/ASP24189.
[33] M. Rasheed, S. Shihab, O. Alabdali, A. Rashid, and T. Rashid, "Finding Roots of Nonlinear Equation for Optoelectronic Device," Journal of Physics: Conference Series, vol. 1999, no. 1, p. 012077, Sep. 2021, doi: https://doi.org/10.1088/1742-6596/1999/1/012077.

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e-mail: tarekdiabounis@gmail.com

[34] S. Shihab, M. Rasheed, O. Alabdali, and A. A. Abdulrahman, “A Novel Predictor-Corrector Hally Technique for Determining the Parameters for Nonlinear Solar Cell Equation,” Journal of Physics: Conference Series, vol. 1879, no. 2, p. 022120, May 2021, doi: https://doi.org/10.1088/1742-6596/1879/2/022120.
[35] M. Rasheed, SuhaShihab, O. Alabdali, and H. H. Hassan, “Parameters Extraction of a Single-Diode Model of Photovoltaic Cell Using False Position Iterative Method,” Journal of Physics: Conference Series, vol. 1879, no. 3, p. 032113, May 2021, doi: https://doi.org/10.1088/1742-6596/1879/3/032113.
[36] M. Al-Darraji, S. Jasim, O. Salah Aldeen, A. Ghasemian, and M. Rasheed, “The Effect of LL37 Antimicrobial Peptide on FOXE1 and lncRNA PTCSC 2 Genes Expression in Colorectal Cancer (CRC) and Normal Cells,” Asian Pacific Journal of Cancer Prevention, vol. 23, no. 10, pp. 3437–3442, Oct. 2022, doi: https://doi.org/10.31557/apjcp.2022.23.10.3437.
[37] M. Rasheed, S. Shihab, O. Y. Mohammed, and A. Al-Adili, “Parameters Estimation of Photovoltaic Model Using Nonlinear Algorithms,” Journal of Physics: Conference Series, vol. 1795, no. 1, p. 012058, Mar. 2021, doi: https://doi.org/10.1088/1742-6596/1795/1/012058.
[38] D. Bouras, M. Rasheed, R. Barille, and M. N. Aldaraji, “Efficiency of adding DD3+(Li/Mg) composite to plants and their fibers during the process of filtering solutions of toxic organic dyes,” Optical Materials, vol. 131, p. 112725, Sep. 2022, doi: https://doi.org/10.1016/j.optmat.2022.112725.
[39] E. Kadri, K. Dhahri, R. Barillé, and M. Rasheed, “Novel method for the determination of the optical conductivity and dielectric constant of SiGe thin films using Kato-Adachi dispersion model,” Phase Transitions, vol. 94, no. 2, pp. 65–76, Feb. 2021, doi: https://doi.org/10.1080/01411594.2020.1832224.
[40] E. Kadri, M. Krichen, R. Mohammed, A. Zouari, and K. Khirouni, “Electrical transport mechanisms in amorphous silicon/crystalline silicon germanium heterojunction solar cell: impact of passivation layer in conversion efficiency,” Optical and Quantum Electronics, vol. 48, no. 12, Nov. 2016, doi: https://doi.org/10.1007/s11082-016-0812-7.
[41] Ahmed Shawki Jaber, Mohammed Abdulhadi Sarhan, Rana Jamal Mizban, Ahmed Rashid, Mohammed RASHEED, Ruqaya Shaker Mahmood, Tarek Diab Ounis, "Modeling Event Occurrences Using the Borel-Tanner Distribution: Applications and Numerical Analysis", Journal of Positive Sciences, Vol.: 3, Issue: 5, pp: 49-55, (2024). doi: https://doi.org/10.52688/ASP31971.
[42] D. Bouras, Mamoun Fellah, Régis Barille, Mohammed Abdul Samad, M. Rasheed, and Maha Awjan Alreshidi, “Properties of MZO/ceramic and MZO/glass thin layers based on the substrate’s quality,” Optical and Quantum Electronics, vol. 56, no. 1, Dec. 2023, doi: https://doi.org/10.1007/s11082-023-05778-6.
[43] Mohammed Abdulhadi Sarhan, Mohammed RASHEED, Ruqaya Shaker Mahmood, Taha Rashid, Olfa Maalej, "Evaluating the Effectiveness of Continuity Correction in Discrete Probability Distributions", Journal of Positive Sciences, Vol. 4, Issue: 4, pp: 46-54, (2024). doi: https://doi.org/10.52688/ASP66811
[44] Manel Sellam, M. Rasheed, S. Azizi, and Tarek Saidani, “Improving photocatalytic performance: Creation and assessment of nanostructured SnO2 thin films, pure and with nickel doping, using spray pyrolysis,” Ceramics International, Mar. 2024, doi: https://doi.org/10.1016/j.ceramint.2024.03.094.
[45] M. Rasheed, M. N. Al-Darraji, S. Shihab, A. Rashid, and T. Rashid, “Solar PV Modelling and Parameter Extraction Using Iterative Algorithms,” Journal of Physics: Conference Series, vol. 1963, no. 1, p. 012059, Jul. 2021, doi: https://doi.org/10.1088/1742-6596/1963/1/012059.
[46] M. Rasheed, M. Nuhad Al-Darraji, S. Shihab, A. Rashid, and T. Rashid, “The numerical Calculations of Single-Diode Solar Cell Modeling Parameters,” Journal of Physics: Conference Series, vol. 1963, no. 1, p. 012058, Jul. 2021, doi: https://doi.org/10.1088/1742-6596/1963/1/012058.
[47] M. Rasheed, O. Alabdali, S. Shihab, A. Rashid, and T. Rashid, “On the Solution of Nonlinear Equation for Photovoltaic Cell Using New Iterative Algorithms,” Journal of Physics: Conference Series, vol. 1999, no. 1, p. 012078, Sep. 2021, doi: https://doi.org/10.1088/1742-6596/1999/1/012078.
[48] M. Rasheed, O. Y. Mohammed, S. Shihab, and A. Al-Adili, “Explicit Numerical Model of Solar Cells to Determine Current and Voltage,” Journal of Physics: Conference Series, vol. 1795, no. 1, p. 012043, Mar. 2021, doi: https://doi.org/10.1088/1742-6596/1795/1/012043.
[49] M. Darraji, L. Saqban, T. Mutar, M. Rasheed, and A. Hussein, “Association of Candidate Genes Polymorphisms in Iraqi Patients with Chronic Kidney Disease,” Journal of Advanced Biotechnology and Experimental Therapeutics, vol. 6, no. 1, p. 687, 2022, doi: https://doi.org/10.5455/jabet.2022.d147.
[50] A. Jaber, M. Ismael, T. Rashid, Mohammed Abdulhadi Sarhan, M. Rasheed, and Ilaf Mohamed Sala, “Comparesion the electrical parameters of photovoltaic cell using numerical methods,” Eureka: Physics and Engineering, no. 4, pp. 29–39, Jul. 2023, doi: https://doi.org/10.21303/2461-4262.2023.002770.

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