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# TABLE OF CONTENTS

<b>DESIGNING THE INTERACTIVE MULTIMEDIA LEARNING FOR ELEMENTARY STUDENTS GRADE 1<sup>ST</sup>-3<sup>RD</sup></b> .....	1
<i>Hudaivani Andarini, Wirania Swasty, Dicky Hidayat</i>	
<b>FACTORS PREVENTING MALAYSIAN TEACHERS FROM USING ICT IN TEACHING MATHEMATICS</b> .....	6
<i>Abdul Halim Abdullah, Mahani Mokhtar, Johari Surif, Nor Hasniza Ibrahim, Marlina Ali</i>	
<b>IMPLEMENTATION OF SOCRATIC METHOD IN ONLINE LEARNING TO ENHANCE CREATIVE THINKING: ANALYSIS REVIEW</b> .....	12
<i>Salihuddin Md. Suhadi, Hasnah Mohamed, Norasykin Zaid, Zaleha Abdullah, Baharuddin Aris, Mageswaran Sanmugam</i>	
<b>A PROPOSAL OF INFORMATION QUALITY FRAMEWORK: INTEGRATION INFORMATION QUALITY ASSESSMENT AND IMPROVEMENT STRATEGIES</b> .....	16
<i>Arfive Gandhi, Achmad Hidayanto, Muhammad Rifki Shihab</i>	
<b>CONTENT DELIVERY STRATEGIES IN CONTEXT AWARE UBIQUITOUS LEARNING SYSTEM USING CASPS</b> .....	22
<i>Nungki Selviandro, Mira Sabariah, Nendi Junaedi</i>	
<b>OPTIMIZATION OF FUZZY INFERENCE SYSTEM USING EVOLUTIONARY PROGRAMMING ALGORITHM FOR TEACHER CERTIFICATION IN INDONESIA</b> .....	27
<i>Bogi Wicaksono, Fhira Nhita, Danang Triantoro Murdiansyah</i>	
<b>ADAPTIVE NAVIGATION WITH KNOWLEDGE TRACING METHOD</b> .....	31
<i>Yurian Iqbal, Dade Nurjanah</i>	
<b>PREDICTING STUDENTS ACHIEVEMENT BASED ON MOTIVATION IN VOCATIONAL SCHOOL USING DATA MINING APPROACH</b> .....	37
<i>Nunik Purwaningsih, Jamila Adi, Yuli Suwarno</i>	
<b>CLASSIFYING ABNORMAL ACTIVITIES IN EXAM USING MULTI-CLASS MARKOV CHAIN LDA BASED ON MODEC FEATURES</b> .....	42
<i>Janson Hendryli, Ivan Fanany</i>	
<b>CONTEXT AWARENESS SYSTEM ON UBIQUITOUS LEARNING WITH CASE BASED REASONING AND NEAREST NEIGHBOR ALGORITHM</b> .....	48
<i>Nungki Selviandro, Mira Sabariah, Surya Saputra</i>	
<b>THEMATIC DEVELOPMENT FOR MEASURING COHESION AND COHERENCE BETWEEN SENTENCES IN ENGLISH PARAGRAPH</b> .....	54
<i>Derwin Suhartono, Diah Fadilah</i>	
<b>ADAPTED WEIGHTED GRAPH FOR WORD SENSE DISAMBIGUATION</b> .....	60
<i>Bagus Rintyarna, Riyanarto Sarno</i>	
<b>COMBINATION OF LDA AND TFXICF IN INDONESIAN TEXT CLUSTERING WITH LABELING</b> .....	65
<i>Lya Hulliyyatus Suadaa, Ayu Purwarianti</i>	
<b>COMPREHENSIVE COMPARISON OF TERM WEIGHTING METHOD FOR CLASSIFICATION IN INDONESIAN CORPUS</b> .....	71
<i>Burhanudin Utomo, Moch Arif Bijaksana</i>	
<b>WORD STEMMING CHALLENGES IN MALAY TEXTS: A LITERATURE REVIEW</b> .....	76
<i>Mohamad Nizam Kassim, Mohd Aizaini Maarof, Anazida Zainal, Amirudin Abdul Wahab</i>	
<b>DIGITAL ADVERTISING MEDIA ADOPTION IN CONSUMER GOODS INDUSTRY (AN INDONESIAN PERSPECTIVE)</b> .....	82
<i>Indrawati Indrawati, Nadia Primasari</i>	
<b>NETWORK TEXT ANALYSIS TO SUMMARIZE ONLINE CONVERSATIONS FOR MARKETING INTELLIGENCE EFFORTS</b> .....	88
<i>Andry Alamsyah, Marisa Paryasto, Feriza Putra, Rizal Himmawan</i>	
<b>ONTOLOGY-BASED RECOMMENDATION INVOLVING CONSUMER PRODUCT REVIEWS</b> .....	93
<i>Zk Baizal, Abdurrahman Iskandar, Erliansyah Nasution</i>	
<b>FEATURE EXTRACTION USING CLASS SEQUENTIAL RULE ON CUSTOMER PRODUCT REVIEW</b> .....	99
<i>Hani Nurrahmi</i>	
<b>PREDICTING SMART METERING ACCEPTANCE BY RESIDENTIAL CONSUMERS: AN INDONESIAN PERSPECTIVE</b> .....	104
<i>Indrawati Indrawati, Lina Tohir</i>	

<b>UI DESIGN OF COLLABORATIVE LEARNING APP FOR FINAL ASSIGNMENT SUBJECT USING GOAL-DIRECTED DESIGN</b> .....	110
<i>Siti Laila, Mira Sabariah, Dawam Dwi Jatmiko Suwawi</i>	
<b>SERVICE CATALOGUE IMPLEMENTATION MODEL</b> .....	116
<i>Monika Sembiring, Kridanto Surendro</i>	
<b>KANSEI ANALYSIS OF INTERFACE'S ELEMENTS FOR MOBILE COMMERCE APPLICATION</b> .....	122
<i>Ana Hadiana</i>	
<b>SMART GUIDE EXTENSION FOR BLIND CANE</b> .....	126
<i>Giva Mutiara, Gita Hapsari, Ramanta Nasution</i>	
<b>CRITICAL SUCCESS FACTORS TO IMPROVE INTERACTIONS IN ONLINE SOCIAL LEARNING ENVIRONMENT</b> .....	132
<i>Noriesah Ahmad, Nurul Farhana Jumaat</i>	
<b>LAMBDA VALUE ANALYSIS ON WEIGHTED MINKOWSKI DISTANCE MODEL IN CBR OF SCHIZOPHRENIA TYPE DIAGNOSIS</b> .....	137
<i>Ause Labellapansa, Akmar Efendi, Ana Yulianti, Evizal Abdul Kadir</i>	
<b>KINEMATIC FEATURES FOR HUMAN ACTION RECOGNITION USING RESTRICTED BOLTZMANN MACHINES</b> .....	141
<i>Ahmad Arinaldi, Mohamad Ivan Fanany</i>	
<b>RED BLOOD CELL AND WHITE BLOOD CELL CLASSIFICATION USING DOUBLE THRESHOLDING AND BLOB ANALYSIS</b> .....	147
<i>Jullend Gatc, Febri Maspiyanti, Yulius Denny Prabowo</i>	
<b>OPTIMIZATION OF MULTIPROBE PLACEMENT FOR COMPUTERIZED CRYOSURGERY PLANNING USING FORCE-FIELD ANALOGY</b> .....	152
<i>Romadhona Fajar, Dede Tarwidi, Erwin Budi Setiawan</i>	
<b>DIGITAL MEDICAL IMAGE COMPRESSION ALGORITHM USING ADAPTIVE HUFFMAN CODING AND GRAPH BASED QUANTIZATION BASED ON IWT-SVD</b> .....	158
<i>Putu Savitri, A Adiwijaya, Danang Triantoro Murdiansyah</i>	
<b>TOWARDS DOCUMENT TRACKING MEASUREMENT MODEL TO SUPPORT E-GOVERNMENT BUSINESS PROCESSES</b> .....	163
<i>Bayu Hendradjaya, Wikan Sunindyo</i>	
<b>INFORMATION SYSTEMS DESIGN FOR SUSTAINABILITY FINANCIAL SERVICES COMPANY</b> .....	168
<i>Yohannes Kurniawan, Siti Elda Hiererra</i>	
<b>DESIGNING ARCHITECTURE OF INFORMATION DASHBOARD SYSTEM TO MONITOR IMPLEMENTATION PERFORMANCE OF ECONOMIC CENSUS 2016 IN STATISTICS INDONESIA</b> .....	174
<i>Zulyadi Zulyadi, Adyanata Lubis, B. Herawan Hayadi</i>	
<b>INFORMATION TECHNOLOGY GOVERNANCE EVALUATION AND PROCESSES IMPROVEMENT PRIORITIZATION</b> .....	179
<i>Rahayu Yuni Susanti, Yudho Sucahyo</i>	
<b>BUILDING ENTERPRISE ARCHITECTURE FOR HOSPITAL INFORMATION SYSTEM</b> .....	185
<i>Dilla Purnawan, Kridanto Surendro</i>	
<b>A GAME WITH PURPOSE TO FILTER SPAMS FROM INDONESIAN TWITTER TRENDING TOPICS</b> .....	191
<i>Rian Hardinata, Jimmy Tirtawangsa</i>	
<b>WORD ASSOCIATION NETWORK APPROACH FOR SUMMARIZING TWITTER CONVERSATION ABOUT PUBLIC ELECTION</b> .....	196
<i>M Adib Imtiyazi, Andry Alamsyah, Danang Junaedi, Jaka Arya Pradana</i>	
<b>PUBLIC MOOD ANALYSIS FROM TWITTER FOR BANDUNG</b> .....	200
<i>Ayu Purwarianti</i>	
<b>IMPROVED MODULARITY FOR COMMUNITY DETECTION ANALYSIS IN WEIGHTED GRAPH</b> .....	206
<i>Maya Mairisha, Putri Saptawati</i>	
<b>SENTIMENT ANALYSIS SYSTEM FOR INDONESIA ONLINE RETAIL SHOP REVIEW USING NAIVE BAYES TECHNIQUE</b> .....	212
<i>Cut Fiarni</i>	
<b>SEMANTICS ARGUMENT CLASSIFICATION USING WORD/POS IN CONSTITUENT AND LEFT ARGUMENT FEATURES</b> .....	218
<i>Syaban Muhyiddin, Moch Arif Bijaksana, Siti Sa'Adah</i>	

<b>THE K-MEANS WITH MINI BATCH ALGORITHM FOR TOPICS DETECTION ON ONLINE NEWS</b> .....	222
<i>Siti Rofiqoh Fitriyani, Hendri Murfi</i>	
<b>MULTI WORDS QURAN AND HADITHS SEARCHING BASED ON NEWS USING TF-IDF</b> .....	227
<i>Eko Darwiyanto, Ganang Pratama, Sri Widowati</i>	
<b>ANALYSIS OF COMBINED FEATURES AT SEMANTIC ARGUMENT CLASSIFICATION</b> .....	233
<i>Najih Azkalhaq, Moch Arif Bijaksana, Siti Sa'Adah</i>	
<b>IMPLEMENTATION OF MCL ALGORITHM IN CLUSTERING DIGITAL NEWS WITH GRAPH REPRESENTATION</b> .....	239
<i>Alwan M Ubaidillah A., Kemas Wiharja, Siti Sa'Adah</i>	
<b>MY REFLECTION MOBILE APP PROMOTES CRITICAL REFLECTIVE PRACTICE</b> .....	245
<i>Johari Surif, Nor Hasniza Ibrahim, Abdul Halim Abdullah, Marlina Ali, Siti Anisha Samsudin</i>	
<b>METASTASIS IDENTIFICATION BASED ON CLINICAL PARAMETERS USING BAYESIAN NETWORK</b> .....	251
<i>Arida Ferti Syafiandini, Ito Wasito</i>	
<b>ASSOCIATION RULE MINING FOR IDENTIFYING DHF AND TF DISEASE WITH IST-EFP ALGORITHM</b> .....	257
<i>Shaufiah Shaufiah, Bobby Siswanto</i>	
<b>FIREFLY ALGORITHM FOR LOG-LIKELIHOOD OPTIMIZATION PROBLEM ON SPEECH RECOGNITION</b> .....	263
<i>Hilal H. Nuha, Mohammad A. Abido</i>	
<b>IMPLEMENTATION OF LOCAL REGRESSION SMOOTHING ON FUZZY EAS FOR PLANTING SEASON CALENDAR FORECASTING BASED ON RAINFALL (CASE STUDY RICE PLANTS)</b> .....	269
<i>Sigit Wahyu Pratama, Fhira Nhita, A Adiwijaya</i>	
<b>TOWARDS THE MODELLING OF DYNAMIC TRAIN SYSTEMS: DISRUPTION PATTERN ANALYSIS</b> .....	274
<i>Yanti Rusmawati, Rita Rismala</i>	
<b>SIMULATION GAME OF AVIATION PASSENGER SAFETY</b> .....	279
<i>Muhammad Multahada, Wirania Swasty, Patra Aditia</i>	
<b>INTELLIGENT TRAFFIC LIGHT CONTROL USING COLLABORATIVE Q-LEARNING ALGORITHMS</b> .....	285
<i>Andhika Rizky Rosyadi, Tjokorda Agung Budi Wirayuda, Said Al Faraby</i>	
<b>APPLICATION OF RFID TECHNOLOGY AND E-SEAL IN CONTAINER TERMINAL PROCESS</b> .....	291
<i>Evizal Abdul Kadir, Sri Listia Rosa, Hendra Gunawan</i>	
<b>PROTOTYPING DESIGN OF MECHANICAL BASED END-DEVICES FOR SMART HOME APPLICATIONS</b> .....	297
<i>Braham Lawas Lawu, Maulana Yusuf Fathany, Khilda Afifah, Muhammad Santraji, Rachmad Vidya Wicaksana Putra, Syifaul Fuada, Trio Adiono</i>	
<b>DESIGN AND DEVELOPMENT OF VOTING DATA SECURITY FOR ELECTRONIC VOTING (E-VOTING)</b> .....	303
<i>Suveno Djanali, Baskoro Adi Pratomo, Karsono Cipto, Astandro Koesripuranto, Hudan Studiawan</i>	
<b>A TYPOLOGY OF EMPLOYEES' INFORMATION SECURITY BEHAVIOUR</b> .....	307
<i>Zauwiyah Ahmad, Mariati Norhashim, Ong Thian Song, Tze Hui Liew</i>	
<b>A FUZZY-BASED METHODOLOGY TO ASSESS SOFTWARE USABILITY RISK</b> .....	311
<i>Afriyanti Dwi Kartika, Kridanto Surendro</i>	
<b>SOFTWARE ASSESSMENT MODEL USING METRICS PRODUCTS FOR E-GOVERNMENT IN THE G2B MODEL</b> .....	316
<i>Rian Andrian, Bayu Hendradjaya, Wikan Sumindyo</i>	
<b>SOFTWARE ARCHITECTURE DESIGN OF COLLABORATIVE LEARNING SYSTEM FOR UNDERGRADUATE THESIS GUIDANCE APPLICATION USING ASPECT ORIENTED ARCHITECTURE DESCRIPTION LANGUAGE (AO-ADL)</b> .....	322
<i>Syifa Fatharani, Dana Kusumo, Dawam Dwi Jatmiko Suwawi</i>	
<b>OBJECT ORIENTATION ESTIMATION FOR HIGH SPEED 3D OBJECT RETRIEVAL SYSTEM</b> .....	327
<i>Vicky Sintunata, Terumasa Aoki</i>	
<b>COMPARISON OF DATA ACQUISITION TECHNIQUE USING LOGICAL EXTRACTION METHOD ON UNROOTED ANDROID DEVICE</b> .....	333
<i>Novelino Yona Pribadi Lukito, Fazmah Arif Yulianto, Erwid Jaded</i>	
<b>SEMANTIC ROLES LABELING FOR REUSE QA-PAIRS</b> .....	339
<i>Wiwin Suwarningsih</i>	
<b>MINING THE GPS BIG DATA TO OPTIMIZE THE TAXI DISPATCHING MANAGEMENT</b> .....	344
<i>Fransiskus Tatas Dwi Atmaji</i>	

<b>HANDWRITING DIGIT RECOGNITION USING LOCAL BINARY PATTERN VARIANCE AND K-NEAREST NEIGHBOR CLASSIFICATION .....</b>	<b>348</b>
<i>Nurul Ilmi, Tjokorda Agung Budi Wirayuda, Kurniawan Nur Ramadhani</i>	
<b>EDGE BASED APPROACH IN OBJECT BOUNDARY DETECTION ON MULTICLASS FRUIT IMAGES.....</b>	<b>353</b>
<i>Emas Rachmawati, Masayu Leylia Khodra, Iping Supriana</i>	
<b>DESIGN OF A GRIPPING IMITATOR ROBOTIC ARM FOR TAKING AN OBJECT .....</b>	<b>364</b>
<i>Ali Chaidir, Alfredo Satriya, Guido Kalandro</i>	
<b>CONVOLUTIONAL NEURAL NETWORKS APPLIED TO HANDWRITTEN MATHEMATICAL SYMBOLS CLASSIFICATION.....</b>	<b>369</b>
<i>Irwansyah Ramadhan, Bedy Purnama, Said Al Faraby</i>	
<b>DENYING COLLISION IN THE SECOND ROUND OF KECCAK HASH FUNCTION BY CAMOUFLAGING FREE BITS.....</b>	<b>373</b>
<i>Ratna Puspita Dewi, Ari Moesriami Barmawi</i>	
<b>ON THE CONSTRUCTION OF SECURE PUBLIC PARAMETERS FOR MEGRELISHVILI PROTOCOL .....</b>	<b>380</b>
<i>Muhammad Arzaki, Bambang Wahyudi</i>	
<b>A PERFORMANCE EVALUATION OF CRYPTOGRAPHIC ALGORITHMS ON FPGA AND ASIC ON RFID DESIGN FLOW.....</b>	<b>385</b>
<i>Shugo Mikami, Dai Watanabe, Kazuo Sakiyama</i>	
<b>HIDDEN AUTONOMOUS MULTI-SENDERS FOR KLEPTOWARE .....</b>	<b>391</b>
<i>M. Rifqi Tambunan, Surya Michrandi Nasution, Yudha Purwanto</i>	
<b>A SYMMETRIC KEY BASED SECURE COMMUNICATION FRAMEWORK USING ADAPTIVE STEGANOGRAPHY .....</b>	<b>396</b>
<i>Sudantha Gunawardena, Dhananjay Kulkarni</i>	
<b>KNOPPIX - PARALLEL COMPUTER DESIGN AND RESULTS COMPARISON SPEED ANALYSIS USED AMDAHL THEORY .....</b>	<b>400</b>
<i>Yudhi Arta, Evizal Abdul Kadir, Des Suryani</i>	
<b>PERFORMANCE ANALYSIS OF WIRELESS LAN 802.11N STANDARD FOR E-LEARNING .....</b>	<b>405</b>
<i>Evizal Abdul Kadir, Apri Siswanto, Abdul Syukur</i>	
<b>MULTIPATH ROUTING WITH LOAD BALANCING AND ADMISSION CONTROL IN SDN .....</b>	<b>411</b>
<i>Maris Ramdhani, Sofia Hertiana, Burhanuddin Dirgantoro</i>	
<b>THE SUPPORTING ASSESSMENT SYSTEM FOR CATWALK MODELING USING VARIABLE MODULE GRAPH METHOD BASED ON VIDEO .....</b>	<b>417</b>
<i>Suci Aulia</i>	
<b>IDENTITY RECOGNITION WITH PALM VEIN FEATURE USING LOCAL BINARY PATTERN ROTATION INVARIANT.....</b>	<b>427</b>
<i>Annisa Yuditya Pratiwi, Tjokorda Agung Budi Wirayuda, Kurniawan Nur Ramadhani</i>	
<b>PHYSICAL AUTHENTICATION USING SIDE-CHANNEL INFORMATION .....</b>	<b>433</b>
<i>Kazuo Sakiyama, Momoka Kasuya, Takanori Machida, Arisa Matsubara, Yunfeng Kuai, Yuichi Hayashi, Takaaki Mizuki, Noriyuki Miura, Makoto Nagata</i>	
<b>INTRUSION DETECTION SYSTEM (IDS) SERVER PLACEMENT ANALYSIS IN CLOUD COMPUTING.....</b>	<b>439</b>
<i>Aryachandra Ardyansyah Agustian, Fazmah Arif Yulianto, Novian Anggis Suwastika</i>	
<b>DIGITAL IMAGE AUTHENTICATION BASED ON SECOND-ORDER STATISTICS.....</b>	<b>444</b>
<i>Bias Sekar Avi Shena, Rimba Whidiana Ciptasari, Febryanti Sthevanie</i>	
<b>PALM VEIN BIOMETRIC IDENTIFICATION SYSTEM USING LOCAL DERIVATIVE PATTERN .....</b>	<b>450</b>
<i>Akhmad Akbar, Tjokorda Agung Budi Wirayuda, Mahmud Dwi Sulistiyo</i>	
<b>PERFORMANCE ANALYSIS OF CONTAINER-BASED HADOOP CLUSTER:OPENVZ AND LXC .....</b>	<b>456</b>
<i>Rizki Rizki, Andrian Rakhmatsyah, Muhammad Arief Nugroho</i>	
<b>DATA ANALYSIS USING SYSTEM IDENTIFICATION TOOLBOX OF HEAT EXCHANGER PROCESS CONTROL TRAINING SYSTEM .....</b>	<b>460</b>
<i>Tatang Mulyana, Judi Alhilman, Ekki Kurniawan</i>	
<b>DATA ANALYSIS OF LI-ION AND LEAD ACID BATTERIES DISCHARGE PARAMETERS WITH SIMULINK-MATLAB.....</b>	<b>466</b>
<i>Ekki Kurniawan, Tatang Mulyana</i>	
<b>SCIENTIFIC PARALLEL COMPUTING FOR 1D HEAT DIFFUSION PROBLEM BASED ON OPENMP.....</b>	<b>471</b>
<i>Gunawan Putu Harry</i>	

<b>SEED: SECURE AND ENERGY EFFICIENT DATA TRANSMISSION IN WIRELESS SENSOR NETWORKS</b> .....	476
<i>Jetendra Joshi, Divya Kurian, Rishabh Kumar, Prakhar Awasthi, Sibeli Mukherjee, Manash Jyoti Deka</i>	
<b>THE AFFILIATION BETWEEN STUDENT ACHIEVEMENT AND ELEMENTS OF GAMIFICATION IN LEARNING SCIENCE</b> .....	482
<i>Mageswaran Sanmugam, Hasnah Mohamed, Norasykin Mohd Zaid, Zaleha Abdullah, Baharuddin Aris, Salihuddin Md. Suhadi</i>	
<b>ENHANCING QOS CONTEXT-AWARE UBIQUITOUS LEARNING BY UTILIZING LOGICAL AND PHYSICAL CHARACTERISTIC OF DEVICE</b> .....	486
<i>Nungki Selviandro, Mira Sabariah, Novandy Dwiyan</i>	
<b>FACEBOOK AS A PLATFORM FOR ACADEMIC-RELATED DISCUSSION AND ITS IMPACT ON STUDENTS SUCCESS</b> .....	492
<i>Nurul Farhana Jumaat</i>	
<b>DECISION SUPPORT SYSTEM IN DETERMINING THE STUDY PROGRAM CONCENTRATION</b> .....	498
<i>Evaristus Madyatmadja, Tanty Oktavia</i>	
<b>CONTEXT-AWARE UBIQUITOUS LEARNING ON THE CLOUD-BASED OPEN LEARNING ENVIRONMENT: TOWARDS INDONESIA OPEN EDUCATIONAL RESOURCES (I-OER)</b> .....	504
<i>Nungki Selviandro, Gia Septiana</i>	
<b>Author Index</b>	



# Adapted Weighted Graph for Word Sense Disambiguation

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**Abstract**—In Natural Language Processing, Word Sense Disambiguation is defined as the task to assign a suitable sense of words in a certain context. Word Sense Disambiguation takes an important role and considered as the core research problem in computational linguistics. In this research, we conduct an experiment with Adapted Lesk Algorithm compared to original Lesk Algorithm to improve the performance of weighted graph-based word sense disambiguation. Both Algorithms base their measure to the gloss of the dictionary used, not like the other similarity measure that base their measure to the path or information content of the concept being compared. Thus, both Lesk and Adapted Lesk has the highest coverage of part-of speech since they can measure between different part-of-speech. Results of the experiment indicate that Adapted Lesk improves the performance of weighted graph-based Word Sense Disambiguation by 19 % of precision compared to Original Lesk in individual similarity measure experiment.

**Keywords** : Natural Language Processing; Word Sense Disambiguation.

## I. INTRODUCTION

In the field of computational linguistics, Word Sense Disambiguation (WSD) can be defined as the computational task to identify the meaning of words in particular context [1]. The task is important in Natural Language Processing since almost all of English word has more than one meaning. In such field, the word is called polysemy. As the core research problem in computational linguistics, WSD takes an important role to remove ambiguity from text [2] by assigning appropriate sense of a word in a particular context. Moreover, WSD is also essential as a tool for text processing (eg.: machine translation and information retrieval) which is needed to extract information from text data since text left by the people from online activities is an important source of information [20].

According to Aggirre and Edmonds [2], there are four basic approach to WSD : 1) Knowledge-based, 2) Unsupervised corpus-based, 3) Supervised corpus-based and 4) Combination approach. The principal difference between Knowledge-based and corpus-based relies on the lexical resource used in the algorithm. While knowledge based takes advantage of lexical resource which is rich and systematic, corpus-based undertake a knowledge-lean resource which is potential to evolve or

adapt as circumstances warrant [3]. Unsupervised corpus-based uses un-annotated corpora while supervised use aligned one [2]. Like in the other fields of study (eg.: data mining, process mining, decision mining), supervised takes advantage from Machine Learning technique [4], [5].

A knowledge-based WSD system employs lexical dictionary [2]. In this research, we propose an Adapted Weighted Graph WSD which uses large english lexical dictionary of Wordnet [6]; therefore this method is a promising knowledge-based wsd which is free of training sample [7]. Wordnet is a lexical database that is considered beyond Machine Readable Dictionary since it arranges concept in a rich semantic network based on psycholinguistic principle [8]. The contribution of this research focuses on the improvement of weighted graph-based WSD method proposed by Sinha and Mihalcea [9] by integrating a better similarity metrics. The similarity metrics to be adapted to Sinha and Mihalceas graph based WSD is Adapted Lesk [10].

We conduct experiment by using Senseval-3 dataset [11] to search the effect of Adapted Lesk Algorithm to the performance of the weighted-graph on WSD. Lesk algorithm is potential since in such WSD approach it is independent of part-of-speech. In other word Lesk is similarity measure with the highest coverage on part-of-speech since it is capable to return similarity measure across different part-of-speech (eg., verb-noun, adjective-noun). The other similarity measure (ie : Leacock and Chodorow, Wu and Palmer, Resnik, Lin, and Jiang and Conrath) can only measure the similarity between the same part-of-speech. Although the use of combined similarity measure outperforms individual one, yet Lesk work better in the use of individual similarity measure. In this paper we will prove that improving Lesk by using Adapted Lesk [10] will improve the entire system of graph-based WSD.

## II. METHODS

In the field of computational linguistics, Word Sense Disambiguation (WSD) can be defined as the computational task to identify the meaning of words in particular context [1]. The task is important in Natural Language Processing since almost all of English word has more than one meaning. In such field,

the word is called polysemy. As the core research problem in computational linguistics, WSD take an important role to remove ambiguity from text [2] by assigning appropriate sense of a word in a particular context.

The contribution of this research concerns on the improvement of Graph Based WSD model proposed by Sinha and Mihalcea [9]. In such approach of WSD, the weight of the graph is extracted by using several similarity measure (ie : Leacock & Chodorow, Wu & Palmer, Resnik, Lin and Jiang & Conrath). This research proposes to improve the model by improving Lesk Algorithm with Adapted Lesk [10]. Lesk is potential since it is part-of-speech independent so by improving Lesk we argue that the WSD system will perform better. To evaluate the performance of the adapted weighted graph we will use Senseval-3 [11] all-words data set.

Given a sentence  $S$  to disambiguate containing  $n$  words  $(w_1, w_2, \dots, w_n)$ . Each word has several word sense picked from WordNet Database Taxonomy  $(ws_1, ws_2, \dots, ws_o)$ . Each word sense become candidate edge in the graph. The next step is extracting weight of the graph by counting similarity measure with several formulae between word sense. The new formula that will be evaluated in this research to be adapted in the graph is Adapted Lesk [10]. Step of the method proposed can be seen in Fig. 1.

To simplify the illustration of the methods, suppose we have a sentence : I like the red camera. Tagging using Stanford POS Tagger resulting part-of-speech of I(PRP)-like(VBP)-the(DT)-red(JJ)-camera(NN). Filtering to select verb, noun and adjective from the sentence resulting a sequence of words  $(w_1, w_2$  and  $w_3)$  ie. : like-red-camera. The sense of the word like, red and camera is then picked from WordNet [6] database. Every sense of the word becomes edge of the graph. The similarity measure between word senses is then assigned by several similarity measure. Whenever the similarity between the senses is not zero, an edge is created to connect the node associated with the senses. The value of the similarity is then assigned as the weight of such vertice. The final step is to determine the most important sense by applying connectivity measure of the graph.

The contribution of this research is to evaluate the effect of the improvement of Lesk algorithm to entire WSD method since Lesk outperforms the other similarity measure in individual experiment and is part-of-speech independent [9].

A simple example to illustrate the result of every step of the method can be seen in this description (for the reason to simplify the description of the method we only pick 3 sense out of 5 sense of the word like from WordNet Version 3.0).

Step 1 : I like the red camera

Step 2 :

I(prp) like(vbp) - the(dt) red(jj) - camera(nn)  
like-redcamera  
like - camera red

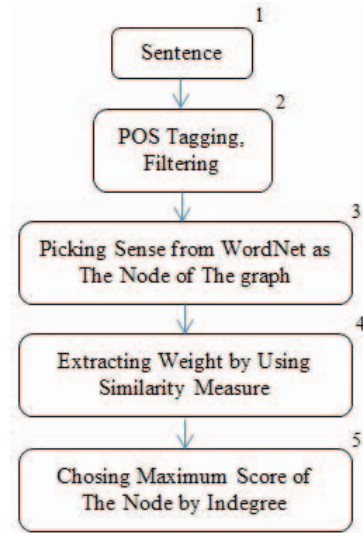


Fig. 1. Step of The Method Proposed

TABLE I  
DESCRIPTION OF POS USED IN THE EXAMPLE

Tag	Description
PRP	Personal Pronoun
VBP	Verb in Present Tense
DT	Determiner
JJ	Adjective
NN	Noun, Singular or Mass

Step 3 : Picking Sense from WordNet

TABLE II  
SENSE OF THE WORD "LIKE"

Index	Senses	Notation
like#v#1	prefer or wish to do something	$ws_1^1$
like#v#2	find enjoyable or agreeable	$ws_1^2$
like#v#3	be fond of	$ws_1^3$

TABLE III  
SENSE OF THE WORD "CAMERA"

Index	Senses	Notation
camera#n#1	equipment for taking photograph	$ws_2^1$
camera#n#2	television equipment consisting of lens system	$ws_2^2$

TABLE IV  
SENSE OF THE WORD "RED"

Index	Senses	Notation
red#adj#1	of a color of the color spectrum next to orange	$ws_3^1$
red#adj#2	characterized by violence or bloodshed	$ws_3^2$
red#adj#3	especially of the face	$ws_3^3$

## Step 4 and 5 : Choosing Maximum Score by Indegree

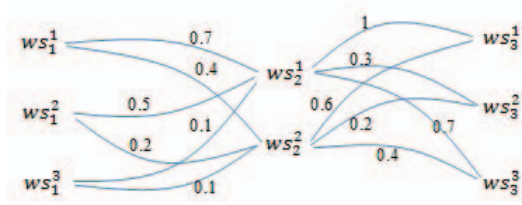


Fig. 2. Graph Extracted from The Example

As an example of the method proposed, the weight of the Graph In Fig. 2 is extracted by using adapted Lesk Algorithm. The complete measure between sense of like, camera and red is presented in Table 4. The result of the measure is then assigned as the weight of the graph as can be seen in Fig. 2. We use Wordnet::Similarity Tools from T. Pedersen and Jason Michellizi to generate most similarity measure used in this research.

TABLE V  
RESULT OF MEASURE OF THE SENSE OF THE EXAMPLE

Index	Adapted Lesk Measure	After Normalization
$ws_1^1$ to $ws_2^1$	23	0.7
$ws_1^1$ to $ws_2^2$	12	0.4
$ws_1^2$ to $ws_2^1$	16	0.5
$ws_1^2$ to $ws_2^2$	8	0.2
$ws_1^3$ to $ws_2^1$	3	0.1
$ws_1^3$ to $ws_2^2$	2	0.1
$ws_2^1$ to $ws_3^1$	33	1
$ws_2^1$ to $ws_3^2$	9	0.3
$ws_2^2$ to $ws_3^1$	24	0.7
$ws_2^2$ to $ws_3^2$	20	0.6
$ws_2^2$ to $ws_3^3$	8	0.2
$ws_2^3$ to $ws_3^2$	12	0.4

The final step is to determine the edge with the maximum score by using Indegree Algorithm. Indegree Algorithm counts the value of indegree that is equivalent to the degree of the node. Like was used in [9], for an undirected weighted graph  $G$  with node  $N$  and edge  $E$ ,  $G = (N, E)$ , where  $w_{ab}$  is weight between Node  $N_a$  and  $N_b$ , the indegree of node  $N_a$  is defined as in Equation (1).

$$Indegree(N_a) = \sum_{(N_a, N_b) \in E} w_{ab} \quad (1)$$

For graph in Fig. 2, Indegree Algorithm score is presented in Table 5. The node with the maximum score corresponds to the sense chosen for the word in that context of sentence. From Table 6, we can see that the sense chosen is like#v#1, camera#n#1 and red#adj#1. The bold number indicates the maximum score of Indegree of the sense.

TABLE VI  
SCORE OF INDEGREE ALGORITHM

Word	Sense(Edge)	Indegree Score	Sense Chosen
like	$ws_1^1$	<b>1.1</b>	like#v#1
like	$ws_1^2$	0.7	
like	$ws_1^3$	0.2	
camera	$ws_2^1$	<b>3.3</b>	camera#n#1
camera	$ws_2^2$	1.9	
red	$ws_3^1$	<b>1.6</b>	red#adj#1
red	$ws_3^2$	0.5	
red	$ws_3^3$	1.1	

### A. Similarity Measure

In this chapter we will briefly overview similarity measure used in the experiment. If  $S$  is similarity between two concept, Leacock and Chodorow [15] define similarity as in Equation (2) where  $l$  is length of shortest path of two concept being measured and  $D$  is maximum depth of the taxonomy.

$$S_{lch} = -\log \frac{l}{2 * D} \quad (2)$$

Wu and Palmer [16] defines a term of Least Common Subsumer ( $LCS$ ) to measure similarity  $S$  between concept  $c_1$  and  $c_2$  as can be seen in Equation (3).

$$S_{wup} = \frac{2 * Depth(LCS)}{Depth(c_1) + Depth(c_2)} \quad (3)$$

While Resnik [17] simply defines similarity  $S$  between two concept is equal with information content ( $IC$ ) of the  $LCS$  between both concept.

$$S_{res} = IC(LCS) \quad (4)$$

with

$$IC(c) = -\log P(c) \quad (5)$$

If  $t_f$  is term frequency of a concept,  $i_f$  is inherited frequency of a concept, and  $N$  is number of term in taxonomy, then

$$P(c) = \frac{t_f + i_f}{N} \quad (6)$$

Lin [18] introduces a similar formula of similarity measure with Wu and Palmer but using information content as in Equation (7).

$$S_{lin} = \frac{2 * IC(LCS)}{IC(c_1) + IC(c_2)} \quad (7)$$

While Jiang & Conrath [19] uses both  $IC$  and  $LCS$  and but with different formula.

$$S_{jcn} = \frac{1}{IC(c_1) + IC(c_2) - 2 * IC(LCS)} \quad (8)$$

Adapted Lesk Algorithm is the improvement of Lesk Algorithm [12]. In this research, we use Adapted Lesk to improve

weighted-graph-based WSD [9]. Original Lesk algorithm picks the gloss from traditional dictionaries such as Oxford Advanced Learners Dictionary of Current English and Webster's 7th Collegiate while Adapted Lesk is based on Wordnet. Yet, for the purpose of fair comparison of the effect of Lesk and Adapted Lesk on the WSD method, in this experiment, we will pick the gloss for both algorithms from Wordnet Version 3.0.

The principal difference between Lesk and Adapted Lesk is that Adapted Lesk extends its comparison not just to the sense of words being disambiguate [10]. Adapted Lesk extends its comparison to the sense of words that are connected to the words to be disambiguated in certain relationship defined in WordNet as can be seen in Table 7.

TABLE VII  
SCORE OF INDEGREE ALGORITHM

Noun	Verb	Adjective
Hypernym	Hypernym	Attribute
Hyponym	Troponym	Also See
Holonym	Also See	Similar to
Meronym		Pertainym of
Attribute		

### B. WordNet

WordNet is an online lexical dictionary [7], [13] that is inspired by psycholinguistics theories of human lexical memory [13]. Thus it arranges its lexical information in the terms of word sense, not simply word form that is organized alphabetically. Rational representation of word sense in WordNet is called synonym sets (henceforth synsets). WordNet can be viewed as a graph and synsets is the node while the semantic and lexical relation between synsets is the edge [8].

As a large lexical dictionary, Wordnet has a wide range of application, not only in the field of Computational Linguistics and Natural Language Processing, but also in another field of application. In [14] for example, Wordnet is used to support a business process application of a workflow management system.

### III. RESULTS

To validate the proposed method, we use Precision, Recall and F-Measure. While precision is percentage of correctly tagged words out of the words addressed by the system, recall is out of all words in the test set. By using Senseval-3 Dataset which contains approximately 5000 words collected from two Wall Street Journal articles and one excerpt from Brown Corpus [11], we compare the proposed method with Sinha and Mihalceas baseline [7]. We conduct several experiment to evaluate the performance of Adapted Lesk on weighted graph WSD method compared to Original Lesk. In this experiment, we extract the weight of the graph by individual similarity measure including Adapted Lesk. This experiment is aimed to evaluate the performance of Adapted Lesk in individual similarity measure compared to the other similarity measure

especially Lesk Algorithm in weighted graph WSD scheme. We evaluate the results on every part-of-speech (Noun, Verb and Adjective). The result of experiment is presented in Table 8 to Table 14.

TABLE VIII  
RESULT OF THE EXPERIMENT USING LEACOCK & CHODOROW

	Noun	Verb	Adjective	All
Precision	0.25	0.45	0.55	0.39
Recall	0.03	0.08	0.0005	0.001
F Measure	0.05	0.14	0.001	0.002

TABLE IX  
RESULT OF THE EXPERIMENT USING WU & PALMER

	Noun	Verb	Adjective	All
Precision	0.29	0.43	0.52	0.45
Recall	0.03	0.08	0.001	0.001
F Measure	0.05	0.13	0.002	0.002

TABLE X  
RESULT OF THE EXPERIMENT USING RESNIK

	Noun	Verb	Adjective	All
Precision	0.27	0.5	0.55	0.41
Recall	0.03	0.09	0.0005	0.001
F Measure	0.054	0.15	0.001	0.002

TABLE XI  
RESULT OF THE EXPERIMENT USING LIN

	Noun	Verb	Adjective	All
Precision	0.27	0.5	0.55	0.41
Recall	0.03	0.09	0.0005	0.001
F Measure	0.054	0.15	0.001	0.002

TABLE XII  
RESULT OF THE EXPERIMENT USING JIANG & CONRATH

	Noun	Verb	Adjective	All
Precision	0.21	0.45	0.55	0.375
Recall	0.02	0.08	0.0005	0.001
F Measure	0.04	0.14	0.001	0.002

TABLE XIII  
RESULT OF THE EXPERIMENT USING LESK

	Noun	Verb	Adjective	All
Precision	0.09	0.4	0.38	0.25
Recall	0.01	0.07	0.0004	0.0007
F Measure	0.018	0.12	0.0008	0.001

From the result of the experiment presented in Table 8 to Table 14, we evaluate the performance of WSD that the weight

TABLE XIV  
RESULT OF THE EXPERIMENT USING ADAPTED LESK

	Noun	Verb	Adjective	All
Precision	0.27	0.45	0.48	0.44
Recall	0.03	0.09	0.0005	0.001
F Measure	0.054	0.15	0.001	0.002

is extracted by using individual similarity measure (Leacock & Chodorow, Wu & Palmer, Resnik, Lin, and Jiang & Conrath) in every part of speech (Noun, Verb and Adjective). The goal of the experiment is to find the best performance of similarity measure in every part of speech. The result indicates that every similarity measure works best on Adjective. For Noun, Wu & Palmer yield the best performance, while for Verb, Resnik and Lin work best. As Adapted Weighted Graph for Word Sense Disambiguation is an improvement of weighted graph wsd proposed by Sinha and Mihalcea [7] by using Adapted Lesk [10], we try to compare the performance of Adapted Lesk (this research) and Lesk as the baseline method. From Table 11 and Table 12 we notice that Adapted Lesk outperform Lesk by 0.18 on Noun, 0.05 on Verb, and 0.1 on Adjective. Overall, Adapted Lesk outperforms Lesk by 0.19 on precision.

In the future work, we plan to combine similarity measure that achieved the best performance on certain part of speech to get the best performance of the method proposed. We also plan to integrate a better state of the art similarity measure in Sinha and Mihalcea's random walk WSD model to increase the recall as well as another better centrality algorithm instead of Indegree Algorithm.

#### IV. CONCLUSION

In order to improve the performance of weighted graph WSD, we improve Lesk similarity measure by using Adapted Lesk in random walk wsd framework. Several similarity measures are compared and examined. Experiments indicate that Wu & Palmer work best for noun while Resnik and Lin work best for verb. Almost all similarity measures achieve best performance on adjective. Results of the experiment indicate that Precision of Adapted Lesk outperform Lesk in weighted graph-based WSD method in individual use similarity measure by 19 %.

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