

Halimah Badioze Zaman · Peter Robinson ·
Alan F. Smeaton · Renato Lima De Oliveira ·
Bo Nørregaard Jørgensen · Timothy K. Shih ·
Rabiah Abdul Kadir · Ummul Hanan Mohamad ·
Mohammad Nazir Ahmad (Eds.)

LNCS 14322

Advances in Visual Informatics

8th International Visual Informatics Conference, IVIC 2023
Selangor, Malaysia, November 15–17, 2023
Proceedings

Lecture Notes in Computer Science

14322


Founding Editors

Gerhard Goos
Juris Hartmanis

Editorial Board Members

Elisa Bertino, *Purdue University, West Lafayette, IN, USA*

Wen Gao, *Peking University, Beijing, China*

Bernhard Steffen , *TU Dortmund University, Dortmund, Germany*

Moti Yung , *Columbia University, New York, NY, USA*

The series Lecture Notes in Computer Science (LNCS), including its subseries Lecture Notes in Artificial Intelligence (LNAI) and Lecture Notes in Bioinformatics (LNBI), has established itself as a medium for the publication of new developments in computer science and information technology research, teaching, and education.

LNCS enjoys close cooperation with the computer science R & D community, the series counts many renowned academics among its volume editors and paper authors, and collaborates with prestigious societies. Its mission is to serve this international community by providing an invaluable service, mainly focused on the publication of conference and workshop proceedings and postproceedings. LNCS commenced publication in 1973.

Halimah Badioze Zaman · Peter Robinson ·
Alan F. Smeaton · Renato Lima De Oliveira ·
Bo Nørregaard Jørgensen · Timothy K. Shih ·
Rabiah Abdul Kadir · Ummul Hanan Mohamad ·
Mohammad Nazir Ahmad
Editors

Advances in Visual Informatics

8th International Visual Informatics Conference, IVIC 2023
Selangor, Malaysia, November 15–17, 2023
Proceedings

Editors

Halimah Badioze Zaman
Universiti Tenaga Nasional
Kajang, Selangor, Malaysia

Peter Robinson
University of Cambridge
Cambridge, UK

Alan F. Smeaton
Dublin City University
Dublin, Ireland

Renato Lima De Oliveira
MIT Sloan School of Management
Asia School of Business
Cambridge, MA, USA

Bo Nørregaard Jørgensen
University of Southern Denmark
Odense, Denmark

Timothy K. Shih
National Central University
Jhongli, Taiwan

Rabiah Abdul Kadir
Universiti Kebangsaan Malaysia
Bangi, Selangor, Malaysia

Ummul Hanan Mohamad
Universiti Kebangsaan Malaysia
Bangi, Selangor, Malaysia

Mohammad Nazir Ahmad
Universiti Kebangsaan Malaysia
Bangi, Selangor, Malaysia

ISSN 0302-9743

ISSN 1611-3349 (electronic)

Lecture Notes in Computer Science

ISBN 978-981-99-7338-5

ISBN 978-981-99-7339-2 (eBook)

<https://doi.org/10.1007/978-981-99-7339-2>

© The Editor(s) (if applicable) and The Author(s), under exclusive license
to Springer Nature Singapore Pte Ltd. 2024

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors, and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Paper in this product is recyclable.

Preface

The International Visual Informatics Conference (IVIC) 2023 once again brought together experts from academia and industries in a multidisciplinary field that encompasses Computer Science, Information and Communications Technology and Computing Engineering. The conference took place amidst tremendous challenges of the post-COVID-19 pandemic, Energy Transition, Climate Change, Digital Transformation, Wars, Security, low education standards, unemployment and corruption. Despite these challenges, nations are braving it through and embracing opportunities that come their way. Emphasizing its multidisciplinary nature, this time the conference returned to its original home, Universiti Kebangsaan Malaysia (UKM) and was hosted once again by the Institute of Visual Informatics (IVI). Together with other institutional partners of this conference, research findings in various specialized areas of Visual Informatics integrated into various fundamental domains were shared together at this conference. We have seen the areas of Visual Informatics grow since the conference first began in 2009. We are grateful to all our partners, locally and internationally, for making this 8th IVIC a specially exciting and meaningful one.

The Eighth International Visual Informatics Conference (IVIC 2023) was conducted for the first time face-to-face after more than three years of not being able to have physical meetings but only virtual ones. For the first time after a long time too, participants could meet co-researchers from different institutions and different countries; and interact with potential partners from different institutions and industries physically. Participants were also able to appreciate exhibitions and discuss with the respective researchers the works exhibited to get first-hand explanations on matters that they did not understand or were concerned about. Like the previous conferences, the main objective of this conference was to bring together experts and researchers from academia and industry to discuss and share new knowledge, ideas and innovations through internationalization and industrialization. Like the previous IVIC conferences, this conference was organized collaboratively by the Visual Informatics fraternity from various public and private universities, professional institutions and industry players from various parts of the world (their names are listed in the proceedings). The conference was co-sponsored by the Malaysian Information Technology Society (MITS), Malaysia Chapter MyAIS, Institute of Informatics and Computing for Energy (IICE), UNITEN, ARB Berhad and MatrixStreams Sdn. Bhd. The conference was co-chaired by six (6) Professors from Cambridge University, MIT Sloan Management School/ABS, Dublin City University, University of Southern Denmark, National Central University and Universiti Tenaga Malaysia (UNITEN).

The theme of the conference mentioned earlier reflects the importance of the need for organizations and nations to create innovations to achieve Energy Transition efforts and digital transformation for societal well-being. All these innovations were undertaken at a time when disruptive technologies, Climate Change, Sustainability and Generative

AI had brought about interesting emerging visual technologies such as Electric Vehicles; Autonomous and semi-autonomous vehicles, Smart Energy Efficient Chat-bots, as well as Internet of things (IoT) and Blockchain for various domains such as smart buildings, healthcare, agriculture and education. The human-centric future smart society and citizenry of the various nations required new digital innovations that were adopting advanced AI such as Generative Artificial Intelligence (GAI) and data-driven AI and secured AI; they also required digital transformation through strategic digital adoption and sustainable technologies for better technological and economic growth of their respective countries. Thus, the theme of the conference was relevant, apt and timely.

The conference focused on six (6) tracks: *Modeling & Simulation, Mixed Reality & HCI, Systems Integration & IoT, Cybersecurity, Energy Informatics* and *Intelligent Data Analytics*, which lasted for two days (15th and 16th November 2023) and ended with four (4) half-day workshops (17th November 2023) that ran concurrently online entitled: *Data Development for Information Visualisation; Designing Questionnaires for Product, Process, Organizational & Marketing Innovation; Introduction to Deep Learning; and Advanced Techniques in Cybersecurity- Safeguarding your Digital Assets* respectively. There were five keynote speakers and 51 paper presentations based on topics covered by the six (6) main tracks. The reviewing of the papers was conducted by experts who represented the Programme Committee locally and internationally from Asia, Europe, and Oceania. Each paper was single-blind by three reviewers and the acceptance rate was 50%. The reviewing process was managed using the system Conference Bay. The conference also included an exhibition portraying research and innovations by academia and industry.

On behalf of the organizing and program committee of IVIC 2023, we thank all authors for their submissions and camera-ready copies of papers, and all participants for their thought-provoking ideas and active participation at the conference. We also thank the Vice-Chancellor of UKM (host university), and Vice-Chancellors and Deans of all Computer Science & IT and Business faculties and Research Institutes of the IHLs and Industry for their support in organizing this conference. We also acknowledge the sponsors, members of the organizing committees, program committee members, support committees and individuals who gave their continuous help and support in making the conference a success. We believe that IVIC will grow from strength to strength and will one day be hosted by not only different institutions in Malaysia but also in different host countries around the world.

November 2023

Halimah Badioze Zaman
 Peter Robinson
 Alan F. Smeaton
 Renato Lima De Oliveira
 Bo Nørregaard Jørgensen
 Timothy K. Shih
 Rabiah Abdul Kadir
 Ummul Hanan Mohamad
 Mohammad Nazir Ahmad

Organization

The 8th International Visual Informatics Conference (IVIC 2023) was organized by the Institute of Visual Informatics, Universiti Kebangsaan Malaysia (UKM), in collaboration with local public and private Universities in Malaysia, Multimedia Development Corporation (MDEC), and ICT Cluster of the National Professors' Council (MPN).

Local Executive Committee

General Chair

Halimah Badioze Zaman UNITEN, Malaysia

Deputy Chairs

Rabiah Abdul Kadir UKM, Malaysia
Zainab Abu Bakar AeU, Malaysia

Secretaries

Ummul Hanan Mohamad UKM, Malaysia
Nazrita Ibrahim UNITEN, Malaysia
Siti Nor Umi Khalilas UKM, Malaysia

Treasurers

Shafrida Sahrani UKM, Malaysia
Chaw Jun Kit UKM, Malaysia
Siti Norazimah Ahmat UKM, Malaysia

Program Committee

Program Co-chairs

Halimah Badioze Zaman UNITEN, Malaysia
Peter Robinson University of Cambridge, UK

Alan F. Smeaton	Dublin City University, Ireland
Renato Lima De Oliveira	Asia School of Business (in collaboration with MIT Sloan), USA
Bo Nørregaard Jørgensen	University of Southern Denmark, Denmark
Timothy K. Shih	National Central University, Taiwan

Technical Program Committee

Mohammad Nazir Ahmad (Head)	UKM, Malaysia
Ely Salwana Mat Surin	UKM, Malaysia
Muhamad Firdaus Abdull Razab	GAE, Malaysia
Rabiah Abdul Kadir	UKM, Malaysia
Ummul Hanan Mohamad	UKM, Malaysia

Sponsorship

Azlina Ahmad (Head)	UKM, Malaysia
Halimah Badioze Zaman	UNITEN, Malaysia
Mohammad Nazir Ahmad	UKM, Malaysia
Rahmat Hidayati	JOIV, Indonesia
Wan Fatimah Wan Ahmad	UTP, Malaysia

Publicity (Web Portal)

Mohamad Hidir Mhd Salim (Head)	UKM, Malaysia
Hafizhah Suzana	UKM, Malaysia
Norazlin Binti Othman	UKM, Malaysia
Nur Adilah Binti Shahli	UKM, Malaysia
Zarul Azham Bin Amin	UKM, Malaysia
Marina Ng	University of Nottingham (Malaysia Campus), Malaysia
Nur Intan Raihana	USM, Malaysia
Mohd Almuet	Irbid National University, Jordan
Norizan	UiTM, Malaysia
Nur Intan Raihana Ruhaiyem	USM, Malaysia
Syed Nasir Alsagoff	UPNM, Malaysia
Dahlan	UniKL, Malaysia
Nizam	UTHM, Malaysia
Suhaidi Hassan	UUM, Malaysia
Suraya Yaacob	UTM, Malaysia
Rosalina Abdul Salam	USIM, Malaysia

Mohd Hafiz Faizal	UniKL, Malaysia
Ibrahim Mohamed	UKM, Malaysia
Wong Seng Yue	UM, Malaysia
Nur Hanani Binti Azami	UNITEN, Malaysia
Yazeed AlSayed Ali Al Moayed	MEDIU, Malaysia
Titik Khawa Abdul Rahman	AeU, Malaysia
Joshua Thomas	UOW, Malaysia
Amelia Ritahani Ismail	IIUM, Malaysia
Angela Lee	Sunway University, Malaysia
Robietul A'dawiah Jamaluddin	IUKL, Malaysia
Munir	UPI, Indonesia
Aliza Sarlan	UTP, Malaysia
Suziah Sulaiman Sarlan	UTP, Malaysia
Choo Wou Onn	INTI, Malaysia
Noramiza Hashim	MMU, Malaysia
Muzaffar Hamzah	UMS, Malaysia
Azreen Azman	UPM, Malaysia
Rabiah Ahmad	UTHM, Malaysia
Faaizah Shahbodin	UTEM, Malaysia

Logistics

Mohamad Taha Ijab (Head)	UKM, Malaysia
Syed Nasir Syed Zakaria Alsagoff	UPNM, Malaysia
Hafizhah Suzana Hussien	UKM, Malaysia
Aziah Ali	MMU, Malaysia
Mujahid Abu Bakar	UKM, Malaysia
Nur Adilah Binti Shahli	UKM, Malaysia
Zarul Azham Bin Amin	UKM, Malaysia
Abdul Mutalib Omar	UKM, Malaysia

Workshop

Ang Mei Choo (Head)	UKM, Malaysia
Juhana Salim	MITS, Malaysia
Md. Mahidur Rahman Sarker	UKM, Malaysia
Joshua Thomas	UOW, Malaysia
Mohd Almuiet	Irbid National University, Jordan
Esmadi Abu Abu Seman	UMS, Malaysia
Kasturi Dewi Varathan	UM, Malaysia
Dhanapal Durai Dominic	UTP, Malaysia
Wong Seng Yue	UM, Malaysia

Conference Management System

Ely Salwana Mat Surin (Head)	UKM, Malaysia
Muhamad Firdaus Abdull Razab	GAE, Malaysia
Mohammad Nazir Ahmad	UKM, Malaysia

Tour

Prasanna Ramakrisnan (Head)	MITS, Malaysia
Hajah Norasiken Bakar	UTEM, Malaysia
Azreen Azman	UPM, Malaysia

Exhibition

Riza Sulaiman (Head)	UKM, Malaysia
Hanif Baharin	UKM, Malaysia
Arif Roslan	UKM, Malaysia
Zarul Azham Amin	UKM, Malaysia
Zaina Nabila Binti Zainol Mahdzir	UKM, Malaysia

Special Task

Norshita Mat Nayan (Head)	UKM, Malaysia
Mohd Syahmi Shahril	UKM, Malaysia
Nor Zakiah Binti Gorment	UNITEN, Malaysia
Eddren Law Yi Feng	UNITEN, Malaysia
Low Loi Ming	UNITEN, Malaysia
Nur Aimi Syaqlah Binti Aziz	UNITEN, Malaysia
Nor Nashrah Binti Azmi	UNITEN, Malaysia
Rajeshkumar A/L Sugu	UNITEN, Malaysia
Bavani Ramayah	University of Nottingham Malaysia Campus, Malaysia
Siti Nor Umi Khalilas	UKM, Malaysia

Floor Managers

Syed Nasir Alsagoff Syed Zakaria (Head)	UPNM, Malaysia
Hafizhah Suzana	UKM, Malaysia
Mujahid Abu Bakar	UKM, Malaysia

Registration

Chaw Jun Kit (Head)	UKM, Malaysia
Prasanna Ramakrisnan	UiTM, Malaysia
Marizuana Mat Daud	UKM, Malaysia

Technical Committee

International

Alan F. Smeaton	Dublin City University, Ireland
Timothy K. Shih	National Central University, Taiwan
Sergio Velastin	Queen Mary Univ. of London, UK
Terutoshi Tada	Toyo University, Japan
Emanuele Trucco	University of Dundee, UK
Hang-Bong Kang	Catholic University of Korea, South Korea
Marta Fairén	Universitat Politècnica de Catalunya, Spain
Erich Neuhold	University of Vienna, Austria
Theng Yin Leng	Nanyang Technological University, Singapore
Tony Pridmore	University of Nottingham, UK
Neil A. Gordon	University of Hull, UK
Hyowon Lee	SUTD, Singapore
Jianguo Zhang	University of Dundee, UK
Jing Hua	Wayne State University, USA
Nick Holliman	Durham University, UK
Qingde Li	University of Hull, UK
Wenyu Liu	Huazhong Univ. of Science and Technology, China
Malcolm Munro	Durham University, UK
Huang Jiung-yao	National Taipei University, Taiwan
Li Kuan-Ching	Providence University, Taiwan
Khider Nassif Jassim	University of Wasit, Iraq
Kamal Badr Abdalla Badr	Qatar Foundation, Qatar
Yunis Ali	Simad University, Somalia
Furkh Zeshan	University of Islamabad, Pakistan
Kamarul Faizal Hashim	University of Dubai, UAE
Omar Ahmed Ibrahim	University of Mosul, Iraq
Sommai Khantong	Maharakham University, Thailand

Malaysia

Azlina Ahmad	UKM
Afzan Adam	UKM
Amalina Farhi Ahmad Fadzhiah	UPNM
Asama Kuder Nseaf	UKM
Aslina Baharum	Sunway University
Azreen Azman	UPM
Ang Mei Choo	UKM
Anusha Achuthan	USM
Bahari Belaton	USM
Bavani Ramayah	University of Nottingham Malaysia Campus
Chiung Ching Ho	MMU
Chaw Jun Kit	UKM
Dahlan Abdul Ghani	UNIKL
Dayang Rohaya Awang Rambli	UTP
Ely Salwana Mat Surin	UKM
Eddren Law Yi Feng	UNITEN
Falah Y. H. Ahmed	MSU
Fauziah Zainuddin	UMP
Halimah Badioze Zaman	UKM
Hanif Baharin	UKM
Hajah Norasiken Bakar	UTEM
Hoo Meei Hao	UTAR
J. Joshua Thomas	UOW
Jamaiah Yahaya	UKM
Khairul Shafee Kalid	UTP
Magiswary Dorasamy	MMU
Mahidur Rahman Sarker	UKM
Marizuana Mat Daud	UKM
Marwan D. Saleh	MSU
Noor Afiza Mat Razali	UPNM
Mohamad Taha Ijab	UKM
Mohd Fairuz Iskandar Othman	UTeM
Mohammad Nazir Ahmad	UKM
Mohammad Hidir Mhd Salim	UKM
Mohd Afizi Mohd Shukran	UPNM
Mohd Nadhir Ab Wahab	USM
Mohd Nizam Husen	UNIKL
Mohd Rizal Mohd Isa	UPNM
Nor Hidayati Zakaria	UTM
Nazlena Mohamad Ali	UKM

Noor Hafizah Hassan	UTM
Noor Hayani Abd Rahim	IIUM
Noorminshah Iahad	UTM
Nor Zakiah Gorment	UNITEN
Nor Zairah Ab. Rahim	UTM
Norizan Mat Diah	UiTM
Norshahriah Abdul Wahab	UPNM
Norzihah Megat Mohd. Zainuddin	UTM
Nur Azaliah Abu Bakar	UTM
Nur Fazidah Elias	UKM
Nurulhuda Firdaus Mohd Azmi	UTM
Noor Afiza Mat Razali	UPNM
Norshita Mat Nayan	UKM
Nor Fatimah Awang	UPNM
Prasanna Ramakrisnan	UiTM
Puteri Nur Ellyza Nohuddin	UKM
Rabiah Abdul Kadir	UKM
Rahayu Ahmad	UUM
Rahmah Mokhtar	UMP
Rasimah Che Mohd Yusoff	UTM
Razatulshima Ghazali	MAMPU
Ridzuan Hussin	UPSI
Riza Sulaiman	UKM
Robiatul A'Dawiah Jamaluddin	IUKL
Roslina Ibrahim	UTM
Rahayu Ahmad	UUM
Savita K. Sugathan	UTP
Siti Nurul Mahfuzah Mohamad	UTEM
Stephanie Chua	UNIMAS
Suraya Hamid	UM
Suzaimah Ramli	UPNM
Suziah Sulaiman	UTP
Syed Nasir Alsagoff	UPNM
Syahaneim Marzukhi	UPNM
Ummul Hanan Mohamad	UKM
Wan Fatimah Wan Ahmad	UTP
Zahidah Abd Kadir	UNIKL
Zarul Fitri Zaaba	USM
Zuraini Zainol	UPNM
Zahidah Zulkifli	IIUM

Strategic Partners

Yayasan Canselor UNITEN (YCU)
Tenaga Nasional Berhad (TNB)
National Council of Professors (MPN)
Malaysia Digital Economy Corporation (MDEC)
Malaysian Information Technology Society (MITS)
Malaysia Association for Information Systems (MyAIS)
ARB Berhad

Co-organizers

Universiti Kebangsaan Malaysia (UKM)
Universiti Pertahanan Nasional Malaysia (UPNM)
Universiti Sains Islam Malaysia (USIM)
Universiti Teknikal Malaysia Melaka (UTeM)
Universiti Teknologi PETRONAS (UTP)
Universiti Sains Malaysia (USM)
Infrastructure University Kuala Lumpur (IUKL)
Universiti Kuala Lumpur (UniKL)
Universiti Teknologi Malaysia (UTM)
Universiti Malaya (UM)
Universiti Teknologi MARA (UiTM)
Al-Madinah International University (MEDIU)
International Islamic University Malaysia (IIUM)
University of Malaysia, Sarawak (UNIMAS)
Universiti Pendidikan Sultan Idris (UPSI)
Universiti Tenaga Nasional (UNITEN)
Universiti Utara Malaysia (UUM)
University of Nottingham, UK (Malaysia Campus)
UOW Malaysia
Sunway University

Contents

Keynote

Managing Personal Information	3
<i>Alan F. Smeaton</i>	

Modeling and Simulation

A Visual Real-Time Mobile E-Logbook System to Capture Design Activities, Decisions, and Ideas for Engineers	15
<i>Kok Weng Ng, Yun Ching Tan, JianBang Liu, and Mei Choo Ang</i>	

A Virtual Reality Development Methodology: A Review	26
<i>Mohd Amran Md Ali, Mohammad Nazir Ahmad, Wan Salwina Wan Ismail, Nur Saadah Mohamad Aun, Mohd Akif Farhan Ahmad Basri, Shima Dyana Mohd Fazree, and Nor Hidayati Zakaria</i>	

Deep Learning and Sentiment Analysis-Based Cryptocurrency Price Prediction	40
<i>Jia Ming Low, Zi Jian Tan, Tiong Yew Tang, and Narishah Mohamed Salleh</i>	

A Comparative Study of Univariate and Multivariate Time Series Forecasting for CPO Prices Using Machine Learning Techniques	52
<i>Juz Nur Fatiha Deena Mohd Fuad, Zaidah Ibrahim, Noor Latiffah Adam, and Norizan Mat Diah</i>	

Improving Autonomous Robot Gripper Position on Lifting Trash Objects based on Object Geometry Parameters and Centroid Modification	63
<i>Emil Naf'an, Riza Sulaiman, and Nazlena Mohamad Ali</i>	

A Web Application to Recommend Songs Based on Human Facial Expressions and Emotions	76
<i>Qhairun Nisa' Mohd Hanafi, Suziah Sulaiman, and Saipunidzam Mahamad</i>	

Understanding Text Messages for Anxiety Therapy Through Topic Modeling	87
<i>Teh Faradilla Abdul Rahman and Norshita Mat Nayan</i>	

Mixed Reality and Human-Computer Interaction

Theoretical Analysis of Research Methodology to Study Emotions Using Emotion AI Among Malaysian E-Learning Tertiary Students for Prototype of Adaptive Interface	101
<i>Vasaki Seenivasagam, Zainab Abu Bakar, Norshuhani Zamin, and Yazrina Yahya</i>	
Human Gesture Recognition for Elderly People Using User Training Interaction Data	109
<i>Nur Ani, Nazlena Mohamad Ali, and Vina Ayumi</i>	
Virtual Reality for Social-Emotional Learning: A Review	119
<i>Irna Hamzah, Ely Salwana, Mark Billingham, Nilufar Baghaei, Mohammad Nazir Ahmad, Fadhilah Rosdi, and Azhar Arsad</i>	
Embodied Narrative: Data Storytelling of Online Artwork Experiences	131
<i>Hanif Baharin, Afdallyna Fathiyah Harun, and Noris Mohd Norowi</i>	
Participatory Design Workshop to Create a Virtual Reality Musical Instrument Based on Tumbuk Kalang	142
<i>Hanif Baharin, Noris Norowi, Khatriza Ahmad Saffian, and Yap Eng Sim</i>	
Evaluating the Effectiveness of E-Learning Website Using Electroencephalogram	152
<i>Alberto Aning, Aslina Baharum, Nur Faraha Mohd Naim, Nurhafizah Moziyana Mohd Yusop, Dian Darina Indah Darius, Noorsidi Aizuddin Mat Noor, and Farhana Diana Deris</i>	
Compustory: A Virtual Museum Game for Modeling the History of Computer Evolution	161
<i>Warda Azzahra, Munir, and Wahyudin</i>	
The Use of Augmented Reality, Virtual Reality, and Mixed Reality in Communication Children's with ASD: Systematic Literature Review	175
<i>Azizah Nurul Khoirunnisa, Munir, Laksmi Dewi, Rasim, Nissa Nur Azizah, and Zsalza Puspa Alivia</i>	
Hybrid on a Budget: An Autoethnographic Study	191
<i>Shariffah Bahyah Binti Syed Ahmad and Syed Nasir Alsagoff Bin Syed Zakaria</i>	

Adoption Barriers of Assistive Ambient Technology: A Systematic Literature Review	200
<i>Nik Izyan Fatini Musri, Rozianawaty Osman, Nurzeatul Hamimah Abdul Hamid, and Fariza Hanis Abdul Razak</i>	
The Affordances and Usability Evaluation for HeartM 3.0: A Mobile Heart Monitoring Application	209
<i>Muhammad Sobri, Mohamad Taha Ijab, Norshita Mat Nayan, and Alexander Edo Tondas</i>	
Game-Based Mobile Application for Tarannum Learning	223
<i>Muhammad Irfan Mohd Nadziman, Haslizatul Fairuz Mohamed Hanum, Nur Aina Khadijah Adnan, Norizan Mat Diah, and Zainab Abu Bakar</i>	
Review of User Satisfaction Models in the Context of Digital Libraries Setting	234
<i>Hend Ali Musbah Jebiril and Mohammad Nazir Ahmad</i>	
Systems Integration and IoT, Cybersecurity, Energy Informatics	
Design and Development of an Automated Filament Changing System for Fused Deposition Modelling (FDM) 3D Printer Using Axiomatic Design and TRIZ	249
<i>Kok Weng Ng, Jia Wei Wong, JianBang Liu, and Mei Choo Ang</i>	
Blockchain-Based Traceability Method - A Review	261
<i>David Wong You King, Muhammad Arif Riza, Liew Kok Leong, Ummul Hanan Mohamad, Rabiah Abdul Kadir, Mohammad Fairus Zulkifli, and Mohammad Nazir Ahmad</i>	
Responding to Regional Revitalisation and Socio-economic Challenges in Japan: Government Approaches and Use of Advanced Technologies	276
<i>Yasuki Shima and Ali Fathelalem Hija</i>	
Evaluation of Smart Community Engagement in Riyadh, Saudi Arabia	288
<i>Norshuhani Zamin, Mervin Esckalin Mary, Abdul Wahab Muzaffar, Ku Ruhana Ku-Mahamud, and Mohd Azhar Ibrahim Residi</i>	
Cloud Service Provider Cost for Online University: Amazon Web Services versus Oracle Cloud Infrastructure	302
<i>Yazeed Al Moaiad, Zainab Abu Bakar, Ahamd Mhd Emad Diab, Norshuhani Zamin, and Yazrina Yahya</i>	

Elevating Database Performance: Current Caching and Prefetching Strategies for Online Databases in Nigeria	314
<i>Olatunji Austine Kehinde, Zahidah Zulkifli, Ely Salwana Mat Surin, Nur Leyni Nilam Putri Junurham, and Murni Mahmud</i>	
Exploring Data Wiping Practices in the Royal Malaysian Air Force (RMAF) HQ	328
<i>Syed Nasir Alsagoff Bin Syed Zakaria, Kuan Fook Chao, and Zuraini Zainol</i>	
Affordances-Based Behavior Change for Energy Efficiency Among Malaysians: A Conceptual Model	339
<i>Mohamad Taha Ijab, Hamizah Mohamad Hariri, Norshita Mat Nayan, Mohd Azul Mohamad Salleh, and Suraya Hamid</i>	
Intelligent Data Analytics	
The Role of Mass Media as a Communications Distributor for Tourism Villages in Indonesia	353
<i>Prasiwi Citra Resmi, John J. O. I. Ihalauw, Dwiyono Rudi Susanto, Damiasih Damiasih, Suhendroyono Suhendroyono, and Tutut Herawan</i>	
Creating Values for Big Data Analytics through Business and Technology Alignment	369
<i>Luen Mun Chong, Suraya Yaacob, Wan Farahwani Wan Fakhruddin, and Nur Azaliah Abu Bakar</i>	
Web-Based Mental Health Predicting System Using K-Nearest Neighbors and XGBoost Algorithms	381
<i>Nurul Farhanaa Zulkefli, Norizan Mat Diah, Azlan Ismail, Haslizatul Fairuz Mohamed Hanum, Zaidah Ibrahim, and Yunifa Miftachul Arif</i>	
Genre Classification in Music using Convolutional Neural Networks	397
<i>Andrew Bawitlung and Sandeep Kumar Dash</i>	
Harnessing Technology for Efficient Coagulation Profile E-Reporting: A Design Thinking Approach	410
<i>Puteri N. E. Nohuddin, Prasis Ja Singh, Kelvin Ch'ng, Phan Nop So Phon, Nora Azima Noordin, Zahidah Abd Kadir, and Zuraini Zainol</i>	
The Impact of Preprocessing Techniques Towards Word Embedding	421
<i>Mustazzihim Suhaidi, Rabiah Abdul Kadir, and Sabrina Tiun</i>	

Predict Traffic State Based on PCA-KMeans Clustering of neighbouring roads	430
<i>Bagus Priambodo, Bambang Jokonowo, Samidi, Azlina Ahmad, and Rabiah Abdul Kadir</i>	
Unleashing Trustworthy Cloud Storage: Harnessing Blockchain for Cloud Data Integrity Verification	443
<i>Zhenxiang Li, Mohammad Nazir Ahmad, Yuanrong Jin, Wang Haipei, and Liang Zhantu</i>	
A Novel Approach of Adaptive Window 2 Technique and Kalman Filter-“KalADWIN2” for Detection of Concept Drift	453
<i>Anagha Chaudhari, Hitham Seddig A.A., Roshani Raut, and Aliza Sarlan</i>	
Unleashing the Power of Visuals: A Captivating Exploration of Scientific Data Visualization Methods and Techniques	468
<i>Aslina Baharum, Rozita Ismail, Ismassabah Ismail, Noorsidi Aizuddin Mat Noor, Farhana Diana Deris, and Suhaida Halamy</i>	
Blockchain Technology for Traceability Monitoring in Food Supply Chain	478
<i>Mohammad Fairus Zulkifli, Rabiah Abdul Kadir, Mohammad Nazir Ahmad, David Wong You King, and Muhammad Badrun Al-Muhaimin Baharon</i>	
Data Mining in Establishing the Indirect Reference Intervals of Biochemical and Haematological Assays in the Paediatric Population: A Review	493
<i>Dian N. Nasuruddin, Ely Salwana, Mahidur R. Sarker, Adli Ali, and Tze Ping Loh</i>	
A Visual-Based Energy Efficient Digital Agro (EE i-Agro) Project for Design & Technology Subject, Based on Computational Thinking Skills Across STEM	508
<i>Halimah Badioze Zaman, Rahimah Ismail, Nazrita Ibrahim, and Ummul Hanan Mohamad</i>	
Multilingual Speech Emotion Recognition Using Deep Learning Approach	526
<i>Chu Sheng Liau and Kai Sze Hong</i>	
Covid-19 Detection Using Coughing Sounds with Mel-frequency Cepstral Coefficients and Long Short-Term Memory	541
<i>Jia Chong Lim and Kai Sze Hong</i>	

Enhancing Diabetes Prediction and Classification Using the Bidirectional Neighbor Graph Algorithm	557
<i>Bashar Hamad Aubaidan, Rabiah Abdul Kadir, and Mohamad Taha Ijab</i>	
Feature Selection Techniques on Breast Cancer Classification Using Fine Needle Aspiration Features: A Comparative Study	568
<i>Shahiratul A. Karim, Ummul Hanan Mohamad, and Puteri N. E. Nohuddin</i>	
Machine Learning Trends in Mushroom Agriculture: A Systematic Review Methodology	583
<i>Bayu Priyatna, Zainab Abu Bakar, Norshuhani Zamin, and Yazrina Yahya</i>	
Is ChatGPT not Appropriate for Religious Use?	595
<i>Tengku M. T. Sembok and Sharyar Wani</i>	
A Visual-Based Energy Efficient Chatbot: Relationship between Sentiment Analysis and Customer Satisfaction	606
<i>Nurul Muizzah Johari, Halimah Badioze Zaman, Hanif Baharin, and Puteri N. E. Nohuddin</i>	
Abstractive Summarization Evaluation for Prompt Engineering	629
<i>Shayak Chakraborty and Partha Pakray</i>	
Fuzzy Soft Set Based Classification for Rock Dataset	641
<i>Rahmat Hidayat, Azizul Azhar Ramli, Mohd Farhan Md. Fudzee, and Iwan Tri Riyadi Yanto</i>	
A Diabetes Prediction Model with Visualized Explainable Artificial Intelligence (XAI) Technology	648
<i>Yanfeng Zhao, Jun Kit Chaw, Mei Choo Ang, Marizuana Mat Daud, and Lin Liu</i>	
Author Index	663



Fuzzy Soft Set Based Classification for Rock Dataset

Rahmat Hidayat^{1,2(✉)}, Azizul Azhar Ramli¹, Mohd Farhan Md. Fudzee¹,
and Iwan Tri Riyadi Yanto³

¹ Universiti Tun Hussein Onn Malaysia, Parit Raja, Malaysia
rahmat@pnp.ac.id

² Politeknik Negeri Padang, Padang, Indonesia

³ Universitas Ahmad Dahlan, Yogyakarta, Indonesia

Abstract. One of the main tasks in geological studies is rock classification. To examine rock samples in this classification usually requires a human expert. Thus, the igneous rocks' classification task will become challenging because of igneous rocks' diverse composition. One data mining technique based on Fuzzy soft set can be used for classification. Several similarity measures have been proposed on the fuzzy soft set. In this paper, we conduct an experiment to explore the fuzzy soft set classifier applying several measurement to calculate the similarity, i.e., generalized fuzzy soft sets, similarity based on matching function, similarity based on set theoretic approach, similarity measure based on distance. The classification of igneous rocks is carried out in this experiment based on their chemical composition and compared it in terms of accuracy, precision, and recall. According to our simulation results, the Euclidean distance still outperforms to another measure in terms of classification accuracy, precision, and recall.

Keywords: Fuzzy soft set · similarity measures · igneous rocks · chemical composition

1 Introduction

The study of igneous rocks is one of the fundamental branches of geology [1]. In geology there are three main rocks, namely sedimentary, metamorphic, and igneous rocks [2]. Formation of igneous rock from molten material through a compacted process. In its past history, all rocks on the Earth's surface should have had a freezing process, although igneous rock deposits in some areas were not abundant. Therefore, Understanding the composition of the earth's interior is very important. This can be done through the study of igneous rocks. Both within and between rock bonds, igneous rock is not homogeneous. This is possible due to differences in rock and mineral composition. The place and time at which rocks form is sometimes related to the diversity of these igneous rocks [3]. In addition, differences in the origin of rocks result in the elemental composition of igneous rocks from one place to another. The diversity of chemical and mineral compositions results in a diversity of igneous rocks. In igneous rock, chemical analysis is expressed

as weight percent oxides (wt%) for the main elements (SiO_2 , TiO_2 , Al_2O_3 , FeO , Fe_2O_3 , MnO , MgO , CaO , Na_2O , K_2O , and P_2O_5) and parts per million (ppm) for trace element [3]. In quantitative classification, the classification of igneous rocks can be carried out on the basis of their chemical or mineralogical composition. The category of silicate or felsic rock, ultramafic rock, mafic rock, and intermediate rock is a classification of igneous rock based on its mineral composition. Meanwhile, the category of intermediate rock, acid rock, ultrabasic rock, and bare rock are classified as igneous rocks based on their chemical composition [4]. The diversity in the composition of igneous rocks presents a challenge in classifying these rocks.

Bana et al. proposed the fuzzy soft set (FSS) based on the generalized fuzzy soft set's similarity to classify the data numerically called FSSC [5]. In the pre-processing stage of the algorithm, a fuzzy approach is used to obtain the similarity of concepts and features in the classification process. This process can not only be applied to binary valued datasets but can also be used to classify data consisting of real numbers. They compare the FSSC with the Soft Set Classifier on data set taken from UCI machine learning. The Algorithm is implemented for text classification and has a better performance than SVM and KNN [6]. Another fuzzy soft set has been proposed by Yanto et al. using hamming distance to measure the similarity called HDFSSC [7]. The HDFSSC technique consists of four phases: data acquisition (1st phase), feature fuzzification (2nd phase), training (3rd phase), and testing (4th phase). The technique is evaluated by comparing with the baseline fuzzy soft set classifiers, including FSSC using the data taken from the Mammographic Image Analysis Society (MIAS) with good results.

Measurement of similarities has an essential role in the Classification using FSS [8, 9]. The similarity measure is a measure to find out how similar the two data objects are. The similarity measure in the context of data mining is the distance to dimensions that represent object features. If this distance is small, it can be interpreted that the two objects have a high degree of similarity, and if there is a considerable distance, then both objects have a low level of similarity. The similarity is subjective and is very dependent on the domain and application. There are many similarity measures of the soft set, and FSS have been studied, i.e., generalized fuzzy soft sets, similarity based on matching function, similarity based on set-theoretic approach, and similarity measure based on distance. Another distance is based on new similarity measures of FSS, where the usage of this distance measure in this research is more reasonable [10]. However, not all similarity measure has been exploration to know the performance for Classification. We conduct experiments to explore the similarity measure of generalized fuzzy soft sets, similarity based on matching function, similarity based on set-theoretic approach, and similarity measure based on distance on the rock dataset.

2 Fuzzy Soft Set (FSS)

Maji et al. define and apply the fuzzy soft set concept, hereinafter referred to as FSS in decision making problems. It is known that a convenient tool for representing concept uncertainty is provided by fuzzy sets using partial membership. In the definition of a FSS, substitute for sharp subsets uses fuzzy subsets. Thus, each soft set can be treated as a FSS [11]. In addition, on the basis of an analogy such as a soft set, it can be seen easily

that each FSS can be viewed as a fuzzy information system. In such systems, data tables with entries included in the unit interval [0,1] represent the FSS. Suppose that E is the set of parameters that have relations with objects in a non-empty universe denoted by U , the set of powers of U is denoted by $P(U)$ and $A \subseteq E$. Then, the parameterized family of the subset U is called the soft set [12, 13]. A soft set of U can also be interpreted as a pair of $f:E \rightarrow P(U)$ maps. The definition is based on the consideration that set of ϵ -approximate elements of the soft set or set ϵ -elements of the soft set, rather than a (crisp) set. Meanwhile, in FSS Theory, shows the power of all fuzzy subsets. Furthermore, a fuzzy soft set over is a pair, with is mapping represented by. Thus, the substitute for subset U is the fuzzy subset in universe U . Example 1 is given as an illustration.

Example 1. A description of the attractiveness of the shirt to be purchased is given against the given parameters stated in the FSS (F, E) . Suppose that the set of all the shirts being considered is represented by $U = \{x_1, x_2, x_3, x_4, x_5\}$. Next, the aggregate of all fuzzy subsets of U is represented by $P(U)$ and the colorful, bright, cheap, and warm parameters are expressed in terms of the set $E = \{e_1, e_2, e_3, e_4\}$. Let

$$\underline{F}(e_1) = \{x_1/0.5, x_2/0.9, x_3/0.0, x_4/0.0, x_5/0.0\}$$

$$\underline{F}(e_2) = \{x_1/1.0, x_2/0.8, x_3/0.7, x_4/0.0, x_5/0.0\}$$

$$\underline{F}(e_3) = \{x_1/0.0, x_2/0.0, x_3/0.0, x_4/0.6, x_5/0.0\}$$

$$\underline{F}(e_4) = \{x_1/0.0, x_2/1.0, x_3/0.0, x_4/0.0, x_5/0.0\}$$

and the family $E(e_i)$ with $i = \{1, 2, 3, 4\}$ of $P(U)$. Table 1 is given as a form of FSS representation.

Table 1. FSS representation

(U, E)	e_1	e_2	e_3	e_4
x_1	0.5	1.0	0	0
x_2	0.9	0.8	0	1.0
x_3	1	0.7	0	0
x_4	1	0	0.6	0
x_5	0	0	0	0.3

3 Similarity and Distance Measure

There are several measurement models within the scope of data clustering and grouping, one of which is the similarity between the two entities [12]. Several researchers have carried similarity measurement between fuzzy number, fuzzy sets, and vague sets.

Recently we found that the similarity measure of soft set and fuzzy fine set has also been investigated [13]. In this paper, the FSS was measured based on similarity, i.e., generalized fuzzy soft sets, similarity based on matching function, similarity based on the set-theoretic approach, and Similarity measure distance. Lets $U = \{x_1, x_2, \dots, x_n\}$ be a universe set, $E = \{e_1, e_2, \dots, e_m\}$ be a parameter set. Assume that the fuzzy soft set (F, A) and (G, B) have the same parameter set, $A, B \subset E$. The similarity between two generalized fuzzy soft set is defined as follows

$$d_1((F, A), (G, B)) = \max_i \left(1 - \frac{\sum_{j=1}^n |F(e_i)(x_j) - G(e_i)(x_j)|}{\sum_{j=1}^n |F(e_i)(x_j) + G(e_i)(x_j)|} \right). \tag{1}$$

The following provides a definition of similarity based on the set-theory approach presented in the formula

$$d_2((F, A), (G, B)) = \max_i \left(\frac{\sum_{j=1}^n F(e_i)(x_j) \wedge G(e_i)(x_j)}{\sum_{j=1}^n F(e_i)(x_j) \vee G(e_i)(x_j)} \right). \tag{2}$$

On the basis of the set-theory approach, similarities are also defined in terms of form

$$d_3((F, A), (G, B)) = \frac{\sum_{i=1}^n F(e_i) \cdot G(e_i)}{\sum_{i=1}^n (F(e_i)^2 \vee G(e_i)^2)}. \tag{3}$$

Meanwhile, on the basis of the distance, similarity measure by Munjandar et al. can be defined as

$$d_4((F, A), (G, B)) = \min T_i((F, A), (G, B)), \tag{4}$$

where $T_i((F, A), (G, B)) = \frac{1}{1+d_\infty^i}$, d_∞^i is the distance between the e -approximations $F(e_i)$ and $G(e_i)$ which is $d_\infty^i = \max_j |F(e_i)(x_j) - G(e_i)(x_j)|$.

Another distance-based similarity measure for the fuzzy soft set is explored by Feng et al. called new similarity measures of FSS based on hamming and Euclidean distance as a distance measure. The Hamming and normalize distance in FSS are using Eqs. (5) and (6).

$$d_5((F, A), (G, B)) = \frac{1}{mn} \sum_{i=1}^m \sum_{j=1}^n |F(e_i)(x_j) - G(e_i)(x_j)| \tag{5}$$

and

$$d_6((F, A), (G, B)) = \frac{1}{mn} \left(\sum_{i=1}^m \sum_{j=1}^n |F(e_i)(x_j) - G(e_i)(x_j)|^2 \right)^{\frac{1}{2}} \tag{6}$$

4 Methodology

In this research, methodology consists are data collection, observation stage and laboratories stage. Data collection and observation stage is in the form of data collection in the field, in the form of lithology selected after detailed geological mapping of the meticulous area in Yogyakarta. Data collection in the form of igneous rock retrieval for petrographic analysis and chemistry. Laboratories stage is divided into sample preparation stages, in the form of making thin incisions of rocks for the study of petrography and chemical analysis of rocks (main oxides, trace elements, and rare soil elements) with XRF (X-ray fluoresces) and ICP-OES (Inductively Coupled Plasma optical emission spectrometry) devices by PT laboratories. Main Intertek Service. Petrographic observations were made in the Hard-rock Laboratory, with the Olympus CX-31P polarizing microscope.

The steps of the classification algorithm that is learning (training) and classification step. Before the two steps are done, first applied fuzzification and formation of the FSS. This step is used to obtain the feature vector for all data, be it training and testing datasets. The set model for each class in fuzzy soft is obtained at the training step The data will be learned based on the data class group [7]. The Learning step is to determine the center of each class that exists. If data $U = \{u_1, u_2, \dots, U_N\}$, there is C class of data with n_r ; $r = 1, 2, \dots, K$ data of each class where $\sum_{r=1}^K n_r = N$, and E be the set of parameters, $A \subseteq E, A\{e_i, i = 1, 2, \dots, m\}$. Suppose F_{C_r} is the set of fuzzy soft sets of the r -th class. Then the center vector of the class is denoted as P_{C_r} can be defined as

$$P_{C_r} = \frac{1}{n_r} \sum_{j=1}^{n_r} \mu_{C_r(e_i)}(u_1), \tag{7}$$

where $i = 1, 2, \dots, m$ and $r = 1, 2, \dots, k$.

The classification is used to label the unknown data to the target class. The new data of the training step results will be used to determine the classes in the new data measuring the similarity of two sets of fuzzy soft sets acquired in the class center vector and new data. This comparative study uses the formula for similarity measure as follows:

$$S(F_{P_{C_r}}, F_G) = 1 - d_i(F_{P_{C_r}}, F_G). \tag{8}$$

where d_i is the similarity and distance measure that have been discussed i.e., generalized fuzzy soft sets, similarity based on matching function, similarity based on set-theoretic approach and similarity measure based on distance, respectively.

After the value of the similarity for each class is obtained then it will look for which class label is appropriate for new data F_G by determining the maximum value of the result of measuring similarity for all classes. The class label is;

$$label_{clas} = \arg \left[\max_{r=1}^k S(F_{P_{C_r}}, F_G) \right]. \tag{9}$$

5 Result and Discussion

There are 11 features in this real world dataset collected from Mount Wungkal, Godean, Yogyakarta, Indonesia. namely Titanium dioxide (TiO_2), Silicon dioxide (SiO_2), Iron (II) oxide + Iron(III) oxide ($FeO + Fe_2O_3$), Aluminum oxide (Al_2O_3), Magnesium oxide

(MgO), Manganese(II) oxide (MnO), Sodium oxide (Na₂O), Calcium oxide (CaO), Phosphorus pentoxide (P₂O₅), Class Label, and Potassium oxide (K₂O). MATLAB version 7.14.0.334 (R2012a) was used to develop this experiment. Windows 10 operating system with an Intel Core i3-3217U CPU @ 1.80Ghz, and a total main memory of 8G RAM is used to run this algorithm. The dataset is divided into two sets of data used for training and testing where each experiment is carried out randomly in the process of separating the dataset. A total of 80 times were carried out in this experiment, with the percentage of training and testing being 80% and 20%, respectively. With this algorithm, the experiments conducted focus on calculation (precision, accuracy, recovery), and the experimental results are presented in Table 2. Based on Table 2 it can be seen that in igneous rock classification, fuzzy soft set has good performance.

Table 2. The experiment results

Methods	Accuracy	Precision	Recall
set theoretic approach	0.5833	0.7000	0.6000
Similarity distance	0.3667	0.4500	0.6000
Matching function	0.6000	0.5500	0.7500
Generalized fuzzy soft set	0.8000	0.8000	0.7500
Euclidean distance	0.8667	1.0000	0.8500

6 Conclusion

In this research, we conducted experiments on six different similarity-deductors to obtain the classification accuracy of the fuzzy soft set classification algorithm. In terms of which algorithm is better used to classify igneous rock based on its chemical analysis. This is done on the basis of the chemical composition of the igneous rock which is a fundamental characteristic. Furthermore, the classification will become a quantitative classification. It is clear from the simulation results that the best performance is for fuzzy classifier based on the Euclidian distance. The more generalized Euclidian distance of fuzzy soft set is one of the Future works.

References

1. Joseph, S., Ujir, H., Hipiny, I.: Unsupervised classification of Intrusive igneous rock thin section images using edge detection and colour analysis. In: 2017 IEEE International Conference on Signal and Image Processing Applications (ICSIPA), pp. 530–534 (2017)
2. Rangel, D.N., Reyes Santiago, O., Rodríguez, A.N., Rojas, A.F., González, E.A.P.: Correlation between morphometric parameters and geology of igneous and metamorphic basins in Colombia. In: 2020 Congreso Internacional de Innovación y Tendencias en Ingeniería (CONIITI), pp. 1–6 (2020)

3. Bai, Z., Zhong, H., Hu, R., Zhu, W., Hu, W.: Composition of the chilled marginal rocks of the panzhihua layered intrusion, emeishan large igneous province, SW China: implications for parental magma compositions, sulfide saturation history and Fe–Ti oxide mineralization. *J. Petrol.* **60**(3), 619–648 (2019)
4. Schön, J.H.: Chapter 1 - rocks—their classification and general properties. In: Schön, J.H. (ed.) *Physical Properties of Rocks*, vol. 65, pp. 1–19. Elsevier (2015)
5. Handaga, B., Herawan, T., Deris, M.M.: FSSC: an algorithm for classifying numerical data using fuzzy soft set theory. *Int. J. Fuzzy Syst. Appl.* **2**(4), 29–46 (2012)
6. Handaga, B., Deris, M.M.: Text categorization based on fuzzy soft set theory. In: Murgante, B., Gervasi, O., Misra, S., Nedjah, N., Rocha, A.M.A.C., Taniar, D., Apduhan, B.O. (eds.) *ICCSA 2012. LNCS*, vol. 7336, pp. 340–352. Springer, Heidelberg (2012). https://doi.org/10.1007/978-3-642-31128-4_25
7. Yanto, I.T.R., Saedudin, R.R., Lashari, S.A., Haviluddin, H.: A numerical classification technique based on fuzzy soft set using hamming distance. In: *Advances in Intelligent Systems and Computing*, vol. 700, pp. 252–260 (2018)
8. Handaga, B., Mat Deris, M.: Similarity approach on fuzzy soft set based numerical data classification BT - software engineering and computer systems, pp. 575–589 (2011)
9. Singhal, N., Verma, A., Chouhan, U.: *An Application of Similarity Measure of Fuzzy Soft Sets in Vendor Selection Problem* (2018)
10. Feng, Q., Zheng, W.: New similarity measures of fuzzy soft sets based on distance measures. *Ann. Fuzzy Math. Informatics* **7**(4), 669–686 (2014)
11. Rehman, N., Ali, A., Park, C.: Note on fuzzy soft sets and fuzzy soft lattices. *Rev. la Real Acad. Ciencias Exactas, Fis. y Nat. - Ser. A Mat.*, **113**(1), 41–48 (2019)
12. Cross, V., Mokrenko, V., Crockett, K., Adel, N.: Using fuzzy set similarity in sentence similarity measures. In: *IEEE International Conference on Fuzzy Systems*, vol. 2020 (July 2020)
13. Majumdar, P., Samanta, S.K.: Generalised fuzzy soft sets. *Comput. Math. with Appl.* **59**(4), 1425–1432 (2010)