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Computing & Informatics

Computer Science for Improving the Quality of Life

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KEYNOTE ADDRESS

- DIGITAL GRAPHIC NOVELS: TECHNOLOGY ENHANCED NARRATIVE FOR LEARNING [01](#)
Zulikha Jamaludin

CHAPTER 1

- USER INTERFACE DESIGN: A STUDY OF EXPECTATION-CONFIRMATION THEORY [17](#)
Aslina Baharum and Azizah Jaafar
- ASSESSING THE SIMULATION PERFORMANCES OF MULTIPLE MODEL SELECTION ALGORITHM [25](#)
Norhayati Yusof, Suzilah Ismail and T Zalizam T Muda
- ALGORITHMIC APPROACHES IN MODEL SELECTION OF THE AIR PASSENGERS FLOWS DATA [32](#)
Suzilah Ismail, Norhayati Yusof and T Zalizam T Muda

CHAPTER 2

- IMPLEMENTATION OF AN AUTOMATED SMART HOME CONTROL FOR DETECTING HUMAN EMOTIONS VIA FACIAL DETECTION [39](#)
Lim Teck Boon, Mohd Heikal Husin, Zarul Fitri Zaaba and Mohd Azam Osman
- THE SENTINEL: A PROPOSED POTENTIAL INTRUDER ALERT SYSTEM BASED ON HUMAN BEHAVIOURS [46](#)
Lee Chi Ngan, Mohd Azam Osman, Zarul Fitri Zaaba and Wan Mohd Nazmee Wan Zainon
- COOKING GUIDE: DIRECT AND INDIRECT FORM OF INTERACTION IN THE DIGITAL KITCHEN ENVIRONMENT [52](#)
K.N.F. Ku. Azir, Chris Baber and M.Jusoh
- FACE-VOICE ASSOCIATION TOWARDS MULTIMODAL-BASED AUTHENTICATION USING MODULATED SPIKE-TIME DEPENDENT LEARNING [58](#)
Nooraini Yusoff and Mohammed Fadhil Ibrahim
- ENHANCING THE PERFORMANCE OF MULTI-MODALITY ONTOLOGY SEMANTIC IMAGE RETRIEVAL USING OBJECT PROPERTIES FILTER [65](#)
Mohd Suffian Sulaiman, Sharifalillah Nordin and Nursuriati Jamil
- COMPARISON BETWEEN PIXEL-BASED AND OBJECT-BASED CLASSIFICATIONS USING RADAR SATELLITE IMAGE IN EXTRACTING MASSIVE FLOOD EXTENT AT NORTHERN REGION OF PENINSULAR MALAYSIA [73](#)
Syaifulnizam Abd Manaf, Norwati Mustapha, Helmi Zulhaidi Mohd Shafri, Md Nasir Sulaiman and Nor Azura Husin

CHAPTER 3

- A CONCEPTUAL MODEL OF UBIQUITOUS LANGUAGE LEARNING ENVIRONMENT (ULLE) [81](#)
Mohd Khairul Ikhwan Zolkefley, Zurainee Mohd Tahir, Anitawati Mohd Lokman, Azhar Abd Aziz, and Shamsudin Md Sharif
- LEARNING FROM NEWS: IS ONLINE BETTER THAN PRINT? [89](#)
Bahiyah Omar
- A CONCEPTUAL FRAMEWORK FOR MEASURING THE ACCEPTANCE OF PERVASIVE LEARNING [97](#)
Muhammad Yaqoob Koondhar, Nurul Nuha Binti Abdul Molok, Fida Chandio, Muhammad Malook Rind, Ali Raza, and Asadullah Shah
- A FRAMEWORK FOR THE ANALYSIS OF DETERMINANTS OF SOCIAL MEDIA ACCEPTANCE IN HIGHER EDUCATIONAL INSTITUTES OF PAKISTAN [104](#)
Ali Raza, Fida Hussain Chandio, M Yaqoob Koondhar, M Malook Rind, and Asadullah Shah

CHAPTER 4

- DEVELOPMENT OF INSTRUMENT FOR EVALUATING WEBSITE USABILITY FOCUSING ON UNIVERSITY WEBSITE [114](#)
Nur Sukinah Aziz and Adzhar Kamaludin
- TELEHEALTH IN YEMEN: AN OVERVIEW AND A PROPOSED MODEL [121](#)
Abdulrahman A Al-Fadhli, Marini Othman, Abdullah Rashed, and Ammuthavali Ramasamy
- AN EMPIRICAL INVESTIGATION ON THE REQUIRED ICT COMPETENCY READINESS TOWARDS THE DIGITAL ECONOMY IN THAILAND [127](#)
Kriengkrai Bhuvanij, M.L. Kulthon Kasemsan and Prasong Praneetpolgrang

CHAPTER 5

- PROJECTING IMAGE ON NON-PLANAR SURFACE WITH ZERO-TH ORDER GEOMETRIC CONTINUITY USING SIMPLE DUAL-LINEAR FUNCTION AND MANIPULATION OF STRICT INTEGER IMPLEMENTATION IN PROGRAMMING LANGUAGE [134](#)
Fakhrul Hazman Yusoff and Muhammad Amirul Azhar
- EXPERIMENTAL ANALYSIS OF CAMERA CALIBRATION TECHNIQUES USED FOR EYE TRACKING [142](#)
AlKassim and Qurban Memon
- USING SOUND FOR STRESS THERAPY IN A VIRTUAL-REALITY ENVIRONMENT [152](#)
Rubijesmin Abdul Latif, Rozita Ismail and Ahmad Redza Razieff Zainudin
- THE POTENTIAL USE OF AUGMENTED REALITY IN GAMIFICATION [159](#)
Nurtihah Mohamed Noor, Fakhrul Hazman Yusoff, Rahmah Lob Yussof and Marina Ismail
- ESTABLISHING A FRAMEWORK FOR VISUALISING MUSIC MOOD USING VISUAL TEXTURE [168](#)
Adzira Husain, Mohd Fairuz Shiratuddin and Kok Wai Wong
- MULTICLASS CLASSIFICATION FOR CHEST X-RAY IMAGES BASED ON LESION LOCATION IN LUNG ZONES [174](#)
Mohd Nizam Saad, Zurina Muda, Noraidah Sahari and Hamzaini Abd Hamid
- FIRST CYCLE OF USER EXPERIENCE ON ASSISTIVE COURSEWARE FOR YOUNG LOW VISION (AC4LV) LEARNERS [180](#)
Nurulnadwan Aziz, Ariffin Abdul Mutalib and Siti Mahfuzah Sarif
- SOCIAL ENGINEERING AWARENESS GAME (SEAG): AN EMPIRICAL EVALUATION OF USING GAME TOWARDS IMPROVING INFORMATION SECURITY AWARENESS [187](#)
Abdus-Samad Temitope Olanrewaju and Nur Haryani Zakaria
- CAN AUDITORY ICONS INDUCE FOOD INTAKE MIMICRY? [194](#)
Nadiyah Zin, Hanif Baharin, and Athirah Rosli
- ACCESSIBILITY FACTORS FOR TOTALLY BLIND USERS OF PALESTINIAN UNIVERSITIES WEBSITES [200](#)
Mohammed Saleh Hassouna, Noraidah Sahari, and Amirah Ismail

- THE USE OF MODIFIED THEORY OF ACCEPTANCE AND USE OF TECHNOLOGY 2 TO PREDICT PROSPECTIVE USERS' INTENTION IN ADOPTING TV STREAMING [206](#)
Indrawati and Kusumoaji Sri Haryoto
- MALAY COMPUTER-AIDED SPEECH THERAPY USING AUDIO-FINGERPRINT AND VISUALIZATION [216](#)
Nor Azan Mat Zin, Seyed Yashar Banihashem, Salwani Mohd Daud, Siti Norul Huda Sheikh Abdullah and Hiroyuki Iida
- A USER-CENTERED DESIGN: METHODOLOGICAL TOOLS TO DESIGN AND DEVELOP COMPUTER GAMES FOR MOTOR-IMPAIRED USERS [223](#)
Nurul Hidayah Mat Zain, Azizah Jaafar and Fariza Hanis Abdul Razak
- DESIGN OF ASSISTIVE VIDEO FOR HEARING-IMPAIRED (AV4HI) BASED ON VISUAL PERCEPTION THEORY [229](#)
Ariffin Abdul Mutalib, Syarifah Nadia Syed Yahaya, Sobihatun Nur Ab Salam, Mazida Ahmad, Massudi Mahmuddin
- APPLICABILITY OF MOBILE AUGMENTED REALITY USAGE AT MELAKA CULTURAL HERITAGE SITES [235](#)
Syamsul Bahrin Zaibon, Ulka Chandini Pendit and Juliana Aida Abu Bakar
- SMART PRAYER MAT: A TEXTILE-BASED PRESSURE SENSOR TO ASSIST ELDERLY WITH COGNITIVE IMPAIRMENT IN PRAYING ACTIVITY [241](#)
Juhaida Ismail, Nor Laila Md Noor and Wan Abdul Rahim Wan Mohd Isa
- SMART PHONE MENU LAYOUT FOR ELDERLY USERS [247](#)
Nur Hamizah and Fariza Hanis Abdul Razak
- WEB BASED 3D TERRAIN VISUALIZATION USING GAME ENGINE [254](#)
Ruzinoor Che Mat, Abdul Rashid Mohamed Shariff, Abdul Nasir Zulkifli, Mohd Shafry Mohd Rahim and Mohd Hafiz Mahayudin
- AN APPROACH TO RESTRICT VIEWING OF MEDIA [261](#)
Norazah Abd Aziz and Raja Mohamad Fairuz R. Mohamad Yusoff
- PERSONA DEVELOPMENT: ANALYZING VARYING CHARACTERISTICS OF SLOW LEARNER CONTEXT IN RELATION TO READING ABILITIES [267](#)
Marzita Mansor, Wan Adilah Wan Adnan and Natrah Abdullah

CHAPTER 6

- EVOLUTIONARY ALGORITHM APPROACH FOR SOLVING ANIMAL DIET FORMULATION [274](#)
Rosshairy Abd. Rahman, Razamin Ramli, Zainoddin Jamari and Ku Ruhana Ku-Mahamud
- ADOPTING GENETIC ALGORITHM TO ENHANCE STATE-SENSITIVITY PARTITIONING [280](#)
Ammar Mohammed Sultan, Salmi Baharom, Abdul Azim Abd Ghani, Jamilah Din and Hazura Zulzalil
- FOOD TOUR RECOMMENDATION USING MODIFIED ANT COLONY ALGORITHM [287](#)
Kritsada Sriphaew and Kannita Sombatsricharoen
- CELLULAR AUTOMATA MODEL FOR PEDESTRIAN EVACUATION IN FIRE SPREADING CONDITIONS [293](#)
Omar Khair Alla Alidmat, Fadratul Hafinaz Hassan and Ahamad Tajudin Khader
- REACTIVE MAX-MIN ANT SYSTEM: AN EXPERIMENTAL ANALYSIS OF THE COMBINATION WITH K-OPT LOCAL SEARCHES [300](#)
Rafid Sagban, Ku Ruhana Ku-Mahamud and Muhamad Shahbani Abu Bakar
- LOW AND HIGH LEVEL HYBRIDIZATION OF ANT COLONY SYSTEM AND GENETIC ALGORITHM FOR JOB SCHEDULING IN GRID COMPUTING [306](#)
Mustafa Muwafak Alobaedy and Ku Ruhana Ku-Mahamud
- IMPROVED CHEMOTAXIS DIFFERENTIAL EVOLUTION OPTIMIZATION ALGORITHM [312](#)
Y. Emre Yildiz, Oğuz Altun and A. Osman Topal
- INTELLIGENT EXAMINATION TIMETABLING SYSTEM USING HYBRID INTELLIGENT WATER DROPS ALGORITHM [318](#)
Bashar A. AlDeeb, Norita Md Norwawi, Mohammed A. Al-Betar, and Mohd Z. Jali
- ANT SYSTEM-BASED FEATURE SET PARTITIONING ALGORITHM FOR K-NN AND LDA ENSEMBLES [326](#)

CHAPTER 7

- UTILIZING INTELLIGENT RESOURCE MANAGEMENT SYSTEM (IRMS) DASHBOARD TO AUTOMATE BUSINESS REPORTING TASK [334](#)
Noorhasmaniza Ahmad
- ANALYZING COLOR FOR PERCEPTION BY FUZZY LOGIC [340](#)
Waiwit Chanwimalueng
- ADDING SMP SUPPORT TO FASTPATHS IN AN L4 MICROKERNEL [347](#)
Petre Eftime, Lucian Mogosanu, Mihai Carabas, Laura Gheorghe and Razvan Deaconescu
- REVIEWS ON FUNCTIONAL SIZE MEASUREMENT IN MOBILE APPLICATION AND UML MODEL [353](#)
Nur Atiqah Sia Abdullah and Nur Ida Aniza Rusli
- MONITORING TASK PERFORMANCE USING VALUE STREAM MAPPING (VSM) TECHNIQUE [359](#)
Mazni Omar and Ku Munirah Ku Aman
- LOCALIZING USER EXPERIENCE FOR MOBILE APPLICATION: A CASE STUDY AMONG USM UNDERGRADUATES [366](#)
Jap Show Fong, Lok Li Ching, Khor Choon Chiat, Nurul Hashimah Ahamed Hassain Malim, Mohd Heikal Husin and Manmeet Mahinderjit Singh
- THE SOFTWARE REQUIREMENTS FRAMEWORK FOR DOCUMENT CHANGES USING REVERSE ENGINEERING APPROACH [374](#)
Hannani Aman and Rosziati Ibrahim

CHAPTER 8

- DCT DOMAIN STEGASVM-SHIFTED LSB MODEL FOR HIGHLY IMPERCEPTIBLE AND ROBUST COVER-IMAGE [381](#)
Saadiah Yahya, Hanizan Shaker Hussain and Fakariah Hani M. Ali
- EXPLORING THE ROLE OF SOCIAL MEDIA CREDENTIALS IN MOBILE LEARNING: THE ENGAGEMENT PERSPECTIVE [388](#)
Norliza Katuk, Kang Hean Yong and Nur Haryani Zakaria
- SMART METER: APPLICATIONS, SECURITY ISSUES AND CHALLENGES [395](#)
Imen Aouini and Lamia Ben Azzouz
- ENHANCED RISK ASSESSMENT EQUATION FOR IPV6 DEPLOYMENT [403](#)
Athirah Rosli, Abidah Mat Taib, Hanif Baharin, Wan Nor Ashiqin Wan Ali and Ros Syamsul Hamid
- UTILIZING PERSUASION APPROACH TO IMPROVE COMPLIANCE BEHAVIOUR WITH PASSWORD GUIDELINES [410](#)
Nur Haryani Zakaria
- CONTEXT-AWARE ANALYSIS FOR ADAPTIVE UNIFIED AUTHENTICATION PLATFORM [417](#)
Khairul Azmi Abu Bakar and Galoh Rashidah Haron
- A PARALLEL PREVENTION ALGORITHM FOR BLACK HOLE ATTACKS IN MANET [423](#)
Abdul Razak Yaakub and Khalil I. Ghathwan
- RSA AUTHENTICATION MECHANISMS IN CONTROL GRID COMPUTING ENVIRONMENT USING GRIDSIM TOOLKIT [432](#)
Saiful Adli Ismail, Md Asri Ngadi, Johan Mohd Sharif, Mohd Nazri Kama and Haslina Sarkan
- STEPPING-STONE DETECTION TECHNIQUE FOR RECOGNIZING LEGITIMATE AND ATTACK CONNECTIONS [440](#)
Ali Yusny Daud, Osman Ghazali and Mohd Nizam Omar
- MOBILE QURAN APP SECURITY VULNERABILITIES [447](#)

- INFORMATION SECURITY CULTURE: A SYSTEMATIC LITERATURE REVIEW [456](#)
Noor Hafizah Hassan, Zuraini Ismail and Nurazeen Maarop
- HYBRID MACHINE LEARNING TECHNIQUE FOR INTRUSION DETECTION SYSTEM [464](#)
Hatim Mohamad Tahir, Wael Hasan, Abas Md Said, Nur Haryani Zakaria, Norliza Katuk, Nur Farzana Kabir, Mohd Hasbullah Omar, Osman Ghazali and Noor Izzah Yahya
- JPEG2000 COMPATIBLE NEURAL NETWORK BASED CIPHER [473](#)
Qurban A Memon

CHAPTER 9

- WABS: A WEB ACCESSIBILITY BARRIER SEVERITY METRIC [481](#)
Hayfa.Y.Abuaddous, Mohd Zolisham Jali and Nurlida Basir
- ASSESSING MALAYSIAN CROWDSOURCING PLATFORMS USING WEB OF SYSTEM PERFORMANCE (WOSP) MODEL [488](#)
Adib Habbal, Suwannit Chareen Chit, Rahayu Ahmad and Musyirifah Mahmud
- A SURVEY OF EXPLORATORY SEARCH SYSTEMS BASED ON LOD RESOURCES [495](#)
Karwan Jacksi, Nazife Dimililer and Subhi R. M. Zeebaree
- WEB-BASED REWARD AND REDEMPTION SYSTEM FOR SMART RECYCLE SYSTEM [501](#)
Mohd Helmy Abd Wahab, Aeslina Abdul Kadir, Mohd Razali Md Tomari and Mohamad Hairol Jabbar

CHAPTER 10

- FORMULATION OF A KNOWLEDGE TRANSFER FRAMEWORK FOR UNIVERSITY STUDENT ORGANIZATIONS [519](#)
Sulfeeza Mohd Drus and Mohd Shahimi Mohd Yusoff
- KNOWLEDGE MANAGEMENT ADOPTION: A CASE STUDY OF MALAYSIAN ELECTRICITY SUPPLY INDUSTRY [524](#)
Sulfeeza Mohd Drus, Siti Salbiah Mohamed Shariff and Marini Othman
- CONTRIBUTING FACTOR TO BUSINESS CONTINUITY MANAGEMENT (BCM) FAILURE– A CASE OF MALAYSIA PUBLIC SECTOR [530](#)
Nurul Aisyah Sim Abdullah, Nor Laila Md Noor and Emma Nuraihan Mior Ibrahim
- INTEGRATED PROJECT DELIVERY FRAMEWORK FOR SUSTAINABLE CAMPUS DEVELOPMENT: A QUALITATIVE STUDY ON JPP UUM [539](#)
Faizatul Akmar Abdul Nifa, Mohd Nasrun Mohd Nawir, Suria Musa and Wan Nadzri Osman.
- MEASURING THE EFFECTIVENESS OF UNDERGRADUATE PROGRAMS BY A NONPARAMETRIC METHOD [545](#)
Maznah Mat Kasim, Rosmaini Kashim, Rahela Abdul Rahim and Siti Safura Hassan
- A TEST MODEL FOR TELECENTRE VALUE CREATION [551](#)
Zulkhairi Md Dahalin, Nor Iadah Yusop, Huda Ibrahim, Zahurin Mat Aji, Nafishah Othman, Rosmadi Bakar, Yussalita Md Yussop and Mohd Khairudin Kasiran

CHAPTER 11

- ANALYSIS OF USAGE OF INFORMATION SYSTEMS AND TECHNOLOGY: CLOUD COMPUTING [558](#)
Anass Bayaga
- CLOUD COMPUTING: USE AND IMPACT OF TECHNOLOGY [564](#)
Haslinda Hassan and Noor Azizi Ismail
- DESIGN OF A MULTICAST ROUTER FOR NETWORK-ON-CHIP ARCHITECTURES WITH IRREGULAR TOPOLOGIES [570](#)

- UNEQUAL ERROR PROTECTION OF H.264/AVC VIDEO TRANSMITTED OVER WIRELESS NETWORK [576](#)
Boudjadja Rima, Azni Mohamed and Zennir M.Nadjib
- CAPACITY ENRICHMENT OCDMA BASED ON ALGORITHM OF NOVEL FLEXIBLE CROSS CORRELATION (FCC) ADDRESS CODE [583](#)
Rashidi, C. B. M., Aljunid, S. A., Anuar, M. S., and Rahman, A. K.

CHAPTER 12

- INFORMATION SEEKING BEHAVIOUR AND INTERNATIONAL STUDENTS: THE ROLE OF SOCIAL MEDIA IN ADDRESSING CHALLENGES WHILE ABROAD [590](#)
Suraya Hamid and Sarah Bukhari
- DOING PROBES DIARY WITH CHILDREN IN REPORTING SOCIAL NETWORKING BEHAVIOUR [597](#)
Noor Hidayah Azmi and Fariza Hanis Abdul Razak
- KNOWLEDGE SHARING PROCESS FOR PAIR PROGRAMMING PRACTICE AMONG UNIVERSITY STUDENTS [604](#)
Syamsul Bahrin Zaibon, Mazida Ahmad, Mazni Omar and Azida Zainol
- A PROBLEM BASED LEARNING MODEL FOR IT COURSES [611](#)
Norida Muhd Darus, Haslina Mohd, Nurnasran Puteh, Zaharin Marzuki @ Matt, Fauziah Baharom, Mohamed Ali Saip, Mohd Zabidin Husain, Azman Yasin
- CURRENT PRACTICES OF VIRTUAL COMMUNITY AND THEIR INFLUENCE ON SOCIAL COHESION [618](#)
Zulkhairi Md Dahalin, Nor Iadah Yusop, Zahurin Mat Aji, Huda Hj Ibrahim and Mohd Khairudin Kasiran
- CIVILIANS HEROES: A SOCIAL NETWORK ANALYSIS OF INFORMATION STRUCTURE ON SOCIAL MEDIA DURING DISASTER [625](#)
Rahayu binti Ahmad, and Abdus-samad Temitope Olanrewaju

CHAPTER 13

- A SENTIMENT-BASED FILTERATION AND DATA ANALYSIS FRAMEWORK FOR SOCIAL MEDIA [632](#)
Norjihan Abd Ghani and Siti Syahidah Mohamad Kamal
- FUZZY AND SMOTE RESAMPLING TECHNIQUE FOR IMBALANCED DATA SETS [638](#)
Maisarah Zorkeflee, Aniza Mohamed Din and Ku Ruhana Ku-Mahamud
- EXPONENTIAL SMOOTHING TECHNIQUES ON TIME SERIES RIVER WATER LEVEL DATA [644](#)
Noor Shahifah Muhammad and Aniza Mohamed Din

CHAPTER 14

- DIETARY ASSESSMENT AND OBESITY AVOIDANCE SYSTEM BASED ON VISION: A REVIEW [651](#)
Salwa Khalid Abdulateef, Massudi Mahmuddin, Nor Hazlyna Harun and Yazan Aljeroudi
- USING SENTIMENT ANALYSIS TECHNIQUE FOR ANALYZING THAI CUSTOMER SATISFACTION FROM SOCIAL MEDIA [659](#)
Todsanai Chumwatana
- STRUCTURAL COMPONENTS OF STUDENTS' DATA-FOCUSED INFORMATION VISUALIZATION [665](#)
Semiu A. Akanmu and Zulikha Jamaludin
- SINGLE DECISION TREE CLASSIFIERS' ACCURACY ON MEDICAL DATA. [671](#)
Md. Rajib Hasan, Nur Azzah Abu Bakar, Fadzilah Siraj, Mohd Shamrie Sainin and Shariful Hasan
- RULE BASED REASONING AND CASE BASED REASONING TECHNIQUES FOR JUVENILE DELINQUENCY LEGAL REASONING MODEL [677](#)
Sharifah Lailee Syed-Abdullah, Hidayah Daniyal, Rusnadewi A.Rashid, Sarina M Noor, and Noorzila Sharif

- APPLICATION OF GIS ON THE DETERMINATION ANALYSIS OF SUSTAINABLE FOOD AGRICULTURAL LAND IN SERANG REGENCY [684](#)
Rifiati Safariah and Denny Kurniadie
- FORECASTING MODEL FOR THE CHANGE OF RESERVOIR WATER LEVEL STAGE BASED ON TEMPORAL PATTERN OF RESERVOIR WATER LEVEL [692](#)
Nur Athirah Ashaary, Wan Hussain Wan Ishak, and Ku Ruhana Ku Mahamud
- INTELLIGENT SUPPORT MODEL FOR FLOOD VICTIMS [698](#)
Noraziah ChePa, Azizi Ab Aziz, Vera Aulia, Juliana Aida Abu Bakar, Asmidah Alwi and Ahmad Hanis Mohd Shabli
- ACADEMIC LEADERSHIP BIO-INSPIRED CLASSIFICATION MODEL USING NEGATIVE SELECTION ALGORITHM [706](#)
Hamidah Jantan, Siti 'Aisyah Sa'dan, and Nur Hamizah Syafiqah Che Azemi
- FORECASTING LINEAR TIME SERIES MODELS WITH HETEROSKEDASTIC ERRORS IN A BAYESIAN APPROACH [713](#)
Esmail Amiri

CHAPTER 15

- A SYSTEMATIC REVIEW OF ENTERPRISE ARCHITECTURE ESTABLISHMENT PROCESS [720](#)
Nur Azaliah A.Bakar, Nazri Kama and Harihodin S
- USE OF INFOSTRUCTURE FOR DISASTER: TOWARDS DEFINITION OF INFOSTRUCTURE [728](#)
Aliza Abdul Latif, Noor Habibah Arshad and Norjansalika Janom
- PROPOSING A MODEL ON RISK MITIGATION IN IT GOVERNANCE [737](#)
Noraini Che Pa, Bokolo A. J., Rozi Nor Haizan Nor and Yusmadi Yah Jusoh
- ANALYSIS OF USER ACCEPTANCE OF A NETWORK MONITORING SYSTEM WITH A FOCUS ON ICT TEACHERS [743](#)
Siti Rahayu Abdul Aziz, Mohamad Ibrahim and Suhaimi Sauti

CHAPTER 16

- ENSEMBLE CLASSIFIER AND RESAMPLING FOR IMBALANCED MULTICLASS LEARNING [751](#)
Mohd Shamrie Sainin, Faudziah Ahmad and Rayner Alfred
- OCTASOM- AN OCTAGONAL BASED SOM LATTICE STRUCTURE FOR BIOMEDICAL PROBLEMS [757](#)
Shafaatunnur Hasan and Siti Mariyam Shamsuddin
- ADVERTISING THEORIES IN IMPULSE PURCHASE ELEMENTS FOR ITV ADVERTISEMENT [763](#)
Azizah Che Omar, Siti Mahfuzah Sarif, and Norshuhada Shiratuddin
- PREDICTING INSTANT MESSENGER APPLICATION ADOPTION USING A UNIFIED THEORY OF ACCEPTANCE AND USE OF TECHNOLOGY 2 [772](#)
Indrawati and Gusti Ayu Made Mas Marhaeni
- EVALUATION OF SOFTWARE QUALITY ATTRIBUTES FOR VESSEL TRACKING MANAGEMENT SYSTEM (VTMS) [779](#)
Hazura Zulzalil, Hazliana Talha and Khaironi Yatim Sharif

KEYWORD INDEX

[785](#)

AUTHOR INDEX

[788](#)

PAPER SIMILARITY INDEX

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ANT SYSTEM-BASED FEATURE SET PARTITIONING ALGORITHM FOR K-NN AND LDA ENSEMBLES CONSTRUCTION

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ABSTRACT. Combination of several classifiers has been very useful in improving the prediction accuracy and in most situations multiple classifiers perform better than single classifier. However not all combining approaches are successful at producing multiple classifiers with good classification accuracy because there is no standard resolution in constructing diverse and accurate classifier ensemble. This paper proposes ant system-based feature set partitioning algorithm in constructing k-nearest neighbor (*k*-NN) and linear discriminant analysis (LDA) ensembles. Experiments were performed on several University California, Irvine datasets to test the performance of the proposed algorithm. Experimental results showed that the proposed algorithm has successfully constructed better classifier ensemble for *k*-NN and LDA.

Keywords: *k*-nearest neighbor, linear discriminant analysis, feature set partitioning, ant system algorithm, classifier ensemble

INTRODUCTION

Several classification algorithms for pattern classification have been developed. The *k*-nearest neighbor (*k*-NN) and linear discriminant analysis (LDA) are two of the most widely used algorithm for classification tasks. However, there is not a single classifier that can be considered optimal for all pattern classification problems. Therefore the multiple classifier combination (or ensemble method) in the form of a hybrid intelligent approach is considered as a new direction in pattern classification. Combining classifier is considered as a general solution to solve classification problems (Koyuncu & Ceylan, 2013; Margoosian & Abouei, 2013). Previous studies have shown that the combination of several classifiers has been very useful in improving the prediction accuracy (Turhal et al., 2013). It has been shown that in most situations multiple classifiers perform better than single classifier. However not all combining approaches are successful at producing multiple classifiers with good classification accuracy.

Multiple classifier combinations consist of a set of classifiers called ensemble. Classifier ensemble construction aims to establish a set of accurate and diverse classifiers. It has been shown theoretically and empirically that a good ensemble is in which the individual classifier has both good accuracy and diversity (Parvin et al., 2009). However, classifier ensemble construction problems have not been fully resolved. There is no standard resolution in constructing diverse and accurate classifier ensemble (Schiele, 2002; Hernandez-Lobato & Martinez-Munoz, 2013).

The commonly used approach in constructing classifier ensemble is the training data manipulation (Yang et al., 2010). This approach works very well with unstable classifiers which can produce diverse predictions even though there is only a very small change in the training data. However k -nearest neighbor (k -NN) and linear discriminant analysis (LDA) are very stable classifiers, thus generally this approach is not suitable in constructing the classifier ensemble. Stable classifier means that small changes in the training data set will not cause large changes in the classifier output.

Another approach in building a classifier ensemble is to use input feature manipulation (Roli, 2009). Feature decomposition methods are those that manipulate the input feature set in creating diverse classifier ensemble. In this method the input features on the training set are decomposed in order to build a classifier ensemble. Feature decomposition method potentially facilitates the creation of a classifier for high dimensionality data sets without the feature selection drawback (Rokach, 2010). The feature decomposition method is also known as the feature subset based ensemble. Feature set partitioning is a special case of feature subset-based ensemble. Feature set partitioning does not just search for single useful subset but the original feature set is decomposed into several subsets and a set of classifiers trained on a disjoint feature subset. This approach is appropriate for the classification task with large number of features.

Classifier ensemble built with a different subset of features has been shown to be effective in practice. Based on this approach, one popular way to generate different feature subset is through random subspace (RS) method (Ho, 1998). This method produces feature subspaces that are selected randomly from a subset of features in the original representation of space, and then a set of classifiers is built based on the selected subspace. Random subspace method has performed satisfactorily and has proven resistant to irrelevant features. Bay (1999) presented multiple feature subset (MFS) approach that combines many k -NN classifiers each using random feature subset. The final decision is obtained as the majority voting result of the classifiers. The experimental results showed that the MFS improved classification performance. Ahn et al. (2007) showed that the randomly partitioned input features to several subsets thus each classifier was trained on different subsets, particularly useful for high-dimensional datasets and unbalanced data. However random selection could not find the optimal subset of features for a combination of several classifiers.

Several studies have applied Ant System (AS) algorithm for set partitioning problems were reported by Maniezzo and Milandri (2002), Randall and Lewis (2010) and Crawford et al. (2013). AS algorithm is an original and most popular variant of ant colony optimization (ACO) based algorithm that has been used and proven to solve various optimization problems (Rebeiro & Enembreck, 2013). ACO was introduced by Marco Dorigo as a metaheuristic method for the solution of hard combinatorial optimization problems (Dorigo & Blum, 2005). The Ant System is also applied to solve the set partitioning problem which is one of the most difficult (NP-Hard) and very constrained combinatorial problems due to their complexities.

The work presented here aims at optimizing the number of classifier in an ensemble by using the appropriate feature manipulation while maintaining classification performance. In this paper, a new algorithm is proposed to construct better k -NN and LDA ensembles. Section 2 explains the proposed ant system-based feature set partitioning (ASFSP) algorithm. Section 3 presents the experiments and comparisons were performed with several other methods by using several benchmark dataset from UCI to test the performance of the proposed algorithm. Section 4 briefly concludes the work.

PROPOSED METHOD

In this proposed ASFSP, classifier ensemble is constructed based on input feature manipulation approach. A disjoint feature set decomposition is performed based on the original training set. Feature set is partitioned into different feature subset. There is no feature in the training set that is eliminated. Furthermore each classifier in the ensemble is trained on a different projection of the original training set to induce diversity. The number of features subsets or partitions determines the number of classifiers in the ensemble. Ant system-based algorithm is developed to perform feature set partitioning. The required inputs are the feature set and class labels of original training set. The flowchart of feature decomposition algorithm is provided in Figure 1.

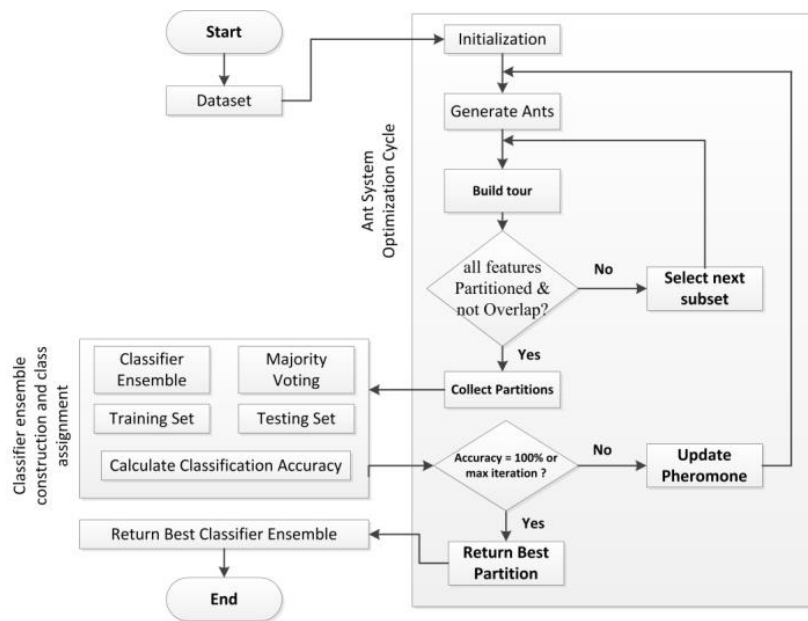


Figure 1. Flowchart of the generic ant system-based feature set partitioning algorithm

In the implementation of ASFSP, the required inputs are features in dataset. The pheromone table is initialized followed by the generation of the ants. Each ant then builds a tour in the form of a feature partition which is considered as a possible solution. The tour is evaluated if it contains all the features and no overlap features. Otherwise the next feature subset is selected until the feature partitions have been collected. This will be done repeatedly until a possible solution is built. Furthermore partitioned feature is used to construct classifier ensemble. The class assignment is performed using constructed classifier ensemble by using majority voting combiner. The best partition will be formed if classification accuracy reaches 100% or the maximum iteration limit has been reached. The pheromone is then updated and another ant is generated if any criterion is not fulfilled. The whole process is repeated until the best partition is formed.

EXPERIMENTAL RESULTS

Experiments were conducted to test the proposed algorithm to construct k -NN and LDA ensembles. Prediction class label of unknown pattern is obtained by using the majority voting. Experiments were performed using nine (9) data sets from University California, Irvine (UCI) repository. Ten (10) experiments were performed to estimate the accuracy of the constructed classifier ensembles by using random subspace method and newly constructed classifier ensembles by using ASFSP algorithm. The 10-fold cross validation approach is used to validate

the proposed algorithm. Tables 1 and 2 depict the average and standard deviation of the classification accuracy. It can be shown that a small deviation of the classification accuracy was obtained and this showed that the experiments were accurate. It can also be shown that the ASFSP algorithm give better accuracy than RS method in constructing k -NN ensembles.

Table 1. Classification Accuracy of k -NN Ensembles using RS

Experiment #	Haberman	Iris	Lenses	Liver	Ecoli	Pima	Tic-Tac-Toe	Glass	Breast Cancer
1	67.32	93.33	70.83	55.07	80.36	69.79	72.13	73.83	97.36
2	65.03	94.00	58.33	60.00	81.25	71.09	76.10	71.96	97.36
3	69.28	92.67	62.50	58.84	78.87	68.10	77.56	74.77	96.93
4	69.28	94.00	66.67	66.09	84.23	72.66	77.56	71.50	97.80
5	67.32	93.33	58.33	57.97	80.95	69.53	72.13	73.36	96.93
6	68.30	92.67	62.50	56.81	79.46	70.83	76.10	73.36	97.22
7	64.38	93.33	58.33	57.10	81.25	69.92	74.53	75.70	96.78
8	70.26	93.33	58.33	60.29	82.44	70.96	78.18	71.96	97.07
9	70.59	93.33	62.50	64.35	83.63	70.31	78.18	68.69	97.66
10	67.32	94.00	66.67	64.06	79.46	72.66	74.53	71.96	97.22
Average	67.91	93.40	62.50	60.06	81.19	70.59	75.70	72.71	97.23
Standard deviation	1.96	0.47	4.17	3.48	1.70	1.32	2.19	1.86	0.31

Table 2. Classification Accuracy of k -NN Ensembles using ASFSP

Experiment #	Haberman	Iris	Lenses	Liver	Ecoli	Pima	Tic-Tac-Toe	Glass	Breast Cancer
1	72.22	96.00	79.17	65.80	80.95	71.48	74.74	73.36	97.95
2	72.88	96.00	79.17	62.61	81.25	71.74	74.32	72.43	97.51
3	72.22	96.00	79.17	65.51	81.25	70.18	76.83	72.90	97.80
4	72.55	96.00	79.17	64.06	80.65	70.44	75.78	72.90	97.51
5	72.22	96.00	79.17	62.61	82.14	71.48	76.10	72.90	97.51
6	73.20	96.00	79.17	62.61	81.25	70.18	75.47	74.30	97.51
7	72.88	96.00	79.17	64.06	80.36	71.22	76.10	73.83	97.36
8	72.22	96.00	79.17	65.51	80.95	70.44	76.83	71.03	97.36
9	74.51	95.33	79.17	66.25	81.55	72.14	75.05	72.90	97.80
10	72.55	96.00	79.17	62.61	81.55	70.83	76.10	72.43	97.66
Average	72.75	95.93	79.17	64.16	81.19	71.01	75.73	72.90	97.60
Standard deviation	0.71	0.21	0.00	1.50	0.50	0.70	0.84	0.88	0.20

Tables 3 and 4 depict the average and standard deviation of the classification accuracies of constructed LDA ensembles based on RS and newly constructed LDA ensembles based on ASFSP respectively. Small deviation of the classification accuracy was obtained which indicate that the experiments were good. The ASFSP algorithm always gives better accuracy than RS method in constructing LDA ensembles for all the datasets.

Table 3. Classification Accuracy of LDA Ensembles using RS

Experiment #	Haberman	Iris	Lenses	Liver	Ecoli	Pima	Tic-Tac-Toe	Glass	Breast Cancer
1	74.84	96.00	79.17	62.03	73.23	75.00	65.66	57.48	96.19
2	72.88	95.33	79.17	62.03	73.23	74.87	65.66	57.94	96.49
3	72.88	94.67	83.33	63.77	73.03	75.00	65.66	59.35	96.19
4	74.84	95.33	87.50	62.03	73.23	74.61	66.18	60.28	96.49
5	73.20	94.67	79.17	63.48	73.23	74.87	65.66	56.54	95.90
6	73.20	97.33	79.17	62.61	74.41	75.39	64.72	59.81	96.19
7	72.88	96.00	79.17	60.58	73.23	73.44	65.66	59.81	96.49
8	74.84	96.67	79.17	63.48	73.00	75.13	64.72	60.75	95.90
9	74.84	95.33	83.33	60.58	73.23	75.13	66.18	59.81	96.05
10	73.20	96.00	75.00	63.77	72.99	75.91	66.18	60.28	96.19
Average	73.76	95.73	80.42	62.44	73.28	74.94	65.63	59.21	96.21
Standard deviation	0.94	0.84	3.43	1.21	0.41	0.63	0.53	1.39	0.22

Table 4. Classification Accuracy of LDA Ensembles using ASFSP

Experiment #	Haberman	Iris	Lenses	Liver	Ecoli	Pima	Tic-Tac-Toe	Glass	Breast Cancer
1	74.84	98.00	87.50	63.48	75.96	75.52	73.05	62.66	97.07
2	75.16	98.00	87.50	63.77	75.90	75.91	72.79	62.66	97.07
3	74.51	98.00	83.33	63.77	75.96	76.17	72.53	62.76	97.22
4	74.51	98.00	87.50	63.77	76.00	75.78	72.92	62.66	97.22
5	74.51	98.00	87.50	64.06	75.89	75.65	73.70	61.79	97.51
6	74.51	98.00	87.50	64.06	75.96	76.04	73.18	62.66	97.22

7	75.16	98.00	87.50	64.06	75.96	76.17	72.53	62.66	97.22
8	74.84	98.00	83.33	63.48	75.79	76.17	73.96	62.03	97.22
9	75.16	98.00	87.50	64.06	75.96	76.04	72.79	62.66	97.22
10	75.16	98.00	87.50	64.06	75.96	76.82	72.79	62.66	97.07
Average	74.84	98.00	86.67	63.86	75.93	76.03	73.02	62.52	97.20
Standard deviation	0.31	0.00	1.76	0.24	0.06	0.36	0.47	0.33	0.13

Table 5 and Table 6 show the summary of result in constructing k -NN and LDA ensembles respectively. The average of accuracy of newly constructed ensemble classifiers by ASFSP are compared with single approach and RS method.

Table 5. Comparison of Single Approach, RS and ASFSP in Constructing k -NN Ensembles

No	Dataset	Single Approach	RS	ASFSP
1	Haberman	66.83	67.91	72.75
2	Iris	95.67	93.40	95.93
3	Lenses	77.92	62.50	79.17
4	Liver	62.32	60.06	64.16
5	Ecoli	81.19	81.19	81.19
6	Pima	67.37	70.59	71.01
7	Tic-Tac-Toe	75.51	75.70	75.73
8	Glass	72.71	72.71	72.90
9	BreastCancer	95.78	97.23	97.60

Table 6. Comparison of Single Approach, RS and ASFSP in Constructing LDA Ensembles

No	Dataset	Single Approach	RS	ASFSP
1	Haberman	73.73	73.76	74.84
2	Iris	97.33	95.73	98.00
3	Lenses	86.25	80.42	86.67
4	Liver	62.35	62.44	63.86
5	Ecoli	72.91	73.28	75.93
6	Pima	75.34	74.94	76.03
7	Tic-Tac-Toe	65.62	65.63	73.02
8	Glass	58.83	59.21	62.52
9	BreastCancer	96.18	96.21	97.20

Based on the results, it can be shown that the RS method does not always give better accuracy than a single classifier. Instead ASFSP algorithm gives better results than the single classifier approach. This is because the usage of ASFSP has successfully formed the optimal feature set partition to induce diversity in constructing ensembles. Table 7 and Table 8 present the feature set partition and the number of classifier in ensemble with respect to ensemble accuracy. The number of partitions determines the number of classifiers. It can be shown that features set partitions are not formed on several dataset. This means that this proposed algorithm able to determine either the single classifier or an ensemble classifier is better for the dataset.

Table 7. Feature Set Partition and Number of k -NN Classifier

No	Dataset	Partition	# of Classifier	Accuracy
1	Haberman	[1 3][2]	2	72.75
2	Iris	[1 2 3 4]	1	95.93
3	Lenses	[1 2 3 4]	1	79.17
4	Liver	[1 4 6][3 5][2]	3	64.16
5	Ecoli	[1 2 3 4 5 6 7]	1	81.19
6	Pima	[1 3 4 7][5 6 8][2]	3	71.01
7	Tic-Tac-Toe	[1 2 3 4 5 6 7 8 9]	1	75.73
8	Glass	[1 2 3 4 5 6 7 8 9]	1	72.90
9	BreastCancer	[1 2 4 7 9][3 5][6][8]	4	97.60

Table 8. Feature Set Partition and Number of LDA Classifier

No	Dataset	Partition	# of Classifier	Accuracy
1	Haberman	[1][2 3]	2	74.84
2	Iris	[1 2 3 4]	1	98.00
3	Lenses	[1 2 3 4]	1	86.67
4	Liver	[1 3 4 6][2][5]	3	63.86
5	Ecoli	[1 3 5][4 6][2 7]	3	75.93
6	Pima	[1 2 3 4 5 6 7 8]	1	76.03
7	Tic-Tac-Toe	[2 4 5 6 8][1][3][7][9]	5	73.02
8	Glass	[2 3 5 7][4 8 9][1 6]	3	62.52
9	BreastCancer	[2 4 8][7 9][3][1 5 6]	4	97.20

The proposed algorithm has successfully partition the feature set to several feature subsets which may lead to a better classification performance. Improvement on accuracy is obtained on datasets where feature partitions have been performed. This is due to the classifier ensembles being constructed on datasets that form feature partition, where each individual classifier is trained on a different subset of features to induce diversity. Otherwise the relatively same accuracy with the original single classifier will be obtained on several datasets where no feature partition is performed.

CONCLUSION

A new feature set partitioning algorithm based on AS has been presented. Feature set partition is performed and ant system algorithm is used for optimization. Base classifier is trained on a different feature partition to induce diversity. The majority voting rule was used as combination rule in the experiments. The proposed algorithm was evaluated on several datasets from UCI repository. The results show that implementation of this algorithm in constructing both k -NN and LDA ensembles outperforms their single version and also RS method. Results indicated that the proposed algorithm can be used in constructing better k -NN and LDA ensembles. Future work is to implement this algorithm on other classifiers and by using other ACO-based algorithm.

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