5th Annual Innovative Engineering Research Conference: Book of Abstracts

AIERC

2022

Editors: Kavian Cooke, Raluca Lefticaru and Therese Sheehan,

5th

Annual Innovative Engineering Research Conference

Book of Abstracts

Norcroft Auditorium

UNIVERSITY of BRADFORD
Faculty of Engineering & Informatics

Conference Agenda

TIME	EVENT
08:00 - 08:45	Registration
08:45 - 09:00	Welcome and introduction of Programme **Professor Martin Priest**, Dean of the Faculty of Engineering & Informatics – Professor of Tribology **Professor Felician Campean**, Associate Dean of Research & Knowledge Transfer, Faculty of Engineering & Informatics
09:00 - 09:45	KEYNOTE SPEAKER **Ms. Aisha Ahmad**, Smart Grid Engineer, Northern Powergrid. Title: Enhancing the understanding of network losses in the UK
09:45 - 10:00	Coffee break
10.00 - 11.45	Presentation Session 1: Room: Norcroft Auditorium
11.45 - 12.15	3 Minute Thesis Presentations Room: Norcroft Auditorium
12.15 - 13.15	Poster Session, Lunch break and Networking
13.15 - 14.00	KEYNOTE SPEAKER **Professor Susan A Bernal**, University of Leeds Title: Transitioning toward low carbon cements
14.00 - 15.45	Presentation Session 2 Room: Norcroft Auditorium
15:45 - 16:00	Coffee break
16.00 - 16.15	AWARDS CEREMONY **Professor Felician Campean**, Associate Dean of Research & Knowledge Transfer, Faculty of Engineering & Informatics
16.30 - 16.45	CLOSING REMARKS **Dr Kavian Cooke**, Director of Post Graduate Research

Session 1

Chairs: Daniele Scrimieri and Amr Abdullatif

Presentation Room: Norcroft Auditorium

PRESENTER	PRESENTATION TITLE	TIME
Ismail A Mageed and Kit Quichun Zhang	Significant Role of Entropy in Information Theory, Queuing Theory, Engineering, Computer Science and Statistical Mechanics: An Overview	10:00
Francis Lewe	A review into Self-Driving Cars development with a focus on the methods for software testing	10:15
Thabang Selalame, Yakubu John, Rajnikant Patel and Iqbal Mujtaba	FCC riser reactor modelling: Effect of vaporisation models	10:30
Ramsha Ali, Dhaval Thakker, Raluca Lefticaru and Marian Gheorghe	The Role of Indoor Air Quality Ontology Domain Model in the development of COPD self-management system	10:45
Ismail A Mageed and Kit Quichun Zhang	The Entropic Impact in Power Systems-An Overview	11:00
George Kumi Kyeremeh, Mohamed Abdul-Al, Raed Abd-Alhameed, Rami Qahwaji and Nabeel Abduljabbar	Finger vein Recognition	11:15
Aisha Mohammed and Ci Lei	Analytic representations of finite quantum systems based on SU(2) coherent states in the extended complex plane	11:30

Session 2

Chairs: Yakubu John and Sohag Kabir
Presentation Room: Norcroft Auditorium

PRESENTER	PRESENTATION TITLE	TIME
Ali Algaddafi, Philip Drake and Thomas Swift	Developing a Novel Heating Coil with Integration into a Spectrophotometer	14:00
Keamogetse Taziba, Mostafa Mohamed and Therese Sheehan	Vertical Stress Distribution Evaluation of Geosynthetic Reinforced Railway Track Bed Soil Materials: Experimental Investigation	14:15
Martin Harwood	Slowloris – A "Low and Slow" hacking attack tool	14:30
Morteza Sheibani, Savas Konur and Irfan Awan	A Novel Detection and Mitigation Method for DDoS Attacks using Multi-Controller Software-Defined Networking	14:45
Richard Matzko, Laurentiu Mierla and Savas Konur	3D Multicellular Multiscale Simulations as Explored Through Multiple Methodologies For Synthetic Biology	15:00
Mohammad Rezaul Karim	Safety and Security Co-Analyses for IoT EcoSystem	15:15
Xinxin Xu	Numerical Study on Structural Behaviour of Slim-Floor Composite Beams	15:30

Poster Competition

Chair: Therese Sheehan
Room: Norcroft Auditorium

PRESENTER	POSTER TITLE
Ismail A Mageed and Kit Quichun Zhang	Revolutionary Impact of Information Theory and Information Geometry on Traffic Flows with Heavy Tailed Distributions
George Kumi Kyeremeh, Mohamed Abdul-Al, Raed Abd-Alhameed, Rami Qahwaji and Nabeel Abduljabbar	Finger Biometric System
Ruth E. Emberru, Raj Patel, Iqbal. M. Mujtaba, John M. Yakubu	Simulation study of Direct Petroleum Crude Cracking in Conventional Fluid Catalytic Cracking Unit
Hussein Aldaffar and Cuong Dao	Life Cycle Assessment of Multi-Megawatt Floating Offshore Wind Turbines
Mohsin Iqbal, Cuong Dao and Hussein Aldaffar	Offshore wind farm operation modelling and factors affecting the levelised cost of wind energy
Daniele Scrimieri, Omer Adalat, Mohammed Ali Cherif and Muhammad Talal	Automatic Synthesis of Manufacturing Process Controllers

Keynote Speakers

Transitioning toward low carbon cements

Professor Susan A. Bernal
School of Civil Engineering, University of Leeds, UK

ABSTRACT

In the UK, the development, maintenance, repair and replacement of infrastructure account for at least 50% of the national CO2e emissions. A value that is projected to increase in the upcoming decades, as a consequence of the threats posed by climate change to our existing and aged infrastructure. There is also a clear need to provide shelter and better infrastructure to tackle social inequalities as well as adapting to the challenges presented by the global pandemic. We often hear the phrase 'built back better' in a figurative context, but we have the responsibility of making it a reality. The construction sector is currently taking serious actions to become more resilient and sustainable in the years to come, particularly regarding the materials selected for infrastructure development. New policies in resource efficiency, circular economy and carbon management in infrastructure, open a unique opportunity for innovation in construction materials. There is a particular interest in low carbon cements for production of concrete. In this presentation, a brief overview of some of the decarbonisation strategies being proposed to improve sustainability of cement and concrete will be discussed in the context of existing roadmaps and guidelines developed in recent years, in an effort to achieve net-zero by 2050.

Susan Bernal Lopez is Professor of Structural Materials in the School of Civil Engineering at the University of Leeds. She is the Materials and Structures Group Director at this University, serves as co-Director of the EPSRC Transforming Foundation Industries Network Plus and as Deputy Chair of the largest international RILEM Technical Committee - RILEM TC 281-CCC on carbonation of concretes with supplementary cementitious materials. With >15+ years of experience, Prof. Bernal Lopez and her team's research centres on development of solutions for decarbonise future infrastructure including waste valorisation for developing new low carbon cementitious materials; understanding interaction between concrete materials and the environment; development of infrastructure for wellbeing, among others.

Enhancing the understanding of network losses in the UK

Aisha Ahmad
Smart Grid Engineer, Northern Powergrid

ABSTRACT

Within the UK losses in distribution network is particularly important. This presentation will provide an overview of electrical losses, which, in the electricity network operator world, are commonly known as 'losses'. It will address the meaning of 'losses', and answer some of the following questions:

- How much electricity is lost in the UK distribution networks and in Northern Powergrid networks in a year?
- Who pays for losses?
- Why are losses are important to network operators like Northern Powergrid?
- What will happen in the future energy scenario with high penetration of low carbon technologies? Will the losses increase?

In the second half of the talk I will share my personal experience, vantage points and opinions on being a PGR student and being in the energy industry for 10 years.

Aisha Ahmad is a Smart Grid Engineer, Northern Powergrid. She graduated from the University of Warwick B.Eng (Hons) Electrical Engineering in 2001. Spent a couple more years at Warwick to pursue PhD in Electrical Power Systems but did not complete the study. She later joined Northern Powergrid in 2011 as a graduate trainee engineer. Worked as an operational engineer from 2013-2015 in network reinforcement after completed traineeship. Joined the system improvement design team from 2015 – 2018 as a design engineer, focusing on the 11kV network design. From 2018 until now, working as a smart grid development engineer, looking at introducing new technologies, updating company policies and regulatory aspects

Papers presented at the AIERC 2022

Information Geometry? Exercises de Styles

Ismail A Mageed

Department of Computer Science, Faculty of Engineering and Informatics, University of Bradford, Bradford, West Yorkshire, BD7 1DP,UK iammoham@bradford.ac.uk

ORCID 0000-0002-3691-0773

Kit Qichun Zhang
Department of Computer Science, Faculty of Engineering and Informatics, University of Bradford, Bradford, West Yorkshire, BD7 1DP, UK Q.Zhang17@bradford.ac.uk
ORCID 0000-0003-2479-8195

Abstract

Indeed, information geometry, IG is an ever-growing area with a great scope of applications ranging from Probability & Statistics, Machine Learning (ML), Artificial Intelligence (AI), Signal Processing, Mathematical Programming, etc... There is always a great race to distil information from data to models. Since its inception, IG as a concept has been known under a variety of guises and been used in numerous contexts, establishing an almost rock-star status in both sciences and popular culture. The three most prominent “styles” which IG has been (re)told in and which have determined its popularity are Deep Learning, Statistical learning and Machine Learning. Following the footsteps of the relentless hunt for the core of the concept that kindled this underlying development, connections with emergence of time combined with irreversibility, the elegant nature of probability and the generated information which add to its illusiveness as much as simulating its cross-contextual adoption and proliferation. In this review, we search and retrace through the five main perspectives from which IG has been regarded, emphasizing the motivations behind each application, their ramifications as well as the bridges that have been constructed to justify them. Consequently, this analysis of the foundations provides a beautiful panorama of several characteristic traits of the concept that underline its significance and exceptionality as an engine of conceptual progress

Keywords-Survey, information geometry, Geometric Deep Learning, Statistical Learning, Machine Learning.

An Introductory Survey of Entropy Applications to Information Theory, Queueing Theory, Engineering, Computer Science and Statistical Mechanics

Ismail A Mageed
Department of Computer Science, Faculty of Engineering and Informatics, University of Bradford, Bradford, West Yorkshire, BD7 1DP,UK iammoham@bradford.ac.uk

ORCID 0000-0002-3691-0773

Kit Qichun Zhang

Department of Computer Science, Faculty of Engineering and Informatics, University of Bradford, Bradford, West Yorkshire, BD7 1DP, UK Q.Zhang17@bradford.ac.uk
ORCID 0000-0003-2479-8195

Abstract

The credit of uncovering Entropy as a concept refers to Clausius, around 160 years ago. Since that time, there has been an ongoing tireless improvement and interpretation by many researchers in many scientific disciplines. The current paper reviews entropy applications to information theory, queueing theory, engineering, computer science and statistical mechanics. The creation of unified vision of the applicability of classical entropies as well as the provision of a compact detailed explanation which combines conceptual extraction of the most up-to-date literature and technical pertinence are the main goals of this survey. We conclude this review with a representative list of references.

Keywords-Survey, entropy, information theory, queueing theory, engineering, computer science, statistical Mechanics

The Odyssey of Entropy: Power Systems

Ismail A Mageed

Department of Computer Science, Faculty of Engineering and Informatics, University of Bradford, Bradford, West Yorkshire, BD7 1DP,UK iammoham@bradford.ac.uk ORCID 0000-0002-3691-0773

Kit Qichun Zhang

Department of Computer Science, Faculty of Engineering and Informatics, University of Bradford, Bradford, West Yorkshire, BD7 1DP, UK Q.Zhang17@bradford.ac.uk
ORCID 0000-0003-2479-8195

Abstract

Entropy, a measure of disorder and uncertainty has been introduced by Shannon. Since then, several routes of applying entropy to most scientific disciplines were undertaken by many researchers. In this paper, an overview of the applications of entropy principles in power systems is undertaken. Moreover, some suggestions are given for future research on applying entropy principles to power systems.

Keywords-Entropy, applications, power system

The Role of Indoor Air Quality Ontology Domain Model in the Development of COPD Self-Management System

Ramsha Ali
Dept. of Computer Science
Faculty of Engineering & Informatics University of Bradford, Bradford, UK rali51@bradford.ac.uk

Prof. Marian Gheorghe
Dept. of Computer Science
Faculty of Engineering & Informatics University of Bradford, Bradford, UK
m.gheorghe@bradford.ac.uk

Dr. Dhaval Thakker
Dept. of Computer Science
Faculty of Engineering & Informatics University of Bradford, Bradford, UK
d.thakker@bradford.ac.uk

Dr. Raluca Lefticaru
Dept. of Computer Science
Faculty of Engineering & Informatics University of Bradford, Bradford, UK
r.lefticaru@bradford.ac.uk

Abstract

Indoor Air Quality (IAQ) is the primary concern of every individual and specifically since the Covid'19 outbreaks. IoT devices or sensors are used for detecting and monitoring indoor air pollutants. Indoor air pollution has a direct effect on human health in terms of respiratory conditions, cardiovascular problems, and endocrine conditions. There is a recognized need for providing a self-management system to the patients getting affected by respiratory conditions and indoor air pollutants. There has been substantial research undertaken on the role of Indoor air quality monitoring systems. Previous research has indicated a potential association between indoor air quality and a human respiratory health condition such as Chronic Obstructive Pulmonary Disease (COPD). COPD is estimated to be the world's main cause of death. However, the effect of indoor air quality on COPD patients has yet to be understood. The principal finding of this research is the role of an indoor air quality ontology domain model based on the ontology engineering methodology that is Human-Centered Ontology Engineering Methodology (HCOME) in the development of a COPD self-management system.

Keywords
indoor air quality, IoT, respiratory problems, chronic obstructive pulmonary disease, HCOME, ontology domain modelling, self-management systems

A Review into Self-Driving Cars Development with a Focus on the Methods for Software Testing

Francis Lewe

Department of Computer Science, University of Bradford, Bradford, BD7 1DP, UK
f.k.lewe@bradford.ac.uk

Abstract

The development of self-driving vehicles has seen a lot of improvement over the years and this has party been achieved with the advances in software testing. Testing of autonomous vehicles is the only way to ensure that they meet safety and practical requirements. Faults in software can lead an automobile to behave in unexpected ways, therefore pre-emptive testing can identify defects in software before the vehicle is put on the road. This article looks into the previous researches carried out to improve testing of self-driving vehicles, reviews them, analyses the gaps and future improvements. This research is concluded with a table comparing a few search-based software testing articles to show the reader some of the work that has been carried out.

Keywords-Self-driving vehicles; autonomous vehicles; self-driving cars; search-based software testing.

Developing a Novel Magnetic Heating Coil with Integration into a Fluorescence Spectrophotometer

Ali Algaddafi*[1], Philip Drake[1], Thomas Swift[1], and Raed Abd-Alhameed[2]
[1]Faculty of Life Sciences, Department of Chemistry and Biosciences

[2]Faculty of Engineering and Informatics, Department of Biomedical and Electronics Engineering University of Bradford, Richmond Rd, Bradford, BD7 1DP, UK aaalgadd@bradford.ac.uk or ORCID: 0000-0002-1104-2279

Abstract

We have designed a Magnetic Heating Coil (MHC) that heats magnetic nanoparticles via induction. The coil was designed via computational modelling and experimental testing to produce a device small enough to safely insert into a fluorescence spectrophotometer. The specific absorption rate of particles within this coil was measured and shown to sufficiently heat up solutions via induction at various concentrations. A fluorescent dye was then studied to see how the emission properties change with both temperatures (raising the temperature of an adjacent water-cooling system) and via the use of magnetic induction. In this paper, we summarise the principles of MHC therapy. The two coils were used experimentally with two cooling systems (Haake K20 and IKA ICC control pumps). The Haake K20 (equipped with a Haake DC 30 temperature controller) was shown to be a more effective cooling system than the IKA ICC control pump.

Keywords-Fluorescence, Magnetic, Induction, Nanoparticles.

FCC riser reactor modelling: Effect of vaporisation models

Thabang Selalame
Department of Chemical Engineering, Faculty of Engineering and Informatics University of Bradford, Bradford, UK tselalam@bradford.ac.uk

Yakubu M. John
Department of Chemical Engineering, Faculty of Engineering and Informatics University of Bradford, Bradford, UK

Raj Patel
Department of Chemical Engineering, Faculty of Engineering and Informatics University of Bradford Bradford, UK

Iqbal M. Mujtaba
Department of Chemical Engineering, Faculty of Engineering and Informatics University of Bradford, Bradford, UK

Abstract

The aim of this present work is to present a steady-state one dimensional (1D) model for the fluidized catalytic cracking riser considering the vaporisation of the gas oil feed and the cracking reactions occurring thereafter. Evaporation of droplets is studied using three models: classical homogeneous vaporisation model, heterogeneous vaporisation model of Buchanan [1] to account for Leidenfrost effects around the vaporizing droplet, and the heterogeneous model of Nayak et al. [2] that considers direct collisions between vaporizing droplets and catalyst particles. Motion of the droplets was modelled using the Lagrangian framework model for particles, with temporally varying mass, moving through a fluid with non-zero slip. The motion of the droplets was coupled with the Eulerian-Eulerian gas-solid flow field describing the pneumatic conveying of the catalyst in the riser. Cracking reaction kinetics are modelled using a four-lump model. It was demonstrated that the effect of the vaporisation model is largely insignificant at the bottom of the riser as the cracking reactions are usually always the limiting step. This result gives validity to the assumption of instantaneous vaporisation which is commonly used in modelling the riser in the literature. The model of Buchanan [1] was shown to predict intermediate droplet penetration lengths in the riser. The results from the simulation were shown to be in close agreement with the industrial data for the region of interest.

Keywords—FCC riser, Modeling, Simulation, Vaporisation

Analytic representations of finite quantum systems based on SU(2) coherent states in the extended complex plane

Aisha Faraj Abukhzam Mohammed
Department of Computer Science, University of Bradford, UK, afamoham@bradford.ac.uk

Ci Lei
Department of Computer Science, University of Bradford, UK, c.lei1@bradford.ac.uk

Abstract

Quantum systems of finite-dimensional Hilbert spaces are considered. Analytic representation functions of the states in this space, based on SU(2) coherent states in the extended complex plane (stereo-graphically equivalent to a sphere), are created. Zeroes paths for these analytic representation functions, which represent the system's evolution over time, are studied in detail.

Keywords- Analytic representations, Finite dimensional Hilbert space, zeros of analytic functions, extended complex plane, coherent states.

Slowloris – A "Low and Slow" hacking attack tool

Martin Harwood MSc

Department of Computer Science University of Bradford, Bradford, UK mrharwoo@bradford.ac.uk
'

Abstract

Denial of Service (DoS) attacks are a threat to the Availability leg of the CIA triad (Confidentiality, Integrity and Availability). The majority of DoS attacks are based on volumetric attacks, also known as flooding – these utilise high volumes of traffic to overwhelm available bandwidth. A second type of DoS attack is based on protocol attacks, these are similar to volumetric attacks but are fashioned to exhaust local resources such as tcp ports. A third and less commonly known type of DoS attack is a "low and slow" attack, such attacks exploit vulnerabilities in networking or application protocols to cause a denial of service using low bandwidth.
This document focusses on a particular low and slow attack tool called the "Slowloris", it is both an interesting and dangerous attack. It is interesting because it operates unlike most other Denial of Service attack tools. It is dangerous because it is hard to detect.
As part of the research a testbed website was setup and Slowloris attacks launched against it. The research found that machine learning is able to detect Slowloris attacks. While the detection metrics were broadly in line with other research, it was discovered that the Slowloris has numerous variants in circulation with the ability to detect attacks varying between Slowloris variants.

Keywords: Slowloris, Denial of Service, low and slow attack

Numerical Study on Structural Behaviour of Slim-Floor Composite Beams

Xinxin Xu

Supervisor: Xianghe Dai, Dennis Lam

Faculty of Engineering and Informatics, University of Bradford

Abstract

This paper presents the numerical modelling and parametric study in the Composite Slim-Floor Beams. The CoSFB (Composite Slim-Floor beams) is a new type of composite structure in which the key feature is that an asymmetric steel-section with holes in the web is embedded in the infill concrete slab, and the infill concrete (with rebars or not) can pass through the holes in the web. The shear transfer mechanism of CoSFB is dependent on the concrete dowels in the web of steel section, and the internal forces have a complex superposition and redistribution in this composite system. Therefore, the better understand of mechanism between the concrete slab and steel beam is important to develop the investigation of the CoSFB. Related simulations have been conducted, which are the Push-out test of shear connections, shear behavior and flexural behavior of composite slim floor beams, and parametric study has conducted from the simulation results.

Keywords: Composite Slim-Floor beams, Simulation,

Finger vein Recognition

George Kumi Kyeremeh, M. Abdul-Al,., Nabeel Abduljabbar, R. Qahwaji and R.A. Abd-Alhameed

Faculty of Engineering and Informatics, University of Bradford, Bradford, BD7 1DP, UK,
g.k.kyeremeh@bradford.ac.uk; M.Abdul.Al@bradford.ac.uk; n.a.abduljabbar3@bradford.ac.uk; R.A.A.Abd@bradford.ac.uk; R.S.R.Qahwaji@bradford.ac.uk

Abstract

Biometric systems are quickly replacing traditional password authentication solutions. Security and recognition accuracy are the two most important factors to consider when designing a biometric system. Biometric identification is the study of an individual's physiological and behavioral features to solve security and identification challenges. Fingerprint biometrics have been used for a long time, but finger-vein image identification has lately gained traction as a potential biometric technique. Fingerprints have long been a widely accepted biometric for identification, but their flaws and vulnerability to spoofing prompted the development of finger vein biometrics, which were thought to be safer and more dependable. Finger vein recognition (FVR) is a technology in biometric that analyses the patterns of a person's finger veins to authenticate their identity. This article evaluates all aspects of fingerprint and finger vein recognition (FVR), including image acquisition, pre-processing, feature extraction, and matching. An overview of fingerprint and finger vein biometric systems has been presented, along with some benefits and drawbacks. For the development of an auto fingerprint and finger vein identification system, it is critical to extract fingerprint minutiae. Deep learning and algorithms can both be utilized to determine the best ways for feature extraction for fingerprints and finger veins, which will improve the fusion to create a multimodal system.

Keywords—Finger vein, Biometrics, Minutiae, Recognition, Image, Extraction

A Novel Detection and Mitigation Method for DDoS Attacks using Multi-Controller Software-Defined Networking

Morteza Sheibani
Department of Computer Science, Faculty of Engineering and Informatics, University of Bradford
Bradford, UK
m.sheibani@bradford.ac.uk

Savas Konur
Department of Computer Science, Faculty of Engineering and Informatics
University of Bradford, UK, s.konur@bradford.ac.uk

Irfan Awan
Department of Computer Science, Faculty of Engineering and Informatics, University of Bradford
Bradford, UK, i.u.awan@bradford.ac.uk

Abstract

Distributed Denial-of-Service (DDoS) attacks is considered to be an important cause of security issues in 5G mobile networks. In order to control the network in a centralized way and to detect and mitigate the network attacks, Software defined networking (SDN) has been proposed. SDNbased 5G networks equipped with a single (centralized) controller result in some issues regarding scalability and reliability. The use of dispersed controllers seems to be a promising solution to overcome these limitations. Nevertheless, there exist some problems like how to coordinate the processing load among these controllers and how to advance the security aspects of the SDN-based 5G networks using multiple controllers. In this paper, a novel method is proposed to dynamically coordinate the processing load among the dispersed controllers in SDN-based 5G networks. We propose a system that is built based on two levels of controllers: dispersed controllers and a master controller. Managing and grouping of the dispersed controllers as well as decision making for groups' reconstruction (when a controller is overloaded) is the responsibility of the master controller. We further employ the proposed dispersed algorithm in SDN based 5G networks to defend the network against the DDoS attacks. Based on our simulation results, it can be concluded that the proposed method works well in adjusting the processing load among controllers and detection and mitigation of DDoS attacks in SDN-based 5G networks.

Keywords: 5G mobile networks, DDoS attacks, Software Defined Networking, Multiple Controllers.

3D Multicellular Multiscale Simulations As Explored Through Multiple Methodologies For Synthetic Biology

Richard Matzko
Department of Computer Science University of Bradford, Bradford, UK r.matzko@bradford.ac.uk

Laurentiu Mierla
Department of Computer Science University of Bradford, Bradford, UK l.m.mierla@bradford.ac.uk

Savas Konur
Department of Computer Science University of Bradford, Bradford, UK s.konur@bradford.ac.uk

Abstract

Cellular diversity gives rise to specialized function at the phenotypic scale through an assortment of modulated phenomena and metabolic/regulatory profiles, all capable of being manipulated through Synthetic Biology at the genetic level. This work explores this diversity conceptually and begins to apply spatiotemporal simulations for Synthetic Biological CAD prototyping in the multicellular context, including key sub-models such as growth, division, physical interactions and the commencement of metabolic stochastic integration, all in three spatial dimensions and through the implementation of the SBML model exchange standard. As a consequence of the computational demands of such simulations, the following work demonstrated the limitations of using conventional hardware in order to highlight the need for scalable solutions supported by powerful computing capabilities in the domain of multicellular simulation. This work was developed in support of the Infobiotics Workbench Synthetic Biology Suite with extensibility in mind.

Keywords: Synthetic, Biology, Multicellular, Stochastic, Simulation, CAD

Safety and Security Co-Analyses for IoT EcoSystem

Mohammad Rezaul Karim
Department of Computer Science, University of Bradford, UK, mrkarim2@bradford.ac.uk

Abstract

This study outlines an IoT framework, including its information and knowledge structure, fundamental aspects, and safety and security. IoTSan, IotMon, Blockchain, and FTA are addressed to find a unified safety and security solution.
Furthermore, safety and security co-analysis shows that FTA and Blockchain would be better solutions for IoT systems in a collaborative effort. Therefore, a formal approach for dynamic FTA is explored for IoT safety, where Blockchain is evaluated for the security of the IoT system.

Keywords —IoT; Security; Safety; FTA; CPS;

Effect of Geosynthetics on Vertical Stress Distribution and Load Spread Angle on Track Bed Soil Materials: Experimental Study

Keamogetse Taziba
Civil Engineering Dept. Faculty of Engineering and Informatics, University of Bradford, United Kingdom, ktaziba@bradford.ac.uk

Mostafa Mohamed
Civil Engineering Dept., Faculty of Engineering and Informatics,
University of Bradford, United Kingdom, m.h.a.mohamed@bradford.ac.uk

Therese Sheehan
Civil Engineering Dept. Faculty of Engineering and Informatics, University of Bradford
United Kingdom t.sheehan@bradford.ac.uk

Abstract

This experimental study evaluates the effect of geosynthetics on vertical stress distribution and load spread angle on track bed materials, using a small-scale testing tank.
The bearing capacity of reinforced individual and coupled track bed materials is compared. It was found that the inclusion of geosynthetics improves the bearing capacity of track bed materials and the load spread angle. The inclusion of geosynthetic also increased the load spread angle, spreading over a larger surface area.

Keywords —geosynthetics, railway track bed, vertical stress distribution, load spread angle

Developing a Novel Magnetic Heating Coil with Integration into a Fluorescence Spectrophotometer

Ali Algaddafi*[1], Philip Drake[1], Thomas Swift[1], and Raed Abd-Alhameed[2]
[1]Faculty of Life Sciences, Department of Chemistry and Biosciences

[2]Faculty of Engineering and Informatics, Department of Biomedical and Electronics Engineering
University of Bradford, Richmond Rd, Bradford, BD7 1DP, UK aaalgadd@bradford.ac.uk or
ORCID: 0000-0002-1104-2279

Abstract

We have designed a magnetic heating coil (MHC) that heats magnetic nanoparticles via induction. The coil was designed via computational modelling and experimental testing to produce a device small enough to safely insert into a fluorescence spectrophotometer. The specific absorption rate (SAR) of particles within this coil was measured and shown to sufficiently heat up solutions via induction at various concentrations. A fluorescent dye were then studied to see how the emission properties change with both temperatures (raising the temperature of an adjacent water-cooling system) and via the use of magnetic induction.

In this paper, we summarise the principles of MHC therapy. The two coils were used experimentally with two cooling systems (Haake K20 and IKA ICC control pumps). The Haake K20 (equipped with a Haake DC 30 temperature controller) was showed to be a more effective cooling system than the IKA ICC control pump.

Keywords-Fluorescence, Magnetic, Induction, Nanoparticles.

The Entropic Impact in Power Systems-An Overview

Ismail A Mageed
Department of Computer Science, Faculty of Engineering and Informatics, University of Bradford, Bradford, West Yorkshire, BD7 1DP, UK iammoham@bradford.ac.uk
ORCID 0000-0002-3691-0773

Kit Qichun Zhang

Department of Computer Science, Faculty of Engineering and Informatics, University of Bradford, Bradford, West Yorkshire, BD7 1DP, UK Q.Zhang17@bradford.ac.uk
ORCID 0000-0003-2479-8195

Abstract

Entropy, a measure of turbulence and uncertainty, was introduced by Shannon. Since then, many researchers have explored different ways to apply entropy to most scientific disciplines. This paper outlines the application of the principle of entropy in power systems. In addition, some suggestions have been made for future research on the application of the principle of entropy to power systems, with some suggestions to further advancements.

Keywords-Entropy, measure, applications, power system

Significant Role of Entropy in Information Theory, Queueing Theory, Engineering, Computer Science and Statistical Mechanics: An Overview

Ismail A Mageed
Department of Computer Science, Faculty of Engineering and Informatics, University of Bradford, Bradford, West Yorkshire, BD7 1DP, UK iammoham@bradford.ac.uk
ORCID 0000-0002-3691-0773

Kit Qichun Zhang
Department of Computer Science, Faculty of Engineering and Informatics, University of Bradford, Bradford, West Yorkshire, BD7 1DP, UK Q.Zhang17@bradford.ac.uk
ORCID 0000-0003-2479-8195

Abstract

The credit of uncovering Entropy as a concept refers to Clausius, around 160 years ago. Since that time, there has been an ongoing tireless improvement and interpretation by many researchers in many scientific disciplines. The current paper reviews entropy applications to information theory, queuing theory, engineering, computer science and statistical mechanics. The creation of unified vision of the applicability of classical entropies as well as the provision of a compact detailed explanation which combines conceptual extraction of the most up-to-date literature and technical pertinence are the main goals of this survey. Additionally, a critical discussion of maximum entropy production principle was provided. We conclude this review with a representative list of references. Possible future research advancements are given.

Keywords: Overview, entropy, information theory, queueing theory, engineering, computer science, statistical
Mechanics

Posters presented at the AIERC 2022

LIFE CYCLE ASSESSMENT OF MULTI-MEGAWATT FLOATING OFFSHORE WIND TURBINES

Hussein Aldaffar and Cuong Dao
Mechanical and Energy Systems Engineering, University of Bradford, BD7 1DP
UNIVERSITY of BRADFORD Faculty of Engineering & Informatics

AIERC

INTRODUCTION

- Offshore wind turbines (OSWT) will play a critical role to achieve the 2050 net-zero target.
- The floating OSWT offers a future solution for wind turbines to produce higher energy by mounting them over a semisubmersible platform in deep offshore sites of higher wind potential.
- Researching the whole life cycle of floating OSWT is essential to enhance its performance.
- The life cycle assessment (LCA) method is a powerful tool to investigate the environmental impact of all the life stages of floating OSWT starting from raw material extraction and manufacturing to end of life and recycling.

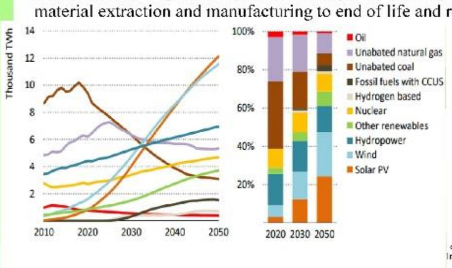


Figure 1, Energy trends for the next three decades [3]

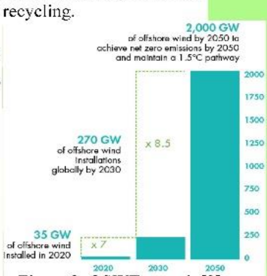


Figure 2, OSWT growth [2]

AIM AND OBJECTIVES

- Investigate the components and inventory of modern large-scale OSWT.
- Develop the product system processes and flows for manufacturing, installation, operation and maintenance, and decommissioning/recycling of floating OSWT.
- Estimate the climate change impact (CO2 emission) of OSWT components in its entire life cycle.
- Analyse the results and inspect the impact of different life cycle scenarios of the floating OSWT.

METHODOLOGY

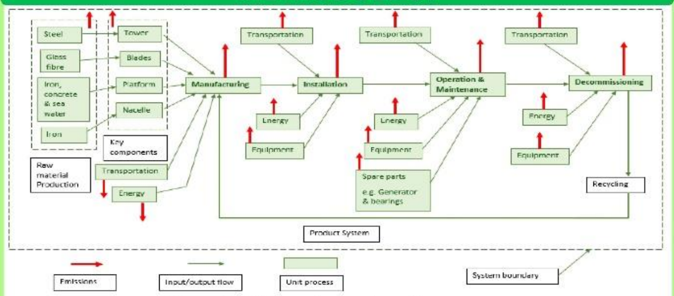


Figure 3, OSWT product system flow

- The product system model in figure 3 was designed based on the floating OSWT inventory, key components and life cycle phases.
- The product system consists of unit processes which are the smallest elements of the system whereas input/output flows are specified as the products, materials, and energy that enter or leave the unit process.
- After importing the LCA databases into OpenLCA software, calculations were conducted based on the IPCC method to estimate the global warming impact.

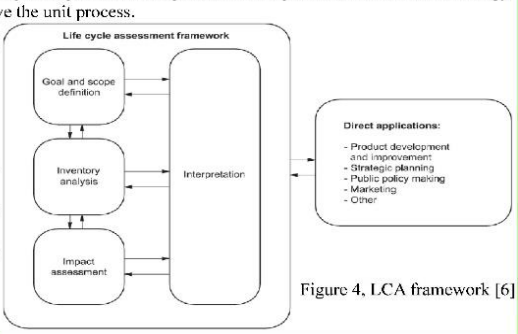


Figure 4, LCA framework [6]

IPCC method total emissions for product system [7]

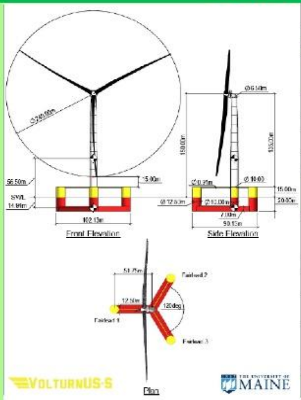
$$\text{Total Emissions} = \Sigma\ \text{Manufacturing Emissions} + \Sigma\ \text{Installation Emissions} + \Sigma\ \text{Use Emissions} + \Sigma\ \text{Disposal Emissions}$$

Example of emission calculations using IPCC method for pig iron and crude steel production [7]

$$\text{Emissions}_{\text{pig iron}} = \text{Emission Factor}_{\text{reducing agent}} \bullet \text{Mass of Reducing Agent} + (\text{Mass of Carbon in the Ore} - \text{Mass of Carbon in the Crude Iron}) \bullet 44 / 12$$

$$\text{Emissions}_{\text{crude steel}} = (\text{Mass of Carbon in the Crude Iron used for Crude Steel Production} - \text{Mass of Carbon in the Crude Steel}) \bullet 44 / 12 + \text{Emission Factor}_{\text{EAF}} \bullet \text{Mass of Steel Produced in EAF}$$

CASE STUDY



Component	Mass (Ton)
Tower	1,263
Total Rotor Nacelle Assembly (RNA)	1,017
Nacelle total mass	820.888
Mechanical parts	449.318
Generator	371.57
Blades	65.25 X 3
Semisubmersible platform mass	17,839
Fixed iron-ore-concrete ballast	2,540
Sea water ballast	11,300
Hull steel mass	3,914
Tower interface mass	100
Mooring System	685 kg/m * 850 m * 3 = 1,746.75 KG
Total system mass	20,093

Figure 5, IEA 15 MW reference OSWT [1] Table 1, 15 MW OSWT inventory [1]

- Inventory analysis was implemented to estimate the carbon footprint of the IEA Wind 15 MW reference OSWT.
- Transportation distances were assumed for the offshore distance 50Km and for the land transportation of materials 500Km.

RESULTS AND ANALYSIS

Indicator	Blade	Generator	Nacelle Mechanical Parts	Nacelle Total	Platform	Tower	Unit
climate change - GTP 100a	1.95E+05	7.77E+05	9.40E+05	1.72E+06	7.50E+06	7.06E+05	kg CO2-Eq
climate change - GTP 20a	2.32E+05	8.40E+05	1.02E+06	1.86E+06	8.39E+06	8.32E+05	kg CO2-Eq

Table 2, 15 MW OSWT components impact results

Figure 6, climate change - GTP 100a for 15 MW OSWT components

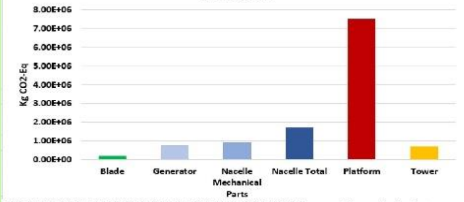
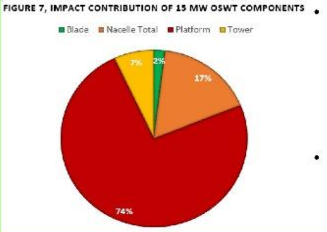


FIGURE 7, IMPACT CONTRIBUTION OF 15 MW OSWT COMPONENTS



- The global temperature potential (GTP) and global warming potential (GWP) impacts were estimated by using IPCC methods for two scenarios (20 and 100 years impact).
- The results present the CO2 emission contribution from each component of the OSWT during the whole life cycle.

CONCLUSION AND FUTURE WORKS

- The LCA method provides a scientific and holistic assessment of the product system.
- The semisubmersible platform has the largest impact compared to other components with 74% contribution.
- Future studies of different scenarios are suggested such as end-of-life waste treatment assumptions to investigate the impact of OSWT recycling.
- The Impact of transportation methods on the product system could be investigated by evaluating variety of scenarios.
- Comparison between the floating OSWT and the fixed bottom OSWT will be useful to assess the green house gas (GHG) emissions per energy unit of both systems.

REFERENCES

1. Allen et al, 2020. Definition of the Umaine VolturnUS-S Reference Platform Developed for the IEA Wind 15-Megawatt Offshore Reference Wind Turbine.
2. GWEC, 2021. Global Offshore Wind Report - Global Wind Energy Council.
3. IEA, 2021. Net Zero by 2050 - A Roadmap for the Global Energy Sector.
4. IRENA, 2020. Statistics Time Series.
5. IRENA, 2021. World Energy Transitions Outlook: 1.5°C Pathway.
6. ISO 14040/14044, 2006.
7. IPCC, 2021. 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

UNIVERSITY of BRADFORD
Faculty of Engineering & Informatics

Offshore wind farm operation modelling and factors affecting the levelised cost of energy

Mohsin Iqbal, Cuong Dao, and Hussein Aldaffar
Mechanical and Energy Systems Engineering, University of Bradford, BD7 1DP

AIERC

Introduction

There has been a higher global demand for energy than ever before and an increasing drive for zero-carbon emissions. A greater outlook of the benefits of wind power with the annual energy generation being amplified 715% in the last 11 years and anticipated to growing faster in the coming decade. This research highlights critical areas of windfarm operation modelling and investigates the factors affecting wind farm economic performance.

Aims and Objectives

- Research preceding studies on operation and the critical components of a wind farm
- Develop a Monte-Carlo simulation to model the operation of offshore wind farms
- Amass data on wind farms and simulate the probable cost of energy and future scenarios that may arise
- Analyse results and conclude the benefits and limitations of this research

Offshore wind turbines and wind farms

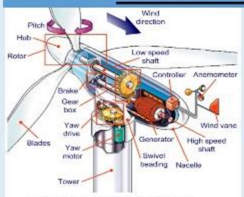


Figure 1. Components of a WT [1]

Offshore Wind Turbine (OWT) and Wind Farms (WF) are complex systems of systems with many electrical, mechanical, power electronics and structural subsystems and components.

Areas of research are:

- WT (Wind Turbine) structure & WF layout
- Modelling of various parameters on the WF/WT operation
- The cost of energy and economic factors for its estimation

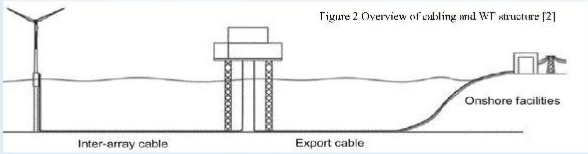


Figure 2 Overview of cabling and WT structure [2]

Methodology

Amass applicable data from a assortment of sources relating to cost and failure

Run the data through a MATLAB sequence that incorporates MCS

Repeat for a array in order to compare a selection of case studies

In order for the results to be valid, the method must replicate ideal conditions. For that we must know:

- The Monte-Carlo Simulation (MCS)
- The states that a WF can reside in
- The necessary calculations

The Sequential MCS:

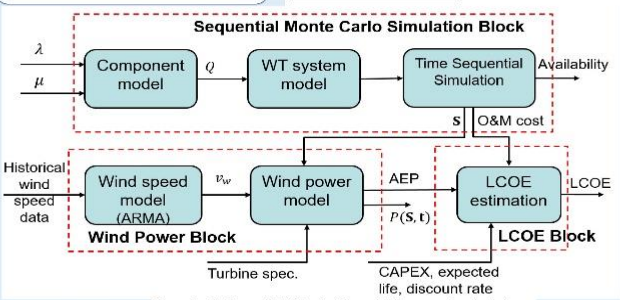


Figure 3 – The Sequential MSC and offshore wind farms operation simulation

LCOE estimation:

NPVC (Net present value of costs)	$= \sum_n \frac{(\text{CAPEX and OPEX COSTS})_n}{(1+r)^n}$
Annual CAPEX (Capital expenditure)	$= \sum \text{initial costs} \times \frac{r}{(1-(1+r)^{-n})}$
Total OPEX (Operating expenditure)	$= \sum \text{fixed opex} + \text{variable opex}$
NPVE (Net present value of energy)	$= \sum_n \frac{(\text{Annual net energy generated})_n}{(1+r)^n}$
LCOE (Levelised cost of energy)	$= \frac{\text{NPVC}}{\text{NPVE}}$

Case study

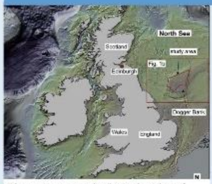


Figure 4 – Dogger bank, the location of utilised wind data [3]

Table 1 - The case study with input cost data [4-8]

Parameter	Database: (Dao et al. 2019b)	BVGA (associates)	BEIS (*ELECTRICITY GENERATION COSTS 2020 2020*)	(Voormolen et al. 2016)	(Ioannou et al. 2018)
CAPEX (M£ per MW)	2.42	2.37	1.63	3.75	2.54*
Fixed OPEX(£/MW)	448000	76000	36300	53433*	56300
No. of WTs	25	25*	25	25*	25*
Distance to shore (km)	100*	60	100*	30	120
Operating years	25	27	30	25*	25

Table 2 – The input data failure data and downtimes for various WT components [4, 9-11]

	Database								
	(Dao et al. 2019b)		(Pinar Pérez et al. 2013)			(Dao et al. 2019a)		(Dao et al. 2021)	
Component	FR	DT	FR	FR*	DT**	FT	DT***	FT	DT
Blades (and hub)	0.1723	99.35	0.27	0.2525	14.125	0.75	97.5	0.52	288
Pitch	0.1175	51.22		0.1	1.75	1.1	50		
Drivetrain	0.0239	156.85	0.02					0.633	231
Generator	0.1189	179.34	0.08	0.2	10.625	1	177.5	0.999	81
Converter	0.1222	66.54							
electrical	0.2815	52.48	0.25	0.3575	8.875	1.5	56.25	0.675	110

Results and Analysis

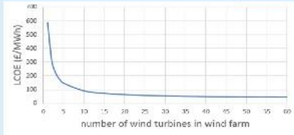


Figure 5 – Impact of the number of WTs on LCOE

LCOE – Levilsed cost of energy

NPVC – Net present value of costs

NPVE – Net present value of energy

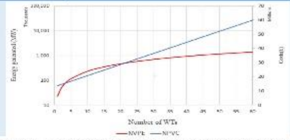


Figure 6 – Impact of the number of WTs on the NPVC & NPVE

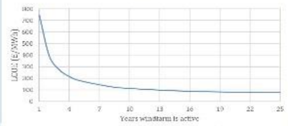


Figure 7 – The life of WF on the expected LCOE

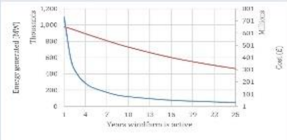


Figure 8 – The life of WF on the NPVC & NPVE

Table 3 – The LCOE of a 10MW vs 15MW WT

	10MW	15MW
LCOE	75.0758	57.533
NPVC	34871000	46321000
NVPE	464480	805120
OPEX	16327000	24067000
AEP	1088100	1888700

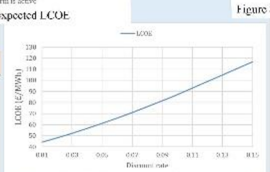


Figure 9 The discount rate vs the LCOE

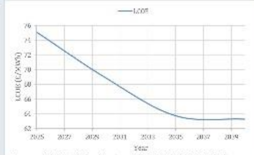


Figure 10 & 11 (below) – The LCOE, NPVC & NPVE of a WF when established at varying years

Table 4 Results of LCOE, NPVC & NPVE variation depending on cost input

source	(Dao et al. 2019b)	BVGA	BEIS	(Voormolen et al. 2016)	(Ioannou et al. 2018)
LCOE	186.69	100.14	75.08	124.65	100.23
NPVC	86719000	46509000	34871000	57900000	46087000
NVPE	464520	464440	464450	464500	459810
OPEX	119250000	26252000	16327000	20611000	21284000
AEP	1088100	1088000	1088000	1088100	1077200

Table 5 Results of LCOE, NPVC & NPVE variation depending on reliability data

source	(Dao et al. 2019b)	(Pinar Pérez et al. 2013)	(Dao et al. 2019a)	(Dao et al. 2021)	(Tavner et al. 2013)	
LCOE	76.31	75.95	90.62	87.48	76.37	76.72
NPVC	35443000	35452000	35136000	35194000	35441000	35432000
NVPE	464430	466800	387740	402330	464050	461810
OPEX	15652000	15674000	14931000	15067000	15648000	15627000
AEP	1088000	1093500	907730	941870	1087000	1081800

Key findings:

- Increasing the number of turbines causes the LCOE to decrease, similarly to when the years the WF is active increases. Due to a much higher rise in energy production than that of the costs
- We can highlight the benefits of using a 15MW WT. Its reduced LCOE is due to the doubling of energy production.
- From case studies, we can map the LCOE and concur that it is beneficial to have components with low failure rates, albeit they may support a larger downtime per component.

Conclusion & future works

- For future work, once key data and statistics are accessible, the method should be replicated to offer a higher accuracy and reliability.
- The industry is growing rapidly. Innovative advances show promise of either minimising costs or increasing energy output, equally beneficial for an effective LCOE.

References

[1] GE Renewable Energy et al., Wind Turbine Components Market Analysis Focusing on Top Key Players (2018).
[2] Ng, C. and Ran, L. Offshore Wind Farms - Technologies, Design and Operation. Elsevier 2016.
[3] Cotterill 2017. The evolution of the Dogger Bank, North Sea: A complex history of terrestrial, glacial and marine environmental change.
[4] Dao, C. D., Kazemtabrizi, B. and Crabtree, C. J. (2019) Impacts of Reliability on Operational Performance and Cost of Energy Evaluation of Multi-Megawatt, Far-Offshore Wind Turbines. ASME 38th International Conference on Ocean, Offshore and Arctic Engineering, Glasgow, UK.
[5] BVG associates. B. Guide to an offshore windfarm. BVGA (2020).
[6] BEIS. ELECTRICITY GENERATION COSTS 2020. (2020)
[7] Voormolen, J. A., Junginger, H. M. and van Sark, W. G. J. H. M. (2016) Unravelling historical cost developments of offshore wind energy in Europe. Energy Policy 88, 435-444.
[8] Ioannou, A., Angus, A. and Brennan, F. (2018) Parametric CAPEX, OPEX, and LCOE expressions for offshore wind farms based on global deployment parameters. 13 (3), 281-290.
[9] Pinar Perez, J. M., Garcia Márquez, F. P., Tobias, A. and Papaelias, M. (2013) Wind turbine reliability analysis. Renewable and Sustainable Energy Reviews 23, 463-472.
[10] Dao, C., Kazemtabrizi, B. and Crabtree, C. (2019) Wind turbine reliability data review and impacts on levelised cost of energy. Wind Energy 22 (12), 1848-1871.
[11] Dao, C. D., Kazemtabrizi, B., Crabtree, C. J. and Tavner, P. J. (2021) Integrated condition-based maintenance modelling and optimisation for offshore wind turbines. Wind Energy 24 (11), 1180-1198.

THE REVOLUTIONARY IMPACT OF INFORMATION THEORY AND INFORMATION GEOMETRY ON TRAFFIC FLOWS WITH HEAVY TAILED DISTRIBUTIONS

UNIVERSITY of BRADFORD
Faculty of Engineering & Informatics

ISMAIL A MAGEED & Kit QUICHUN ZHANG

ABSTRACT

Many studies of Internet traffic flows revealed that they are characterised by burstiness, self-similarity (SS) and/or long-range dependence (LRD) that are attributed to the heavy (long) tails of the various distributions of interest, such as interevent times and queue lengths. These traffic patterns have adverse impact on the efficient operation of networks and are significant towards their performance prediction, optimisation and capacity planning. Telecommunication engineers have widely employed heavy–tailed distributions to generate workloads for use in simulation studies, which, unfortunately, may display unusual traffic characteristics. Thus, there is a need to devise new and credible analytic methodologies for the cost-effective assessment of the impact of various network traffic patterns on the heavy tallness of the queues.

This project will establish a novel analytic framework, based on the optimisation of generalised entropy measures, such as those proposed in the fields of Information Theory and Statistical Physics by Shannon, Rényi, Tsallis and others, subject to appropriate linear and non-linear system constraints. New analytic performance distributions with heavy tails and associated algorithms will be devised in the discrete and continuous time domains with particular emphasis to those displaying a power law behaviour observed in different contexts of the Internet.

OBJECTIVES

1. To solve the open problem of extended Properties of the Class of Rényi Generalized Entropies in the Discrete Time Domain

2. To solve the most sophisticated open problem of obtaining a unified information-theoretic framework for stable queueing systems.

3. To solve the unsolvable problem of revealing the hidden info-geometric (IG) impact on the analysis of stable M/G/1 queues

4. To obtain for first time ever both service time distribution as well as the service time cumulative function for a stable queue with balking.

METHODS

1. Differential Calculus and Calculus of Belief Functions

2. Entropy Optimization technique with the Lagrangian function subject to given constraints

3. The info –Geometric Potential function and Fisher information matrix.

SOME CONTRIBUTIONS/RESULTS

1. An exploration was carried out of Rényi's and Tsallis's NME formalisms as methods of inductive inference for a physical system Q with a finite or countably infinite set S of states $\{S_n, n = 0, 1, 2, \dots\}$ and 'long-range' interactions of order, q (0.5<q<1). In this context, the respective NME state probabilities $p_{q,R}(S_n)$and $p_{q,T}(S_n)$ were analytically devised, based on the maximisation of the respective entropy functionals, subject to normalisation and a finite number of suitable mean value constraints. Moreover, the credibility of these NME formalisms, as methods of inductive inference, was justified in terms of four consistency axioms, namely uniqueness, invariance, system independence and subset independence, which were associated with Shannon's EME formalism of systems with 'short-range' interactions. Specifically, it was verified that both Rényi's and Tsallis's formalisms, even though satisfied the consistency axioms of uniqueness, invariance and subset independence, nevertheless defied, as they should, the axiom of system independence due to the existence of 'long-range' interactions. Moreover, both service time distribution and service time cumulative distributions that make our solution exact were obtained. Additionally, the exact form of both service time and cumulative functions of the Shannonian formalism of M/G/1 queue with balking were devised.

2. The revealing of the new knowledge that all the queueing parameters $\rho, \beta = C_s^2$ of the stable M/G/1 queue manifold are time dependent functions;

3. The discovery of the informational geometric equations of motion (IGEMs) for the M/G/1 queue manifold and their analytic solutions;

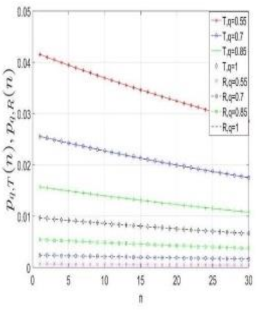
4. The proposed new approach to visualize queueing systems via computational information geometry;

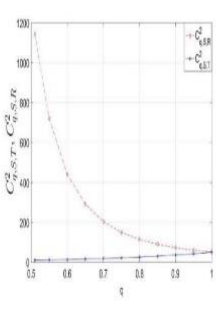
5. The determination of a new approach to analyse the regions of stability for the M/G/1 (QM) based on the obtained solutions of the IGEMs for the related coordinates, server utilization $\rho$and squared coefficient of variation β .

6. The establishment of new links between queueing theory and other mathematical disciplines such as information geometry, matrix theory Riemannian geometry and the theory of Relativity.

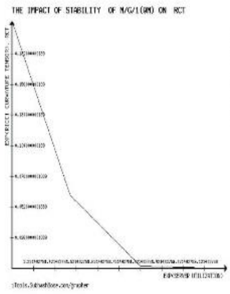
7. Providing a novel link between Ricci Curvature (RCT) and the stability analysis of the stable M/G/1 queue manifold.

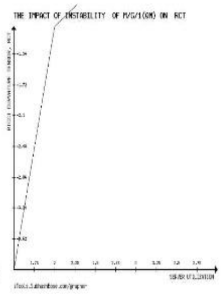
CHARTS





The above two data portraits have revealed the information theoretic impact of the non-extensive parameter q (0.5<q<1). on the performance of the underlying queueing system





The above portraits have clearly revealed the significant Info-Geometric impact on the overall analysis of stable M/G/1 queue manifold

CONCLUSION AND FUTURE WORK

This thesis has produced several major breakthroughs. Beyond the remit of complex technicality, we have devised two new fields of knowledge, namely

1. Solving the longstanding open problem of extended properties of the class of Rényi generalized entropies in the discrete time domain.

2. Information-theoretic theory of queueing systems(ITQS) and the info-geometric theory of queueing systems(IGQS).

3. Extending the work to higher level entropies and different queues. Also, extending IG impact to time-dependent queues and to other time independent(dependent) distributions in other scientific disciplines such as quantum mechanics, control theory and much more.

REFERENCES

1. I.A. Mageed, and D.D. Kouvatsos, "Extended Properties of the Class of Rényi Generalized Entropies in the Discrete Time Domain", Extended version of paper [1], 11-13 July 2011, IEEE *International Conference on Computer Networks and Information Technology*, Abbottabad, Pakistan, pp. 1-7, doi: 10.1109/ICCNIT.2011.6020894. Online available at https://ieeexplore.ieee.org/document/6020894

2. D.D. Kouvatsos, and I.A Mageed, "Non-Extensive Maximum Entropy Formalisms and Inductive Inferences of Stable M/G/1 Queue with Heavy Tails", in "Advanced Trends in Queueing Theory", March 2021, Vol. 2, Vladimir Anisimov and Nikolaos Limnios (eds.), Books in 'Mathematics and Statistics', Sciences by ISTE & J. Wiley, London, UK.

3. D.D Kouvatsos, et I.A. Mageed, "Formalismes de maximum d'entropie non extensive et inférence inductive d'une file d'attente M/G/1 stable á queues Lourdes", "Théorie des files d'attente 2", Mars 2021,Théorie et Practique, Sous la direction de Vladimir Anisimov et Nikolaos Limnios, Mathématique, Sciences by ISTE & J. Wiley, Londres, Royaume-Uni.

4. I.A. Mageed, and D.D. Kouvatsos, "The Impact of Information Geometry on the Analysis of the Stable M/G/1 Queue Manifold", 4-6 February 2021, In Proceedings of the 10th International Conference on Operations Research and Enterprise Systems - Volume 1: ICORES, ISBN 978-989-758-485-5, pages 153-160. DOI: 10.5220/0010206801530160.

Simulation study of Direct Petroleum Crude Cracking in Conventional Fluid Catalytic Cracking Unit

Ruth E. Emberru, Raj Patel, Iqbal. M. Mujtaba, John M. Yakubu

reekperi@bradford.ac.uk, y.john@bradford.ac.uk

Department of Chemical Engineering, Faculty of Engineering and Informatics, University of Bradford

Abstract

- This poster displays a reaction scheme of six-lumped kinetic model used to describe the cracking of direct **crude oil** to produce basic chemicals, using Fluid Catalytic Cracking (FCC) riser with the aim to study yield profiles.
- Using mathematical modelling and simulation in **gPROMS software 7.0.7.** The mathematical equations are written for fluid and cracking reactions coupled in 1-D model. Results obtained were compared with literature data.

Introduction

- Traditionally, the FCC unit consists of the cracking reactor riser and the regenerator (Han and Chung 2001).
- The conventional FCCU is used to process straight-run atmospheric gas oils, vacuum gas oils, atmospheric residues and other heavy oil into high octane gasoline, light fuel oil and olefin gases
- Directly cracking crude oil in an FCC unit would be cost-effective as it will bypass some of the costly refining processes and could also be an ideal process to expanding chemicals including olefin gases production which is the central aim of this study.

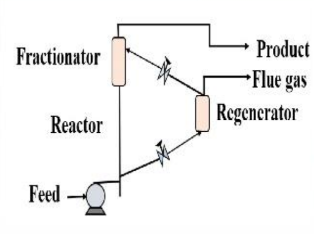


Figure 1. A schematic diagram of the FCC unit

Methodology

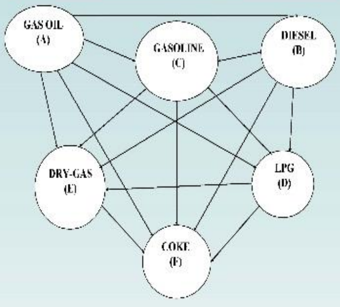


Figure 2. Six-lump model for catalytic cracking of direct crude oil in FCC (John et al. 2019).

The proposed model for the catalytic cracking of direct crude oil in FCC is shown in Figure 1. has five products and a feed, resulting in a six-lumped kinetic model; the products include Gas oil (0.19 wt%), Diesel (0.31wt%), Gasoline (0.46 wt%), LPG (0.0 wt%), Dry gas (0.0 wt%), and Coke (0.0 wt%) (John et al. 2019). It was assumed that Crude oil will behave and have the same reaction scheme as gas oil.

Kinetic model equations for the six-lump model

Overall rate of reaction

Gas oil $R_{go} = -(K_1 + K_2 + K_3 + K_4 + K_5) y_{go}^2 \emptyset_c$ (1)

Diesel $R_{dz} = \left((K_1 y_{go}^2) - (K_6 + K_7 + K_8 + K_9) y_{dz} \right) \emptyset_c$ (2)

Gasoline $R_{gs} = (K_2 y_{go}^2 + K_7 y_{dz}) - ((K_{10} y_{gs} + K_{11} y_{gs} + K_{12} y_{gs}) \emptyset_c$ (3)

LPG $R_{LPG} = (K_4 y_{go}^2 + K_8 y_{dz} + K_{10} y_{gs} - K_{13} y_{LPG} - K_{14} y_{LPG}) \emptyset_c$ (4)

Dry gas $R_{dg} = (K_5 y_{go}^2 + K_9 y_{dz} + K_{11} y_{gs} + K_{13} y_{LPG} - K_{15} y_{dg}) \emptyset_c$ (5)

Coke $R_{ck} = (K_3 y_{go}^2 + K_6 y_{dz} + K_{12} y_{gs} + K_{14} y_{LPG} + K_{15} y_{dg}) \emptyset_c$ (6)

Some of the model equations used in this simulation were derived from the literature (John et al. 2019; Han and Chung 2001).

Results

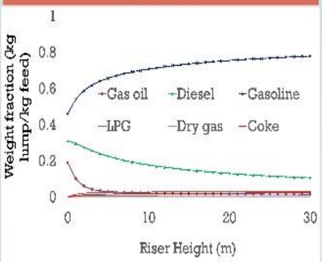


Figure 3. Profile of crude oil cracking in the riser

Table 1. The six-lump kinetic model riser simulation results

Height of Riser (m)	$T_c RS$ (K)	$T_g RS$ (K)	V_c (m/s)	V_g (m/s)
0.0	900	600	1.25	12
10.0	804.2	804.2	15.11	15.22
20.0	799.9	799.9	23.23	23.39
30.0	797.7	797.7	30.47	30.66

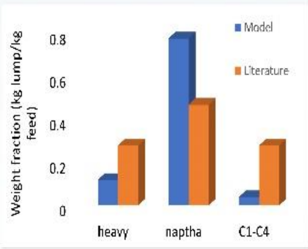


Figure 4. Literature values of product distribution obtained over model results (Al-Khattaf and Ali 2018)

Conclusion

- This model demonstrated that direct catalytic cracking of crude oil in FCC unit is possible, but the results showed low yield of light gases, however some literature data has showed that up to 20 % of light gases can be attained as indicated in Figure 4. Also Gasoline purity increased to 80 % and the Gas oil yield decreased to 0.014 wt %.
- The FCC model predicts a larger conversion of heavy fraction compared to literature data from MAT (Micro Activity Test) reactors despite having significant lower residence time (2s) compared to 10s in MAT reactors.
- The temperatures of the catalyst and the gas phases, which were initially set at 900 K and 600 K, decreased and increased simultaneously, eventually reaching a thermal equilibrium of around 797.7K.
- Hence, optimisation of olefins (light gases) is required for future work to meet ever-growing demands for petrochemical feedstock.

Acknowledgements

This work was funded by Tertiary Education Trust Fund (TETFund) of Nigeria.

References

- Al-Khattaf, Sulaiman S and Ali, S.A. (2018) Catalytic cracking of Arab super light crude oil to light olefins: an experimental and kinetic study. *Energy & Fuels* 32 (2), ACS Publications2234–2244.
- Han, I.-S. and Chung, C.-B. (2001) Dynamic modeling and simulation of a fluidized catalytic cracking process. Part I: Process modeling. *Chemical Engineering Science* 56 (5), 1951–1971.
- John, Y.M., Mustafa, M.A., Patel, R. and Mujtaba, I.M. (2019) Parameter estimation of a six-lump kinetic model of an industrial fluid catalytic cracking unit. *Fuel* 235, 1436–1454.

REVOLUTIONARY IMPACT OF INFORMATION THEORY AND INFORMATION GEOMETRY ON TRAFFIC FLOWS WITH HEAVY TAILED DISTRIBUTIONS

UNIVERSITY of BRADFORD
Faculty of Engineering & Informatics

ISMAIL A MAGEED & Kit QUICHUN ZHANG

ABSTRACT

Many studies of Internet traffic flows revealed that they are characterised by burstiness, self-similarity (SS) and/or long-range dependence (LRD) that are attributed to the heavy (long) tails of the various distributions of interest, such as interevent times and queue lengths. These traffic patterns have adverse impact on the efficient operation of networks and are significant towards their performance prediction, optimisation and capacity planning. Telecommunication engineers have widely employed heavy–tailed distributions to generate workloads for use in simulation studies, which, unfortunately, may display unusual traffic characteristics. Thus, there is a need to devise new and credible analytic methodologies for the cost-effective assessment of the impact of various network traffic patterns on the heavy tallness of the queues.

This project will establish a novel analytic framework, based on the optimisation of generalised entropy measures, such as those proposed in the fields of Information Theory and Statistical Physics by Shannon, Rényi, Tsallis and others, subject to appropriate linear and non-linear system constraints. New analytic performance distributions with heavy tails and associated algorithms will be devised in the discrete and continuous time domains with particular emphasis to those displaying a power law behaviour observed in different contexts of the Internet.

OBJECTIVES

1. To solve the open problem of extended Properties of the Class of Rényi Generalized Entropies in the Discrete Time Domain
2. To solve the most sophisticated open problem of obtaining a unified information-theoretic framework for stable queueing systems.
3. To solve the unsolvable problem of revealing the hidden info-geometric (IG) impact on the analysis of stable M/G/1 queues
4. To obtain for first time ever both service time distribution as well as the service time cumulative function for a stable queue with balking.

METHODS

1. Differential Calculus and Calculus of Belief Functions
2. Entropy Optimization technique with the Lagrangian function subject to given constraints
3. The info –Geometric Potential function and Fisher information matrix.

SOME CONTRIBUTIONS/RESULTS

1. An exploration was carried out of Rényi's and Tsallis's NME formalisms as methods of inductive inference for a physical system Q with a finite or countably infinite set S of states $\{S_n, n = 0, 1, 2, \ldots\}$ and 'long-range' interactions of order, q (0.5<q<1). In this context, the respective NME state probabilities $p_{q,R}(S_n)$ and $p_{q,T}(S_n)$ were analytically devised, based on the maximisation of the respective entropy functionals, subject to normalisation and a finite number of suitable mean value constraints. Moreover, the credibility of these NME formalisms, as methods of inductive inference, was justified in terms of four consistency axioms, namely uniqueness, invariance, system independence and subset independence, which were associated with Shannon's EME formalism of systems with 'short-range' interactions. Specifically, it was verified that both Rényi's and Tsallis's formalisms, even though satisfied the consistency axioms of uniqueness, invariance and subset independence, nevertheless defied, as they should, the axiom of system independence due to the existence of 'long-range' interactions. Moreover, both service time distribution and service time cumulative distributions that make our solution exact were obtained. Additionally, the exact form of both service time and cumulative functions of the Shannonian formalism of M/G/1 queue with balking were devised.

2. The revealing of the new knowledge that all the queueing parameters $\rho, \beta = C_s^2$ of the stable M/G/1 queue manifold are time dependent functions;

3. The discovery of the informational geometric equations of motion (IGEMs) for the M/G/1 queue manifold and their analytic solutions;

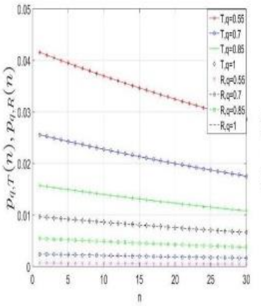
4. The proposed new approach to visualize queueing systems via computational information geometry;

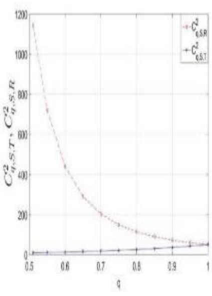
5. The determination of a new approach to analyse the regions of stability for the M/G/1 (QM) based on the obtained solutions of the IGEMs for the related coordinates, server utilization ρ and squared coefficient of variation β.

6. The establishment of new links between queueing theory and other mathematical disciplines such as information geometry, matrix theory Riemannian geometry and the theory of Relativity.

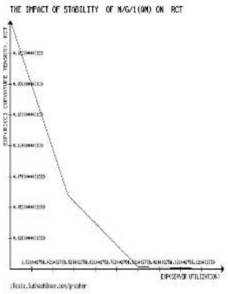
7. Providing a novel link between Ricci Curvature (RCT) and the stability analysis of the stable M/G/1 queue manifold.

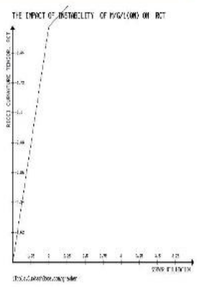
CHARTS





The above two data portraits have revealed the information theoretic impact of the non-extensive parameter q (0.5<q<1). on the performance of the underlying queueing system





The above portraits have clearly revealed the significant Info-Geometric impact on on the overall analysis of stable M/G/1 queue manifold

CONCLUSION AND FUTURE WORK

This thesis has produced several major breakthroughs. Beyond the remit of complex technicality, we have devised two new fields of knowledge, namely

1. Solving the longstanding open problem of extended properties of the class of Rényi generalized entropies in the discrete time domain.

2. Information-theoretic theory of queueing systems(ITQS) and the info-geometric theory of queueing systems(IGQS).

3. Extending the work to higher level entropies and different queues. Also, extending IG impact to time-dependent queues and to other time independent(dependent) distributions in other scientific disciplines such as quantum mechanics, control theory and much more.

REFERENCES

1. I.A. Mageed, and D.D. Kouvatsos, "Extended Properties of the Class of Rényi Generalized Entropies in the Discrete Time Domain", Extended version of paper [1], 11-13 July 2011, IEEE *International Conference on Computer Networks and Information Technology*, Abbottabad, Pakistan, pp. 1-7, doi: 10.1109/ICCNIT.2011.6020894. Online available at https://ieeexplore.ieee.org/document/6020894

2. D.D. Kouvatsos, and I.A Mageed, "Non-Extensive Maximum Entropy Formalisms and Inductive Inferences of Stable M/G/1 Queue with Heavy Tails", in "Advanced Trends in Queueing Theory", March 2021, Vol. 2, Vladimir Anisimov and Nikolaos Limnios (eds.), Books in 'Mathematics and Statistics', Sciences by ISTE & J. Wiley, London, UK.

3. D.D Kouvatsos, et I.A. Mageed, "Formalismes de maximum d'entropie non extensive et inférence inductive d'une file d'attente M/G/1 stable à queues Lourdes", "Théorie des files d'attente 2", Mars 2021,Théorie et Practique, Sous la direction de Vladimir Anisimov et Nikolaos Limnios, Mathématique, Sciences by ISTE & J. Wiley, Londres, Royaume-Uni.

4. I.A. Mageed, and D.D. Kouvatsos, "The Impact of Information Geometry on the Analysis of the Stable M/G/1 Queue Manifold", 4-6 February 2021, In Proceedings of the 10th International Conference on Operations Research and Enterprise Systems - Volume 1: ICORES, ISBN 978-989-758-485-5, pages 153-160. DOI: 10.5220/0010206801530160.

EXTENDED ENTROPY MAXIMISATION AND TRAFFIC FLOWS WITH HEAVY TAILED DISTRIBUTIONS

UNIVERSITY of BRADFORD
Faculty of Engineering and Informatics

ISMAIL A MAGEED & Kit QUICHUN ZHANG

Abstract

Many studies of Internet traffic flows revealed that they are characterised by burstiness, self-similarity (SS) and/or long range dependence (LRD) that are attributed to the heavy (long) tails of the various distributions of interest, such as interevent times and queue lengths. These traffic patterns have adverse impact on the efficient operation of networks and are of significant importance towards their performance prediction, optimisation and capacity planning. Telecommunication engineers have widely employed heavy–tailed distributions to generate workloads for use in simulation studies, which, unfortunately, may display unusual traffic characteristics. Thus, there is a need to devise new and credible analytic methodologies for the cost-effective assessment of the impact of various network traffic patterns on the heavy tallness of the queues.

This project will establish a novel analytic framework, based on the optimisation of generalised entropy measures, such as those proposed in the fields of Information Theory and Statistical Physics by Shannon, Rényi, Tsallis and others, subject to appropriate linear and non-linear system constraints. New analytic performance distributions with heavy tails and assosiated algorithms will be devised in the discrete and continuous time domains with particular emphasis to those displaying a power law behaviour observed in different contexts of the Internet.

Moreover, a revolutionary approach was uncovered by employing Information Geometry to analyse the stability of queueuing systems.

Objectives

1. To solve the open problem of extended Properties of the Class of Rényi Generalized Entropies in the Discrete Time Domain
2. To solve the most sophisticated open problem of obtaining a unified information-theoretic framework for stable queueing systems.
3. To solve the unsolvable problem of revealing the info-geometric(IG) impact on the analysis of stable M/G/1 queues
4. To obtain for first time ever both service time distribution as well as the service time cumulative unction for a stable queue with balking

Methods

1. Differential Calculus and Calculus of Belief Functions

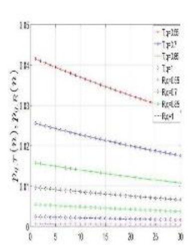
2. Entropy Optimization technique with the Lagrangian function subject to given constraints

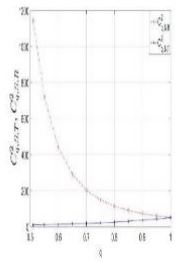
3. The info –Geometric Potential function and Fisher information matrix

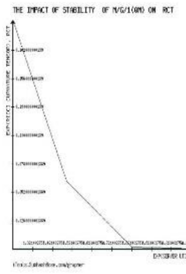
SOME CONTRIBUTIONS OUT OF MANY

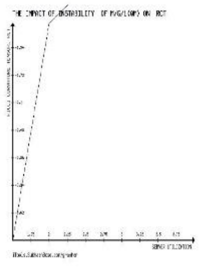
- An exploration was carried out of Rényi's and Tsallis's NME formalisms as methods of inductive inference for a physical system Q with a finite or countably infinite set S of states $\{S_n, n = 0, 1, 2, \dots\}$ and 'long-range' interactions of order, q ($0.5<q<1$). In this context, the respective NME state probabilities $p_{q,R}(S_n)$ and $p_{q,T}(S_n)$ were analytically devised, based on the maximisation of the respective entropy functionals, subject to normalisation and a finite number of suitable mean value constraints. Moreover, the credibility of these NME formalisms, as methods of inductive inference, was justified in terms of four consistency axioms, namely uniqueness, invariance, system independence and subset independence, which were associated with Shannon's EME formalism of systems with 'short-range' interactions. Specifically, it was verified that both Rényi's and Tsallis's formalisms, even though satisfied the consistency axioms of uniqueness, invariance and subset independence, nevertheless defied, as they should, the axiom of system independence due to the existence of 'long-range' interactions.. Moreover, both service time distribution and service time cumulative distributions that make our solution exact were obtained.
- The revealing of the new knowledge that all the queueing parameters $\rho, \beta = C_s^2$ of the stable M/G/1 queue manifold are time dependent functions;
- The discovery of the informational geometric equations of motion (IGEMs) for the M/G/1 queue manifold and their analytic solutions;
- The proposed new approach to visualize queueing systems via computational information geometry;
- The determination of a new approach to analyse the regions of stability for the M/G/1 (QM) based on the obtained solutions of the IGEMs for the related coordinates , server utilization ρ and squared coefficient of variation β .
- The establishment of new links between queueing theory and other mathematical disciplines such as information geometry, matrix theory Riemannian geometry and the theory of Relativity.
- Providing a novel link between Ricci Curvature (RCT) and the stability analysis of the stable M/G/1 (QM).

Charts









Conclusion AND FUTURE WORK

This thesis has produced several major breakthroughs. Beyond the remit of complex technicality, we have devised two new fields of knowledge, namely

- SOLVING THE LONSTANDING OPEN PROBLEM OF EXTENDED PROPERTIES OF THE CLASS OF RÉNYI GENERALIZED ENTROPIES IN THE DISCRETE TIME DOMAIN.
- INFORMATION-THEORETIC THEORY OF QUEUEUING SYSTEMS(ITQS) AND THE INFO-GEOMETRIC THEORY OF QUEUEING SYSTEMS(IGQS).
- EXTENDING THE WORK TO HIGHER LEVEL ENTROPIES AND DIFFENT QUEUES. ALSO, EXTENDING IG IMPACT TO TIME-DEPENDENT QUEUES

References

- 1. I.A. Mageed, and D.D. Kouvatsos, "Extended Properties of the Class of Rényi Generalized Entropies in the Discrete Time Domain", Extended version of paper [1], 11-13 July 2011, IEEE *International Conference on Computer Networks and Information Technology*, Abbottabad, Pakistan, pp. 1-7, doi: 10.1109/ICCNIT.2011.6020894. Online available at
- https://ieeexplore.ieee.org/document/6020894
- 2. D.D. Kouvatsos, and I.A Mageed, "Non-Extensive Maximum Entropy Formalisms and Inductive Inferences of Stable M/G/1 Queue with Heavy Tails", in "Advanced Trends in Queueing Theory", March 2021, Vol. 2, Vladimir Anisimov and Nikolaos Limnios (eds.), Books in 'Mathematics and Statistics', Sciences by ISTE & J. Wiley, London, UK.
- 3. D.D Kouvatsos, et I.A. Mageed, "Formalismes de maximum d'entropie non extensive et inférence inductive d'une file d'attente M/G/1 stable à queues Lourdes", "Théorie des files d'attente 2", Mars 2021,Théorie et Practique, Sous la direction de Vladimir Anisimov et Nikolaos Limnios, Mathématique, Sciences by ISTE & J. Wiley, Londres, Royaume-Uni.
- 4 I.A. Mageed, and D.D. Kouvatsos, "The Impact of Information Geometry on the Analysis of the Stable M/G/1 Queue Manifold", Major extension of paper [3], 4-6 February 2021, In Proceedings of the 10th International Conference on Operations Research and Enterprise Systems - Volume 1: ICORES, ISBN 978-989-758-485-5, pages 153-160. DOI: 10.5220/0010206801530160.

5th

Annual Innovative

Norcroft

UNIVERSITY of BRADFORD
Faculty of Engineering & Informatics