METAMODEL-BASED FRAMEWORK IN DESIGNING FAULT MANAGEMENT IN NETWORK MANAGEMENT SYSTEM

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ABSTRACT

Fault management is the first element that matters in network management to ensure the high availability of the network. The existing fault management models are mostly specific to an organization's standard. The proposed model can guide and help network managers to perform their routine task. Thus, the purpose of this research is to develop a generic and unified Fault Management Metamodel (FMM) that would create a fault management model, which in turn could be referred to as to better understand the flow of fault management. The FMM is developed by extracting and reconciling the fault management components from various fault management models. Then, the FMM is validated to ensure the correctness and logic of the proposed FMM. The FMM is validated using three validation techniques, which are the Frequency-based Selection, Face Validity and Tracing. The metamodelling framework that was used in this research is the Meta Object Facilities (MOF), and it was chosen because of its wide acceptance and coverage in many domains. The outcome of this research is the final validated FMM v1.2, which would guide network managers and other network users to better understand the fault management concepts flow and issues for their network. As for the future work, besides fault management, there are four other functional areas in network management that should be developed. The other areas are configuration management, accounting management, performance management and security management.

ABSTRAK

Pengurusan kerosakan adalah elemen pertama yang penting dalam pengurusan rangkaian untuk memastikan tahap ketersediaan yang tinggi bagi sesebuah rangkaian. Model pengurusan kerosakan yang sedia ada kebanyakkannya lebih terarah dalam menepati piawaian sesebuah organisasi berkenaan. Model yang dicadangkan boleh membimbing serta membantu pengurus rangkaian untuk melaksanakan tugas rutin mereka. Oleh itu, tujuan kajian ini adalah untuk membangunkan suatu Model Meta Pegurusan Kerosakan (FMM) yang akan mewujudkan satu model pengurusan kerosakan generik dan bersepadu yang boleh dirujuk untuk lebih memahami aliran pengurusan kerosakan. FMM dibangunkan dengan mengekstrak dan menyatukan komponen pengurusan kerosakan daripada pelbagai model pengurusan kerosakan. Kemudian, FMM akan disahkan untuk memastikan tahap ketepatan dan logik FMM yang dicadangkan. FMM kemudiannya akan disahkan menggunakan tiga teknik pengesahan yang berasaskan kekerapan pemilihan, temuduga pakar dalam bidang dan pengesanan. Rangka kerja metamodelling digunakan dalam kajian ini adalah Fasiliti Objek Meta (MOF), dan ia dipilih berdasarkan penerimaan dan liputan yang luas dalam pelbagai bidang. Hasil daripada kajian ini adalah FMM v1.2, yang akan membimbing pengurus rangkaian dan pengguna rangkaian lain untuk lebih memahami aliran konsep pengurusan kerosakan dan isu-isu rangkaian mereka. Bagi kerja-kerja masa hadapan, di samping pengurusan kerosakan, terdapat empat bidang fungsian lain dalam pengurusan rangkaian yang boleh dibangunkan. Bidang-bidang tersebut adalah pengurusan konfigurasi, pengurusan perakaunan, pengurusan prestasi dan pengurusan keselamatan.

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LIST OF ABBREVIATIONS

MOF	-	Meta Object Facility
NMS	-	Network Management System
FCAPS	-	Fault, Configuration, Accountability, Performance and Security
DSR	-	Design Science Research
ISO	-	International Organization for Standards
ISP	-	Internet Service Provider
OAM	-	Operation, Administration, Maintenance
OMG	-	Object Management Group
FMM	-	Fault Management Metamodel

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Network management is an important component of the network in the expansion and complexity of network scale, management and maintenance of network. A network provider needs efficient tools to control, monitor and manage their network where there are many kinds of devices which encompassess active and passive devices.

These devices comes from different vendors, has different control and monitoring attributes that needs monitoring to achieve certain level of customer demand on quality of service. A network manager must have experience managing networks especially for larger area network. In network management, an organization invest great amount of time and money to maintain complex network, which includes management of fault, configuration, accounting, performance and security (Rajan et al., 2011). There are reasons why network management is important and some of its purpose is to monitor and control the network (Gong et al., 2013).

Many researchers use metamodelling as an approximation technique that can help design optimization (Gerber et al., 2010; Pan et al., 2010; Othman and Beydoun, 2010; Dhouib et al., 2012). Gerber et al. (2010), use metamodelling to develop Togaf Content Metamodel in Entreprise Architecture field. For Pan et al. (2010), metamodelling is use to design B-pillar structure at automotive structure. Othman and Beydoun (2010) develop a Disaster Management Metamodel to help user manage

disaster and Dhouib et al. (2012) use metamodel to design, simulate and deploy robotic application for autonomous robots. Metamodelling is the contruction of a model from collection of models, aimed to create a generic model for selected revised issues. The choice of metamodelling framework depends on the modelling application, for example simulation, mathematical, information, engineering and others (Othman, 2012). Meta Object Facility (MOF) framework is used for this research to develop the metamodel and discussed futher in Chapter 2.

This research investigates how metamodelling addresses the problem of fault management by producing a Fault Management Metamodel (FMM) framework for reference, which guides the network manager in understanding the flow of fault in the network.

1.2 Problem Background

As network devices must function perfectly to impart services to customers, they should be monitored regularly. Monitoring can be proactive or reactive, depending on the type of device. Proactive monitoring is essential for critical devices. Reactive monitoring is possible in devices where failure can be expected on the basis of information obtain from other devices that do not affect the services offered to users.

Proactive monitoring is not free and requires bandwidth to send requests and receive responses from the draft. It also requires a good management system to handle the volume of traffic (Hood and Ji, 1997). Among the issues in the monitoring, the interval between each request to monitor device status is also an important factor. The optimum interval for monitoring should be determined by the service provider when designing a monitoring system.

The monitoring system must be design and take into account about the device that is not working. The system must notify the operator when the device does not respond to a request for monitoring. Sometimes, failure of a single device can cause

some other device is not achieved. In this case, the monitoring system must filter out all alarms and a single alarm is sent to the operator. Information about errors observed by a network device can be useful in detecting and anticipating the damage. Errors can also provide useful information for troubleshooting.

Network management issues are critical aspects handled by service providers to ensure that all the network devices and services work seamlessly (Leinwand and Fang, 1993). Specifically for a large network service provider, a wide network can consist of several cities where the devices installed will be in several locations and far apart from one another.

For Network Management System (NMS), it is a distribution and management system that consists of an integrated suite of applications (Davidson et al., 2009). User interface is a combination of switching, security management, event processing, control power transfer and many more amenities. The system is designed to meet the needs of operational staff in the day to day control of the network and also provides management information needed to assist in the planning and development of the network.

The service provider needs to have a good infrastructure to manage and access the devices from a central office remotely, so that the operational staff or network engineer will not have to configure every device at the exact location. NMS has an important role to manage these issues that may affect hardware and software implementation. Fault, configuration, accounting, performance and security (FCAPS) management are aspects that must also be taken into account when managing a network where the access to critical network elements must be protected from any attack (Rajan et al., 2011) and fault management, is the first element that matters in network management to ensure the high availability of the network (Jailani and Patel, 1998). It is the key element to consider in network management. There are lack of generic and unified fault model for network manager to refer. Existing fault management model are mostly specific to an organization's network standard. All information on this and other issues in network management is taken into consideration in this study.

1.3 Problem Statement

In network management, many network management software exist and most organization and service provider spend most of their resources to build and maintain a network. Also, the network manager themselves depend on the software or tools to manage network whether for large or small organization. For large organization such as universities and large company, they may have a professional network manager to handle their network but in small organizations, their network manager may lack experience in handling the network if fault event occur.

Therefore, this FMM development can act as knowledge sharing among practitioners which will help them in fault management. Implementation of knowledge sharing in fault management will give advantage to network managers and network administrators. In organizational perspective, knowledge sharing can improve their organization performance by transferring knowledge from a person, group or organization to another (Lee J.N, 2001).

In network management field, lack of generic and unified model for the network manager or admin to refer. The existing fault management models are mostly specific to an organization's network standard. The development of this metamodel will create a generic fault model that can be used to understand the flow of fault management. To enable a well organized methodology or modelling language, metamodelling is applied. Metamodel is used because of its wide acceptance and coverage of many domains (Picka M., 2004). Therefore, this research will identify the essential aspects of network management (focus on fault management) in order to develop a metamodel that will guide the network manager to understand the flow of fault in the network which can also be used by newcomers in network management field.

1.4 Research Question

The research question to address problems stated:

i. How is metamodelling approach capable in supporting the network managers in managing their fault management issue in their network?

1.5 Research Objective

Objectives of the research are:

i. To investigate the network management components focusing on fault management.

ii. To develop the Fault Management Metamodel by using 8-Steps of metamodel development.

iii. To validate the correctness and logicness of the proposed Fault Management Metamodel by using metamodel validation technique.

1.6 Research Scope

The scope of research can be refered as follows:

i. The research will focus on the creation of a metamodel in M2 level of Meta Object Facility Framework created by Object Management Group. The FMM used the 8-Step of Metamodel Development as explain in Chapter 3. The creation use a set of existing fault management models.

ii. For the purpose of metamodel validation, the proposed metamodel use three techniques of metamodel validation known as the Frequency-based Selection, Face Validity, and Tracing.

iii. The research only covers fault management; out of the five functional area of network management which are fault, configuration, accounting, performance and security in network management.

iv. In fault management, attribute covered in this research metamodel development are Fault Detection, Fault Recovery and Fault Analysis and Isolation. The FMM generally focuses on fault in hardware and device but can also be applied to other types of fault too.

1.7 Summary

There are many aspect that need to be considered and investigated when making a metamodel for fault management in a network. This research explain about aspects that need to be identified in fault and network management before using the metamodel approach.

Chapter 1, explains about the problem background, problem statement, objective, research question and scope. This research describes the problem background and the problem statement state that lack of generic and unified model in network fault management field and existing model mostly specific to an organization standard. This research also point out three objectives, a research question and four research scope.

Chapter 2 will discuss more about the network, network management, network management system (focus on fault management) and what the aspects and the attributes involved in network management. This chapter also explains about model, metamodel development, metamodel validation and what metamodel approach is used in this research.

Chapter 3, examines research methodology conducted in this research, where a Design Science Research methodology is used. This chapter also justifies the use of

methodology and describes the four phases of research used in this research: fault management problem identification, FMM creation, FMM validation and Metamodel result.

Chapter 4, explains about the FMM creation (metamodel development) and its result, FMM version 1.0, followed by the process of metamodel validation I, II and III. First validation process is Frequency-based Selection, an approach to validate the correctness of initial derived concept. Second validation is Face Validity, a technique that needs to interview expert in the domain of the research. Third validation is Tracing, a technique to check flow and logic of the metamodel.

Finally, Chapter 5 concludes all of this thesis and the research future work. This chapter discussed to show the achievement of the objective for this research. Research constraint are explained and followed with recommendation for future work.

REFERENCES

Ahmad, Mohammad Nazir, Colomb, Robert M, & Sadiq, Shazia W. (2010). A UML profile for perdurant ontology of domain interlocking Institutional Worlds. *International Journal of Internet and Enterprise Management, 6*(3), 213-232.

Argent, Robert M, Voinov, Alexey, Maxwell, Thomas, Cuddy, Susan M, Rahman, Joel M, Seaton, S, . . . Braddock, Roger D. (2006). Comparing modelling frameworks–a workshop approach. *Environmental Modelling & Software, 21*(7), 895-910.

Asim, Muhammad, Mokhtar, Hala, & Merabti, Madjid. (2010). A self-managing fault management mechanism for wireless sensor networks.

Baik, Seongbok, Jeon, YooSung, Hwang, Chankyou, & Lee, Yungwoo. (2013). *A tiering architecture for integrated network management system.* APNOMS.

Bakar, AABA, Hashim, NBA, Din, NBM, Jamaludin, MZB, & Zabil, MHBM. (2002). *Development of network management console: SNMP based network mapping and fault management.* Paper presented at the Research and Development, 2002. SCOReD 2002. Student Conference.

Bermell-Garcia, Pablo. (2007). A metamodel to annotate knowledge based engineering codes as enterprise knowledge resources.

Beydoun, Ghassan, Low, Graham, Henderson-Sellers, Brian, Mouratidis, Haralambos, Gomez-Sanz, Jorge J, Pavon, Juan, & Gonzalez-Perez, Cesar. (2009). FAML: a generic metamodel for MAS development. *Software Engineering, IEEE Transactions on, 35*(6), 841-863.

Davidson, Euan M, McArthur, Stephen DJ, Dolan, Michael J, & McDonald, James R. (2009). *Exploiting intelligent systems techniques within an autonomous regional active network management system.* Power & Energy Society General Meeting, 2009. PES'09. IEEE.

De Kok, Daniël. (2010). *Feature selection for fluency ranking*. Proceedings of the 6th International Natural Language Generation Conference.

De la Vara, Jose Luis, Ruiz, Alejandra, Attwood, Katrina, Espinoza, Huáscar, Panesar-Walawege, Rajwinder Kaur, López, Ángel, . . . Kelly, Tim. (2016). Model-based specification of safety compliance needs for critical systems: A holistic generic metamodel. *Information and software technology, 72*, 16-30.

Depina, Ivan, Le, Thi Minh Hue, Fenton, Gordon, & Eiksund, Gudmund. (2016). Reliability analysis with Metamodel Line Sampling. *Structural Safety, 60*, 1-15.

Dhouib, Saadia, Kchir, Selma, Stinckwich, Serge, Ziadi, Tewfik, & Ziane, Mikal. (2012). Robotml, a domain-specific language to design, simulate and deploy robotic applications *Simulation, Modeling, and Programming for Autonomous Robots* (pp. 149-160): Springer.

Dumitrescu, Stefan Daniel, Alexandru, Smeureanu, Andreea, Dioşteanu, & Adrian, Cotfas Liviu. (2010). *Adaptable Network Management System using GIS and network ontology*. Roedunet International Conference (RoEduNet), 2010 9th.

Fahy, C, de Leon, M Ponce, van der Meer, S, Marin, R, Vivero, J, Serrat, J, . . . Baesjou, B. (2007). Modelling Behaviour and Distribution for the Management of Next Generation Networks *Advanced Autonomic Networking and Communication* (pp. 43-62): Springer.

Frank, Paul M. (1990). Fault diagnosis in dynamic systems using analytical and knowledge-based redundancy: A survey and some new results. *automatica, 26*(3), 459-474.

Frye, Lisa, Liang, Zhongliang, & Cheng, Liang. (2014). Performance Analysis and Evaluation of an Ontology-Based Heterogeneous Multi-tier Network Management System. *Journal of Network and Systems Management, 22*(4), 629-657.

Gargantini, Angelo, Riccobene, Elvinia, & Scandurra, Patrizia. (2009). A semantic framework for metamodel-based languages. *Automated software engineering, 16*(3-4), 415-454.

Gerber, Aurona, Kotzé, Paula, & Van der Merwe, Alta. (2010). Towards the formalisation of the TOGAF Content Metamodel using ontologies.

Gong, Wei, Liu, Kebin, Li, Xiaoxu, Miao, Xin, & Zhu, Tong. (2013). Quality of Interaction for Sensor Network Energy-Efficient Management. *The Computer Journal.*

Harpster, Stephen, Marshall, Earl, & Whitefield, David. (1994). *EXODUS: an object-oriented network management system.* Global Telecommunications Conference, 1994. GLOBECOM'94. Communications: The Global Bridge., IEEE.

Harrington, David, Wijnen, Bert, & Presuhn, Randy. (2002). An architecture for describing simple network management protocol (SNMP) management frameworks.

Henderson-Sellers, Brian. (2011). Bridging metamodels and ontologies in software engineering. *Journal of Systems and Software, 84*(2), 301-313.

Henderson-Sellers, Brian, & Gonzalez-Perez, Cesar. (2005). A comparison of four process metamodels and the creation of a new generic standard. *Information and software technology, 47*(1), 49-65.

Hevner, Alan, & Chatterjee, Samir. (2010). *Design science research in information systems*: Springer.

Hood, Cynthia S, & Ji, Chuanyi. (1997). Proactive network-fault detection [telecommunications]. *IEEE Transactions on reliability, 46*(3), 333-341.

Isermann, Rolf. (1997). Supervision, fault-detection and fault-diagnosis methods—an introduction. *Control engineering practice, 5*(5), 639-652.

Jailani, Norleyza, & Patel, Ahmed. (1998). FMS: A computer network fault management system based on the OSI standards. *Malaysian journal of computer Science, 11*(1), 22-31.

Jia, Lianxing, Zhu, Wei, Zhai, Chenggong, & Du, Yi. (2007). *Research on an integrated network management system.* Paper presented at the Software Engineering, Artificial Intelligence, Networking, and Parallel/Distributed Computing, 2007. SNPD 2007. Eighth ACIS International Conference.

Jiménez, Luis González. (2006). REERM: Reenhancing the entity–relationship model. *Data & Knowledge Engineering, 58*(3), 410-435.

Jin, Hui-Qin, & Liang, Man-Gui. (2014). The Hierarchical Network Topology Management System based on Managed Object and View Mechanism. *AASRI Procedia, 9*, 12-18.

Khan, Muhammad Zahid, Asim, Muhammad, & Khan, Ijaz Muhammad. (2012). Centralized schemes of Fault Management in Wireless Sensor Networks. *Georgian Electronic Scientific Journals (GESJ), 36*(4), 66-74.

Kim, Bruce C, Fujikawa, Hisao, Tanaka, T, Ishizuka, M, & Abe, M. (1994). *An intelligent network management system in B-ISDN.* Paper presented at the Communications, 1994. ICC'94, SUPERCOMM/ICC'94, Conference Record,'Serving Humanity Through Communications.'IEEE International Conference.

Kuechler, W, Vaishnavi, Vijay, & Kuechler Sr, William L. (2007). *Design [science] research in IS: a work in progress.* Proceedings of the second international conference on design science research in information systems and technology (DESRIST 2007).

Lagerström, Robert, Johnson, Pontus, & Höök, David. (2010). Architecture analysis of enterprise systems modifiability–models, analysis, and validation. *Journal of Systems and Software, 83*(8), 1387-1403.

Lee, Jae-Nam. (2001). The impact of knowledge sharing, organizational capability and partnership quality on IS outsourcing success. *Information & Management, 38*(5), 323-335.

Lee, Kwang-Hui. (1994). *A distributed network management system.* Global Telecommunications Conference, 1994. GLOBECOM'94. Communications: The Global Bridge., IEEE.

Leinwand, Allan, & Conroy, Karen Fang. (1996). Network management: a practical perspective. *Unix and Open Systems Series, Reading, MA: Addison-Wesley,| c1996, 2nd ed.*

Li, Minqi, Yang, Feng, Uzsoy, Reha, & Xu, Jie. (2016). A metamodel-based Monte Carlo simulation approach for responsive production planning of manufacturing systems. *Journal of Manufacturing Systems, 38*, 114-133.

Li, Wenjing, Qi, Feng, & Meng, Luoming. (1998, 22-24 Oct 1998). *Architecture of the optical access network management system.* Communication Technology Proceedings, 1998. ICCT '98. 1998 International Conference.

Li, Xianzheng, & Zhan, Zhiqiang. (2010). *Visio-Based Method for User Mapping Topology Graph in Network Management System.* Biomedical Engineering and Computer Science (ICBECS), 2010 International Conference.

Liang, Likai, & Bi, Yushen. (2012). Research and Design of the Three-tier Distributed Network Management System Based on COM/COM+ and DNA. *Physics Procedia, 25*, 1751-1756.

Liu, Tian-hua, Yi, Si-chao, & Wang, Xiao-wei. (2013). A fault management protocol for low-energy and efficient wireless sensor networks. *J. Inf Hiding Multimedia Signal Process, 4*(1), 34-45.

Lombard, Muriel, & Lhoste, Pascal. (2008). Information Modelling Framework for Knowledge Emergence in Product Design *Global Design to Gain a Competitive Edge* (pp. 241-250): Springer.

Lopes, José LR. (1997). A meta-model for corporate real estate management. *Facilities, 15*(1/2), 22-28.

Lopez, Victor, Gerstel, Ori, Casellas, Ramón, Farrel, Adrian, King, Daniel, López-Buedo, Sergio, . . . Fernandez-Palacios, Juan. (2013). *Adaptive network manager: Coordinating operations in flex-grid networks.* Transparent Optical Networks (ICTON), 2013 15th International Conference.

Macia-Perez, Francisco, Lorenzo-Fonseca, Iren, & Berna-Martinez, Jose Vicente. (2014). A formal framework for modelling complex network management systems. *Journal of Network and Computer Applications, 40*, 255-269.

March, Salvatore T, & Smith, Gerald F. (1995). Design and natural science research on information technology. *Decision support systems, 15*(4), 251-266.

McColl, Chris, & Aggett, Graeme. (2007). Land-use forecasting and hydrologic model integration for improved land-use decision support. *Journal of environmental management, 84*(4), 494-512.

Mikkilineni, Rao, Morana, Giovanni, Zito, Daniele, & Di Sano, Marco. (2012). Service virtualization using a non-von Neumann parallel, distributed, and scalable computing model. *Journal of Computer Networks and Communications, 2012*.

Morana, Giovanni, & Mikkilineni, Rao. (2011). *Scaling and self-repair of Linux based services using a novel distributed computing model exploiting parallelism.* Enabling

Technologies: Infrastructure for Collaborative Enterprises (WETICE), 2011 20th IEEE International Workshops.

OMG. (2011). *Unified Modeling Language (UML).* http://www.uml.org/

Othman, Siti Hajar, & Beydoun, Ghassan. (2010). Metamodelling approach to support disaster management knowledge sharing.

Othman, Siti Hajar. (2012). *Metamodelling Approach for Managing Disaster Management Knowledge*. PhD Thesis. University of Wollongong, Australia.

Othman, Siti Hajar, & Beydoun, Ghassan. (2013). Model-driven disaster management. *Information & Management, 50*(5), 218-228.

Othman, Siti Hajar, Beydoun, Ghassan, & Sugumaran, Vijayan. (2014). Development and validation of a Disaster Management Metamodel (DMM). *Information Processing & Management, 50*(2), 235-271.

Pan, Feng, Zhu, Ping, & Zhang, Yu. (2010). Metamodel-based lightweight design of B-pillar with TWB structure via support vector regression. *Computers & structures, 88*(1), 36-44.

Pfeiffer, Daniel, & Niehaves, Bjorn. (2005). Evaluation of conceptual models-a structuralist approach. *ECIS 2005 Proceedings*, 43.

Picka, M. (2004). Metamodeling and development of information systems. *ZEMEDELSKA EKONOMIKA-PRAHA-, 50*(2), 65-70.

Qiu, Lili, Bahl, Paramvir, Rao, Ananth, & Zhou, Lidong. (2003). Fault detection, isolation, and diagnosis in multihop wireless networks: Technical Report MSR-TR-2004-11, Microsoft Research, Redmond, WA.

Rajan, MA, Balamuralidhar, P, Chethan, KP, & Swarnahpriyaah, M. (2011). *A Self-Reconfigurable Sensor Network Management System for Internet of Things Paradigm.* Devices and Communications (ICDeCom), 2011 International Conference.

Rossi, Matti, Ramesh, Balasubramaniam, Lyytinen, Kalle, & Tolvanen, Juha-Pekka. (2004). Managing evolutionary method engineering by method rationale.

Sargent, Robert G. (2005). *Verification and validation of simulation models.* Proceedings of the 37th conference on Winter simulation.

Scheer, August-Wilhelm, Thomas, Oliver, & Adam, Otmar. (2005). Process modeling using event-driven process chains. *Process-Aware Information Systems*, 119-146.

Simpson, Timothy W, Poplinski, JD, Koch, Patrick N, & Allen, Janet K. (2001). Metamodels for computer-based engineering design: survey and recommendations. *Engineering with computers, 17*(2), 129-150.

Stallings, William. (1998). SNMP and SNMPv2: the infrastructure for network management. *IEEE Communications Magazine, 36*(3), 37-43.

Sturm, Arnon. How to Choose a Metamodeling Approach. *The Knowledge Industry Survival Strategy: Initiative workshop of The International Conference on Object Oriented Programming, Systems, Languages and Applications (OOPSLA)* Orlando, Florida USA.

Trabelsi, Chiraz, Atitallah, Rabie Ben, Meftali, Samy, Dekeyser, Jean-Luc, & Jemai, Abderrazek. (2011). A model-driven approach for hybrid power estimation in embedded systems design. *EURASIP Journal on Embedded Systems, 2011*(1), 1.

Tveit, Merete Skjelten. (2009). A Meta-Model-Based Approach for Specification of Graphical Representations. *Electronic Communications of the EASST, 18*.

Vahidov, Rustam. (2006). *Design researcher's is artifact: a representational framework.* Proceedings of the 1st International Conference on Design Science Research in Information Systems and Technology, Claremont, USA.

Vaishnavi, Vijay K., & William Kuechler, Jr. (2007). *Design Science Research Methods and Patterns: Innovating Information and Communication Technology*: Auerbach Publications.

Van Beers, Wim CM. (2005). Kriging metamodeling for simulation: Tilburg University, School of Economics and Management.

Vandewoude, Yves, & Berbers, Yolande. (2002). *A meta-model driven methodology for state transfer in component-oriented systems.* Proceedings of USE 2003, European Joint Conferences on Theory and Practice of Software.

Venkatasubramanian, Venkat, Rengaswamy, Raghunathan, Yin, Kewen, & Kavuri, Surya N. (2003). A review of process fault detection and diagnosis: Part I: Quantitative model-based methods. *Computers & chemical engineering, 27*(3), 293-311.

Von Alan, R Hevner, March, Salvatore T, Park, Jinsoo, & Ram, Sudha. (2004). Design science in information systems research. *MIS quarterly, 28*(1), 75-105.

Wang, G Gary, & Shan, S. (2007). Review of metamodeling techniques in support of engineering design optimization. *Journal of Mechanical Design, 129*(4), 370-380.

Yu, Mengjie, Mokhtar, Hala, & Merabti, Madjid. (2008). *Self-managed fault management in wireless sensor networks.* Mobile Ubiquitous Computing, Systems, Services and Technologies, 2008. UBICOMM'08. The Second International Conference.