

**University of Medicine, Pharmacy, Sciences and
Technology of Târgu Mureş**

**Contributions to the Intelligent Agent-based
Systems and Measuring the Machine Intelligence**

Summary of Habilitation Thesis

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Summary

This habilitation thesis presents a part of the candidate's research results obtained after defending the PhD thesis at Babes-Bolyai University of Cluj-Napoca in 2007. The thesis presents some of the scientific results that can be considered relevant for his scientific, professional and academic career, being an argument for the future development of his research and teaching career.

The candidate contributed to a number of research projects as researcher and/or director at the same time. His postdoctoral project, entitled *Communication and Cooperation in Intelligent Systems*, performed in the frame of the POSDRU/89/1.5/S/63663 project, is a notable example. The international projects where the candidate contributed as project director are the following: *Electronic Health Records for the Next Generation Medical Decision Support in Romanian and Bulgarian National Healthcare Systems (NextGenElectroMedSupport)*, 461CB/23.10.2010, 2 years duration, Petru Maior University, Technical University of Sofia, University of Medicine and Pharmacy from Tirgu Mures, ICECHIM Research Institute from Bucharest and Lucian Blaga University of Sibiu; *Hybrid Medical Complex Systems (ComplexMediSys)*, 476/07.03.11, 2 years duration, that involved Petru Maior University and Institute of Informatics of the Slovak Academy of Sciences. It is worth to mention the recent international project with a duration of 3 years entitled *Social Network of Machines (SOON)* whose implementation is already in progress, where the candidate acts as director at the institutional level coordinating a team of five specialists. The institutions involved in the project are the University of Medicine, Pharmacy, Sciences, and Technology of Tirgu Mures, the University of Applied Sciences Western Switzerland from Switzerland, Institute of Informatics of the Slovak Academy of Sciences from Slovakia, University of Oviedo from Spain and the industrial partners Tornos SA (CH), MAT-obaly (SK) and ArcelorMittal Innovación Investigación e Inversiones S.L. (ES). Also, the candidate's contribution to the following COST Actions as member in the management committee and researcher can be outlined: IS1408 Action entitled *Industrially Contaminated Sites and Health Network (ICSHNet)* and CA17124 Action entitled *Digital Forensics: Evidence Analysis via Intelligent Systems and Practices (DigForAsp)*.

Since November 2014, the candidate has been the director of the Research Center from the frame of the university called *Advanced Computational Technologies (AdvCompTech)*.

Among the prestigious journals where the candidate published papers, the following can be mentioned: *International Journal of Intelligent Systems*, *Journal of Environmental Informatics*, *Symmetry*, *Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery*, *Epidemiologia and Prevenzione*, *Applied Intelligence*, *Science China Information Sciences*, *Cognitive Systems Research* and some others. Among the prestigious conferences where the candidate disseminated results the following can be mentioned: *ICONIP*, *CEC*, *KES*, *PSIVT*, *SYNASC*, *SOFA* and some others.

The candidate participated in the scientific committee of numerous international conferences; in the editorial board of prestigious journals, like *Complex Adaptive Systems Modeling*, published by Springer and acted as scientific referee at very prestigious journals, like: *IEEE Computational Intelligence Magazine*, *Expert Systems with Applications*, *IEEE Fuzzy Systems*, *Neurocomputing*, *Neural Computing and Applications*, *Measurement*, *Soft Computing*, *IEEE Systems* and many others.

It is worth to mention the contribution as principal scientific organizer and chair of the following successful conferences and workshops: *CANS'08*, *BICS'08*, *UICS'09*, *MedDecSup'11*, *MedDecSup'12* and *AdvMed'12*.

Among the thematic edited books at prestigious publishers the following can be mentioned: *Advanced Intelligent Computational Technologies and Decision Support Systems* and *Advances in Intelligent Analysis of Medical Data and Decision Support Systems*, at *Studies in Computational Intelligence* (Springer book series), and *Advanced Computational Technologies*, published by the Romanian Academy Publishing House, Bucharest. The candidate edited two conference proceedings that were published by the prestigious IEEE Computer Society Press and American Institute of Physics publishers.

The candidate edited the following special issues at international journals focused on some thematic topics that were identified by interest: *Complexity in Sciences and Artificial Intelligence*, *Advances in Soft Computing Techniques and Applications*, *Advances in Applied Sciences* and *Understanding Complex Systems*.

The main research results of the candidate since defending his PhD thesis until the present include the fields of *Intelligent agent-based systems*, *measuring the machine intelligence*, *Nature-inspired problem-solving*, *Advanced data analysis*, and *Data mining*. Many difficult real-life problems' solving, including some NP-hard problems, are efficiently solved by intelligent agent-based systems (IABSs), which include intelligent agents (IAGs) and intelligent cooperative multiagent systems (ICMASs). Design and development of IABSs remain in the upcoming years a very important research topic. There is a very large number of recently developed intelligent systems (ISs), like the intelligent drones able to transport passengers, intelligent agents able to autonomously pilot cars, advanced humanoid robots and intelligent cooperative drones

specialized in performing missions in unknown environments. Some results presented in the thesis are related to the problem-solving using agent-based systems.

Mimic of nature has been proved successful in many types of problem solving in different domains of science. Just to name some approaches, treated in this thesis: the computational hard problems solving using genetic algorithms, NP-hard problem-solving using colonies of artificial ants, multicriteria optimization problem-solving based on the osmosis chemical process.

Measuring the machine intelligence quotient (MIQ) of IABSs is an important actual research topic. There are very few metrics/methods presented in the scientific literature able to effectively measure the machine intelligence. Metrics proposed in the literature rely on different principles/considerations, hindering their effective comparison. There is no standardization or even a unanimous vision of what machine intelligence is and what should be measured. My consideration is that the machine intelligence measuring must be approached from the problem-solving point of view. Intelligence measuring should allow the differentiation between IABSs based on their problem-solving intelligence. A principal property that an intelligence metric could have consists in the universality. The motivation consists in the fact that a type of difficult problem can be solved by a wide diversity of intelligent systems, whose intelligence must be analyzed and measured.

The thesis is structured in four parts as follows.

Chapter 1. Introduction

Chapter 1 presents the context and motivation, the main contributions presented in the thesis, published papers of the candidate the thesis is based on and the structure of the thesis. The professional, scientific and academic carrier, and the academic contributions and impact of the results are briefly outlined.

PART I. Intelligent Agent-based Systems and Measuring Machine Intelligence

PART I includes chapters 2, 3 and 4. In chapter 2 the biological/natural intelligence as a source of inspiration for computational-hard problem-solving is studied. Chapter 3 studies the IABSs. In chapter 4 the state-of-the-art related to measuring machine intelligence is treated. There are outlined the limitations of the state-of-the-art metrics for measuring machine intelligence that claim for results.

PART II. Contributions to Measuring the Machine Intelligence

PART II of the thesis includes chapters 5, 6, 7 and 8 which present some results obtained related to measuring machine intelligence. The concrete obtained results include the metrics *MetrIntMeas* (chapter 5), *MetrIntPair* (chapter 6), *MetrIntSimil* (chapter 7) and the method *ExtrIntdetect* (chapter 8). Particular treated subjects in this part of the thesis include measuring difficult problem-solving machine intelligence of ICMASs, comparison of the ICMASs based on their intelligence, classification of the

ICMASs based on their intelligence in intelligence classes. A definition to the intelligent evolutionary systems is given and the possibility of measuring the evolution in the intelligence of an IABS is presented. Other treated subjects include: the variability in the intelligence of an ICMAS, the number of ICMASs whose intelligence can be simultaneously measured and compared, and detecting the ICMASs that have statistically extreme (low or high) intelligence in a set of studied ICMASs.

PART III. Contributions to Nature Inspired Systems and Algorithms. Difficult Problems Solving

PART III of the thesis includes chapters 9, 10, 11 and 12.

In chapter 9 a novel evolutionary reorganizing adaptive multiagent system called *ERMS* is proposed. *ERMS* successfully uses an evolutionary learning algorithm to discover emergent patterns of reorganization in order to solve more efficiently problems.

Chapter 10 presents a study on the important subject of the cognitive complexity of designing the group decision process (GDP). The presented study is performed in relation to some important related factors such as problem space complexity, and users' creativity.

In chapter 11 a novel perspective for highly intelligent systems called *societal intelligence* is proposed. The idea is based on a specific consideration of the *intelligence of human society* in scientific development and solving extremely complex problems.

Chapter 12 proposes a novel efficient algorithm called *OiMo* for complex multiobjective optimization. The algorithm is based on the osmosis physio-chemical process, that consists in the balancing the concentration of two solutions.

In chapter 13 a novel algorithm called *Intra-cluster Refinement Heuristic (IntraClusSTSP)* for efficient solving of an NP-hard problem, the Travelling Salesman Problem (TSP), is proposed. *IntraClusSTSP* provides an efficient incremental tour generation that improves the tour efficiency for designed algorithms. Also, the application of the proposed algorithm in cluster analysis is presented, including hierarchical cluster analysis, for the determination of the optimal numbers of clusters.

PART IV. Professional Development Plans

PART IV of the thesis includes chapter 14. This chapter briefly presents the principal next research directions that the candidate will work on in the upcoming years. There are also presented some research directions related to the candidate's results, which can be approached by PhD students as individual research, or research performed in the frame of projects. The future development plans of the candidate are briefly presented.