

# **THE E-DECISIONAL COMMUNITY: AN INTEGRATED KNOWLEDGE SHARING PLATFORM**

By

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## STATEMENT OF ORIGINALITY

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*I hereby certify that components of the work embodied in this thesis are from published papers of which I am a joint author. My contribution to these papers covers knowledge and experience management, knowledge representation, multi agent system, virtual organisations, and knowledge measurements and warrants inclusion of their parts in the body of my thesis.*

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## LIST OF ACRONYMS

ACL	Agent Communication Language
API	Application Programming Interface
CC	Cloud Computing
CML	Collective Management Layer
CoP	Community of Practice
DDNA	Decisional DNA
DF	Derivative Follower
FIPA	Foundation for Intelligent Physical Agents
GA	Group Agent
GT	Game Theory
HTTP	Hyper-Text Transfer Protocol
IaaS	Infrastructure as a Service
IEEE	Institute of Electrical and Electronics Engineers
IML	Individual Management Layer
ISO	International Organization for Standardization
KaaS	Knowledge as a Service
KAL	Knowledge-based Application Layer
KBVO	Knowledge Based Virtual Organizations
KE	Knowledge Engineering
KM	Knowledge Management
KOS	Knowledge-Oriented Services
KQML	Knowledge Query and Manipulation Language
MAS	Multi-Agent System
MY	Myoptimal
OWL	Web Ontology Language
PA	Personal Agent
PaaS	Platform as a Service
REST	Representational State Transfer
RF	Reputation Follower
SaaS	Software as a Service
SKMS	Smart Knowledge Management System
SOA	Service-Oriented Architecture
SOAP	Secure Object Access Protocol
SOE	Set of Experience
SOEKS	Set of Experience Knowledge Structure
SQL	Structured Query Language
VO	Virtual Organization
XML	eXtensible Markup Language

# LIST OF PUBLICATIONS DURING PHD

## CANDIDATURE

### *Journal Publications*

1. Mancilla-Amaya, Leonardo, Sanín, Cesar and Szczerbicki, Edward (2010)  
"Smart Knowledge Sharing Platform for E-Decisional Community",  
Cybernetics and Systems, 41: 1, pp. 17-30.
2. Mancilla-Amaya, Leonardo, Sanín, Cesar and Szczerbicki, Edward (2010),  
"A proposal for knowledge sharing in the E-Decisional Community using  
Decisional DNA", Systems Science, vol. 36, pp. 13-19.
3. Mancilla-Amaya, Leonardo, Sanín, Cesar and Szczerbicki, Edward (2010)  
"Using Human Behaviour To Develop Knowledge-Based Virtual  
Organizations", Cybernetics and Systems, 41: 8, pp. 577-591.
4. Mancilla-Amaya, Leonardo, Sanín, Cesar and Szczerbicki, Edward (2012):  
"Quality Assessment of Experiential Knowledge", Cybernetics and  
Systems: An International Journal, 43:2, pp. 96-113.
5. Mancilla-Amaya, Leonardo, Szczerbicki, Edward, and Sanin, Cesar.  
(2012). "Estimating Knowledge Quantity in the e-Decisional  
Community". Cybernetics and Systems *In Press*.
6. Sanin, Cesar, Mancilla-Amaya, Leonardo, Zhang, Haoxi, and Szczerbicki,  
Edward. (2012). "Decisional DNA: The Concept and Its Implementation  
Platforms". Cybernetics and Systems 43 (2):67-80.
7. Toro, Carlos, Sanchez, Eider, Carrasco, Eduardo, Mancilla-Amaya,  
Leonardo, Sanin, Cesar, Szczerbicki, Edward, Graña, Manuel, Bonachela,

Patricia, Parra, Carlos, Bueno, Gloria, and Guijarro, Frank. (2012). Using Set Of Experience Knowledge Structure To Extend A Rule Set Of Clinical Decision Support System For Alzheimer's Disease Diagnosis. *Cybernetics and Systems* 43 (2):81-95.

8. Sanin, Cesar, Toro, Carlos, Haoxi, Zhang, Sanchez, Eider, Szczerbicki, Edward, Carrasco, Eduardo, Peng, Wang, and Mancilla-Amaya, Leonardo. (2012). Decisional DNA: A multi-technology shareable knowledge structure for decisional experience. *Neurocomputing* 88 (0):42-53

### ***Conference Publications***

1. Mancilla-Amaya, Leonardo, Sanin, Cesar, and Szczerbicki, Edward. (2010). The E-Decisional Community: an integrated knowledge sharing platform. Paper read at Proceedings of the Seventh Asia-Pacific Conference on Conceptual Modelling, at Brisbane, Australia, pp. 53-60.

### ***Book Chapters***

1. Mancilla-Amaya, Leonardo, Sanin, Cesar, and Szczerbicki, Edward. (2009). Towards the construction of a knowledge-oriented community. In *Information Systems Architecture and Technology - IT Technologies in Knowledge Oriented Management Process*, edited by Z. Wilimowska, L. Borzemski, A. Grzech and J. Świątek. Wrocław: Oficyna Wydawnicza Politechniki Wrocławskiej, pp. 219-230.
2. Mancilla-Amaya, Leonardo, Sanin, Cesar, and Szczerbicki, Edward. (2010). Implementing Knowledge-Based Virtual Organizations for the E-Decisional Community. In *Information Systems Architecture and Technology - IT Models in Management Process*, edited by Z. Wilimowska, L. Borzemski, A. Grzech and J. Świątek. Wrocław: Oficyna Wydawnicza Politechniki Wrocławskiej, pp. 115-137.

3. Mancilla-Amaya, Leonardo, Sanín, Cesar, and Szczerbicki, Edward. (2010). Knowledge-Based Virtual Organizations for the E-Decisional Community. In Knowledge-Based and Intelligent Information and Engineering Systems, edited by R. Setchi, I. Jordanov, R. Howlett and L. Jain: Springer Berlin / Heidelberg, Vol. 6277. Original Edition, pp. 553-562.
4. Mancilla-Amaya, Leonardo, Sanin, Cesar, and Szczerbicki, Edward. (2011). An Agent-based approach to Measure Knowledge Quality. In Information Systems Architecture and Technology, edited by A. Grzech, L. Borzemski, J. Swiatek and Z. Wilimowska. Wroclaw: Oficyna Wydawnicza Politechniki Wrocławskiej, pp. 143-153.
5. Mancilla-Amaya, Leonardo, Sanin, Cesar, and Szczerbicki, Edward. (2011). An Approach to Measure Quality of Knowledge in the e-Decisional Community. In Knowledge-Based and Intelligent Information and Engineering Systems - 15th International Conference, KES 2011, Kaiserslautern, Germany, September 12-14, 2011, Proceedings, Part II, edited by A. Konig, A. Dengel, K. Hinkelmann, K. Kise, R. J. Howlett and L. C. Jain: Springer Berlin / Heidelberg, Vol. 6882. Original Edition, pp. 621-630.
6. Sanin, Cesar, Mancilla-Amaya, Leonardo, and Szczerbicki, Edward. (2009). A Case Study of Constructing Decisional DNA on Finance. In Information Systems Architecture and Technology - IT Technologies in Knowledge Oriented Management Process, edited by Z. Wilimowska, L. Borzemski, A. Grzech and J. Świątek: Wroclaw University of Technology, pp. 207-216.
7. Sanin, Cesar, Mancilla-Amaya, Leonardo, Szczerbicki, Edward, and CayfordHowell, Paul. (2009). Application of a Multi-domain Knowledge Structure: The Decisional DNA. In Intelligent Systems for Knowledge

Management, edited by N. T. Nguyen and E. Szczerbicki: Springer Berlin / Heidelberg, Vol. 252. Original edition, pp. 65-86.

8. Sanin, Cesar, Mancilla-Amaya, Leonardo, Zhang, Haoxi, and Szczerbicki, Edward. (2010). Towards a Software Platform for Experience Administration: Decisional DNA Manager. In Information Systems Architecture and Technology: IT Models In Management Process, edited by Z. Wilimowska, L. Borzowski, A. Grzech and J. Swiatek. Wrocław: Oficyna Wydawnicza Politechniki Wrocławskiej, pp. 19-29.



# ABSTRACT

In today's knowledge oriented economy, the ability to make accurate decisions becomes crucial for any organization or individual for adapting to new demands and conditions in the environment. Additionally, technology allows for ubiquitous access to knowledge and information from different places and devices at any time, which has created a new generation of highly informed customers and enterprises; thus, precise decisions have become more important in order to increase customer fidelity, maintain competitive advantage, and reduce reaction times and costs.

In spite of all the advances in the field of Knowledge Management, and more specifically in the area of Knowledge Sharing, most of the existing solutions for capturing, storing, and reusing knowledge require a high degree of expert intervention; for instance, expert forums or document bases. Moreover, the process of finding an appropriate solution for a given problem becomes complex when the amount of information and knowledge available increase everyday. Furthermore, unlike traditional organizational assets, knowledge has a unique intangible nature and is highly embedded in the workforce and the business processes, making it hard to measure and estimate its actual availability.

The e-Decisional Community aims at proposing a set of guidelines for the development of a large scale platform to share knowledge and experience in order to support decision-making processes in organizations. The main idea behind the platform is that experiential knowledge is gathered from the constant interaction between users and organizations and from the software applications that they use on a daily basis. Knowledge exchange and evaluation is performed in a semi-automatic way by using smart agent technology, a set of indicators that reflect human behaviour, and an automatized knowledge-based market environment. Additionally, the most important contribution of this research is the definition of a semi-automatic way of assessing quantity and quality of knowledge. The e-Decisional Community is able to provide estimated measures of quantity and quality

of knowledge, endowing organizations with a novel set of tools for assessing the knowledge that resides in their workers and business processes.

Several conceptual elements of this thesis have been implemented in a testing prototype, and the experimental results that were obtained show that the platform has a great potential for reducing the workload on experts, as well as response times for providing accurate solutions. Consequently, overall organizational efficiency is increased because workers can focus on their core tasks without worrying about additional management duties for their knowledge-based systems, such as solution classification, or knowledge quality assessment.