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A UNIFIED TRUST MODEL FOR COMMON CRITERIA RECOGNITION ARRANGEMENT FOR PRODUCT ACCEPTANCE

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A UNIFIED TRUST MODEL FOR COMMON CRITERIA RECOGNITION ARRANGEMENT FOR PRODUCT ACCEPTANCE

By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

A UNIFIED TRUST MODEL FOR COMMON CRITERIA RECOGNITION ARRANGEMENT FOR PRODUCT ACCEPTANCE

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Common Criteria (CC) is introduced as an international body for product testing, verification and certification. It is used for unifying existing international standards that involved users, vendors, manufacturers (industries) and governments. The purpose of the CC evaluation is to establish a one-time assessment without the need for a series of repetitive testing and verification processes for Common Criteria Recognition Arrangement (CCRA) participant nations. The trust problem arises between CC Authorizers and Consumers because the Consumers need to trust the Authorizer nation's laboratory testing and verification of products. There are leading nations among the CCRA's arrangement signatories (e.g. the USA) that want to reduce the mutual recognition level because the nations do not trust foreign nation's laboratory testing and verification.

To overcome the trust problem, J. Kallberg proposed a hypothesis; which is to abandon the global approach of CCRA participants and replace it with well-established groups (e.g. EU, NATO). Secondly, the thesis has improved the J. Kallberg suggestion by introducing intersection members (nations) among the well-established groups that can serve as bridges to spread trust boundaries. A nation that a member of more than one group has a wider coverage of transitive trust. Then, the nation will act as a bridging nation between different groups. Thirdly, in order to minimize the trust gap between CCRA participant nations, choosing a nation that has good international relations with many nations as a candidate for the authorizing nation. This will minimize the trust problem if one chooses a nation that is good international relations as the authorizing nation compared to a nation has historical controversy which may lead to doubtful perception.

In this work, the thesis has modeled and verified the proposed solutions in minimizing the trust problem using a process of relation algebra and formal methods. Precedent methods such as Bayes probability, Dempster-Shaffer theory and subjective logic are referred to. The modeling steps as follows,

selecting requirements and formal specifications; implement and verify the models using Event-B and Atelier theorem prover. The verified models were simulated using ProB simulator for finding trustable CC authorizing nations using case studies from the period 1999 until 2014.

The performance measurement of the proposed models was evaluated based on trust relations of the CC authorizing nations with other CCRA nations; and the trust relations metrics were displayed as a list of CC authorizing nations ranking. From the simulation results, the ranking has shown that the USA, NLD, ESP, ITA, FRA and DEU dominated as the trustable authorizing nations. The thesis has suggested that the CCRA participant nations should choose the authorizing nation with the highest ranking because it is more trustable compared to lower ranking authorizing nations. As the conclusion, choosing the highest ranking authorizing nation can minimize the trust problem between the CCRA participant nations.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

MODEL KEPERCAYAAN BERSEPADU UNTUK PIAWAIAN PRODUK ANTARABANGSA DENGAN MENGGUNAKAN PENGIKTIRAFAN KRITERIA BERSAMA

Oleh

MOHD ANUAR MAT ISA

Januari 2018

Pengerusi: Ramlan Mahmod, PhD
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Kriteria Umum (CC) diperkenalkan sebagai piawaian antarabangsa untuk ujian, pengesahan dan pensijilan produk. Ia digunakan untuk menyatukan piawaian antarabangsa sedia ada yang melibatkan pengguna, penjual, pengeluar (industri) dan kerajaan. Tujuan penilaian CC adalah untuk menubuhkan penilaian sekali tanpa memerlukan beberapa siri proses pengujian dan pengesahan berulang untuk Negara Peserta Pengiktirafan Pengiktirafan Kriteria (CCRA). Masalah ketidak kepercayaan timbul antara pengesah dan pegguna CC kerana pengguna perlu mempercayai pengujian dan pengesahan produk makmal negara pemeriksa. Terdapat negara terkemuka yang telah menandatangan perjanjian CCRA (misalnya Amerika Syarikat) yang ingin mengurangkan tahap pengiktirafan bersama kerana kurang mempercayai ujian makmal dan pengesahan negara asing.

Untuk mengatasi masalah amanah, J. Kallberg mencadangkan suatu hipotesis yang mencadangan untuk meninggalkan pendekatan global Peserta CCRA dan menggantikannya dengan kumpulan antarabangsa yang stabil (cth. EU, NATO). Kedua, tesis telah meningkatkan cadangan J. Kallberg dengan memperkenalkan ahli-ahli persilangan (negara-negara) di kalangan kumpulan antarabangsa yang stabil yang boleh berfungsi sebagai jambatan untuk menyebarkan kepercayaan kepada kumpulan yang berlainan. Negara yang menyertai lebih dari satu kumpulan mempunyai liputan kepercayaan yang lebih luas. Negara ini akan bertindak sebagai negara penghubung antara kumpulan yang berlainan. Ketiga, untuk mengurangkan jurang ketidak kepercayaan antara negara-negara peserta CCRA, tesis telah mencadangkan untuk memilih negara yang mempunyai hubungan internasional yang baik dengan banyak negara lain sebagai calon negara pengesah. Ini akan megurangkan masalah ketidak kepercayaan jika memilih negara yang mempunyai hubungan antarabangsa yang baik sebagai negara yang diberi pengesah berbanding negara yang mempunyai kontroversi sejarah yang mungkin membawa kepada persepsi keraguan.

Di dalam tesis ini, kami telah memodelkan penyelesaian yang dicadangkan untuk megurangkan masalah ketidak percayaan menggunakan proses aljabar perhubungan dan kaedah formal. Aljabar perhubungan menyediakan pengiraan kepercayaan untuk hubungan antarabangsa. Kaedah awal seperti kebarangkalian Bayes, teori Dempster-Shaffer dan logik subjektif adalah dirujuk. Kerja pemodelan adalah seperti berikut, memilih keperluan dan spesifikasi rasmi, memodel menggunakan Event-B dan pengesah teorem Atelier. Model yang telah diuji menggunakan simulator ProB digunakan untuk mencari negara yang prnesah CC yang boleh dipercayai dengan menggunakan kajian kes dari tempoh 1999 hingga 2014.

Pengukuran prestasi model yang dicadangkan dinilai berdasarkan hubungan kepercayaan dari negara-negara yang pengesah CC; dan metrik perhubungan kepercayaan dipaparkan sebagai senarai pengesah CC. Dari hasil simulasi, senarai pengesah telah menunjukkan bahawa USA, NLD, ESP, ITA, FRA dan DEU sebagai negara yang pengesah yang boleh dipercayai. Negara peserta CCRA harus memilih negara pengesah yang mempunayai kedudukan tertinggi di dalam senarai pengesah kerana ia lebih dapat dipercayai berbanding dengan negara-negara pengesah yang berada di senarai terbawah. Sebagai kesimpulan, memilih negra pengesah yang berada di kedudukan tinggi dapat mengurangkan masalah ketidak percayaan antara negara peserta CCRA dengan menggunakan penyelesaian yang telah dicadangkan.

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I certify that a Thesis Examination Committee has met on 16 January 2018 to conduct the final examination of Mohd Anuar Mat Isa on his thesis entitled "A Unified Trust Model for Common Criteria Recognition Arrangement for Product Acceptance" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the degree of Doctor of Philosophy.

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I hereby confirm that:

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This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
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LIST OF ABBREVIATIONS

CC	Common Criteria
AU	African Union
AI	artificial intelligent
CPNIG	CCRA Participant Nations and International Groups
CTM	CCRA Trust Model
CCRA	Common Criteria Recognition Arrangement
CIA	confidentiality, integrity and availability
DoD	Department of Defense
DRM	digital right management
EU	European Union
EAL	Evaluation Assurance Level
GCM	Generic CCRA Model
GWOT	Global War on Terrorism
IT	Information Technology
ITSEC	Information Technology Security Evaluation Criteria
ICBM	intercontinental ballistic missile
INV	invariant
MNNA	Major non-NATO ally
NGTM	Nation in Group Trust Model
NSA	National Security Agency
NAM	Non-Aligned Movement
NATO	North Atlantic Treaty Organization
OIC	Organisation of Islamic Cooperation
PF	probability function
PP	Protection Profile
RAIR	Relation Algebra for International Relations
SARs	Security Assurance Requirements
SFRs	Security Functional Requirement
ST	Security Target
TCSEC	Trusted Computer System Evaluation Criteria
TCB	Trusted Computing Base
TOE	Target of Evaluation
UNASUR	Union of South American Nations
UN	United Nation

CHAPTER 1

INTRODUCTION

1.1 Overview

International standards and certifications play a major role in product distributions and marketing activities. To be well accepted in the global market, all IT products and services require international evaluations and certifications such as the Common Criteria (CC) certification. CC is an international standard body utilized for certifying security products and services. The CC is used for information technology security evaluation that covers features such as: generic security model; security functions; and security assurance components. The standard is published in order to unify the pre-existing security standard for users, vendors, manufacturers (industries) and governments in utilizing standard security requirements and evaluations.

There are six key features in CC [1]–[3]: Target of Evaluation (TOE), Protection Profile (PP), Security Target (ST), Security Functional Requirements (SFRs), Security Assurance Requirements (SARs), and Evaluation Assurance Level (EAL) respectively. TOE is a product or system for CC evaluation. PP is security requirements that should be imposed to the TOE. Manufacturer or vendor must comply their product with PP(s). ST is a standard document that identifies various security properties for TOE evaluation. It may consist one or more PPs. SFRs are security functions that are individually provided by a product. SARs are descriptions of testing that were done to a product. It shows how the product meets a security compliant or security claims. EAL is a rating of a product after passed security evaluations (or SARs). The rating begins with one (EAL1) as a basic security assurance, and seven (EAL7) is the most rigorous security assurance and most expensive one.

By the CCRA agreement, all signatories (participants) have agreed to recognize EALs one until four [1] except the United State of America is EALs one until two [2], [4]. Through EALs recognition scheme, all CCRA Consumers agree to recognize CCRA Authorizer's evaluations [1], [5], which it may be done by a foreign Authorizer [6]. The goal of the CC mutual recognition is "to eliminate the burden of duplicating evaluations of IT products and protection profiles" as well as "to improve the efficiency and cost-effectiveness of the evaluation" [1], [5]. At the last quarter 2016, there are 17 Authorizers and 10 Consumers in CCRA. The CCRA mutual recognition requires its signatories to trust foreign nation security assessments for IT products, which may introduce an unofficial refusal to consume a certified product [6]. For example, restless international relations between Authorizer (e.g. Turkey) and Consumer (e.g. Israel) nations may lead to this problem [6].

1.2 Problem Statement

Recent literature studies [2], [4], [6] have mentioned that the CC paradigm is exposed to the issue of a trust problem in a mutual recognition of CC certification among CCRA participant nations. The trust problem will render the usage of CC as the international body responsible for international certification. The problem is affected by an issue of trust in regard to international relations and foreign policy of nations. The CC paradigm is vulnerable to this issue when the trust problem arises between the CCRA participant nations. This major problem was addressed by J. Kallberg (2012) [6] in his manuscript entitled "Common Criteria meets Realpolitik - Trust, Alliances, and Potential Betrayal". He argues that a mutual recognition of CC among nations that are not the closest of allies makes national policymakers unwilling to accept it even though they have signed CCRA. Kallberg argument is grounded on a national security policy whereby when a national security is at stake, a country tends to become more selfish and concentrate on protecting its own interests. Therefore, if the country policy maker has a lessen trust to the CC Authorizer, then it will render the trustworthiness of the certified product by the CC Authorizer. The trust problems addressed by Kallberg were supported by Kurth (2012) [4] and Ragen (2013) [2]. Both have mentioned that there are leading nations among the CCRA's arrangement signatories (e.g. the USA) that want to reduce the mutual recognition level to lower than Evaluation Assurance Level (EAL) 2 (including augmentation).

The trust problem arises between CC Authorizer and Consumer because the Consumer needs to trust the Authorizer nation's laboratory testing and verification of products [6]. This mutual recognition can, in theory, result in a reduction of cost, resources, and time, but may change due to any complication that may arise in the areas of international relations, foreign policy and national security policy. The trust problem between Authorizer to Consumer has not been well addressed as yet, and there is no direct solution for minimizing the trust problem between Authorizer and Consumer. Referring to the trust problem addressed by Kallberg [6], Kurth [4] and Ragen [2], the thesis has divided the problem statement into three sub-problems as follows:

i. To address the trust problem between nations that have signed CCRA for product acceptance [2], [4], [6]. The international relations between CCRA participant nations should be identified which either friendly (allies), neutral, or hostile. The trust exists between nations that are the closest ally or friendly (e.g. the USA and UK) compared to nations that have historically confrontation (e.g. the USA and Soviet Union/Russia) [6]. Therefore, the international relations between the CCRA participant nations must be identified before one can choose the trustable Authorizer.

ii. To address the trust problem within the international groups which have CCRA participant nations as its members [6], namely NATO; EU; OIC; NAM; and MNNA. The trust literatures [6]–[13] have shown that nations establish and join international groups because of mutual benefits from a coalition (alliance). Coalition nations in the international groups believe that the coalition participants will honor the international coalition with a certain degree of trust. Therefore, finding trustable nations as Authorizer in the

international groups may help to minimize the trust problem between Authorizer and Consumer [6].

iii. To address the trust problem within Common Criteria (CC), the CC should be modeled for identifying CCRA's workflow [14] and the respective roles of CCRA participant nations [1]. The roles can be either Consumer, Authorizer or Manufacturer. Based on the given roles, the Authorizer can be identified for trust evaluation metrics using trust in international relations and trust in international groups.

1.3 Hypothesis

This section presents a research hypothesis (or proposed solution) for the thesis. Based on the problem statement, we use it as a prediction for a tentative conclusion (or research outcome) of this research work [6], [15]. The thesis hypothesis is defined as:

> "Trust in international relations exists between Authorizers and Consumers of CCRA participant nations, and the finest authorizer can be determined from among Authorizers that are friendly and neutral towards many of the CCRA participant nations."

The finest or trustable Authorizer is ideally a nation which has the highest of trust relations with other CCRA participant nations. Simulation of CCRA Trust Model (CTM) with case studies will provide an output of a trust metric (relation) for all Authorizers. The trust metric is calculated using a "group of trust" theory as suggested by J. Kallberg [6]; an overlapping of the "group of trust"; and international relations of all Authorizers with CCRA participant nations. Based on these three categories (variables), the four models, and collected data as case studies, we want to show that the trust problem between Authorizer and Consumer nations can be minimized by choosing the finest Authorizer. It will allow a higher chance of mutual recognition and acceptance of the CC certification among the CCRA participant nations. Consequently, it will help lessen potential vulnerability of the CC paradigm when a trust problem arises between the CCRA participant nations. A deduction of the thesis's hypothesis will be discussed at the end of Chapter 6.

1.4 Research Objective

The objective of this study is to propose a unified trust model for CC, which is then used to determine the trustable authorizing nation in CCRA. The outcome of the research goal is to minimize the trust problem between Authorizer and Consumer nations. In order to achieve the objective, the following processes will be carried out:

i. To design a mathematical formalism for "classifying international relations" between CCRA participant nations. This will allow international relations computation between CCRA participant nations as well as to find the trustable Authorizer.

ii. To design a formal model for international groups which have CCRA participant nations as its members. This will help identify mutual interests and trust relations of CCRA participant nations in the international groups. The trustable Authorizer by international group classification will be identified.

iii. To design a formal model for CCRA's workflow and the respective roles of CCRA nations. The Authorizer can be identified for trust evaluation using the CCRA's workflow and the respective roles using modeling technique. This will also help convey a foreground in understanding the CC evaluation processes to all CC stakeholders.

1.5 Research Scope

This work only used public data which available on the Internet as sources for international relations between CCRA participant nations. An observation by the authors for data collections was done for a limited duration, which will be discussed in Chapter 3. We focused on the headlines trust issues in international relations as inputs for the study. The last chapter provides a brief justification on why we chose to use the public data (including headlines news) on the Internet as the inputs.

1.6 Research Contributions

The research contributions of the thesis are as follows:

i. **A unified trust model for CC**: We present the unified CCRA Trust Model (CTM) to determine the finest authorizing member in CCRA. The CTM combines RAIR, NGTM and GCM models.

ii. **A method by which to compute international relations**: This is a formal calculus of Relation Algebra for International Relations (RAIR) designed for international relations computation. The proposed method will allow international relations computation, which has previously been subjective and incomputable. The method will help to provide government decision-makers (e.g. foreign ministry, defense ministry or presidential) with strategic information concerning other nations.

iii. **A formalism of international relations of nations in an international group**: This is a formal model of Nation in Group Trust Model (NGTM) for international group modeling. None of the existing literature has ever modeled international groups and its member relations. The NGTM will help to identify mutual interests and trust relations of its members such as: defense alliances; economic cooperation agreements; politics and foreign policy; historical events etc.

iv. **A formalism of CC workflows**: This is a formal model of Generic CCRA Model (GCM) designed for the CCRA workflow. Prior literature has

discussed a formalism of product security using CC methodology [16]–[27] but, to date, nobody has ever modeled and verified the CC workflow and its architecture as stated in the CCRA document [1]. The GCM can help convey a foreground in understanding the CC evaluation processes to all stakeholders including: evaluators; evaluation sponsors; system developers; consumers and vendors [14]. This modeling work focuses on relationships between Authorizer, Consumer and Manufacturer (or vendor) in CC's value chain.

v. **A trust metric for all CCRA authorizer nations**: Based on the data collected from case studies, we explored the entire material concerning CCRA participant nations and its relations. We have mapped the trust metric for 17 Authorizers as a trust ranking for all Authorizers. We used ProB simulator to simulate the finest authorizing nation using CTM. A timeline for the case studies covered the period from 1999 until 2014 (15 years). We gathered public data for all case studies over a 6 months period (July 2014 to December 2014). One may use the trust ranking in order to choose the most suitable Authorizer for a product security testing and verification process.

1.7 Thesis Organization

Chapter 1: Introduction.
This chapter provides an overview of the entire research work undertaken for this thesis. It discusses research problems, hypothesis, objectives and contributions respectively.

Chapter 2: Literature Review.
This chapter revisits the state of the art research works. It discusses issues such as: information security standards (e.g. CC); trust definition and its calculus; formal methods; international relations; and related multidiscipline literature.

Chapter 3: Methodology.
This chapter explains the research methodology applied for this research work. It details a formulation of the research hypothesis, identification of case studies, design and implementation of all models, as well as a model verification and simulation using formal methods.

Chapter 4: Trust Model.
This chapter presents the design and implementation of the proposed trust model. It discusses the four models, namely: RAIR, NGTM, GCM and CTM.

Chapter 5: Formal Verification.
This chapter presents model verifications for NGTM, GCM and CTM using formal methods. The model verification is divided into four stages, specifically: model requirement; formal specification; model design and refinement; and model verification.

Chapter 6: Simulation Result and Discussion.

This chapter displays simulation results of the four models. The four models are tested using actual data from the case studies. Simulation results for all models are discussed here. The truth of the thesis's hypothesis is also verified here.

Chapter 7: Conclusion.

This chapter wraps up the thesis achievements with regard to its goals, objectives and research contributions. Lastly, we have suggested some future work whereby the findings made in this study can be extended.

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