

OPTIMISATION OF ENVIRONMENTAL RISK ASSESSMENT  
ARCHITECTURE USING ARTIFICIAL INTELLIGENCE  
TECHNIQUES

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## ACKNOWLEDGMENT

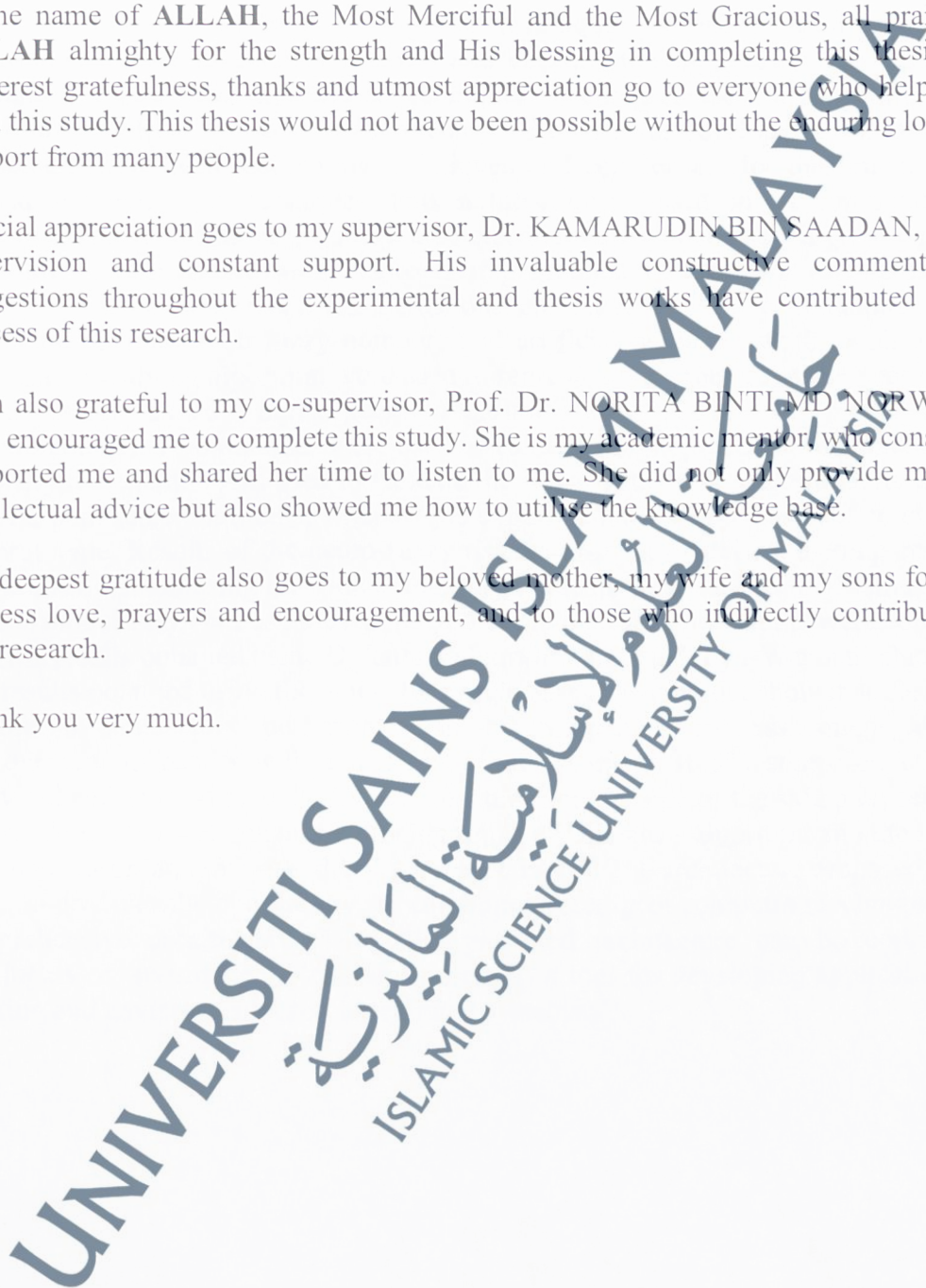
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## ABSTRACT

The integration of artificial intelligence techniques is becoming necessary for environmental risk assessment systems and decision-making, particularly under the limitations of individual intelligence techniques. A comprehensive architecture, called Environmental Risk Assessment Architecture (ERAA), was developed to capitalise the strengths of intelligent computing techniques and compensate for the limitations of individual intelligence techniques. This architecture is based on the combination of three well-known techniques, namely, artificial neural networks, fuzzy logic and genetic algorithm. The proposed architecture is implemented in the form of two models, namely, the neuro-fuzzy risk assessment model and the safe path selection model. Fuzzy arithmetic operations on fuzzy numbers and artificial neural networks, with a back-propagation learning algorithm were used to represent the structure of the neuro-fuzzy risk assessment model, whereas genetic algorithms were used to develop the safe path selection model. Two methods were used to validate the proposed architecture, that is, the analytical method was used to validate the neuro-fuzzy risk assessment model and the safe path selection model, whereas the experimental method was used to evaluate the prototype. Results of the neuro-fuzzy risk assessment model were compared with the results obtained using individual intelligence techniques, such as the Mamdani and Sugeno models. By contrast, the results of the safe path selection model were compared with the results obtained using Dijkstra's algorithm and the Floyd-Warshall algorithm. The results obtained using the neuro-fuzzy risk assessment model show that the model exhibits a satisfactory performance in environmental risk assessment and an improvement in results with a difference rate of up to 10.8% compared with the Mamdani and Sugeno models. By contrast, the running time of the safe path selection model (96  $\mu$ s) is shorter than the running times of Dijkstra's algorithm and the Floyd-Warshall algorithm (150  $\mu$ s and 184  $\mu$ s, respectively). The architecture proposed in this research provides the opportunity for combining intelligent computing techniques in a comprehensive architecture. Thus, the proposed architecture can be applied by developers of environmental risk assessment as a tool for developing applications on tracking and environmental risk assessment systems.

## ABSTRAK

Penyepaduan teknik kecerdasan buatan semakin menjadi keperluan bagi sistem penilaian risiko alam sekitar dan membuat keputusan, terutamanya di bawah batasan teknik-teknik kecerdasan buatan individu. Senibina komprehensif yang dikenali sebagai Senibina Penilaian Risiko Persekitaran telah dibangunkan untuk memanfaatkan kekuatan teknik pengkomputeran pintar dan mengimbangi kekangan teknik-teknik kecerdasan buatan yang digunakan secara berasingan. Senibina ini berdasarkan gabungan tiga teknik terkenal iaitu rangkaian neural buatan, logik fuzzy dan algoritma genetik. Senibina yang dicadangkan dilaksanakan dalam bentuk dua model iaitu model penilaian risiko neuro-fuzzy dan model pemilihan laluan selamat. Operasi aritmetik fuzzy pada nombor fuzzy dan rangkaian neural buatan dengan algoritma pembelajaran back-propagation digunakan untuk mewakili struktur model penilaian risiko neuro-fuzzy manakala algoritma genetik digunakan untuk membangunkan model pemilihan laluan selamat. Dua kaedah telah digunakan untuk mengesahkan senibina yang dicadangkan iaitu kaedah analisis telah digunakan untuk mengesahkan model penilaian risiko neuro-fuzzy dan model pemilihan laluan selamat manakala kaedah ujikaji digunakan untuk menilai prototaip. Keputusan model penilaian risiko neuro-fuzzy dibandingkan dengan hasil yang diperolehi dengan menggunakan teknik-teknik kecerdasan individu seperti model Mamdani dan Sugeno. Sebaliknya, keputusan model pemilihan laluan selamat dibandingkan dengan hasil yang diperolehi dengan menggunakan algoritma Dijkstra dan algoritma Floyd-Warshall. Keputusan yang diperolehi menggunakan model penilaian risiko neuro-fuzzy mendapati bahawa model tersebut mempamerkan prestasi yang memuaskan dalam menilai risiko alam sekitar serta meningkatkan hasil keputusan dengan perbezaan kadar sehingga 10.8% berbanding dengan model-model Mamdani dan Sugeno. Sebaliknya, masa yang digunakan oleh model pemilihan laluan selamat ( $96 \mu s$ ) adalah lebih pendek berbanding algoritma Dijkstra dan Algoritma Floyd-Warshall ( $150 \mu s$  dan  $184 \mu s$ ). Senibina yang dicadangkan dalam kajian ini memberi peluang untuk menggabungkan teknik pengkomputeran pintar dalam senibina yang komprehensif. Oleh itu, senibina yang dicadangkan boleh digunakan oleh peminat penilaian risiko alam sekitar sebagai alat untuk membangunkan aplikasi pengesanan dan sistem-sistem penilaian risiko persekitaran.

## المخلص

أصبح دمج تقنيات الذكاء الاصطناعي ضرورياً لنظم تقييم المخاطر البيئية وصنع القرار، وخاصة في ظل القيود المفروضة على تقنيات الذكاء الاصطناعي الفردية. تم تطوير بنية شاملة تسمى بنية تقييم المخاطر البيئية ، وذلك بالاستفادة من قوة تقنيات الحوسبة الذكية و تعويض النقص الناتج عن القيود المفروضة على تقنيات الذكاء الاصطناعي الفردية. تستند هذا البنية علي الجمع بين ثلاث تقنيات معروفة وهي : الشبكات العصبية الاصطناعية ، والمنطق الغامض والخوارزميات الوراثية. تم تنفيذ هذه البنية في شكل نموذجين هما : نموذج تقييم المخاطر العصبي الغامض ونموذج اختيار المسار الآمن. تم استخدام العمليات الحسابية الغامضة على الأرقام الضبابية ، الشبكات العصبية الاصطناعية و خوارزمية التعلم الخلفية لتمثيل هيكل نموذج تقييم المخاطر العصبي الغامض، في حين استخدمت الخوارزميات الجينية لتطوير نموذج اختيار المسار الآمن. تم استخدام أسلوبين للتحقق من صحة البنية المقترحة حيث تم استخدام الطريقة التحليلية للتحقق من صحة نموذج تقييم المخاطر العصبي الغامض ونموذج اختيار المسار الآمن في حين استخدمت الطريقة التجريبية لتقييم النموذج المبدئي. تمت مقارنة نتائج نموذج تقييم المخاطر العصبي الغامض مع النتائج التي تم الحصول عليها باستخدام تقنيات الذكاء الفردية و هما نماذج مامداني وسوجينو. على النقيض من ذلك، تم مقارنة نتائج نموذج اختيار المسار الآمن مع النتائج التي تم الحصول عليها باستخدام خوارزمية ديجكسترا وخوارزمية فلويد-وارشال. نتائج نموذج تقييم المخاطر العصبي الغامض تبين أن النموذج يظهر أداءً مرضياً في تقييم المخاطر البيئية وتحسناً في النتائج بمعدل فرق يصل إلى 10.8% مقارنة مع نموذجي مامداني وسوجينو. وعلى النقيض من ذلك، فإن زمن التشغيل لنموذج اختيار المسار الآمن (96  $\mu$ s) أقصر من زمن تشغيل خوارزمية ديجكسترا وخوارزمية فلويد - وارشال (150  $\mu$ s و 184  $\mu$ s، على التوالي). البنية المقترحة في هذا البحث توفر فرصة الجمع بين تقنيات الحوسبة الذكية في بنية شاملة. ومن ثم، يمكن للمهتمين بتقييم المخاطر البيئية أن يطبقوا الهيكل المقترح كأداة لتطوير التطبيقات المتعلقة بتقييم المخاطر البيئية و نظم التتبع.

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## LIST OF ABBREVIATIONS

A-GPS	Assisted Global Positioning System
ANNs	Artificial Neural Networks
AP	Anti-Personnel Mines
AT	Anti-Tank Mines
CGI	Cell Global Identity
COO	Cell of Origin
DBMS	Data Base Management System
DSR	The Design Science Research
DSRM	Design Science Research Methodology
E-OTD	Enhanced Observed Time Difference
ERAA	Environmental Risk Assessment Architecture
ERW	Enhanced Radiation Weapon
ES	Expert systems
FIS	Fuzzy inference system
FL	Fuzzy logic
GA	Genetic Algorithm
GIS	Geographic Information System
GPS	Global Positioning System
GSM	Global System for Mobile Communications
JAD	Java Application Descriptor
LAN	Wireless Local Area Networks
LBS	Location Based Services
LCD	Liquid Crystal Display
LMAC	Libyan Mine Action Center
MBMS	Model Base Management System
MRE	Mine Risk Education
NFRAM	Neuro-Fuzzy Risk Assessment Model
OGC	Open Geospatial Consortium
PDA <sub>s</sub>	Personal Data Assistants
RAM	Random Access Memory

ROM	Read Only Memory
SDK	Android Software Development Kit
SI	Swarm Intelligence
SMS	Short Message Service
TOA	Time of Arrival
TOF	Time of Flight
TSP	Travelling Salesman Problem
UML	Unified Modeling Diagrams
UXO	Unexploded Ordnance
XML	Extensible Markup Language

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