Editor **DANA SIMIAN**

MODELLING AND DEVELOPMENT OF INTELLIGENT SYSTEMS

Proceedings of the Fourth International Conference on
MODELLING AND DEVELOPMENT OF INTELLIGENT SYSTEMS

October 28 - November 1, 2015, Sibiu, ROMANIA

Lucian Blaga University Press, 2016

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Preface

This volume contains refereed papers which were presented at the Fourth International Conference Modelling and Development of Intelligent Systems. The conference was held between October 28 - November 1, 2015, at the Faculty of Sciences, "Lucian Blaga" University of Sibiu, Romania.

MDIS conference provides an opportunity for sharing ideas and establishing scientific cooperation in the field of intelligent systems. It aims to bring together scientists, researchers, students, interested and working in fields which can be connected with modeling and development of intelligent systems. Specific topics of the conference includes but are not restricted to: evolutionary algorithms, evolutionary computing, genetic algorithms and their applications, grid computing and clustering, data mining, ontology engineering, intelligent systems for decision support, knowledge based systems, pattern recognition and model checking, motion recognition, e-learning, hybrid computation for artificial vision, knowledge reasoning for artificial vision, geometric modelling and spatial reasoning, modelling and optimization of dynamic systems, large scale optimization techniques, adaptive systems, multiagent systems, swarm intelligence, metaheuristics and applications, machine learning, self learning algorithms, mathematical models for development of intelligent systems. The talks were delivered by universities' members, researchers and students from 7 countries (Estonia, Republic of Moldova, Romania, Philippines, Serbia, United Arab Emirates and USA). During the conference a wide range of theoretical and practical problems related to the conference topics were discussed. The plenary speakers addressed some of the most actual issues in the conference interest field:

- Prof. PhD. Dan Cristea - *Discovering semantic links in texts. Corpora and projects*
- Prof. PhD. Milan Tuba - *RFID Network Optimization Using Swarm Intelligence Algorithms*

We thank all the participants for their interesting talks and discussions. We also thank the members of the scientific committee for their help in reviewing the submitted papers and for their contributions to the scientific success of the conference and to the quality of this proceedings volume.

May 2016

Dana Simian
Conference chairman

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Table of Contents

Plenary Lecturer I

Discovering semantic links in texts. Corpora and projects

Dan Cristea

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Free texts are extremely rich in semantic relations, which we, human beings, are at ease to decipher while reading. If this would not be the case, important messages contained there would be obscure and texts would be incomprehensible. In order to make the machine reach a human-like level of performance, properly annotated corpora should be built. In the first part of my talk I will present an experiment developed with our students in Computational Linguistics to acquire a corpus of entities and semantic relations, the QuoVadis project. In the second part of the talk, I will bring forward another human capacity, which we would like to reproduce on machine, the ability to make connections between mentions of notorious entities in books and their virtual realizations. The MappingBooks project, which I will shortly describe, realizes a technology that transforms the classical book onto a multi-dimensional mash-up which combine textual, geographical and web-found data with personal information related to the reader.

Brief Biography of the Speaker: Dan Cristea is a professor at the „Alexandru Ioan Cuza" University of Iași (UAIC), Faculty of Computer Science (FII), the director of the Research Department in FII. He also holds a part-time position in the Institute of Computer Science of the Romanian Academy, the Iasi branch, and is a correspondent member of the Romanian Academy. Back in the '80s he has initiated a line of research in Computational Linguistics and Natural Language Processing in UAIC, which has grown during the years both numerically and qualitatively, up to the actual NLP-Group@UAIC-FII. He is the initiator of the series of EUROLAN Summer Schools in Natural Language Processing (started in 1993, with its 12th edition, in July 2015, hosted by the University "Lucian Blaga" of Sibiu) and a co-director of the series of conferences dedicated to resources and tools for processing the Romanian language (the ConsILR conferences, with its 11th edition – in November this year, in Iasi). He is known for his work on discourse related topics (such as veins theory and anaphora resolution), hierarchical description of linguistic metadata, multilingual linguistic workflows, computational lexicography, and has contributions in the creation of electronic resources for Romanian language (among which, the Romanian WordNet, the electronic version of the Thesaurus Dictionary of the Romanian Language, and the Computational Representative Corpus of Contemporary Romanian Language).

Plenary Lecturer II

RFID Network Optimization Using Swarm Intelligence Algorithms

Milan Tuba

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Radio frequency identification (RFID) technology has been recently widely adopted in many fields such as logistics, production, supply chain management, asset tracking etc. RFID systems consist of tags and readers which communicate with each other by radio waves through antennas. Tags are cheap and passive, attached to the items that are subject of tracking, while readers are more expansive and powered. Tags respond by backscattering portion of the received reader's signal. Sufficient number of readers should be deployed with the goal of establishing a coverage of the tags in the respective domain. Multiobjective RFID network planning problem (MORNP) is a hard optimization problem which deals with a set of objectives (tag coverage, load balance, economic efficiency, readers' interferences, etc.) by adjusting the control variables (readers' coordinates, the number of readers, antenna parameters, etc.) of the system. Population based stochastic metaheuristics have been successfully used to tackle this problem. Swarm intelligence is one branch of such nature inspired metaheuristics that has been applied to the MORNP optimization. In most implementations a weighted coefficients approach was used to transform MORNP optimization into a single-objective case. However, hierarchical approach can be more promising since objective functions are usually ordered in such a way that, for example, it does not make sense to reduce power if the coverage would be jeopardized. Additionally, the number of deployed readers as an optimization parameter has to be treated separately. Stochastic optimization algorithms in the process of exploitation (intensification) mutate optimization parameters with the goal of staying close to the good known solutions. However, changing the number of readers (which is an integer parameter) destroys previous search information, effectively introducing exploration (diversification). This lecture will show few successful swarm intelligence applications to the multiobjective RFID network planning problem.

- Milan Tuba, Nebojsa Bacanin, Marko Beko: Multiobjective RFID Network Planning by Artificial Bee Colony Algorithm with Genetic Operators, Advances in Swarm and Computational Intelligence, Lecture Notes in Computer Science Volume 9140, 2015, ISBN: 978-3-319-20465-9, Beijing, China, June 2015, pp 247-254, DOI: 10.1007/978-3-319-20466-6_27
- Milan Tuba, Nebojsa Bacanin, Raka Jovanovic: Hierarchical Multiobjective RFID Network Planning Using Firefly Algorithm, ISBN 978-1-4799-8966-9/15, International Conference on Information and Communication Technology Research (ICTRC2015), IEEE and Khalifa University, Abu Dhabi, United Arab Emirates, May 2015, pp. 279-282

- Milan Tuba, Nebojsa Bacanin: Hybridized Bat Algorithm for Multi-objective Radio Frequency Identification (RFID) Network Planning, IEEE Congress on Evolutionary Computation (CEC2015), Sendai, Japan, May 2015, ISBN: 978-1-4799-7491-7, 978-1-4799-7492-4/15, pp. 499-506
- Milan Tuba, Nebojsa Bacanin, Marko Beko: Fireworks Algorithm for RFID Network Planning Problem, 25th International Conference Radioelektronika 2015 (MAREW 2015), IEEE and University of Pardubice, ISBN 978-1-4799-8117-5, Pardubice, Czech Republic, April 2015, pp. 440-444
- Nebojsa Bacanin, Milan Tuba and Ivana Strumberger: RFID Network Planning by ABC Algorithm Hybridized with Heuristic for Initial Number and Locations of Readers, UKSim-AMSS 17th International Conference on Computer Modelling and Simulation, Cambridge, United Kingdom, March 2015, IEEE Computer Society, ISBN 978-1-4799-8712-2, DOI 10.1109/UKSim.2015.83, pp. 39-44
- Milan Tuba, Nebojsa Bacanin, Adis Alihodzic: Firefly algorithm for multi-objective RFID network planning problem, Proceedings of the IEEE 22nd Telecommunications Forum TELFOR 2014, ISBN: 978-1-4799-6190-0, IEEE Catalog Number: CFP1498P-CDR, November 2014, pp. 95-98

Brief Biography of the Speaker: Milan Tuba is the Dean of Graduate School of Computer Science and Provost for mathematical, natural and technical sciences at John Naisbitt University. He received B. S. in Mathematics, M. S. in Mathematics, M. S. in Computer Science, M. Ph. in Computer Science, Ph. D. in Computer Science from University of Belgrade and New York University. From 1983 to 1994 he was in the U.S.A. first as a graduate student and teaching and research assistant at Vanderbilt University in Nashville and Courant Institute of Mathematical Sciences, New York University and later as Assistant Professor of Electrical Engineering at Cooper Union School of Engineering, New York. During that time he was the founder and director of Microprocessor Lab and VLSI Lab, leader of scientific projects and theses supervisor. From 1994 he was Assistant Professor of Computer Science and Director of Computer Center at University of Belgrade, from 2001 Associate Professor, Faculty of Mathematics, University of Belgrade, and from 2004 also a Professor of Computer Science and Dean of the College of Computer Science, Megatrend University Belgrade. He was teaching more than 20 graduate and undergraduate courses, from VLSI Design and Computer Architecture to Computer Networks, Operating Systems, Image Processing, Calculus and Queuing Theory. His research interest includes mathematical, queuing theory and heuristic optimizations applied to computer networks, image processing and combinatorial problems. Professor Tuba is the author or coauthor of more than 150 scientific papers and coeditor or member of the editorial board or scientific committee of number of scientific journals and conferences. Member of the ACM, IEEE, AMS, SIAM, IFNA.

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Agent-Based Computational Models Implemented in 3D Space

Florentin Bota, Dan Dumitrescu

Abstract

The purpose of this project is to design and develop a unique state-of-the-art graphical platform that can be used to simulate and render different computational models in a 3D world. Using this platform we will be able to observe processes like emergent behaviours in a new perspective, using Unity3D as a graphics engine and C# as the main programming language. The finished product will be called VisualAgents and it will provide us with a new tool in our study of Complex Systems and Computational Models. In this paper we will present an agent-based approach of the platform, specifically a multi-agent ant colony. This project intends to create a better simulation tool that will be used in further experiments and for educational purposes.

1 Introduction

A computational model is a mathematical model used to study the behaviour of a complex system by computer simulation.[1] Common computational models are weather forecasting models, earth simulator models, flight simulator models, neural network models etc. Operation theories of the model can be derived or deduced from these experiments by adjusting the parameters of the system in the computer and studying the differences in the results.

An agent-based model (ABM)[2] is a class of computational models for simulating the actions and interactions of autonomous agents. They can be individual or collective entities, with a view to assessing their effects on the system as a whole. An agent-based model combines elements from game theory, complex systems, emergence, computational sociology and evolutionary programming. ABMs can also be considered individual-based models (IBMS), simpler agents than a fully autonomous model. The goal of ABM is to search for explanatory insight into the collective behaviour of agents obeying simple rules, as usually found in nature.[3]. These models are used to simulate operations and interactions of multiple agents in order to re-create and predict more complex phenomena. A recurring notion is that *simple rules can create a complex behaviour*. Also, the fact that the whole is greater than the sum of its parts is embraced.

Custom software was written in order to implement the specific ABM from this project with decision-making heuristics, an interaction topology and a non-agent environment. We studied how changes in individual behaviours affect the emerging overall behaviour of the system. Because we used a real 3D system instead of a simple 2D one and 3D meshes, we encountered several intriguing problems and issues that did not appear before in simpler systems. Forces like collision and gravity were not taken into account in our formal experiments and they did have several effects in the final outcome of the simulations.

2 Motivation and objectives

This project was inspired from another project, *Sotirios*[4], an effective e-learning application (Digital Game Based Learning) which combines cutting-edge graphics with learning puzzles. The video game follows the story of a future robot who dared to question the axioms that ruled his world and the player has to solve different learning puzzles (Fig.1) in order to progress in the immersive world of the game.

Fig.1 Different outcomes, based on the player's answer in Sotirios

It was an important step in developing 3D applications and we proposed a wasp behaviour model that steps in and allows the dynamic assignment of puzzles in the multiplayer mode of the game, taking into account the specialty of the students, their former experience and the complexity of the puzzles. An adaptive method allows students to pass through level 1 and determine their needs for the first time.

The idea for this particular simulation, an ant colony, came while reading a book written by Paul Ormerod, (Butterfly Economics) [5].The ant example was proposed to explain "herding" and "epidemics" described in the literature on financial markets as corresponding to the equilibrium distribution of a stochastic process rather than to switching between multiple equilibria.[6].

The question that picked our interest was *how would an ant colony split itself between two sources of food?* We tried to reproduce the actual results by using a simple agent model composed of a basic ant.

Regarding the practical application, several perspectives were addressed:

1. Creating a basic platform using Unity3D graphics engine
2. Creating one or multiple worlds as non-agent environments
3. Developing a system where the models and agents can be easily changed
4. Implementing an ant colony simulation and observe their behaviour

Secondary objectives in the above examples were:

a. A better understanding of Unity technology and DirectX/OpenGL functions
b. Create a simple scene with basic elements
c. Test the platform viability on multiple systems and operating systems
d. Test the ability to create and import objects from Blender
e. Animate the agents
f. Implement natural movement for the agents

The ant colony system, first proposed by Marco Dorigo in his PhD. thesis [7] is well known and used throughout the industry in multiple areas such as network optimisation, image processing, biology (protein folding), routing vehicles, etc. The algorithms based on the ant colony optimisation have an advantage over the simulated annealing and genetic algorithm approaches. They can adapt in real time to graph changes, a major interest in network routing and transportation systems.

Visual representations of the algorithm are mostly used for teaching purposes and for a better understanding of the mathematical functions. We wanted to take this a step further and allow a regular user to better imagine how these algorithms really work and even permit them to change the parameters in real time.

In figure 2 we can observe a similar approach, but in 2D space and it serves the purpose, but it is highly abstract and linear.

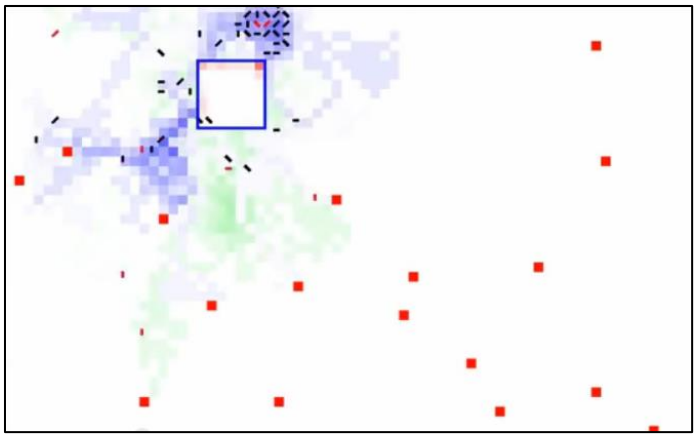

Fig.2: Ant colony simulation in 2D
Author: Gregory Brown
Source:https://practicingruby.com/articles/ant-colony-simulation

3 Implementation

3.1 Software environment

Our approach was implemented within the *Unity engine*, a cross-platform game creation system which includes a game engine and an integrated development environment. The reason we chose Unity was because it can deploy our results on more than 15 systems and operating systems, including Microsoft Windows, Apple iOS, Android, Linux, consoles and even web browsers. Also, a free version of the software is available for educational purposes or for individuals and companies with less than US$100,000 of annual gross revenue. Some characteristics of the engine that we used include:

- Direct3D, OpenGL and some proprietary API's
- texture compression and adaptive resolution for different platforms
- bump mapping, reflections, screen space ambient occlusion
- easy world and character creation

The scripting is built on Mono, an open-source implementation of the .NET Framework and different programming languages can be used, like JavaScript, C# or Boo. In this project, *C# was mainly used*, because it was also possible to use Visual Studio as an IDE

Because we had to create some of the 3D models, we also used *Blender*, an open-source 3D computer graphics software where we did the actual modelling.

3.2 Experiments and platform elements

We started with a basic world, a confined space with a ground layer for navigation and several walls so our agents will not fall over the edge during their interactions, as can be seen in figure 3. A central spawn point is the hive, where the agents will gather to leave their *food* in the event that they find it on the map. There are two identical food sources, shown in figure 3 as white spheres that can be moved by the users around the map and observe the different behaviour of the agents. The users can also change their view of the camera much like in a video game by using a mouse or even by touch input for handheld devices.

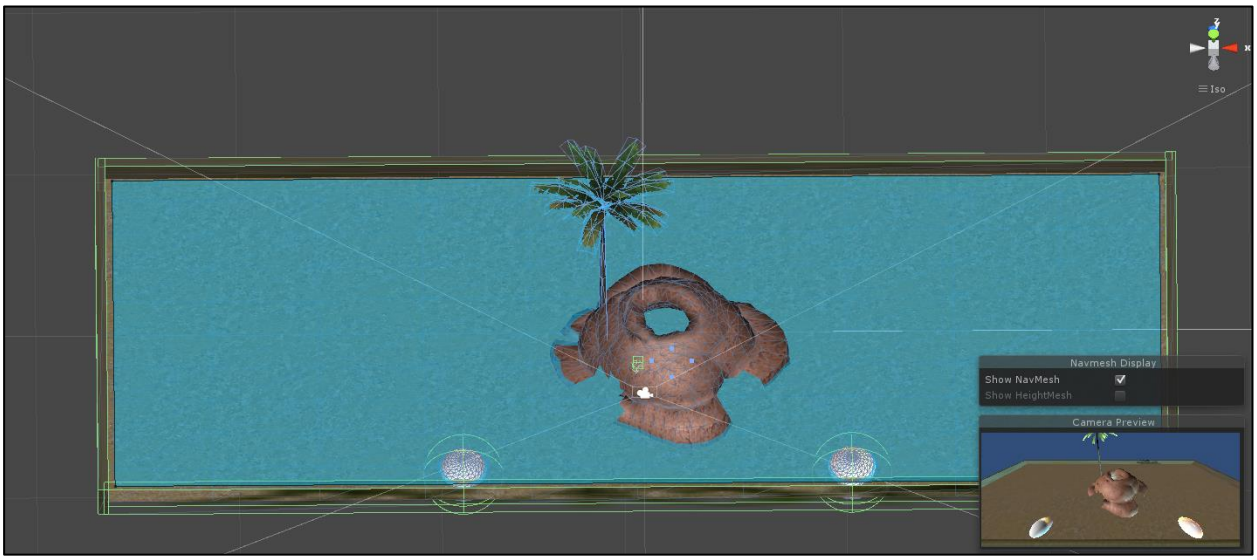

Fig.3: Scene view of our simple world in Unity editor

Our basic agent, which mimics the ant behaviour, follows few basic rules, ant the behaviour can be expressed like a finite state machine (Fig. 4) with a probabilistic determination of the choices.

At first, an ant is in idle state, just as the simulation begins. After that, it can start searching food on the map, or follow the *pheromone* trail of another ant returning with food. This pheromone can evaporate over a *t* period of time, avoiding the convergence to a locally optimal solution [8].

Without the evaporation, the path chosen by the first ants would tend to be excessively attractive to other ants and the exploration of the solution space would be constrained. Of course, this also means that shorter paths between food and the colony will have a higher pheromone density and positive feedback will determine a lot of the ants to follow that path.

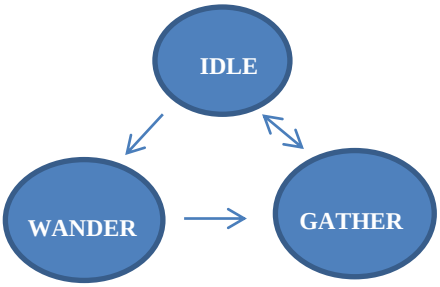

Fig.4: Simplified agent states

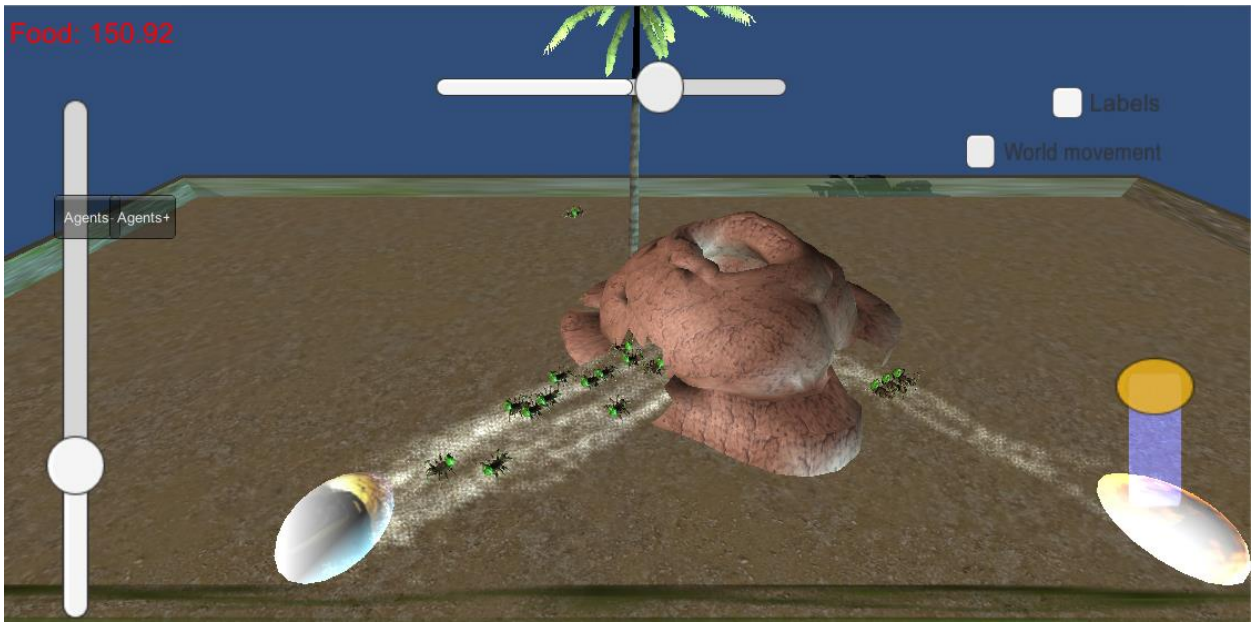

Fig.5: Experiment result showing different pheromone density and uneven distribution of the agents

The pheromones were implemented using a particle emitter attached to the agent container. If a collision between an agent and a pheromone particle is registered, the agents have the possibility to follow the trail to the food source, but only if it is not currently gathering food by itself. If an agent delivers the food to the colony and encounters another pheromone trail, there is a *p* probability that it will change the food source with the new one.

The emission of particles is enabled only when an agent found food and is returning to the colony.

The user also has several controls at his disposal, as can be seen in fig.5. They have a basic design and will probably look different or will be completely changed in the final version of the project, within a more polished graphical user interface (GUI).

We used a spider mesh in these simulations, but further developments will include an ant model or perhaps an array of agents and models that can be chosen before the simulation starts. We also observed several emergent behaviours, like swarming, route optimisation and even line formations (fig. 6)

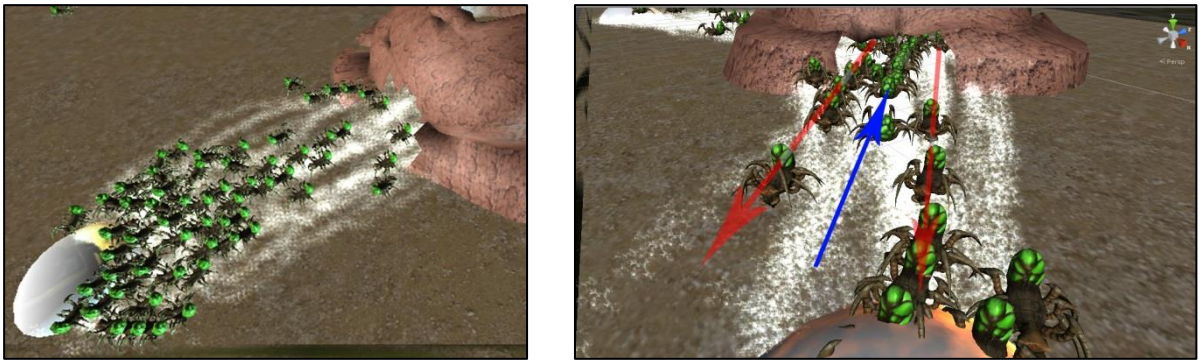

Fig.6: Swarming and line formations

4. Conclusions and future development

In conclusion, most of the objectives have been met and we successfully created an agent-based simulation using a 3D graphics engine. We were able to observe emergent behaviour and the adaptability of the ant colony algorithm. In the final iteration we created an augmented reality application and used it to run our simulations on any surface by using a specific marker. The latest version of the platform can be accessed at http://botashop.ro/va/.

Future developments follow:

- Modular design
- New computational models

Acknowledgement: This paper was realized with the support of POSDRU "QUALITY, EXCELLENCE, TRANSNATIONAL MOBILITY IN DOCTORAL RESEARCH" ID 187/1.5/S/155383 project, co-funded by the European Social Fund.

REFERENCES

[1] Computational model, Wikipedia article**,** http://en.wikipedia.org/wiki/Computational_model (accessed on: 10.02.2015)

[2] Agent-based model, Wikipedia article**,** http://en.wikipedia.org/wiki/Agent-based_model (accessed on: 10.02.2015)

[3] Grimm, Volker; Railsback, Steven F., Individual-based Modeling and Ecology, Princeton University Press, 2005, p. 485.

[4] F. Bota, Game Based Learning, Project Sotirios, Proceedings of the second International

Students Conference on Informatics, “Imagination, Creativity, Design, development”, ICDD 2012, Sibiu, Romania, pp. 44-50, 2012.
[5] Paul Ormerod, Butterfly Economics: A New General Theory of Social and Economic Behavior,Faber and Faber Limited, 1998, p. 50-52.
[6] Alan Kirman, Ants, Rationality, and Recruitment, The Quarterly Journal of Economics, Vol. 108, No. 1, Feb., 1993
[7] M. Dorigo, Optimization, Learning and Natural Algorithms, PhD thesis, Politecnico di Milano, Italy, 1992
[8] X Hu, J Zhang, and Y Li, Orthogonal methods based ant colony search for solving continuous optimization problems. Journal of Computer Science and Technology, 23(1), pp.2-18, 2008
[9] Unity official website, http://unity3d.com/ (accessed on: 4.11.2014)

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Optimization of Control Systems By PENDULAR Concept

Cătălin Nicolae Calistru

Abstract

The paper presents an inciting strategy in control, intire developed by the author, PENDULAR control. PENDULAR is the mnemonic of Pendulum Efficiency with Nonlinear Dynamics in Achievement of Robustness. The main idea is to optimize conventional structures using a nonlinear element on the feedback loop. That will transform a conventional control system into a variable structure system (VSS system). Having in view the simplicity of the control algorithm, a complete description of these systems, the study of stability and the Essential PENDULAR system (EPS) is presented in the paper. Simulation examples and experimental results show the efficiency of the PENDULAR concept.

1 Introduction

The word PENDULAR comes from the Romanian verb "a pendula" that defines the pendulum movement. PENDULAR (Pendulum Efficiency with Nonlinear Dynamics and Unconventional Law in Achievement of Robustness) systems are a class of nonlinear control systems introduced by the author in automatic control. Variable structure systems (VSS) are very interesting to be studied because often reveal surprises. Usually, the feedback control systems are closing the loop via a *negative feedback.* In this manner it is assumed the fact that the control system is robust (stable and effective even if different exogenous will disturb: reference variations, external disturbances, measurement noises, and plant uncertainties). The question is if the positive feedback is always bad for a control system?

A system exhibiting *positive feedback*, in response to *perturbation*, acts to increase the magnitude of the perturbation.In contrast, a system that responds to a perturbation in a way that reduces its effect is said to exhibit *negative feedback. Positive feedback often leads to exponential divergences or the exponential growth of oscillations*. Formally, a system in equilibrium in which there is positive feedback to any change from its current state is said to be in an unstable equilibrium. The magnitudes of the forces which act to move such a system away from its set point are an increasing function of the "distance" from the set point.*In the real world, positive feedback loops are always controlled eventual-*

ly by negative feedback or limiting effects of some sort. Figure 1 gives a simple view of this concept along with scientific terms and symbols.
Note that the response *y* is also called *system's behavior* or *performance*. The input *u* is often called the *control*.

Figure 1. Schematic diagram of a system with its input and output

As seen in Figure 1 one respects the causality principle.
The output $y(t)$ is related to the input $u(t)$ by the following equation:

$$y(t) = Tu(t) \tag{1}$$

where *T* is an operator applied to *u*.

In (1) three elements are involved: the input *u*, the system represented by the operator *T*, and the output *y*. In most of engineering problems *two of these three elements are given and we are asked to find the third one*. This observation is very important because the following three basic engineering problems arise: 1.*The analysis problem*. Here, we are given the input u and the system T and we are asked to determine the output *y*. 2.*The synthesis problem.* Here, we are given the input u and the output y and we are asked to determine the system *T*. *3.The measurement problem.* Here, we are given the system T and the output *y* and we are asked to measure the input *u*.

Definition 1.Given the system T and the output *y* known as the *desired response* we are asked to find an appropriate input signal *u*, such that, when this signal is applied to system *T*, the output of the system has to be the desired response *y*. The appropriate input signal *u* is called *control signal*.
From this definition it appears that the *control design problem* is in fact a signal synthesis problem: the synthesis of the *control signal u*. As it will be shown later, in practice, the control design problem is reduced to that of designing a controller. Control systems can be divided into two categories: *open-loops systems* and *closed-loops systems*.

Definition 2. An *open-loop system*, as shown in Figure 2, is a system whose input u does not depend on the output *y*, i.e., *u* is not a function of *y*.

Definition 3. A *closed-loop system*, Figure 3, is a system whose input u does depend on the output *y*, i.e., *u* is a function of *y*.In control systems, the control signal u is not the output of a signal generator, but the output of another new additional component that we add to the system under control. This new component is called *controller* and in special cases *regulator* or *compensator*. Furthermore, in control systems the controller is excited by an external signal *r* which is called the *reference* or *command* signal.

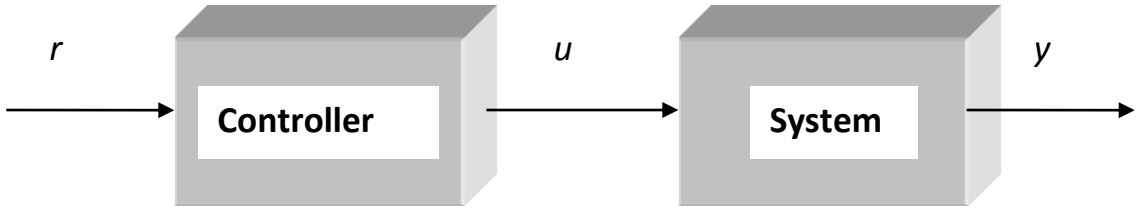


Figure 2 Open-loop system

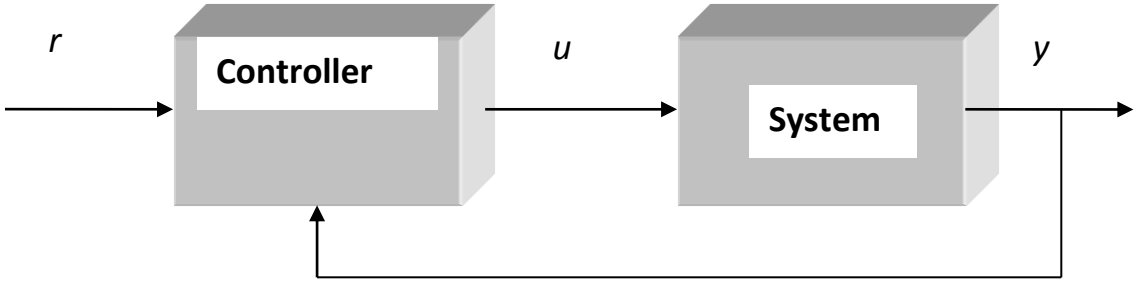
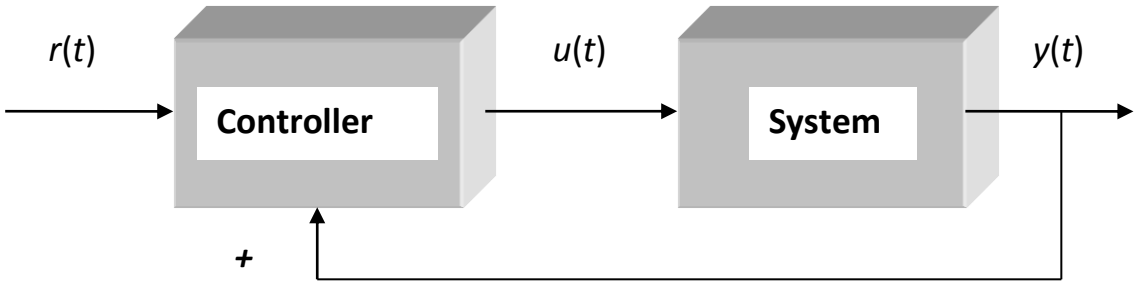


Figure 3 Closed-loop system

The reference signal r specified the desired performance. *That is, in control systems, we aim to design an appropriate controller such the desired output y follows the command signal r as close as possible*. In closed loop systems the controller is excited not only by reference signal *r* but also by the output *y*. Therefore, in this case the control signal *u* depends on both *r* and *y*.What is characteristic for a closed loop system? The answer to this question is very simple: the *feedback*. In fact, a closed loop control system is a *feedback system* because the following dependence can be written:

$$u(t) = u(r(t), y(u(t))) \tag{2}$$

The feedback is a permanent process of *comparison between what we want and what we get* and taking decisions. A positive feedback system is shown below.



For simplicity and for a clear understanding let consider that controller and systems are amplifiers with k_1 and k_2 .gains. Please remark the "+" sign!
Let suppose even more that $1=k_1=k_2$
Then:

$$y = k_2 u = k_2 k_1 (r + y) \Leftrightarrow y = \frac{k_2 k_1}{1 - k_2 k_1} r \to \infty \tag{3}$$

The relation (3) shows "that disaster" represented by infinity. That is mathematics. Intuitively, analyzing the dynamicity of feedback we have:
Step 1 .*r*=1, *f*=0, *u*=0, *y*=0. *Step 2* . *r*=1, *f*=0, *u*=1, *y*=0. *Step 3. r*=1, *f*=0, *u*=1, *y*=1. *Step 4.* *r*=1, *f*=1, *u*=1, *y*=1. *Step 5.r*=1, *f*=1, *u*=2, *y*=1. *Step 6.* *r*=1, *f*=1, *u*=2, *y*=2. *Step 7. r*=1, *f*=2, *u*=3, *y*=3 etc.

In the above considered steps *r* is *reference, f feedback, u command, y output*. One can see that *y increases and tends to infinity*! That means instability, chaos, disaster!

Besides, how *negative feedback* works? *Mutatis mutandis* the *negative feedback system* is depicted in Figure 4.

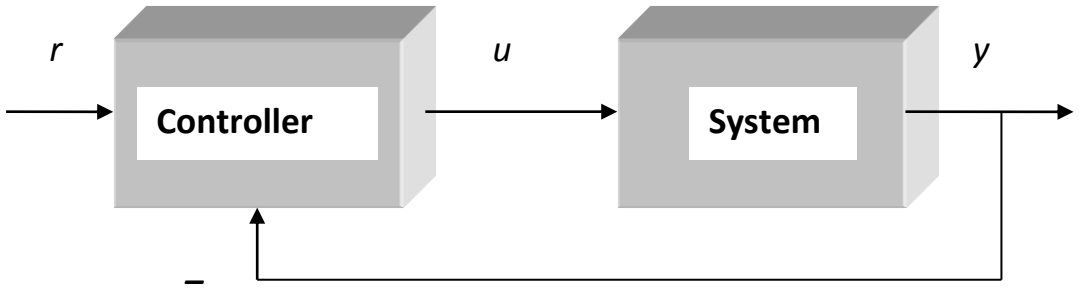


Figure 4. System with negative feedback

Supposing that the controller and systems are amplifiers with k_1 and k_2 .gains and $1=k_1=k_2$

$$y = k_2 u = k_2 k_1 (r - y) \Leftrightarrow y = \frac{k_2 k_1}{1 + k_2 k_1} r = \frac{1}{2} \tag{4}$$

Similar: *Step 1 r*=1, *f*=0, *u*=0, *y*=0. *Step 2 r*=1, *f*=0, *u*=1/2, *y*=0. *Step 3 r*=1, *f*=1/2, *u*=1/2, *y*=1/2. *Step 4 r*=1, *f*=1/2, *u*=1/2, *y*=1/2
So, *intuitively speaking, after 4 steps stability and stationary state can be obtained!*
Negative feedback is "good" while positive feedback with its cumulative effect is "bad"-this would be the natural conclusion expressed in the table below.

GOOD	BAD	COMPROMISE	PERFORMANCE
Negative feedback	*Positive feedback*	*Variable Structure System* (VSS)	*Integral index* IAE, ITAE, ISE, ITSE, etc
Stability	*Instability*	*Switching time ?*	*Minimization*

In fact, the PENDULAR concept philosophy is very simple. For example, let assume that one analyzes "*a level control system*" with "*automation at the level 0*". In other terms, a human operator supervises the water level in a tank. He turns off the tap whenever the water will reach the reference level. For efficiency, and if the tank volume is large, the operator does *not* proceed like this: turns on the tap on the drop by drop position and if the rising level approaches to the reference value turns off the tap. He turns on the tap at a large flow and when the level is near the reference level turns off the tap. Large

flow corresponds to positive feedback, small flow (drop by drop) corresponds to negative feedback. *Extending this very simple idea to the control loops the proposed system starts with positive feedback and at a certain time changes his structure becoming a negative (classic) control system*. In this manner the *PENDULAR control system* is defined.The proposed system will start with positive feedback and changes his structure becoming a negative (classic) control system at a *certain* time.
The paper consists in the following sections: introduction, pendular control system (PCS) (here pendular control principles are detailed), stability of PCS, Essential PCS (the search for simplicity), experimental results (made on a physical plant) and conclusions.

2 Pendular control system

Let the control system depicted inthe figure 5,

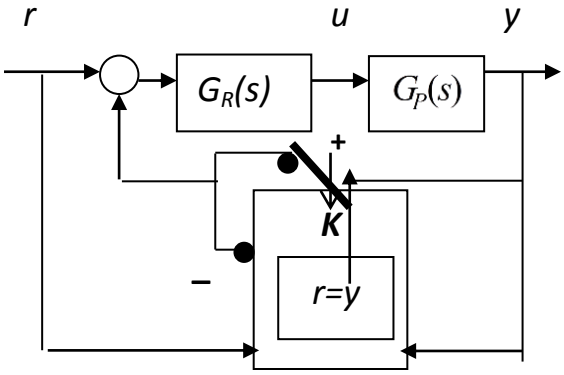


Figure 5 PENDULAR control system

obtained introducing a nonlinear element ***N*** on the conventional system feedback loop. The signals *r*, *e*, *u*, *y*, G_R and G_p are respectively the reference, error, command, output, the controller transfer function and the plant transfer function. ***N*** contains a decision block, a switch ***K***. Initially the switch is on "+" position. The decision block commands the switch ***K***, "+" to **"-"** for the very first time $\boldsymbol{t_c}$. The system changes its structure at time $\boldsymbol{t_c}$, $y(tc)=r$. The simplified control loop is depicted in Fig. 3:

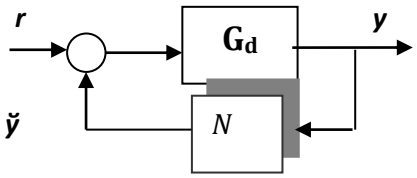


Figure 3 *Simplified control system*

where *Gd* is the open loop transfer function. The nonlinear element *N* is characterized by:

$$\tilde{y}(y)=\begin{cases}+y, & y\in[0,r]\\ -y, & y\in(r,\infty)\end{cases}, \tag{5}$$

Definition 4. *The nonlinear element N with characteristic (5) is called PENDULAR nonlinear element.*
N leads the system to the following behaviour:

• till the moment t_c, $\tilde{y}(y) = y, \quad y \in [0, r]$, $y(t_c) = r$, system has a positive feedback with closed loop tranfer function: $G_{0+}(s) = \dfrac{G_R(s)G_p(s)}{1 - G_R(s)G_p(s)} = \dfrac{G_d(s)}{1 - G_d(s)}$, (6)

•for $t > t_c$, system has a negative feedback ($\tilde{y}(y) = -y$) *only if* $y(t) \geq r$. The closed loop transfer function is: $G_{0-}(s) = \dfrac{G_R(s)G_p(s)}{1 + G_R(s)G_p(s)} = \dfrac{G_d(s)}{1 + G_d(s)}$. (7)

However, $y(t), t \geq t_c$ represents the differential equation Cauchy problem for the negative feedback system (the conventional one), initial condition $y(t_c) = r$. If for $t_{c1} > t_c$, $y(t_{c_1}) = r$ and for $t > t_{c1}$, $y(t) < r$ the system will behave as positive feedback system (*K* comutes "-" to "+") and so on.

In this manner, the controlled variable *y*, may be considered as output signal for the positive feedback system, then at the moment t_c, after the very first commutation, output signal for the negative feedback system; eventually for the moment t_{c1}, again output signal for the positive feedback system,etc. till the controlled signal variable is stabilized at the value *r*.

The pendulum image for the output *y* comes from the movement between the two classes of differential equations solutions: S_+ (for positive feedback sub-system) and S_(for positive feedback sub-system) is represented in Fig 5.

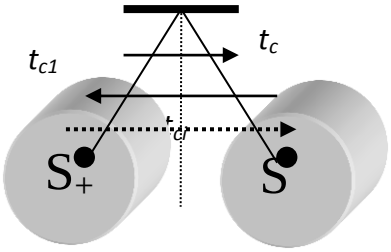


Figure5 *The y oscilatory "movement" scenario*

Definition 5. ***PENDULAR*** *control system (PCS) is the system obtained introducing a PENDULAR nonlinear element N on the feedback loop of a classical control system.*

Illustrative example. Let the disturbance *p* be an exogene signal applied as supplementary input to plant. Let assume that *r=1*, a proportional controller *k>0*, an integrator as plant and no disturbance (*p=0*). One obtains: $G_{0+}(s) = \dfrac{\frac{k}{s}}{1 - \frac{k}{s}} = \dfrac{k}{s-k}$; $G_{0-}(s) = \dfrac{\frac{k}{s}}{1 + \frac{k}{s}} = \dfrac{k}{s+k}$.

The system behaviour:

• $t \in [0, t_c]$.System starts with positive feedback $\dfrac{dy_+}{dt} - ky_+ = k,\ y_+(0) = 0, t \in [0, t_c]$

with the solution $y_+(t) = e^{kt} - 1, \ t \in [0, t_c]$ (8)

Time *tc* is given by $y_+(t_c) = 1 \Leftrightarrow e^{kt_c} - 1 = 1 \Leftrightarrow t_c = \dfrac{1}{k}\ln 2$.

From (8), $t \ge t_c \Rightarrow y_+(t) \ge 1 = r$, that means switching "+"to"-"

• $t > t_c$. System is with negative feedback: $\frac{dy_-}{dt} + ky_- = k,\ y_-(t_c+) = 1,\ t > t_c$, the solution:

$$\begin{cases} y_-(t) = 1 + ce^{-kt},\ t > t_c \\ y_-(t_c+) = 1 \Rightarrow c = 0 \end{cases} \Leftrightarrow y_-(t) = 1,\ t > t_c. \quad (9)$$

The relation (8) shows that the system was stabilized only after a commutation and stays in this state if no disturbance is reported. The system global response is: $y(t) = \begin{cases} e^{kt} - 1,\ t \in [0, t_c] \\ 1, \quad t \in (t_c, \infty) \end{cases}$ (10)

Let suppose that for $t_p > t_c$ a *p*. step disturbance is applied.

$$\frac{dy_-}{dt} + ky_- = k + p,\ y_-(t_p) = 1,\ t \ge t_p.\ y_-(t) = \frac{k+p}{k} - \frac{p}{k}e^{k(t_p - t)},\ t \ge t_p. \quad (11)$$

$$y_-'(t) = pe^{k(t_p - t)},\ t > t_p, \quad (12)$$

The derivative sign is given by *p* sign. For $p > 0 \Rightarrow y_-'(t) > 0 \Rightarrow y_-(t) > y_-(t_p) = 1, \forall t > t_p$ (13)

system stays on negative feedback, if: $p < 0 \Rightarrow y_-'(t) < 0 \Rightarrow y_-(t) < y_-(t_p) = 1, \forall t > t_p$, (14)

the system changes its structure on positive feedback.

The differential equation is: $\frac{dy_+}{dt} - ky_+ = k + p,\ y_+(t_p+) = 1,\ p < 0,\ t > t_p$ (15)

$$y_+(t) = \frac{2k+p}{k}e^{k(t - t_p)} - \frac{k+p}{k},\ p < 0, t > t_p \cdot y_+'(t) = (2k+p)\,e^{k(t - t_p)},\ t > t_p, p < 0, \quad (16)$$

and the derivative sign depends on (*2k+p*).

For *k>0,* one obtains the cases

$-2k < p < 0 \Leftrightarrow 2k + p > 0 \Leftrightarrow y_+'(t) > 0 \Rightarrow$

$y_+(t) > y_+(t_p+) = 1, \forall t > t_p$

The system commutes for *p<0,* on positive feedback, then on negative feedback etc. In this case we have a infinite number of commutations the output is kept on the reference value *r=1.*

• $p = -2k \Rightarrow y_+(t) = 1, t > t_p$.

The system behaviour is as in the first case.

• $p < -2k \Leftrightarrow y_+'(t) < 0 \Rightarrow y_+(t) < y_+(t_p+) = 1,\ t > t_p$.

The system stays on positive feedback the output decreases continuously, system is unstable. In conclusion: 1.*p>0,* system behaviour is identical with the conventional one. 2. $-2k \le p < 0$, the PCS rejects the disturbance component instantaneously, 3.*p<2k,* the system becomes unstable.

Example. PCS with *k=1,* at t_p*=10* sec disturbances *0.5, -0.5* are applied. With *Matlab-Simulink PCS response (y*) and conventional system (*y-)*are represented. The command *u* is also depicted One observe the chattering fenomenon (Fig.7,8,9)

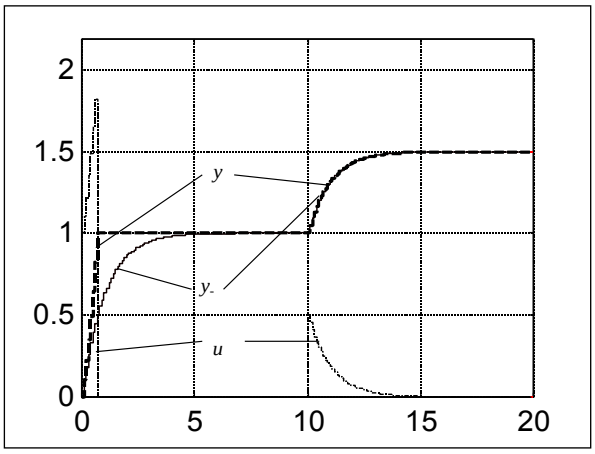


Fig 7. *Disturbance applied p=0.5*

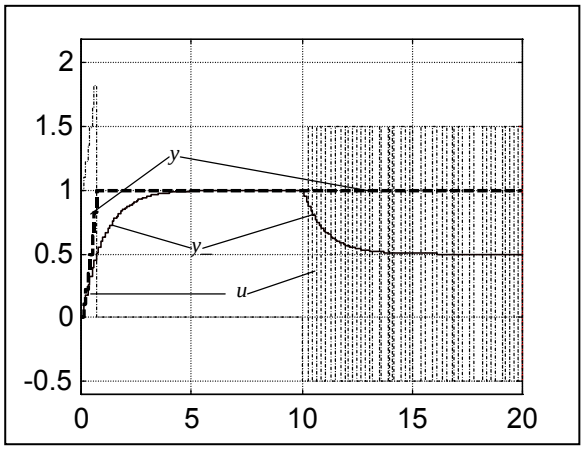


Fig. 8. *Disturbance applied: p=-0.5*

3 Stability of PCS

Definition 6. *The complex function F(s) is called real positive if:*
i.F(s) is analytic in $\{s:\mathrm{Re}\, s>0\}$ *ii.* $\mathrm{Re}\, F(s)\geq 0$ for every *s* with $\mathrm{Re}\, s>0$ *iii.* $F(\bar{s})=\overline{F(s)}$ for every *s* with $\mathrm{Re}\, s>0$.The function *F*(*s*) analycity makes possible the replacement of *iii* with *iii'*. *F*(*s*) is real for every *s* positive real.

Popov stability criterion
Theorem 1 (Popov) *The equilibrium state* $\bar{x}=0$ *is globally asymptotic stable for the closed loop system (closed through h(t)) if*

1. $h(0)=0$, *2.* $0<\frac{h(y)}{y}<K_M, \forall y\neq 0,\ K_M>0$ *3.there is* $\alpha\geq 0$, that $F(s)=(1+\alpha s)G(s)+\frac{1}{K_M}$ *is a real positive function.*

Theorem 2 (Sandberg-Zames)
Let K_1 *and* K_2 *two constants* $K_2>K_1$. *The equilibrium state* $\bar{x}=0$ *is globally asymptotic stable for the closed loop system (closed through h(t)) if*

1. $h(0)=0$, *2* $K_1<\frac{h(y)}{y}<K_2, \forall y\neq 0,$ *3.* $F(s)=\frac{1+K_2G(s)}{1+K_1G(s)}$ *is a real positive function.*

Based on these two therems is very simple to analize the stability of PCS.

4 Essential PCS

Let PCS from *Fig.3,* with a *PI* controller and a innertial plant:

$$G_R(s)=k_R\left(1+\frac{1}{T_i s}\right);\quad G_P(s)=\frac{k_P}{Ts+1};\quad T_i=T. \tag{17}$$

$$G_d(s)=G_R(s)\,G_P(s)=k_R\left(1+\frac{1}{Ts}\right)\frac{k_P}{1+Ts}=\frac{k_Rk_P}{Ts}=\frac{k}{Ts}. \tag{18}$$

The closed loop transfer function: $G_{0-}(s)=\dfrac{G_d(s)}{1+G_d(s)}=\dfrac{k}{Ts+k}$ (19)

The system response for *r=1*:

$$h_-(t)=1-e^{-\frac{k}{T}t},\quad \forall t>0 \tag{20}$$

The response time 5% t_{r-} for the conventional system:

$$h_-(t_{r-})=0{,}95\Leftrightarrow e^{-\frac{k}{T}t_{r-}}=0.05\Leftrightarrow t_{r-}=\frac{T}{k}\ln 20\cong 3\frac{T}{k} \tag{21}$$

The PCS has for $t\in[0,t_c]$ transfer function

$$G_{0+}(s)=\frac{G_d(s)}{1-G_d(s)}\ G_{0+}(s)=\frac{\frac{k}{Ts}}{1-\frac{k}{Ts}}=\frac{k}{Ts-k},$$

unstable for $\forall k>0,\ T>0$.

The step response:

$$h_+(t)=L^{-1}\left\{\frac{G_{0+}(s)}{s}\right\}=L^{-1}\left\{\frac{k}{s(Ts-k)}\right\}=e^{\frac{k}{T}t}-1. \tag{22}$$

Time for the first commutation:

$$h_+(t_c)=e^{\frac{k}{T}t_c}-1=1\Leftrightarrow t_c=\frac{T}{k}\ln 2=0.693\frac{T}{k}. \tag{23}$$

"*Response time 5%*" :

$$h_+(t_{r_+})=0.95\Leftrightarrow t_{r_+}=\frac{T}{k}\ln 1.95\cong 0.667\frac{T}{k}\cdot \tag{24}$$

From (21) and (24) one obtains $t_{r_-}=\dfrac{T}{k}\ln 20\cong 3\dfrac{T}{k}\ \Rightarrow\ t_{r_-}\cong 4.48t_{r_+}$ (25)

Definition 7. *PCS that commutes one time when no disturbance applied is called essential pendular control system EPCS.*

Theorem 3 ***(PENDULAR essential theorem)****The system described above is EPCS. Its step response is given by:*

$$y(t)=\begin{cases}h_+(t),\ t\in[0,t_c)\\ 1,\qquad t\in[t_c,\infty)\end{cases}. \tag{26}$$

Demonstration. For $t\in[0,t_c)$, the response is given by (25).For $t\ge t_c$ the system response is given by the Cauchy problem: $T\dfrac{dh_-}{dt}+k\ h_-=k,\quad h_-(t_c)=1,\quad \forall t\ge t_c$.The general solution for (26) is:

$$h_-(t)=1+c\,e^{-\frac{k}{T}t},\quad t\ge t_c,\quad c\in R \tag{27}$$

with the initial condition from (26) one obtains *c=0*. Q.E.D.

In *Fig.10* the responses for the classic system (with conventional negative feedback) versus PCS system are depicted.

The responses were obtained by simulation via Matlab-Simulink environment. For simplicity *k=T=1*.

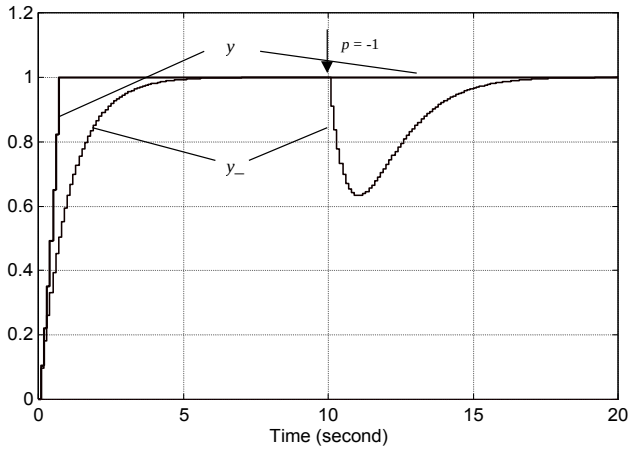


Fig.10 *Simulation results for k=T=1*

If a step disturbance will be applied (at *t=10* sec p=-1) an excelent behavior is reported for EPCS.From *Sandberg-Zames* theorem and the real positeveness theorem, the stability for PCS is very easy to prove.

Theorem 4.

PCS is globally asymptotic stable if $\frac{1-G(s)}{1+G(s)}$, *is a real positive function where G is the open loop trnsfer function.*

Very important observation*.Since G is Gr Gp and Gp is known one find the controller Gr.*

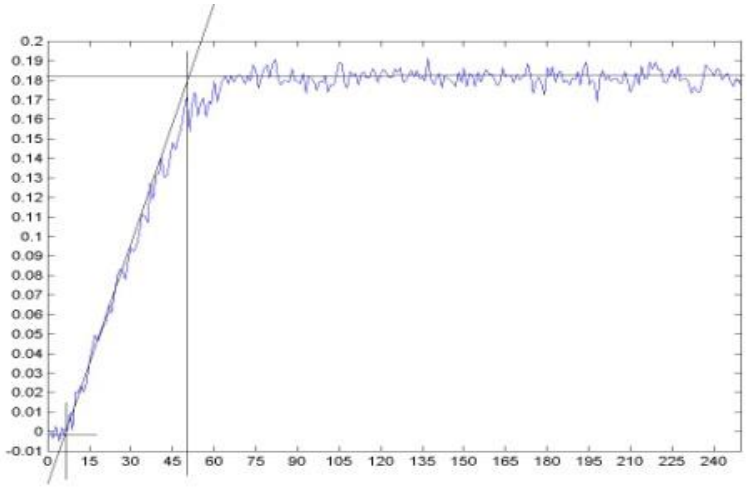
Application. EPCS case : Here $\frac{1-G(s)}{1+G(s)} = \frac{s-k}{s+k}$ and this function is obviously a real positive function.

5 Experimental setup

The set-up consists in a Feedback® Discovery Product for temperature and flow control. In this paper were made tests only for the flow control.The experiments have been done using the Real-Time Workshop from Matlab® Simulink®. The process has been identified as *an inertial order system with dead-time :*

$$G(s) = \frac{0.18}{2.8s+1} e^{-0.5s}$$

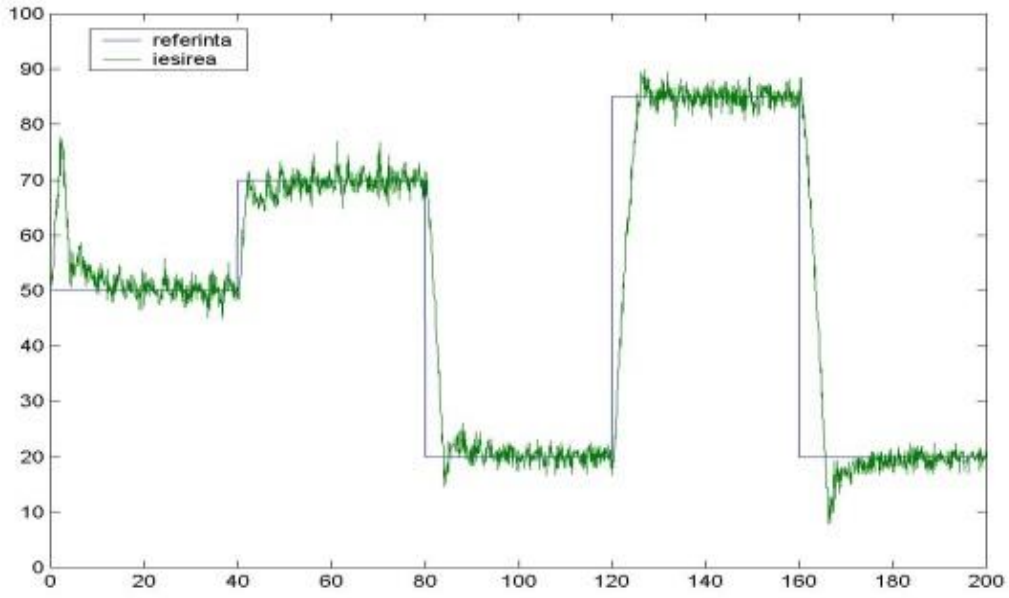
depicted below



Because the process is strongly affected by disturbances, the controller used is a PI type

$$G_R(s) = 2.76\left(1 + \frac{1}{4.66s}\right)$$

Creating a discrete-time model with the sample time of 0.1 seconds, using the PENDULAR control method, the below response is obtained.



6 Conclusions

The paper briefly presents the PENDULAR control systems. The PENDULAR control principles are sustained by a stability study. Essential PENDULAR Control systems were detailed and the simulation results are illustrative.The research is also sustained by experimental results made on different classes of systems. This new control methodology seems to have some impact over the control strategies.

References

[1] Belea, C., *Automatică neliniară. Teorie, exemple şi aplicaţii*, Ed. Tehnică, Bucureşti, 1983.

[2] Buhler, H., *Réglage par mode de glissement*, Presses Polytechniques Romandes, Lausanne, 1986.

[3] Calistru, C.N., *Creşterea robusteţei sistemelor automate folosind criterii integrale şi feedback alternant*, Ed.Matrix Rom, Bucureşti, 2004.

[4] Calistru, C.N.,"A New Variable Structure System", *Proceedings of the IEEE IPCAS'95 Seminar*, Calcutta, 1995.

[5] Calistru, C.N., "A Robust Variable Structure System", *Proceedings of the 4th IFAC Symposium on Advances in Control Education, ACE'97*, Istanbul, 1997.

[6] Calistru, C.N., "A Symbolic Optimization Approach for Tuning of PID Controllers", *Proceedings of the 4th IEEE Conference on Control Applications, CCA'95, ,* pp.174-175, Albany, New York, 1995.

[7] Calistru, C.N., "Self-symbolic Tuning of PID Controllers", *Proceedings of the IEEE Conference on System Man & Cybernetics, SMC'95*, Vancouver, 1995.

[8] Calistru, C.N., "Mixed H_2/H_∞ PID Robust Control via Genetic Algorithms and MATHEMATICA Facilities", *Proceedings on CD-ROM of the 2nd European Symposium on Intelligent Techniques, ESIT'99*, Ortodox Academy of Crete, Chania, 1999.

[9] Calistru, C.N., "A Robust Variable Structure System", *Proceedings of the 9th International Symposium on Modelling, Simulation and Identification Systems, SIMSIS'96*, Galaţi, 1996.

[10] Calistru, C.N., "A New Robust Variable Structure System", *Proceedings of microCAD'97, International Conference on Computer Aided Design*, Miskolc, 1997.

[11] Calistru C.N., "Analysis and Control of a Variable Structure System", *International Conference on Analysis and Control of Differential Systems*, Constanţa-plenary talk recommended by acad.V. Barbu, 1997.

[12] Calistru, C.N., "Sistem de reglare robust cu structură variabilă", *Prima Conferinţă de Sisteme Electromecanice*, Chişinău, 1997.

[13] Calistru, C.N., *Lecture: "Genetic Algorithms and Their Applications in Control Engineering Problems*", Dipartimento di Sistemi é Informatica, Università degli Studi di Firenze, Florence, 2000.

[14] Calistru, C.N., *Lecture: "PENDULAR Control: A New Strategy in Control Engineering*", Dipartimento di Sistemi é Informatica, Università degli Studi di Firenze, Florence, 2000.

[15] Calistru C.N., "PENDULAR Systems-A New Concept in Automatic Control", *The 7th International Symposium of Mathematics and Its Applications*, Timişoara, 1997.

[16] Calistru, C.N., "Stability Analysis of PENDULAR Control Systems", *Proceedings of the International Colloquium on Differential and Difference Equations, CDDE'2000*, Brno, 2000.

[17] Calistru C.N., "Plenary Talk: PENDULAR Control Systems-Trial to Unify Control Design Approaches" *3rd International Conference on Electrical and Power Engineering, Buletinul Institutului Politehnic din Iaşi, Tomul L(LIV), Fasc.5A, Electrotehnica, Energetică, Electronică*, Iaşi, 2004.

[18] Calistru, C.N., "Pendular Control Systems-A Trial to Unify Control Design Approaches", *IEEE TTTC International Conference on Automation, Quality&Testing, Robotics, AQTR2004 (THETA14), Excellency Diploma-best paper*, Cluj Napoca, 2004.

[19] Calistru C.N., *Plenary Lecture 13: An Insight to Pendular Control, Control, Modelling and Simulation*, Proceedings of 11th WSEAS International Conference on Automatic Control, Modelling and Simulation (ACMOS'09), Istanbul, Turkey, 2009, ISSN: 1790-5117, ISBN: 978-960-474-082-6.

[20] Calistru C.N. *Essential Pendular Control Systems*, Proceedings of Identification, Control and Applications IASTED Conference (ICA 2009), August 17–19, 2009, Honolulu, Hawaii, USA, Editor(s): M.H. Hamza, ISBN (CD): 978-0-88986-805-2, (IASTED).

[21] Călin, S., Tertişco, I., Dumitrache, I., ş.a., *Optimizări în automatizări industriale*, Editura Tehnică, Bucureşti, 1979.

[22] Desoer, CA. "A Generalization of the Popov Criterion", *IEEE Trans. On Automatic Control*.

[23] Paraskevopoulos, P.N., *Modern Control Engineering*, Marcel Dekker Publ.,2002.

[24] Popov, V.M., "Absolute Stability of Nonlinear Systems of Automatic Control", *Automat. Remote Control,* vol 22, no.8, pp.857-875,1961.
[25] Răsvan, V., *Teoria stabilităţii,* Ed. Ştiinţifică şi enciclopedică, Bucureşti, 1987.
[26] Sandberg, IW., "A Frequency-Domain Condition for the Stability of Feedback Systems Containing a Single Time Varying Nonlinear Element", *Bell Syst. Tech., J.*,vol 43, no4., pp.1601-1608, 1964.
[27] Voicu, M., *Tehnici de analiză a stabilităţii sistemelor automate*, Ed. Tehnică, Bucureşti, 1986.

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Using the Fourier Transform and the Power Spectral Density functions for Pattern Recognition in Dynamic Light Scattering Time Series

Dan Chicea, Silviu Rei

Abstract

If a coherent beam is incident on a suspension containing scattering centers, light is scattered and a far interference field is produced, having the aspect of speckled image. As the scattering centers undergo a complex motion, the far field presents fluctuations that carry information regarding the motion. The motion can be: a random Brownian motion, a relatively uniform sedimentation motion or a combination of both motions with different weight. Placing a detector in a far field and recording the fluctuations will produce a time series. A previously written and tested code named CHODIN was used to generate time series for several systems. The Fourier transform and the Power Spectral Density were used and the results are discussed in connection with the problem of very fast identification of the type of motion, and therefore the type of scattering centers suspended in the target fluid.

1 Introduction

The process known as Dynamic Light Scattering became more and more interesting in the last decades in the area of Physics and Chemistry. The physical process of light scattering on particles in a suspension can be used for implementing an efficient technique for determining the dynamics of the processes which take place in the suspension, with direct application in determining the size distribution of the particles. The main challenges in the first stages of the method were the difficulty to obtain a coherent monochromatic light beam and the computational complexity of the analysis required, rendering this technique unfeasible [1]. The emergence of LASERs and the increase of computing power in the last 20 years made this technique feasible.

Also known as "photon correlation spectroscopy" or "quasi elastic light scattering", this method involves a coherent monochromatic light source (in most of the situations a laser is used) which illuminates a sample containing a solution or suspension containing particles. Each particle undergoes an elastic interaction with the incident light beam and will act as secondary light source (Huygens principle) and will therefore scatter the light in all directions (Rayleight scattering for smaller particle sizes than the wavelength [2], [3], Mie scattering for bigger particles) [4]. The movement of the particles is, in the most general case, a complex phenomenon caused by the following concurrent processes: Brownian or thermal movement, aggregation and sedimentation.

Due to this complex movement each scattered light wave has a different phase leading to constructive, destructive or any other case in between by superposition, on a scattering image. Therefore the scattering image has spots of fluctuating intensity in each point and becomes a "boiling speckle" image. The intensity fluctuations contain information about the dynamics of the process, information which can be extracted by analysing the time series pattern recorded with a detector on a specific point. The analysis of the time series requires implementation of specific software which is able to recognise patterns in the input series offering as output information about several parameters of the suspension, like particle average size or size distribution.

In this paper we will focus on developing a very simple algorithm based on the Fourier transform and the Power Spectral Density, which is capable of analysing a time series obtained in a Dynamic Light Scattering experiment on particles having sizes in the range 250 – 1000 nm, due to the wide array of application of nano and micro particles in technology and sciences. The algorithm is able to indicate, at a qualitative level, which of the time series corresponds to smaller particles and which to bigger particles, or in other words, is capable to recognise patterns in the time series and to sort them based on particle size.

2 Fourier Transform and Power Spectral Density

The time series is recorded at discrete times, being therefore a stochastic or random discrete time series. Having in focus our target to design a simple algorithm capable of identifying patterns related to particle size, the periodicity of the stochastic time series was used for pattern recognition. For identifying the periodicities within the time series, one useful mathematical function is the Power Spectral Density which can be derived from the Fourier transform of the time series.

The Fourier transform is a reversible mathematical operation, which can transform a temporal signal from its time domain representation to its frequency domain representation. This operation is used for obtaining the frequency spectrum of a specific signal. For any real or complex function $f(t)$ which respects the condition:

$$\int_{-\infty}^{+\infty} f(t)dt < \infty \tag{1}$$

The truncated Fourier transform is defined as [5]:

$$F(\omega) = \frac{1}{\sqrt{2\pi T}} \int_0^T f(t) e^{-i\omega t} dt \tag{2}$$

For the specific case of this article, the time series was first averaged, than the average value was extracted and the new time series was squared, resulting the power time series of the signal. The Fourier transform defined above was used to produce the power spectral density, S(f), using the fast Fourier transform implemented in MATLAB.

3 Theoretical Heuristic Deduction

As described in the introduction, we will focus on several simulated time series produced during a DLS experiment by nano and microparticles. It has been shown [6] that the main process which influences the intensity fluctuations and therefore the variation of the time series recorded for nanoparticles is the Brownian motion. The bigger are the particles, the slower they move, fact that can be also seen in principle by inspecting equation below:

$$v = \sqrt{\frac{3k_B T}{m}} \tag{3}$$

Where v is the root mean square speed, k_B is Boltzmann`s constant, $T$ is the temperature and $m$ is the particle`s mass.

The fluctuation of the intensity is assumed to be more intense if the velocity of the particles is bigger, which means that the smaller particles are assumed to produce more intense

fluctuations. Judging in frequency representation, this means that the higher frequencies have more weight than the lower frequencies in the Fourier transform for smaller particles time series (and the other way around for bigger particles). This means that the Power Spectral Density can be used as an indicator for identifying the pattern: particle size – frequency in the time series.

In this paper a very simple method for identifying this pattern is proposed. The power spectral density frequency domain is split into *n* intervals:

$$0, f_1, f_2, \dots, f_n \tag{4}$$

An average for each interval is computed obtaining *n* average values corresponding to the *n* frequency ranges:

$$\langle S_1 \rangle, \dots, \langle S_n \rangle \tag{5}$$

The ratio of the lowest frequency to the highest frequency is calculated as:

$$R_i = \frac{\langle S_1 \rangle}{\langle S_n \rangle} \tag{6}$$

Data analysis presented in the next section reveals a monotone variation of the ratio R with the particle size, thus allowing the pattern recognition:

$$R_i \sim Size(i) \tag{7}$$

4 Algorithm Description

First a set of dynamic light scattering time series for different particle sizes was generated by using a previously developed and tested program called CHODIN [6]. One of the input parameters for CHODIN is the time step that is used to move the suspended particles at each simulation step. The algorithm for assessing the time step is described in detail in [7], therefore we will not repeat it here. First the time step for particles in the range 250-1000 nm was computed running the code described in [7]. For each particle size a set of input data was prepared for the CHODIN code described in detail in [7] and [8]. For each particle diameter, hence set of input parameters, a time series is generated by simulating Brownian motion in a volume and then calculating the intensity of scattered light at a specific angle and distance [7], [8]. Each time series is an input for the pattern recognition procedure.

For each time series the Power Spectral Density is calculated using the algorithm described in section 2.

In the next step the frequency domain of the Power Spectral Density is divided into *n* intervals, each containing *m* values. For each interval the average is calculated resulting in a series of *n* averages, one for each interval, as described in section3. R_i is calculated for each series using (6). Figure 1 illustrates the flow chart of the whole pattern recognition procedure.

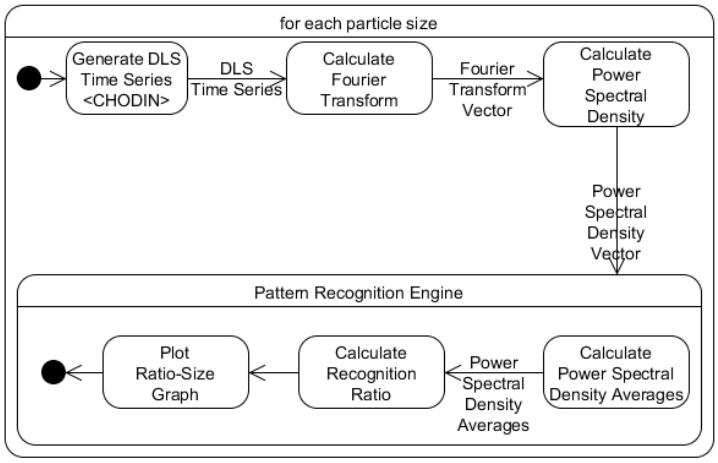

Figure 1 – the flow chart of the pattern recognition procedure

5 Results

Using the procedures described in section 4, DLS time series were generated for particles having a diameter of: 250, 375, 500, 625, 750, 825, 1000 (in nm). Each time series lasted for 1.5 s and were generated with 2000 data points per second. Figure 2 presents a sequence of 0.1 s of the time series generated for particles with a diameter of 250 nm and Figure 3 for particles with a diameter of 1000 nm.

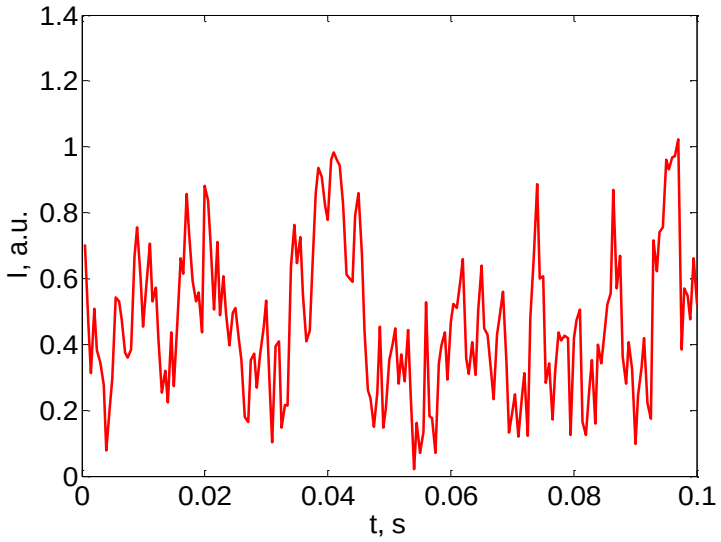

Figure 2 - a sequence of 0.1 s of the time series generated for particles with a diameter of 250 nm

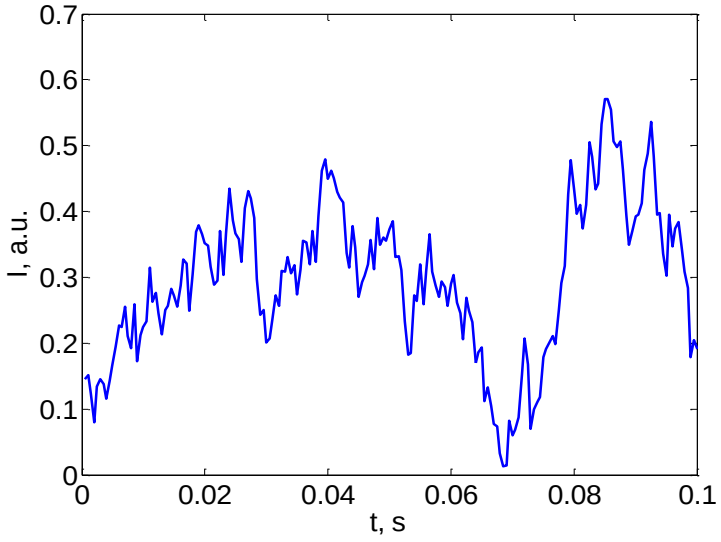

Figure 3 - a sequence of 0.1 s of the time series generated for particles with a diameter of 1000 nm

Examining Figures 2 and 3, we notice, even without any analysis tool, that the fluctuations in the time series produced by smaller particles have faster fluctuations with bigger amplitude. In order to step further from this quantitative observation, we compute the power spectral density as described in section 2. Moreover, we divided the total frequencies range in 10 intervals and computed the averages. Figure 4 illustrates the histogram of the averages of the power spectral density of the time series generated for particles having a diameter of 250 nm and Figure 5 for particles having a diameter of 1000 nm.

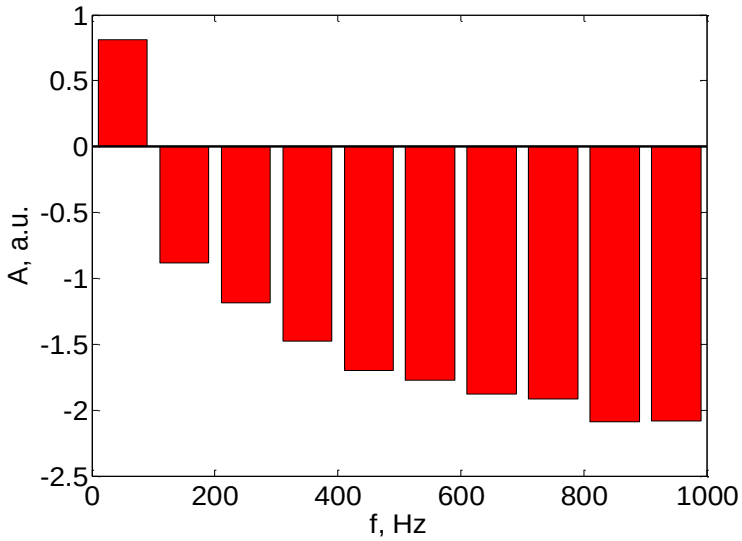

Figure 4 - The histogram of the power spectral density of the time series generated for particles having a diameter of 250 nm

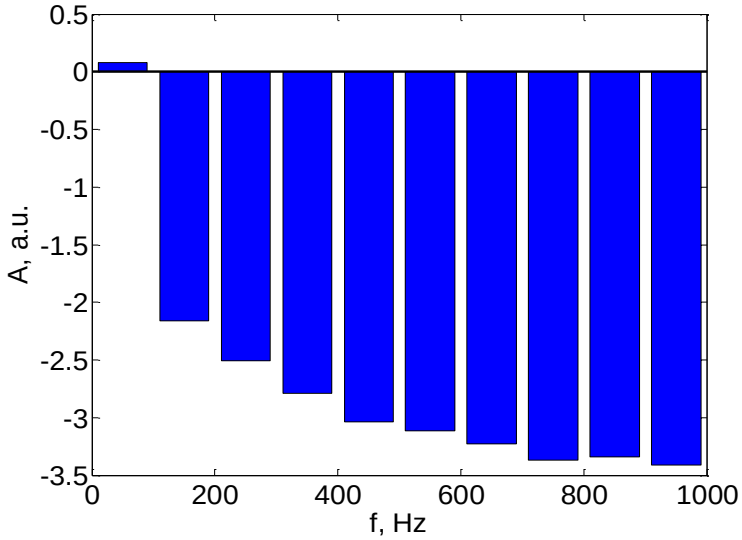

Figure 5 - The histogram of the power spectral density of the time series generated for particles having a diameter of 1000 nm

Again, at a qualitative level, we notice differences in the weight of different groups of frequencies in the power spectral density for the two power spectral densities.

The next step is to compute the ratio R using equation (6) for the time series mentioned at the beginning of this section. Figure 6 illustrates the variation of the ratio R with the diameter used to generate the DLS time series.

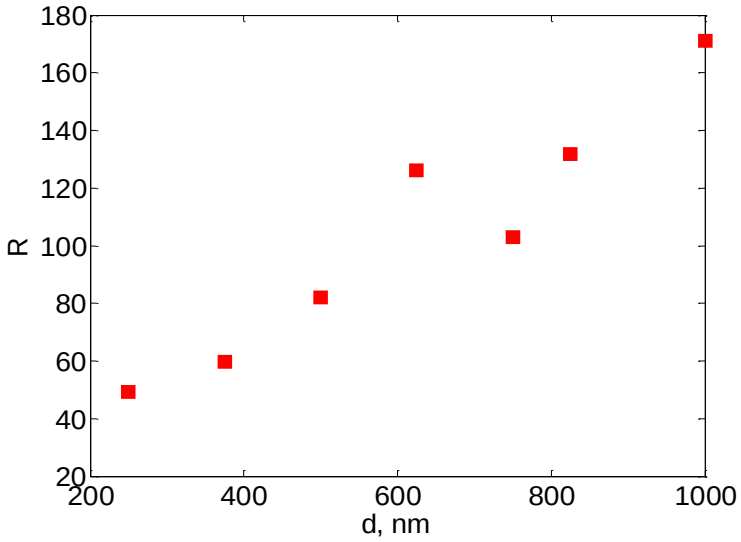

Figure 6 - The variation of the ratio R with the diameter used to generate the DLS time series

Examining Figure 6 we notice a monotone increase of the ratio R with the diameter, which confirms that smaller particles produce fluctuations in a DLS time series that have bigger frequencies.

6 Conclusion and discussions

DLS time series were generated in a realistic manner, using CHODIN, which moves each particle in suspension in an independent manner. The computer simulation of the Brownian motion of the particles in suspension is realistic, as the time step for the Brownian motion is chosen as a the value of a simulated diffusion experiment, that is the value that makes the simulated diffusion coefficient equal to the computed diffusion coefficient for that particular particle diameter and carrier fluid.

The seven time series present qualitative differences in respect of the fluctuations frequencies. The time series generated for smaller particles present faster fluctuations. A simple procedure using averages of the power spectral density on several frequency domains and computing the ratio R of the first (smallest frequencies) to the last (biggest frequencies) values of the averages was used. The results reveal a monotone increase of the ratio with the diameter of the suspended particles.

There are displacements though from the monotone variation, as can be noticed from Fig. 6 that presents the variation. These displacements might be the effect of the relatively small number of particles used in this simulation, 2000, and of the relatively small number of data in a set, 3000.

Nevertheless, the results are promising and suggest that a simple, easier and requiring a smaller amount of computer time, alternative procedure to DLS or Static Light Scattering [9] can be imagined, by calibrating a curve as suggested by the plot in Figure 6 and using it for assessing the diameter once the ratio R is computed for a recorded time series. The results presented here are partial results of the work that is in progress on this subject.

References

[1] J.W. Goodman, *Laser speckle and related phenomena*, Vol.9 in series Topics in Applied Physics, J.C. Dainty, Ed., Springer-Verlag, Berlin, Heidelberg, New York, Tokyo, (1984).
[2] J. Strutt, *On the transmission of light through an atmosphere containing small particles in suspension, and on the origin of the blue of the sky*, Philosophical Magazine, 5(47), 375-394, (1899).
[3] A. T. Young, *Rayleigh scattering*, Appl. Opt. 20, 522–535, (1981).
[4] G. Mie. *Beiträge zur Optik trüber Medien, speziell kolloidaler Metallösungen,* Annalen der Physik **330** (3): 377–445, (1908).
[5] E. Hecht, Optics, 4-th Edition, Addison-Wesley, (2002)
[6] D. Chicea, *Coherent Light Scattering on Nanofluids – Computer Simulation Results*, Applied Optics, Vol. 47, No. 10, 1434-1442, (2008).
[7] D. Chicea, *A Simple Algorithm to Simulate Nanoparticles Motion in a Nanofluid***,** , U.P.B. Sci. Bull., Series A, 76(2), 199-206, (`2014).
[8] D. Chicea, *Nanoparticle Sizing by Coherent Light Scattering – Computer Simulation Results*, Journal of Optoelectronics and Advanced Materials 10(4), 813-818, (2008).
[9] D. Chicea, *A Study of Nanoparticle Aggregation by Coherent Light Scattering*, Current Nanoscience, 8(6), 259-265, (2012), doi: http://dx.doi.org/10.2174/157341312800167704

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Imperialist Competitive Algorithm with Variable Parameters to Determine the Global Minimum of Functions with Several Arguments

Stelian Ciurea

Abstract

We have implemented an Imperialist Competitive Algorithm (ICA) to a determine the global minimum for nine functions. Some of these represent benchmarks of the problem, while others have expressions that we have defined. For a start, we used three of these functions to determine a set of optimal parameters for the ICA. Then we studied the way in which the behaviour of the ICA is affected by these parameters in order to solve the problem put forth for the nine functions. Finally, we studied the behaviour of the ICA as affected by variable parameters for the most difficult of the nine functions. In our algorithm, the values of some of the parameters change dynamically. The results indicate a better behaviour of the solutions provided by this method.

1 The Imperialist Competitive Algorithm: Structure and Parameters

At the "IEEE Congress on Evolutionary Computation" held on September 27-28, in 2007, Esmaeil Atashpaz Gargari and Carlos Lucas presented a paper describing a new type of evolutionary algorithm inspired by history [1]. Called the "Imperialist Competitive Algorithm" (ICA), it is modelled on the political and historical events from the 17th, 18th and 19th centuries. The ICA belongs to the category of meta-heuristic algorithms based on sets of candidate solutions called "populations" (along with genetic algorithms, algorithms of the "swarm of particles" type, GSA gravitational search algorithms, etc.). The standard structure of an ICA as presented in [1] is the following:

1. Generating an initial set of countries;
2. Initializing the imperialist countries;
3. Occupying the colonies;
4. Assimilating the colonies;
5. If a colony has better results than the imperialist country then
    a. Interchanging the colony with the imperialist country
6. The imperialist competition:
    a. Computing the results of the empires
    b. Occupying the weakest colony of the weakest empire by another empire
    c. If the weakest empire has no colonies left then
        i. Removing this empire

7. If the stopping requirements are met then Stop
   Otherwise Repeat the algorithm from step 3.

The imperialist country that has the best results in the last iteration is the solution to the problem. Below is a brief description of the steps of an ICA.

A. Generating an initial set of countries

In the ICA, a country is a possible solution to the problem studied. When determining the minimum for real functions of known expression with n variables (n=2,3,4, ...), a country is represented by a set of n real values. The number of countries is a first parameter of the ICA. As with other evolutionary algorithms, the considerable size of the initial set leads to a higher probability of finding combinations with higher performance. On the other hand, given the complexity of the algorithm, raising the number of countries causes a linear increase in the runtime. In the completed applications, different values were chosen for this parameter: 55, 108 and 210. For the proper generation, the function in the C standard library has been used, as it provides quasi-random values.

B. Assessment of the initial set of countries and their revaluation

The existence of a function that allows the evaluation of the performance of potential solutions, in our case the performance of a country, is a prerequisite to solve a problem by means of this algorithm. In the problem studied, the evaluation function is precisely the function value calculated for the values representing a country. Since we aimed at determining a minimum, the evaluation function was a penalty: the lower the value of the evaluation function, the more efficient a country.

C. Initialization of imperialist countries

The initial number of "imperialist countries" (or original number of empires) is another parameter characteristic of this algorithm. In the applications that we ran, this number was 5%, 10% or 15% of the original number of countries. Following the initial assessment, the countries with the best values of the evaluation function became imperialist countries.

D. Occupying the colonies

In this algorithm, the countries that do not become imperialist countries turn into colonies and "fall within the scope" of imperialist countries. The lower the value of the evaluation function of that imperialist country, the higher the number of colonies assigned to an imperialist country. The ensemble comprising the imperialist country and the occupied colonies form an empire. The formulae for determining the number of colonies belonging to each imperialist country, designated $nrcol_i$, are given below.

$$nrcol_i = v_{nrmet-i-1} \qquad i = 0,1,\ldots,nrmet - 1 \tag{1}$$

where nr_{met} is the initial number of imperialist countries, and values v are calculated by means of the following formula

$$v_i = \left\lfloor \frac{feval(met_i)}{S} nr_{col} \right\rfloor \tag{2}$$

$feval(x)$ is the value of the evaluation function of country x, met_i is the imperialist country with current number i (i=0,1,…,$nrmet$-1), nr_{col} is the initial number of colonies (the difference between the total number of countries and the initial number of imperialist countries) and S is the sum of the values of the evaluation function for all the imperialist countries:

$$S = \sum_{i=0}^{nrmet-1} feval(met_i) \quad (3)$$

E. Assimilation of colonies

By means of this operation characteristic of the ICA, the parameters of the countries of the "colony" type are transformed so that their values can be "attracted" towards the values corresponding to the parameters of the imperialist countries. The way in which this transformation takes place depends on the type of problem that is solved. The formula that we used is the following:

$$paramcol_i = paramcol_{i-1} + p(1 \pm d)(parammet_{i-1} - paramcol_{i-1}) \quad (4)$$

where paramcoli is the value of the colony parameter following iteration i, parammeti is the value of the parameter corresponding to the imperialist country of the colony following i, and d is a random value below par, d∈[-da/2 ; da/2]; da is called assimilation deviation.

F. The revolution operation

Following the historical model, some of the countries of the colony type undergo an operation resulting in modified parameter values. The probability of a country to undergo this operation is called revolution rate. Here is the way in which these values can be modified:

- through a random regeneration: after this operation, all parameters of a country are modified;
- by applying a transformation opposed to that of assimilating some of the parameters ("anti-assimilation"):

$$paramcol_i = paramcol_{i-1} - p(1 \pm d)(parammet_{i-1} - paramcol_{i-1}) \quad (5)$$

$d \in [-d_r/2 ; d_r/2]$, d_r, in this case representing the revolution deviation.

G. The imperialist competition

At this stage of the algorithm, the least powerful empire loses the least efficient colony at the expense of another empire. We start by calculating the performance of each empire using the following formula:

$$performimp_i = preformmet_i + w(\sum performcol_j) \quad (6)$$

where w is the weight that the performance of a colony contributes to the performance of the empire $w \in (0,1)$, $performimp_i$ and $performmet_i$ are the performance of the empire and that of the imperialist country i (i=0,1,…,*nrmet*-1), and $performcol_j$ is the performance of a colony belonging to empire i. To determine the empire that will assimilate the colony, we used the Monte Carlo method. A series of random values a0, a1, … , anrmet-1 / ai∈(0,1) was generated and the colony will belong to the empire for which the value of the expression below is maximum:

$$a_i - \frac{performimp_i}{\sum_{j=0}^{nrmet-1} performimp_j} \quad (7)$$

If, following this operation, an empire loses all the colonies, the imperialist country of that empire also becomes a colony and is assigned to another randomly selected empire.

H. Completion of the algorithm

There are two conditions that determine the completion of the algorithm and that we implemented:

- one empire left (the ideal situation – convergent algorithm);
- the maximum number of iterations was reached.

As with other evolutionary algorithms, there are no mathematical demonstrations to prove that the algorithm converges towards the optimal solution. In fact, the algorithm refines the search in the vicinity of the points where the evaluation functions have good values. The competitive imperialist algorithms have a number of parameters that depend on their structure. For the algorithm structure presented before, the number of parameters is 10.

2 The ICA determining the global minimum of functions with several arguments

A major problem that should be considered when seeking to solve a problem with the help of an algorithm of this type is finding the optimal values for the algorithm parameters. In the specialist literature, we found no recommendations for that purpose. To solve this problem, we considered two categories of parameters: the first category included parameters whose values were combined in the tests observing the principle "with each other":

- Number of countries: 55, 108 and 210;
- The values of the initial set of countries: the algorithm was run for 5,000 initial sets;
- The number of imperialist countries: 5%, 10% and 15% of the total number of countries;
- The method of implementing revolutions: no revolutions, regeneration and anti-assimilation (according to formula 4);
- The maximum number of iterations: 3,000 (a value high enough so that the algorithms end on account of the fact that there is only one empire).

The second category included parameters whose values were combined in the tests, following this rule: each of the five values of one of them was combined with the average values of the others. This was the procedure for the following:

- the approach step used in assimilation and revolution operations: 0.1, 0.3, 0.5, 0.7 and 0.9;
- assimilation deviations: 0.2, 0.6, 1.0, 1.4, 1.8;
- revolution deviation: 0.2, 1.0, 2.0, 4.0, 20.0;
- The percentage that colony contributes to the value of the performance of an empire: 0.01, 0.05, 0.1, 0.5, 1.0;
- The rate of revolution: was chosen as the number of countries whose parameters are modified so as to be proportional to the ratio between the number of countries and the originally defined number of empires, but so that the revolutions are initiated after a number of iterations (marked T) equal to 1, 5, 10, 20 and 50;

Thus, we noted how the values of each of these parameters influenced the performance of the algorithm. The behaviour of the ICA was studied for three functions:

$$f_1(x_1, x_2) = 1 - \sin(1 + 3x_1(x_2 - 1))e^{-(x_1-1)^2 - x_2^2} \tag{8}$$

$$f_2(x_1, x_2, x_3) = 7 + \sin(x_1 - 1)e^{\frac{1}{1+x_1^2}} + \sin(x_2)e^{\frac{1}{1+x_2^2}} + \sin(x_3 x_2)e^{\frac{1}{1+x_3^2}} \tag{9}$$

$$f_3(x_1, x_2, x_3, x_4) = 3 + \frac{\sin(x_1 - 0.5x_2 + 1.2x_3 - x_4)}{(x_1 - 1)^2 + (x_2 + 1)^2 + (x_3 + 2)^2 + x_4^2 + 1}(0.5x_1 - x_2 + x_3 - 2x_4 + 4) \tag{10}$$

For each of these three functions were chosen the fields of definition [-10; 10] and [-100, 100]. By default, these fields were also those of searching the minimum and determining to what extent the size of this field affects the results. By joining the values selected for the ICA parameters, a number of 5,400 combinations resulted. Each of these combinations was run for the 5,000 sets of countries and for each of the two areas. The tests conducted resulted in a set of optimal values for the ICA parameters, i.e.:

- The method of implementing the revolution through regeneration;
- The number of countries: 210;
- The initial percentage of empires in the total number of countries: 5%.
- The approach step, p = 0.1;
- The percentage of colonies within the empire performance, w = 0.5;
- The deviation from assimilation, yes = 1.8;
- The number of iterations at which revolutions T = 1 occur;

ICAs with parameters thus determined were used to calculate the minimum of nine reference functions or with an expression determined by us. Starting from the observation that the ICA does not guarantee finding the solution, we ran the algorithm for 100 initial sets. The number of these sets was selected so that the total running time should be under a minute, all tests being run on an Intel Core i3 microprocessor at 2.93 GHz.

Table 1 shows a summary of the results. The values in column nrOk represent the number of sets for which ICA located the global minimum of the function (out of the 100 sets used).

Function	[-10;10][1]	[-100;100]
	nrOk	nrOk
$f_1(x_1, x_2) = 1 - \sin(1 + 3x_1(x_2 - 1))e^{-(x_1-1)^2 - x_2^2}$	100	100
$f_2(x_1, x_2, x_3) = 7 + \sin(x_1 - 1)e^{\frac{1}{1+x_1^2}} + \sin(x_2)e^{\frac{1}{1+x_2^2}} + \sin(x_3 x_2)e^{\frac{1}{1+x_3^2}}$	100	78
$f_3(x_1, x_2, x_3, x_4) = 3 + \frac{\sin(x_1 - 0.5x_2 + 1.2x_3 - x_4)}{(x_1-1)^2 + (x_2+1)^2 + (x_3+2)^2 + x_4^2 + 1}(0.5x_1 - x_2 + x_3 - 2x_4 + 4)$	100	100
$f_4(x_1, x_2) = x_1^2 + (x_2^2 - 2)^2 - 2$ (De Jong)	100	100
$f_5(x_1, x_2) = J0(x_1^2 + x_2^2) + 0.1\lvert 1 - x_1\rvert + 0.1\lvert 1 - x_2\rvert$ (benchmark in [1])	100	100
$f_6(x_1, x_2) = x_1 \sin 4x_1 + 1.1x_2 \sin 2x_2, \quad x, y \in [0,10]$ (benchmark in [8])	100	
$f_7(x_1, x_2) = 2 + \sin(x_1)\frac{x_1 + 2}{1 + x_1^2} + \sin(x_2 + 1)\frac{x_2 + 1.1}{2.1 + x_2^2} + \sin(x_1 x_2)\frac{x_1 + x_2 - 1}{3 + x_1^2 + x_2^2}$	100	100
$f_8(x_i) = \prod_{i=1}^{7} \sqrt{x_i}\sin(x_i)$, $f_8: [0;10]^7 \to R$ (Alpine)	96	
$f_9(x_i) = \sum_{i=1}^{3} (x_i^2)^{x_{i+1}^2+1} + (x_{i+1}^2)^{x_i^2+1}, \quad xi \in [-1,4]$ (Brown)	100	

Table 1. Results obtained

[1] Valid definition fields except for functions in the expression of which it is explicit: f_6, f_8 and f_9

The following figures shows the behaviour of the algorithm in determining the minimum of function f1: [-100;100]×[-100;100] for one of the 100 initial sets with 108 countries and 5 imperialist countries.

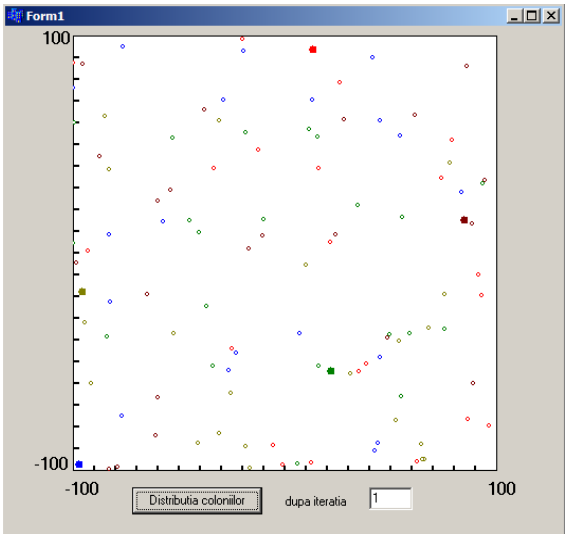

Fig.1 Distribution of colonies following one iteration

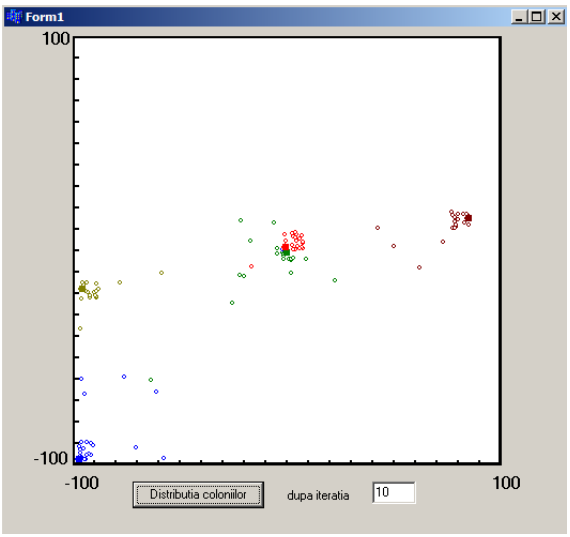

Fig. 2 Distribution of colonies following10 iterations

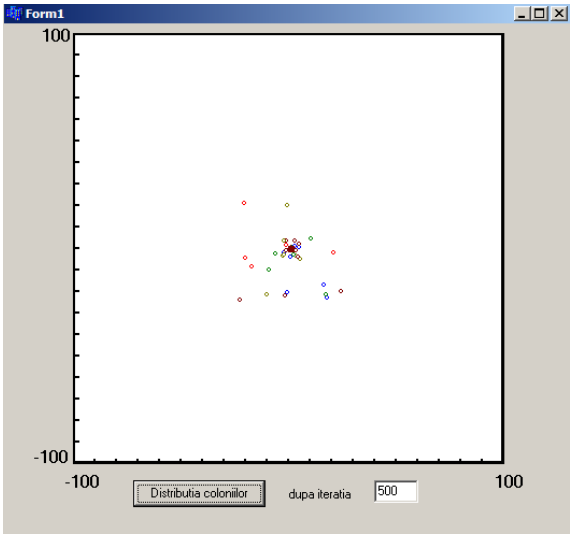

Fig. 3 Distribution of colonies following 500 iterations

The first figure illustrates the initial distribution obtained by random generation. The larger dots represent the location of the imperialist countries. With the same colour are marked the imperialist country and colonies that belong to it. After 10 iterations, we can notice the grouping of colonies around the imperialist country to which they belong as a result of assimilation. We can also see that two potential solutions are closer to the solution sought for. After 500 iterations, all 5 imperialist countries as well as many of the colonies that belong to them are closer to the optimal solution. Figures 4, and 5 illustrate the behaviour of the algorithm in the case of function f2 for one

of the tests in which 108 countries and 5 imperialist countries were used. The first figure illustrates the initial distribution obtained by random generation. The larger dots represent the location of the countries. With the same colour are marked the imperialist country and colonies that belong to it. Following 7 iterations, we can notice the grouping of the colonies around the imperialist country they belong to as a result of assimilation. Following 400 iterations, there is a group consisting of two imperialist countries located very close to each other and a group of three imperialist countries located very closet o them. Many of the colonies that belong to them are located in their vicinity. Following 1283 iterations, three empires were left, their imperialist countries being located very close to them.

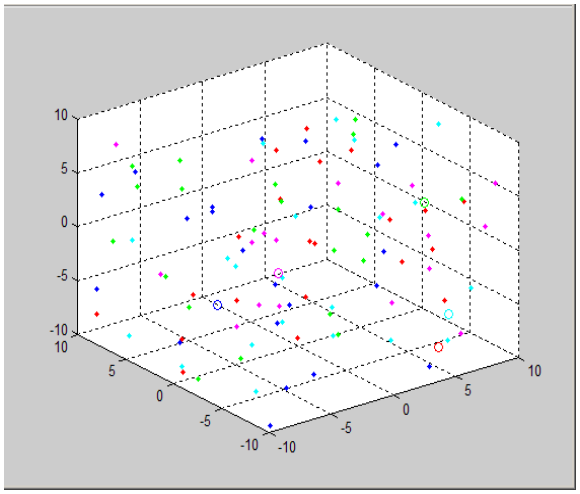

Fig. 4 Distribution of colonies following one iteration

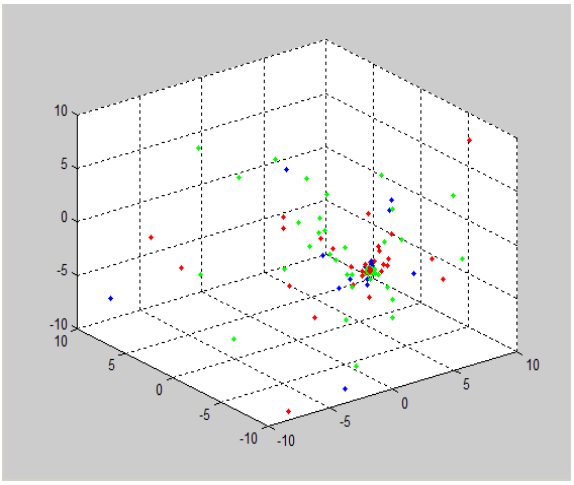

Fig. 5 Distribution of colonies following iteration no. 1283

3 Behaviour of ICA with variable parameters

3.1 ICA with dynamic weight

In the simulations performed, there were many situations in which the standard algorithm converged very slowly or was even stuck because the performance of last two, sometimes even three or four empires left in the algorithm, became very close – differences of the order of 0.1% of the values of the performance. The result was that, from a certain iteration, one and the same colony shifts from one empire to the other. Here is the explanation: when a colony shifts from one empire – be it I1 – to the other – be it I2, (since performance (I1) < performance (I2)), it undergoes an assimilation process by the new imperialist country. The immediate effect is a worsening of the performance of the colony; this value affects the performance of the empire which took over the colony, so that in the next iteration performance (I2) < performance (I1) and the weakest colony is precisely the one which has been taken over. Thus, the colony returns to the first empire, but with a performance value that was worsened by applying a new assimilation operation by I1. Once more, performance (I1) < performance (I2) and the weakest colony that will be taken over by I2 is obviously the one that has just returned to I1. This algorithm follows a loop: one colony shifts between the two empires, the others are assimilated in an increasingly higher percentage, and the chances that colonies with better performance than that of the imperialist country may appear decrease with each iteration. Such blockage has been removed by using weights whose values change dynamically as follows: initially, each colony is assigned the same

weight, having a predetermined value; whenever a colony changes the imperialist country, the value of the weight of that colony is reduced by multiplying it with a below par value. We called this value weight contraction (cw). Thus, equation (7) turned into:

$$performimp_i = preformmet_i + \sum w_j \, performcol_j \qquad (11)$$

where wj is the weight associated to colony j.

Another change to the standard algorithm that was performed in order to avoid blockage was the following: the weakest colony is determined having as a criterion the product between the evaluation function and the weight of the colony in that iteration (and not only the value given by the evaluation function for that colony). Figures 10 and 11 illustrate the comparative evolution of empire performances when the ICA is applied to function f2: [-100;100]×[-100;100] for an initial set of 108 countries and 5 imperialist countries. Figures 12 and 13 illustrate the evolution of the number of colonies within each empire under the same conditions. It can be noted that the ICA with variable weight is completed after 253 iterations, but the performance of the algorithm is not affected.

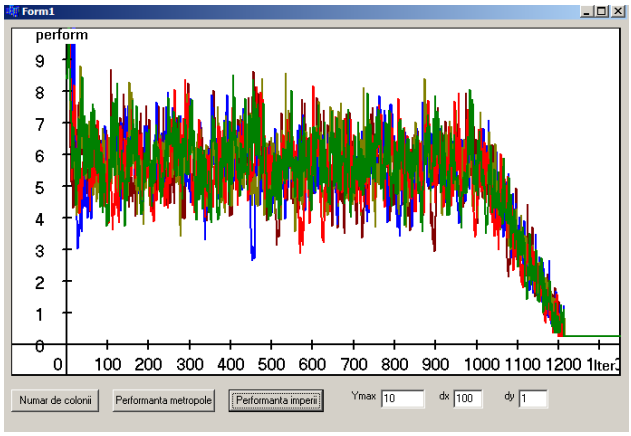

Fig. 6 Empire performances in the case of the ICA with fixed weight

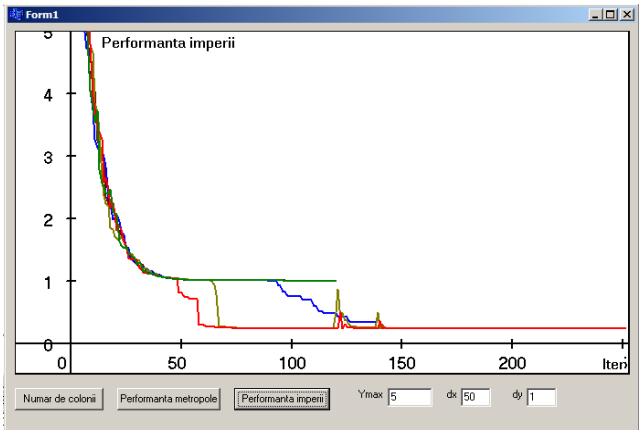

Fig. 7 Empire performances in the case of the ICA with variable weight cw=0.5

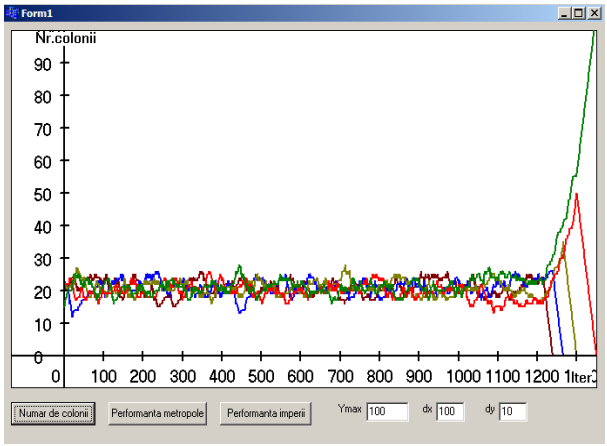

Fig. 8 Evolution of the number of colonies in the case of the ICA with fixed weight

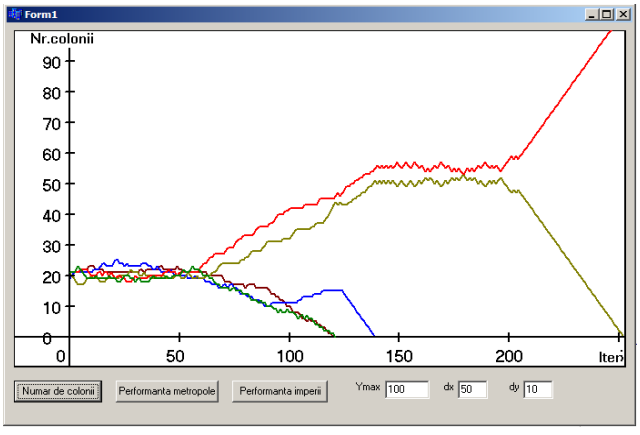

Fig. 9 Evolution of the number of colonies in the case of the ICA with variable weight cw=0.5

In the following, we present the results obtained by applying the ICA with variable weight to determine the minimum of function f2 with the definition field [-100 ; 100]3, practically the most "difficult" of the functions studied. Table 2 shows the behaviour of the ICA in three cases: high fixed weight, low fixed weight and variable weight. The number of sets was 100 for the ICA with w=0.5 and cw=1 (fixed weight). In the other cases, this number was inversely proportional to the average number of iterations. After that, the algorithm stopped (we designated this quantity nrIt) so that the total running time may be the same for each of the three cases analyzed.

	$f_2 : [-100;100]^3 \rightarrow R$								
	55 countries			108 countries			210 countries		
Tip ICA	$\min(f_2)$	nrOk	nrIt	$\min(f_2)$	nrOk	nrIt	$\min(f_2)$	nrOk	nrIt
w=0.5, cw=1	0.844188	51	1150	0.844188	67	1337	0.844188	78	1792
w=0.01, cw=1	0.844188	53	1257	0.844188	58	1593	0.844188	34	1089
w=0.5, cw=0.5	0.844188	3	67	0.844188	47	172	0.844188	**156**	491

Table 2. ICA with fixed weight vs. ICA with variable weight

The most efficient variant of those shown in the table according to the number of cases where the minimum of the function is obtained is that of the algorithm with variable weight and 210 countries in the initial set.

3.2 ICA with variable revolution rate

The ICA behaviour was studied when the number of countries where revolutions occur varies, this number increasing during the sequence of the algorithm. This is because, as the algorithm progresses, the number of colonies that will be in the vicinity of the imperialist countries is increasingly higher, due to the convergent formulae used in the assimilation operation. Hence, the idea of having an increasing number of countries involved in the revolutions.

In the tests conducted, the revolution rate, designated $prob_r$ below, had the following values:

- $$prob_r = \frac{\text{number of countries}}{\text{initial number of empires}} \quad (12)$$
- $$prob_r = \frac{\text{number of countries}}{\text{initial number of empires}} + 20 \quad (13)$$
- $$prob_r = \frac{\text{number of countries}}{\text{initial number of empirea}} + \frac{iteration}{50} \quad (14)$$
- $$prob_r = \frac{\text{number of countries}}{\text{initial number of empires}} + \frac{iteration}{100} \quad (15)$$

As it can be noticed, in the first three formulae, the revolution rate is fixed and, in the last two formulae, it is variable. The other parameters were kept constant at the values determined in section 2. The tests were also carried out in order to determine the minimum of function f2: [-100;100]3→ R. The results are shown in Table 3.

$prob_r$ (formula)	Number of countries					
	55		108		210	
	$min(f_2)$	nrOk	$min(f_2)$	nrOk	$min(f_2)$	nrOk
12	0.844188	51	0.844188	67	0.844188	78
13	0.862990	1	0.844188	52	0.844188	82
14	0.844748	4	0.844188	55	0.844188	**87**
15	0.844201	21	0.844188	62	0.844188	82

Table 3. ICA with fixed revolution rate vs. ICA with variable rate

A better behaviour of the ICA with variable revolution rate can be noticed in tests with a high number of countries (210) according to formula (16). This formula corresponds to the case where there is a more rapid increase in the number of countries subject to the operation of revolution depending on the iteration reached by the algorithm.

4 Conclusions

The ICA proved to be an efficient algorithm in determining the minimum of functions with several arguments. To determine an optimal set of parameters for the algorithm, we ran 27,000,000 tests. The ICA with this optimal set of parameters was used to determine the global minimum for nine functions; for seven of them, we used two fields of definition. In 14 of the 16 cases that resulted, the ICA determined the minimum in 100% of the 100 tests conducted. The lowest probability of obtaining the minimum was 78%.

In section 3, we studied the behaviour of the ICA with two of its characteristic parameters dynamically modified. The studies were conducted for the function considered to be the most difficult. The first study aimed at modifying the parameter that determines the weight with which a colony influences the performance of the whole empire to which it belongs. This parameter was modified with the initial purpose of removing the blockages of the ICA because of very poor performance colonies. Thus modified, the ICA presented superior convergence: if for the ICA with fixed weight the algorithm stopped after 1792 iterations on average, the ICA with variable weight stopped after 491 iterations on average. Thus, within the same time interval, the ICA with fixed weight located the global minimum for the function studied for 78 initial sets and the ICA with variable weight located the minimum in 156 initial sets.

The second study was concerned with the behaviour of the ICA when the number of countries where revolutions take place varies, increasing during the sequence of the algorithm. This is because, as the algorithm progresses, the number of colonies that will be in the vicinity of imperialist countries is increasingly higher, due to the convergent formulae used in the assimilation operation. Hence, the idea of having an increasing number of countries involved in the revolutions. In the tests conducted, we used two formulae for this parameter. For one of them, the ICA located the minimum of function f2 in 86 of the 100 initial sets, which represented an improvement of the performance of the algorithm with 10.25%.

References

[1] Gargari Atashpaz, E., Caro, L.: *"Imperialist Competitive Algorithm: An Algorithm for Optimization Inspired by Imperialistic Competition"*, IEEE Congress on Evolutionary Computation, CEC, 2007.

[2] Beheshti, Y., Shamsuddin, S. M. Hj.: *"A Review of Population-based Meta-Heuristic Algorithms"*, Int. J. Advance. Soft Comput. Appl., Vol. 5, No. 1, March 2013 ISSN 2074-8523.
[3] Forouharfard, S., Zandieh, M.: "*An imperialist competitive algorithm to schedule of receiving and shipping trucks in cross-docking systems*", International Journal of Advanced Manufacturing Technology, 2010
[4] Hojjat, E., Shahriar, L.: "*Graph Colouring Problem Based on Discrete Imperialist Competitive Algorithm*", CoRR, 2013.
[5] Liu, J.Y.-C., Yuan Z., S., Chiang-Tien C.: "*On the Convergence of Imperialist Competitive Algorithm*", 7th Asia Modelling Symposium, 2013.
[6] Soltani-Sarvestani, M. A., Badamchizadeh, M. A., Soltani-Sarvestani, Sh., Javanray, D.: "*Investigation of Revolution Operator in Imperialist Competitive Algorithm*", 4th International Conference on Computer and Electrical Engineering (ICCEE 2011).
[7] Ciurea S., Trifa V.: "*Imperialist Competitive Algorithm with Variable Parameters for the Optimization of a Fuzzy Controller*", International Conference on System Theory, Control and Computing ICSTCC, Sinaia, 2014.
[8] Schwefel, H.-P.: *Numerical optimization of computer models*, Wiley, 1981, ISBN13: 978-0471099888, LC: QA402.5.S3813.

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Data structuring for the ontological modelling of wind energy systems

Adrian Groza

Abstract

Small wind projects encounter difficulties to be efficiently deployed, partly because wrong way data and information are managed. Ontologies can overcome the drawbacks of partially available, noisy, inconsistent, and heterogeneous data sources, by providing a semantic middleware between low level data and more general knowledge. In this paper, we engineer an ontology for the wind energy domain using description logic as technical instrumentation. We aim to integrate corpus of heterogeneous knowledge, both digital and human, in order to help the interested user to speed-up the initialization of a small-scale wind project. We exemplify one use case scenario of our ontology, that consists of automatically checking whether a planned wind project is compliant or not with the active regulations.

1 Introduction

Small wind projects in the sector of renewable energies encounter difficulties to be efficiently deployed, partly because the wrong way data and information are managed [12, 3]. Ontologies can overcome the drawbacks of partially available, noisy, inconsistent, and heterogeneous data sources [15]. Domain specific ontologies have already been developed for the renewable energy sector [14, 10, 13].

In this line, we aim to develop an ontology for wind energy domain. The ontology was developed in the RacerPro (Renamed ABox and Concept Expression Reasoner Professional) knowledge representation and reasoning system [9]. In our view, RacerPro and the corresponding Knowledge Representation System Specification (KRSS) syntax for Description Logic axioms are powerful technical instrumentation that support ontology engineering behind the basic capabilities provided by GUI-based ontology editors. Compared to the ontologies listed in Table 1, the particularity of our ontology is to complement knowledge extracted from various maps with local observations about the location. Aiming to deal with small wind projects, we rely on 30-50 meter height wind maps and we also include community-scale wind resource maps to quantify the wind resource.

The remaining of the paper is structured as follows: Section 2 briefly introduces the KRSS syntax in which the ontology was developed. Section 3 illustrates how the available knowledge was reused. Section 4 shows the main engineering steps of the ontology. Section 5 depicts how the ontology can be interrogated, while section 6 concludes the paper.

2 Technical instrumentation

The wind data is modelled in an ontology, which is a semantic framework for organising information. We formalise the wind ontology in Description Logic (DL). In the description logic $\mathcal{ALC}$, concepts are built using the set of constructors formed by negation, conjunction, disjunction, value restriction, and existential restriction [2], as shown in Table 2. Here, C and D represent concept descriptions, while r is a role name. The semantics is defined based on an interpretation $I = (\Delta^I, \cdot^I)$, where the domain Δ^I of

Table 1: Examples of ontology-based systems in the renewable energy sector.

Ontology	*Ref.*	*Short description*
OpenWatt	[12]	Global schema for data about solar energy, wind energy, and biomasses.
EMA	[4]	RDF/OWL model of the French electricity company. The ontology-based Energy Management Adviser (EMA) provides personalised tips for 300,000 clients of the company.
WONT	[11]	Semi-automatic created ontology from the Wiki articles in the domain of wind energy (http://www.ceng.metu.edu.tr/we120329/wont.owl).
TurbMon	[17]	Ontology for wind turbines' condition monitoring: focus on wind turbine components and fault detection by means of SPARQL queries.
SEMANCO	[5]	Ontology for urban planning and energy management that describes regions, cities, and buildings; energy consumption and CO2 emission indicators (based on ISO/CD 16346, ISO/CD 16343), climate and socio-economic factors that influence energy consumption.

Table 2: KRSS syntax and semantics of $\mathcal{ALC}$ description logic.

Constructor	*Syntax*	*Semantics*
negation	`(not C)`	$\Delta^I \setminus C^I$
conjunction	`(and C D)`	$C^I \cap D^I$
disjunction	`(or C D)`	$C^I \cup D^I$
existential restriction	`(some r C)`	$\{x \in \Delta^I \mid \exists y : (x,y) \in r^I \wedge y \in C^I\}$
value restriction	`(all r C)`	$\{x \in \Delta^I \mid \forall y : (x,y) \in r^I \rightarrow y \in C^I\}$
individual assertion	`(instance a C)`	$\{a\} \in C^I$
role assertion	`(related a b r)`	$(a^I, b^I) \in r^I$

I contains a non-empty set of individuals, and the interpretation function $\cdot^I$ maps each concept name C to a set of individuals $C^I \in \Delta^I$ and each role r to a binary relation $r^I \in \Delta^I \times \Delta^I$. The last column of Table 2 shows the extension of $\cdot^I$ for non-atomic concepts.

An ontology consists of terminologies (or TBoxes) and assertions (or ABoxes). A terminology $TBox$ is a finite set of terminological axioms of the form `(equiv C D)` or `(implies C D)`. An assertional box $ABox$ is a finite set of concept assertions `(instance i C)`, role assertions `(related i j r)`, or attribute fillers `(attribute-filler i value a)`, where C designates a concept, r a role, a an attribute, and i,j are two individuals. Usually, the unique name assumption holds within the same $ABox$. A concept C is satisfied if there exists an interpretation I such that $C^I \neq \emptyset$. The concept D subsumes the concept C, represented by `(implies C D)` if $C^I \subseteq D^I$ for all interpretations I. Constraints on concepts (i.e. `disjoint`) or on roles (`domain`, `range` of a role, `inverse` roles, or `transitive` properties) can be specified in more expressive description logics. We provide only some basic terminologies of DL in this paper to make it self-contained. For a detailed explanation about families of description logics, the reader is referred to [2].

3 Reusing related ontologies

The process of engineering the ontology was started by: 1) specifying use cases of the ontology, 2) defining a set of competency questions, and 3) analysing the existing ontologies for possible reuse.

First, the *use cases* of the ontology include i) "the assessment of the feasibility to install a particular small-scale wind turbine in a given location" or ii) "checking whether a small wind project is compliant with current regulations.

Second, a solution to narrow the scope of an ontology is to start by defining a list of *competency questions* (CQs) [16]. CQs are questions that an ontology should be able to answer in order to satisfy use

Table 3: Sample of competency questions for the wind turbine domain.

CQ_1	Which is the most adequate wind turbine class for a given location?
CQ_2	Is it norm-compliant to install a wind turbine of a specific class in a given location?
CQ_3	Which is the wind rose distribution for a specific location?
CQ_4	What type of vegetation does exist within a radius of 200 meters?
CQ_5	Which wind turbine types are installed nearby?
CQ_6	Which turbines have alarms for the generator component occurred after a maintenance activity?

Table 4: Reusing related ontologies.

Ontology	*URI*	*Short description*
GeoNames	http://www.geonames.org/	Contains 8.3 million geonames toponym.
BayesOWL	http://semanticweb.org/wiki/Bayes_OWL	A probabilistic extension to the Ontology Language OWL.
Sensor	http://www.w3.org/2005/Incubator/ssn/ssnx/ssn	Describes various sensors and observations.

cases. Thereby, CQs represent initial requirements and they can be used to validate the ontology. Having the role of a requirement, each CQs are initially written in natural language (see Table 3). Then, CQs are formalised in the new Racer Query Language (nRQL) [9] for the task of ontology validation, .

Third, several types of ontologies are needed to merge the input data which is collected in different format and several measurements types are exploited. Thus, existing knowledge bases like wind ontology or measurement ontologies can be exploited. For handling data directly coming from sensors, knowledge about the type of sensor or error and transmission rate are needed, which can be extracted from a specific sensor ontology. Merging different GIS maps requires geographical knowledge. The reused ontologies are listed in Table 4. First, from the GeoNames ontology we exploited: i) hypsographic features (concepts like `Mountain, Hill, Valley, Slope, Mesa, Cliff`), ii) road features (concept like `Junction`, or roles like `roadWidth`), iii) populated places (`City, Area, ResidentialArea`), or iv) vegetation features (`Forrest, Orchard, Scrubland, Vineyard`). Second, we used BayesOWL ontology [6] to represent random variables such as `WindRose` or `WindShear`. Third, we reused concepts from the sensor ontology to describe knowledge about wind-related sensors, as in the following definitions:

```
(implies (or Anemometer WindProfiler WindVane) Sensor)
(implies (or CupAnemometer PropellerAnemometer SonicAnemometer) Anemometer)
```

4 Engineering the wind potential assessment ontology

To develop the wind ontology, we follow the methodology in [16] and we also enact various ontology design patterns [18, 8]. The ontology is a modular one, consisting of a core formalisation and T-boxes for modeling various aspects in the wind energy domain: sub-components of a turbine, classes of turbines, potential of a location, etc.

The sub-componets of a wind turbine are represented by the transitive role `hasPart`:

```
(define-primitive-role hasPart :transitive t)
```

A turbine has one base, one tower, one nacelle, and several blades:

```
(implies WindTurbine (and (=1 hasPart Base)
                          (=1 hasPart Tower)
                          (=1 hasPart Nacelle)
                          (some hasPart Blade)))
```

Given the transitivity of the role `hasPart`, the system is able to deduce all the sub-components of a turbine. The nacelle houses a gearbox and generator, which can be either variable or fixed speed:

```
(implies Nacelle (and (=1 hasPart Gearbox) (=1 hasPart Generator)))
(implies Generator (or VariableGenerator FixedSpeedGeneartor))
(disjoint VariableGenerator FixedSpeedGeneartor)
```

Component prices and technical specification are attached to instances of the concept `WindTurbine`:

```
(instance whisperH20 (and WindTurbine (= 595 hasPrice)))
(instance towerKit1 (and Tower (= 450 hasPrice)))
(related whisperH20 towerKit1 hasPart)
(attribute-filler whisperH20 20 hasBladeArea)
```

Small wind turbines, defined as having a swept area less than 200 m^2, are usually installed between 15 and 40 m high:

```
(implies SmallWindTurbine (and WindTurbine
                                (min sweptArea 200)
                                (min high 15)
                                (max high 40)))
```

A good wind resource is one where wind speeds average 16 mph or more over the course of a year:

```
(define-concrete-domain-attrbiute speedAverage :domain Location :type integer)
(implies GoodWindResource (and WindResource (min speedAverage 16)))
```

Wind speeds are categorized by class, from a low of class 1 to a high of class 7. Wind speeds of class 4 or greater are used for wind power production:

```
(implies GoodWindResource (or WindClass4 WindClass5 WindClass6 WindClass7)))
```

The power of the wind is measured in watts per square meter, and this increases by the cube of the wind speed:

```
(implies top (= windpower (* windspeed windspeed windspeed)))
```

GIS maps are the main source of data fed in the Aboxes of the ontology: (1) wind potential map, (2) wind power map, (3) topographical map, (4) open street map (OSM), (5) transmission lines, (6) archaeological map, (7) vegetation map, (8) rivers and lakes map, (9) digital elevation models. For instance, for converting OSM into KRSS syntax we developed a Java-based converter based on the Osmosis API to import facts about roads. From the wind power map, we defined the potential of a particular wind resource in three classes for the wind speed measured at 50m: marginal, promising, or excellent:

```
(implies MarginalPotentialat50 (and (= hasMeasuredHeight 50) (< 7.5 windSpeed)))
(implies PromisingPotentialat50 (and (= hasMeasuredHeight 50) (> 7.5 windSpeed)
                                     (< 10 windSpeed)))
(implies ExcellentPotentialat50 (and (= hasMeasuredHeight 50) (> 10 windSpeed)))
```

The general concept `MarginalPotential` is the union of the marginal potentials at different heigths:

```
(equivalent MarginalPotential (or MarginalPotentialat15
                                  MarginalPotentialat50
                                  MarginalPotentialat100))
```

These concepts can be used to make rough production estimates at sites, given that the accuracy is +/- 10 to 15% what the actual winds at a site may be.

Access roads of at least 4m wide are assumed necessary, given by:

```
1. (define-concrete-domain-attribute width :domain Road :type real)
2. (implies TurbineAccessRoad (and Road (>= width 4.0)))
```

Wind turbines are efficient in coast, hills, and mountains regions:

```
3. (implies WindTurbine (all efficientIn (or Coast Hill Mountain)))
```

Theoretically, wind turbines can extract up to 59% from the energy which passes through it. Practically, an efficient turbine extracts around 40% from the wind potential [3]. The individual `wt1` is an instance of the concept `WindTurbine` that is able to extract 38% from the wind energy:

```
4. (define-concrete-domain-attribute extracts :domain WindTurbine :type real)
5. (instance teoreticalLimit (= extracts 0.59))
6. (instance practicalLimit (< extracts 0.40))
7. (instance wt1 (and WindTurbine (= practicalLimit 38)))
```

The transitive role `isLocated` connects instances of type `Entity` with instances of the concept `Location` (line 21). "Partition ontology design pattern" [18] is used to define various types of locations (lines 22-23). The attributes `hasLatitude` and `hasLongitute` are introduced to define a point in space (lines 25-26). Because GIS maps are usually achieved for small regions, we defined aboxes for each region (line 27). Axiom 29 connects the wind turbine `wt1` with the point `p1`. Because the role `isLocated` is transitive the system is able to infer that `wp1` is located in all concepts representing more general locations than `p1` (i.e. Dobrogea, Romania, given that `(related Dobrogea Romania isLocated)`.

```
21. (define-primitive-role isLocated :domain Entity :range Location :transitive t)
22. (implies (or Point Area) Location)
23. (disjoint Area Location)
24. (implies IndustrialArea (and Area (some has IndustrialActivity)))
25. (define-concrete-domain-attribute hasLatitude :type real)
26. (define-concrete-domain-attribute hasLongitude :type real)
27. (init-abox dobrogea-wind-assesment)
28. (instance p1 (and Point (= hasLatitude 44.56) (= hasLongitude 27.54)))
29. (related wt1 p1 isLocated)
```

When setting a home-sized wind turbine, the rule of thumb states that turbine's rotor should be at least 10 meters above anything within 150 meters of the tower:

```
(define-rule (?wt ProperWindTurbine) (and (?wt WindTurbine)
                                          (?wt ?h1 hasHeight)
                                          (?x top) (?x ?h2 hasHeight)
                                          (?dist DistanceBetween2Objects)
                                          (?dist ?wt hasObject)
                                          (?dist ?x hasObject)
                                          (?dist ?distance hasDistance)
                                          (< distance 150)
                                          (> ?h1 (+ h2 10)))
```

Here, the wind turbine `?wt` is proper if its heigth `?h1` is greater then the height `h2` of any object `?x` in the ontology `(?x top)`. We enacted the "n-ary ontology design pattern" [18] to store the distance between two objects:

```
(equivalent DistanceBetween2Objects (and (=2 hasObject) (=1 hasDistance)))
(define-concrete-domain-attribute hasDistance :domain DistanceBetween2Objects :type real)
```

The role `hasWindShear` is used to describe the differences in wind speed at two different heights (line 12) In general, turbulence decreases and wind speed increases as height increases. A `WindRose` (line 13) shows the direction that the wind blows and the frequency of that direction at a particular location.

```
11. (define-concrete-domain-attribute hasAverageWindSpeed :domain Location :type real)
12. (define-concrete-domain-attribute hasWindShear :domain Location :type real)
13. (implies WindRose (and (=1 hasDirection Direction) (=1 hasFrequency Frequency)))
14. (instance wr (and (= NW hasDirection) (= hasFrequency 0.6)))
```

To represent the random variable `WindRose` given the variable `Day` ($P(WindRose|Day)$) we enact the `ConditionalProbability` concept from the BayesOWL ontology [6]:

```
41. (define-primitive-role hasCondition :domain ConditionalProbability)
42. (define-primitive-role hasVariable :domain ConditionalProbability)
43. (define-concrete-domain-attribute hasProbabilityValue :domain ConditionalProbability
                                                          :type real)
44. (instance cp1 bayesOWL:ConditionalProbability)
45. (instance wr1 (and WindRose RandomVariable))
46. (instance 27June Day)
47. (related cp1 27June bayesOWL:hasCondition)
48. (related cp1 wr1 bayesOWL:hasVariable)
49. (attribute-value cp1 0.6 bayesOWL:hasProbabilityValue)
```

5 Retrieving information from Aboxes

Once a user's situation has been fully described using DL assertions, the RacerPro [9] reasoner was used to classify the location as an instance of one or more of the situation concepts described in the ontology.

Ontology reasoning can be used to check if the location of a wind turbine does not breach active regulations. The following axioms checks whether the wind turbine is located at a minimum distance of 300m from a residential area.

```
31. (instance v1 Village)
32. (implies Village (and geonames:PopulatedPlace geonames:ResidentialArea))
33. (instance a1 (and Area (= hasContourPoint p2) (= hasCountourPoint p3)
                           (= hasContourPoint p4)))
34. (related v1 a1 isLocated)
35. (define-concrete-domain-attribute hasValue :domain Distance :type integer)
36. (instance d1 (and Distance (= hasObject wt1) (= hasObject v1)))
37. (attribute-filler d1 280 hasValue)
38. (instance minimumDistance (= distance 300))
```

Given the village `v1` (line 31), we use axioms from GeoNames ontology (axiom 32) to deduce that a village is a residential area. We enact AllegroGraph [1] to perform geospatial reasoning on various tasks, such as computing the distance between a point and a geographic area. Using also the Harversine formula, the minimum distance `d1` between potential wind turbine location `p1` and residential area `a1`

of v1 (line 34) is asserted in the ontology (line 37). Here, area a1 is a triangular shape defined by three points (line 33) and d1 is an instance of the concept Distance between the starting point the turbine wp1 and the ending point the village v1 (line 36). Given that the minimum distance between a turbine an a residential area should be 300m (fact 38) the ontology is able to infer that the turbine v1 breaches the above normative condition.

Four types of queries on the wind-turbines ontology are illustrated: i) checking the ontology consistency (line 71), ii) retrieving information about individual wt1 (line 72), iii) identifing the sub-concepts of the various concepts in the ontology (lines 73-74) and iv) retrieving all wind turbines located in Dobrogea region (line 75).

```
71. (tbox-cyclic?)  (tbox-coherent?) (abox-consistent?)
72. (describe-individual wt1)
73. (concept-children WindTurbine)
74. (concept-descendents Wind Turbine)
75. (concept-instances (and WindTurbine (some isLocated Dobrogea)))
```

6 Conclusion and ongoing work

The proposed ontology captures knowledge in the wind energy domain. The knowledge was formalised in Description Logic that provides a rich, flexible and fully declarative language for modelling knowledge about environment. The specific reasoning services on DL were exploited to deduce new knowledge and to classify a location according to its wind potential. The ontology can assist the wind farm operators lowering costs and complying with current regulations in the wind energy sector. The wind ontology will help wind farm operators make informed, evidence based decisions about deployment and maintanance of a wind project.

We did not focus here on the problem of reasoning on data streams [7] continously collected from sensors. Ongoing work regards extending the ontology with terrain analysis, infrastructure, environment and complete legal constraints, into a single predictive map that shows the most suitable site to explore for wind energy.

References

[1] Jans Aasman. Allegro graph: RDF triple database. Technical report, Franz Incorporated, 2006. url: http://www.franz.com/agraph/allegrograph/(visited on 20/04/2015), 2006.

[2] Franz Baader. *The description logic handbook: theory, implementation, and applications*. Cambridge university press, 2003.

[3] Octavian Capatina and Ioan Letia. Online knowledge based wind assessment tool. In *Automation Quality and Testing Robotics (AQTR), 2012 IEEE International Conference on*, pages 352–355. IEEE, 2012.

[4] Pierre Chaussecourte, Birte Glimm, Ian Horrocks, Boris Motik, and Laurent Pierre. The energy management adviser at edf. In Harith Alani and et., editors, *The Semantic Web ISWC 2013*, volume 8219 of *Lecture Notes in Computer Science*, pages 49–64. Springer Berlin Heidelberg, 2013.

[5] Vincenzo Corrado, Ilaria Ballarini, Leandro Madrazo, and German Nemirovskij. Data structuring for the ontological modelling of urban energy systems: The experience of the SEMANCO project. *Sustainable Cities and Society*, 14:223–235, 2015.

[6] Zhongli Ding, Yun Peng, and Rong Pan. Bayesowl: Uncertainty modeling in semantic web ontologies. In *Soft Computing in Ontologies and Semantic Web*, pages 3–29. Springer, 2006.

[7] Adrian Groza and Ioan Alfred Letia. Plausible description logic programs for stream reasoning. *Future Internet*, 4(4):865–881, 2012.

[8] Adrian Groza, Anca Marginean, and Vlad Muresan. An ontology-based model for vehicular adhoc networks. In *Intelligent Engineering Systems (INES), 2014 18th International Conference on*, pages 83–88. IEEE, 2014.

[9] Volker Haarslev, Kay Hidde, Ralf Möller, and Michael Wessel. The RacerPro knowledge representation and reasoning system. *Semantic Web Journal*, 3(3):267–277, 2012.

[10] Ahmad Kayed. Renewable energy ontology. In *Applications of Information Technology to Renewable Energy Processes and Systems (IT-DREPS), 2013 1st International Conference & Exhibition on the*, pages 144–148. IEEE, 2013.

[11] Dilek Kk and Yusuf Arslan. Semi-automatic construction of a domain ontology for wind energy using Wikipedia articles. *Renewable Energy*, 62(0):484 – 489, 2014.

[12] D Davide Lamanna and Antonio Maccioni. Renewable energy data sources in the semantic web with OpenWatt. In *EDBT/ICDT Workshops*, pages 128–133, 2014.

[13] Trinh Hoang Nguyen, Rocky Dunlap, Leo Mark, Andreas Prinz, Bjørn Mo Østgren, and Trond Friisø. Offshore wind metadata management. *International Journal of Metadata, Semantics and Ontologies*, 9(4):333–349, 2014.

[14] Trinh Hoang Nguyen, Andreas Prinz, Trond Friis, Rolf Nossum, and Ilya Tyapin. A framework for data integration of offshore wind farms. *Renewable Energy*, 60(0):150 – 161, 2013.

[15] Trinh Hoang Nguyen, Andreas Prinz, and Josef Noll. Proactive maintenance of offshore wind turbine blades using knowledge-based force analysis. In *Innovative Computing Technology (INTECH), 2013 Third International Conference on*, pages 239–245. IEEE, 2013.

[16] Natalya F Noy, Deborah L McGuinness, et al. Ontology development 101: A guide to creating your first ontology, 2001.

[17] P Papadopoulos and L Cipcigan. Wind turbines' condition monitoring: an ontology model. In *Sustainable power generation and supply, 2009. SUPERGEN'09. International conference on*, pages 1–4. IEEE, 2009.

[18] Jeffrey T Pollock and Ralph Hodgson. Ontology design patterns. *Adaptive Information: Improving Business through Semantic Interoperability, Grid Computing, and Enterprise Integration*, pages 145–194.

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Power Monitoring Scheme of a Net Metering Miniature System

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Abstract

Net Metering is an electricity policy wherein renewable power sources at home are integrated into the power utility. One of the reasons these sources must be integrated is to give the excess power to the utility when net generation is produced. However, if this renewable source cannot provide enough power to sustain the exact amount of needed electricity, there is a need to request for more at the utility; thus, the Net Metering policy was established.

This paper aims to validate a Net Metering miniature setup with respect to its power monitoring scheme and seeks to evaluate said power monitoring scheme. We formulated a miniature Net Metering system design to model the actual commercial net meter system and test the validity of the setup by performing three cases for switching action while monitoring power data from the AC analyzer on a real-time basis. There are also three switching action cases for the power monitoring scheme, as well as three different cases for the design's implementation. Real-time power monitoring is executed using Matlab and its xlswrite function; upon performing three different load cases, data is gathered to show the power monitoring method. During case shifting, there is a negligible delay of displaying power data in the GUI due to data communication from AC analyzer to the Matlab GUI and is negligible enough to invalidate the setup.

1 Introduction

A continuing increasing demand for energy world-wide and the exhaustion of available energy resources compels people to find alternative solutions [1]. With the progress of science and technology and the continuous improvement of living standards, various electric equipment are being used on a wider scale. However, such use may lead to the electric power network becoming so overloaded that a widespread power outage seems immenent; therefore, monitoring the operation data of electric equipment is very important. [2]

The domestic use of electricity is the basic unit of social modernized development; therefore, the house is an important place for people's daily lives, work and entertainment. The monitoring of electrical equipment helps users gauge the status of household electricity load in order to further formulate a reasonable energy-saving plan and reduce energy consumption and expenditures [3].

Therefore, strengthening the monitoring of electrical equipment, especially the monitoring of power consumption, is important in enhancing our power utilization rate and realizing the energy [4].

Renewable sources of energy are all around us. The UV rays of the sun, the energy and gravitational force of falling water, and the force of the wind are all sources of energy that cannot be depleted. Households that generally own small renewable energy facilities such as solar modules, micro hydro power plants, and even small wind turbines, can actually integrate these systems into the electric utility. These facilities sometimes cannot provide enough power to sustain the exact amount of electricity needed to operate some household task that requires power. Thus, there is a need to acquire electric power from the electric utility when the renewable facility cannot sustain the household's needed power. This kind of electricity policy is called "Net Metering". [5] Under this metering, the household receives credit for the portion of electricity they generate from the renewable facility when there is net power available after the deduction of the household's consumption. This amount of electricity is then forwarded to the utility. [6]

However, this metering system is still only available in some other countries, most of them first world nations like Australia. [7] Thus, a third world nation like the Philippines needs to further develop available technology in a way adapts this kind of metering system to its own context. We wish to show the power monitoring circuit design available in the research; the concept of this paper is to give the reader the background and basic concept of the power monitoring scheme on a Net Metering Miniature System.

The focus of this study is on the power monitoring scheme of how the Net Metering system works in different load cases; in particular, the process of the net meter system while different load cases are being executed. The project's goal is designed to promote the concept of a Net Metering system so that further studies about the system will be developed, leading to the patenting of a new method of Net Metering that can be applied in the Philippines or else mimic the current commercial Net Metering system device for much cheaper.

The scope of this project is only the power monitoring scheme of the Net Metering system. We wish to show only the power monitoring scheme of the designed circuitry in order to impart the significance of the Net Metering system miniature program's relation to the unsurpassable current Net Metering system used in first world nations. After procuring all the materials and creating the circuit layout, the project can be accomplished in a short period of time.

This study is limited only to the power monitoring indications from the arduino and power analyzer setup available. Matlab will be used for online power monitoring of the setup with the aid of the arduino hardware. Matlab will provide the reading of the Net Metering system miniature through the power monitoring scheme of the power analyzer. This project wants to impart the power monitoring scheme to all grid systems that do not apply the Net Metering systems yet in their respective settings so that further research may be implemented.

Fig. 1 shows the conceptual framework of the research design for the power monitoring scheme to be used. The loading system (1, 2 or 3) will be further explained in Section 2.5 and Section 3.

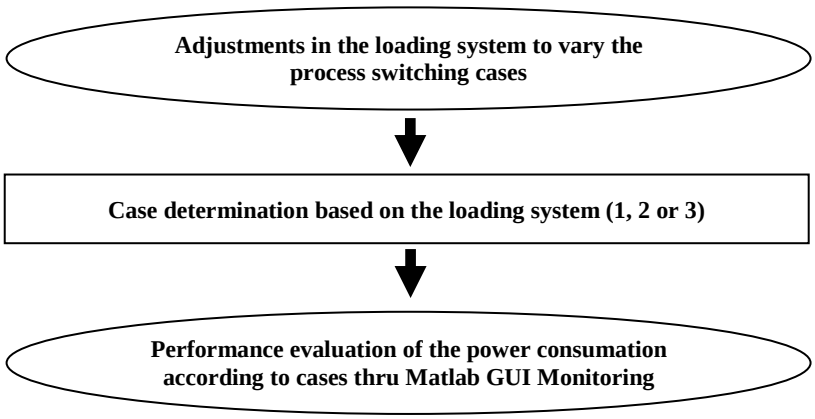


Fig. 1. Conceptual Framework of the Power Monitoring Net Metering Miniature System Design

2 Methodology and Research Design

We formulated our own Net Metering Miniature System design, modeled against the actual commercial net meter system. The following miniature system will demonstrate the switching actions on the net meter system. Refer to Fig. 2 for the design layout.

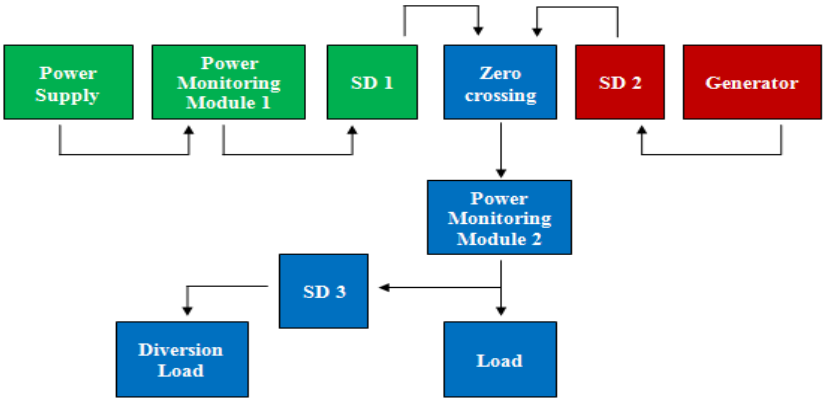


Fig. 2. Research design layout for the net metering miniature system.

2.1 Power Supply and Power Monitoring Module 1 (PMM 1)

The Power Supply represents the utility grid in the actual net meter system, with the power derived from the Lab-Volt ElectroMechanical Traning System (EMS) Module 8821. This module is a primary component in the Lab-Volt EMS. The power supply provides variable single phase AC, variable three-phase AC, and variable DC power levels. However, in the miniature system, the project only needs a 220-volt AC for the setup of the project.

Power Monitoring Module 1 allows for the reading and acquisition of the real-time data of. This monitoring module is an AC power analyzer from e-Gizmo, based on an energy metering IC, as well as a single-phase power analyzer front-end measuring module that can easily be integrated into any circuit and systems requiring AC power measurement functionalities. It can accurately measure RMS voltage and current, and with phase information, resolve into data components essential for a comprehensive AC power analysis.

2.2 Switching Device 1 and 2 (SD 1 and SD 2)

SD 1 is a solid-state relay that connects directly to the power supply discussed on the power supply. The relay triggers the switches on switches on and off depending on the case of the load. Each case has a corresponding switch signal to whether give it an on or off. This relay primarily serves as a switching device for the utility representation part. SD 2 is a solid-state relay that is the same as that of the SD 1. The relay triggers the switches on and off depending on the cases of the load. This switching device serves the generator part of the design. Both SD 1 and SD 2 are interconnected to the zero-crossing detector circuit.

2.3 Generator

The renewable power system is well represented by a generator module. The generator is derived from Lab-Volt EMS Module 8241. This module is a three-phase asynchronous motor and can simultaneously serve as a generator.

Each phase of the stator windings of this machine is independently terminated and identified on the faceplate to permit operation in either delta or star (wye) configuration. The rotor of this machine is equipped with a squirrel-cage damper. Variable DC excitation is fed through externally mounted slip

rings and brushes, which are pre-wired to a rheostat and control switch mounted on the faceplate. This is accomplished by tapping from two terminals only at the synchronous machine.

2.4 Zero Crossing or Zero Cross Function

When connecting the power supply line and the generator line through SD 1 and SD 2, the zero cross function is an important device to be considered. In order to sync into the existing AC line, which is the generator line, the power supply line must be connected to the zero cross function. During zero-reference crossing or first conduction cycle, both AC waves will meet in order to be synchronized with each other. Thus, merging these two AC lines will eventually create a new AC line that will work on the loading system. This new line provides greater current capability compared to the individual AC lines prior to synchronization at the zero cross function. The new AC line then provides power for the load on the condition that the two lines are hereby needed by the principle of Net Metering system.

The zero cross function causes the relay to switch on when the AC load power supply approaches 0 V to suppress noise generated when the load current rises suddenly.

There are two types of noise: the noise in power lines and the noise emitted into open spaces. The zero cross function is effective against both types of noise. A very large inrush current flows when lamps and similar equipment are switched on, but the zero cross function causes the load current to flow always from a point near zero so that inrush current can be more effectively suppressed compared to Solid-state Relays (SSRs) that do not have the zero cross function. Ideally, the function switches on near 0 V, but restrictions in the circuit configuration cause it to operate within the range of 0 V ±20 V. This voltage is called zero cross voltage. [8]

2.5 Power Monitoring Module 2, Loading System, Diversion Loading System, and Switching Device 3

As cited on the Power Monitoring Module 1, Power Monitoring Module 2 (PMM 2) allows us to read and acquire the real time data of the power supply. However, PMM 2 gathers data from the AC line after the zero cross function. Be it the generator line only, power supply line or both, PMM 2 acquires its real time data. The same kit is used in PMM 1 and PMM 2.

The Loading System (Load) is where the loads are installed for application of power consumed. The three cases can occur depending on whether the loading system is lesser than the generator, equal to the generator or even greater than the generator's capability. Given at an instant, the generator's power capacity is limited; that is where the switching action comes in, based on the loading system.

Diversion loads are designed due to the inability of a bidirectional current in the area. The scope of this project is limited only to the availability of a bidirectional system. Since there is no available bidirectional system for research, we designed the said loading system in such a way that when the generator capacity is greater than that of the load and instead passing the excess power to the utility grid, it is hereby directed to the diversion load for consumption. However, Net Metering still applies. This demonstration is for the purpose of sending excess power to the utility grid.

Switching Device 3 (SD 3) is connected to the diversion load. This is the part that switches a line connected to the diversion load on or off, depending on what loading case the current situation is in.

3 Implementation Details

We designed three switching action cases to accurately evaluate the system for power monitoring. There are three different cases of this design implementation. In the first case (Case 1), the generator capacity is greater than the loading system; in the second case (Case 2), the generator capacity is at full load condition; and in the third case (Case 3), the generator capacity is lesser than the loading system. The switching action evaluation will be published in another research paper separate from this paper.

4 Power Monitoring Scheme Through Arduino and Matlab

The research design cannot work or be monitored without the controlling setup of the Arduino (microcontroller) and Matlab power monitoring scheme. The switching devices (SD 1, SD 2, and SD 3) are connected to the Arduino, specifically Gizduino (the name varies because Gizduino is from e-Gizmo and Arduino is from Dynamodo, though they basically have the same function). The codes are set up in Gizduino 1 and sends signals to the switches depending on the loading's case. Through the aide of PMM 1, Gizduino 1 is able to identify the loading system's case status, thus making the switching devices switch on and off accordingly.

Meanwhile, the PMM 2 constantly monitors the power information from the Power Supply (representation of the utility) to make sure that the AC line from the utility is providing enough power, especially during Case 3. Both power modules 1 and 2 are then multiplexed so that a single Gizduino can be used for both analyzer kits. Gizduino 2 is the microcontroller that connects to the multiplexer, and at the same time, to the computer for the Matlab monitoring program. Fig. 3 shows the power monitoring scheme of the power analyzer kit and the Arduino.

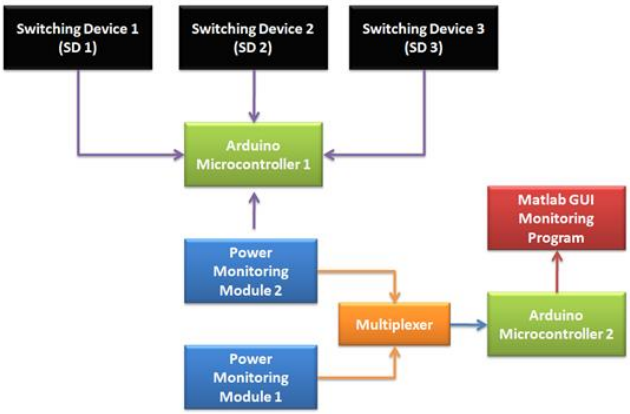


Fig. 3. Monitoring Scheme of the Gizduino Microcontrollers for the switching action, power monitoring and Matlab integration of the project design.

4.1 Arduino 1 and Arduino 2

In order to allow for the switching action of the switching devices connected to Gizduino 1, a certain coding program is constructed. Gizduino 2 allows the monitoring of the two power analyzers connected to it through multiplexer, and then sends data to the Matlab. In order to actually monitor the power analyzer, another coding program is constructed. After which, the data is then forwarded to Matlab for easy monitoring scheme. Then data is then saved in an Excel file through the xlswrite Matlab function.

4.2 Matlab Monitoring Program (GUI)

The Matlab GUI program was created for the power monitoring scheme from the power supply and the loading system. It allows the user to easily interpret the results with the help of the GUI. Fig. 4 is the actual design for this project's research on the Net Metering Miniature System. The 'GRID' data is merely represented by the actual readings of the diversion loading, as provided previously. The 'Main Load' data is taken from the actual readings of the loading system.

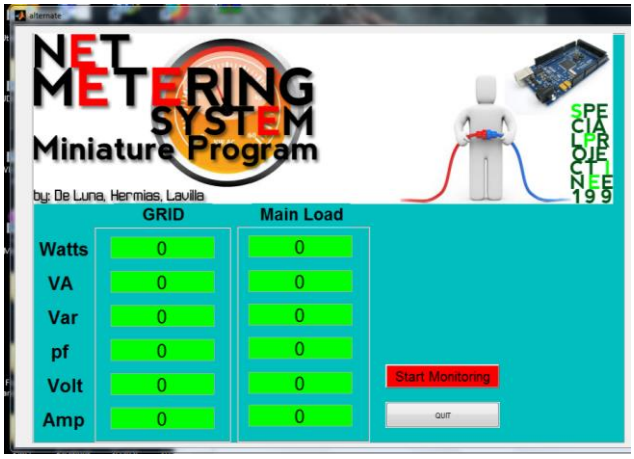


Fig. 4. GUI of the Matlab Monitoring Program

5 Data Gathering Procedure

To truly test the hardware setup, the power monitoring scheme and data acquisition must be effective in performing its operation and function accordingly. Thus, on the power monitoring scheme, the xlswrite function in the Matlab must also work accordingly. The Matlab functions as an online monitoring software and at the same time, a data gathering instrument. From the Arduino to Matlab, there is a code created for pasting data into an active Excel file that will automatically add data once read in the Arduino. The data from the Gizduino that connects the two power analyzers will be automatically saved to the Excel file; and the data from the arduino that is connected to the switching devices will also be copied but in a different sense; and then, later on the data will be checked based on the data gathered by Matlab. Also, users can gather real-time power consumption data from Dynamodo's Arduino software and manually segregate the data according to cases.

6 Results and Discussion

Upon thorough construction of the prototype and setting up available laboratory equipment, the hardware prototype was constructed and deemed able to perform according to its design. The following figures show the setup and components of the Net Metering Miniature System integrating the power monitoring scheme hardware and software.

Fig. 5(a) shows the loading system and the diversion loading system (rightmost column of bulbs) of the miniature setup. Fig. 5(b) shows two Arduino (left) and two power analyzers (right) which are integrated into the net meter system in order to facilitate the power monitoring scheme and the switching action performance.

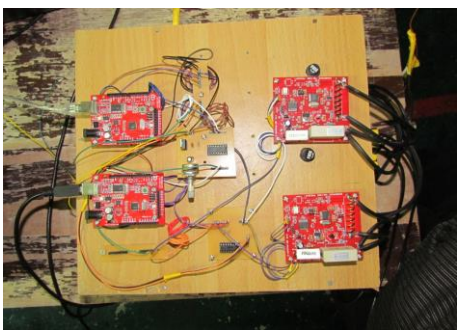
a  b 

Fig. 5. (a) Loading and Diversion Loading System; (b) The arduino and power analyzer of the net meter system

Fig. 6(a) shows the EMS Lab-Volt equipment used as a power source – the AC utility line supply and renewable source representation, respectively. The synchronous generator (yellow boxes) represents the micro hydro plant mean while beside it is the AC power supply representing the utility grid. Fig. 6(b) shows an EMS Lab-Volt equipment close-up of the Synchronous Machine and DC Machine. The DC machine acts as a turbine or prime mover in a hydro power plant setup. This machine is capable of producing a net amount of 110 watts.

a  b 

Fig. 6. (a) Lab Volt Power Source: AC Utility and Synchronous Generator; (b) 3-Phase Synchronous Generator

Fig. 7(a) shows the EMS Lab-Volt equipment close-up of DC/AC power supply. The 120/208V-15A AC power supply represents the utility line wherein the wirings are directly sent to the hardware prototype. Meanwhile, the DC source allows the prime mover/DC Machine to move in line with the synchronous so that hydro power plant representation is made possible. Fig. 7(b) shows the GOAL STAR Digital Energy Meter LCD-Series connected to the loading system. This equipment is used for verification purposes only, to confirm whether the energy used and monitored in the Matlab is the same as that in the energy meter shown.

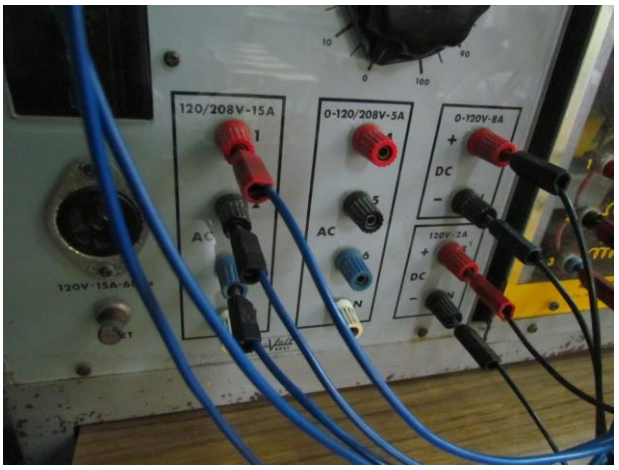
a  b 

Fig. 7. (a) EMS Lab-Volt Equipment Close-up of DC/AC Power Supply; (b) GOAL STAR Digital Energy Meter

Fig. 8 shows the overall setup of the Net Metering Miniature System. This setup is patterned after the research design discussed in Chapter 3. The bulbs represent the loading system and diversion loading, as well. The laptop is used for the Matlab GUI Power Monitoring Program and the Synchronous Machine is the representation of the micro hydro power plant. Meanwhile, Lab Volt also produces constant AC supply as a mere representation of the utility grid.

Fig. 8. The Overall Setup of the Net Metering Miniature System.

6.1 Performance of the Power Monitoring Scheme

This section aims to answer the condition of the actual setup as to its performance regarding the ideal switching condition per case, and the power monitoring scheme as a whole. Table 1 shows the samples of actual results of the prototype during Arduino testing for the Loading System. The case status of the data is also indicated. Table 2 shows the samples of the actual data result of the prototype during Arduino testing for the Diversion Loading System/Grid. The case status of the data is also indicated.

LOAD POWER (in Watts)	LOAD SYSTEM (POWER MONITORING) DATA					Case
	VA	Var	Power Factor	Volt	Amp	
0.9	9	8.7	0.1161	224.38	0.0399	1
3.6	10.8	10.2	0.3392	224.31	0.0492	1
23.4	24.3	6.3	0.9653	224.61	0.1087	1
43.2	43.8	7.2	0.9851	224.22	0.1953	1
51.6	51.3	-0.3	0.9997	224.56	0.229	1
77.5	76.9	-0.3	0.9997	223.85	0.3426	2
90.1	7.2	7.2	0.1353	208.56	0.0355	2
110.6	91.4	8.7	0.1227	225.87	0.0384	3
12.9	20.4	9.9	0.8736	225.93	0.0902	1
38.7	38.1	2.7	0.9969	227.46	0.1672	1
47.7	44.7	2.1	0.9984	214.62	0.2086	1
44.7	24	6	0.9649	222.23	0.1076	1
23.1	22.8	5.4	0.9695	216.74	0.1058	1
22.2	22.8	5.4	0.9695	216.74	0.1058	1

Table 1. Samples of the Actual Data Result of the Prototype for the Loading System;

GRID POWER (in Watts)	GRID SYSTEM (POWER MONITORING) DATA					Case
	VA	Var	Power Factor	Volt	Amp	
0.9	9	8.7	0.1217	224.7	0.0399	1
103	102.1	-0.4	0.9997	224	0.4545	1
78.4	77.5	-0.4	0.9997	223.98	0.3448	1
51.9	49.2	-0.3	0.9997	224.27	0.2197	2
30.6	73.4	-0.4	0.9997	194.9	0.3765	2
10.2	81.5	-0.4	0.9997	208.79	0.3894	3
0.9	8.7	-0.4	0.9997	225.57	0.4044	3
96.3	95.4	-0.4	0.9997	231.75	0.4111	1
107.9	107	-0.4	0.9997	231.31	0.4623	1
82.4	81.5	-0.4	0.9997	231.83	0.3509	1
76.6	76.1	-0.4	0.9997	223.25	0.3403	1
55.5	54.6	-0.4	0.9997	234.26	0.2328	1
51	51	5.3	0.9933	217.52	0.235	1
52.4	52.4	-0.4	0.9997	223.87	0.2339	1
73	72.1	-0.4	0.9997	213.95	0.337	1

Table 2. Samples of the Actual Data Result of the Prototype for the Diversion Loading System or Grid.

6.2 Power Monitoring Scheme Evaluation

There are some instances, such as during the transition power consumption and such as when switching the lights on and off, that the Arduino causes almost a second's delay to give the current reading of the setup. This situation, however, is negligible enough since the actual scenario of a Net Metering system is a stable usage of appliances. That is, when the lights are switched on, then it remains on for hours. This phenomenon of almost one second delay of the monitored data is acceptable enough since the setup is equipped with devices of which when cases occurring, protective relays are installed. That is, when loading reaches a certain case condition, relays automatically switch on and off according to its assignment. The delay is due to the processing time for the acquisition of data from the power analyzer, then forwarded to the Arduino, and to be monitored in Matlab. Processing time takes time, but this amount of time is negligible enough so that the power monitoring scheme is an acceptable setup.

7 Summary and Conclusions

It has always been the aim of engineers, especially electrical engineers, to provide ways and means to generate power through renewable energy sources and at the same time, earn from this green advocacy on electricity. That is why the concept of Net Metering exists; so that households can benefit from this policy program by installing their own renewable power source at home. Space should not be a problem, for one can just affix their renewable system within their houses, thus maximizing the generation of power and saving monetary resources.

In the Philippines, there is no visible movement related to the Net Metering system campaign; only a few are able to access it due to constrained resources as well. The prototype is designed to test the validity of the hardware for power monitoring. Three cases were thoroughly executed to monitor the power consumption of the loading system and the power sent to the diversion loading, which represents the utility grid.

The prototype is designed as such due to the limited scope of this research. Furthermore, when the loading system's power consumption is lesser than or equal to that of the generated capacity of the generator (representation of the renewable power source), the AC line from the power supply (representation of the utility) is unable to provide power to the load, thus giving the household less power consumption from the utility compared to when solely receiving from the power utility. Power consumption from the utility happens only when the loading system has greater power consumption compared to that of the generated capacity of the renewable source.

The data on the monitoring scheme is indeed the actual data of the loading system. Delays are present, but these delays do not invalidate the setup for power monitoring of a Net Metering Miniature System.

As commercial ones are available in the market, there is a very little research being published and conducted with regards to Net Metering System and this paper wanted to make a significance by being one of the pioneers in the field of Net Metering System research. This miniature setup hopes to inspire researchers to do more related projects and researches in relation to Net Metering System.

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References

[1] Fan Cai, Evangelos Farantatos, Renke Huang, A.P. Sakis Meliopoulos and John Papapolymerou. "Self-powered Smart Meter with Synchronized Data." School of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, Georgia, USA 30308 © 2012 IEEE

[2] William Feldman. "Metering, Monitoring, Managing Energy Costs"

[3] Yu Hailong, Zhao Hongwei, Dou Xingwei. "The Electrical Monitoring Technology Based on the Non-intrysive Load of the Community" [J]. Journal of Logistical Engineering University, 2014, 30(1): 75-78.

[4] Yuan Cheng, Bing Qi, XinQuan LV. "The research of household appliance on-line load monitoring." 2014 China International Conference on Electricity Distribution (CICED 2014), Shenzhen, Sept. 23-26, 2014

[5] Watson, Stephanie. "How Net Metering Works" 11 August 2009. HowStuffWorks.com. <http://www.howstuffworks.com/environmental/green-science/net-metering.htm> 10 August 2015.

[6] Starrs, T. "Net Metering: New Opportunities for Home Power." Washington DC: Renewable Energy Policy Project

[7] "Smart Metering in Australia: Smart Meters for Emissions Control." Retrieved last August 10, 2015 from http://www.ericsson.com/res/thecompany/docs/corporate-responsibility/2012/smart-metering.pdf

[8] OMRON Industrial Automation. "FAQ02083 of Solid-state Relays FAQ." Retrieved last September 30, 2015 from https://www.ia.omron.com/support/faq/answer/18/faq02083/

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Top - Down clustering used in analysis of the Romanian Teachers' Training Needs on Information and Communications Technology

Daniel Hunyadi, Daniel Mara

Abstract

This article presents some important aspects regarding the analysis on Romanian Teachers' Training Needs on Information and Communications Technology (ICT), using top-down clustering. The scope of this analysis is to create clusters regarding to the teacher's training needs on ICT. This analysis was made inside a project which generates significant results in the life-long learning of the teachers from all levels of the Romanian education system. The general objective of the project aims to increase the level of the teaching staff information, competences and abilities concerning the Information and Communications Technology. It also aims to improve the e-learning interactive methods and the activity with the disabled in order to use them also within the didactic activity, to improve the results of the educational process as well as to increase the disabled access to education.

1 Introduction

Education and training in Information and Communication Technology (ICT) are crucial in three of the seven flagship initiatives developed under the Europe 2020. "Digital Agenda for Europe" shows that the current information era requires increasing both digital literacy development and students' inclusion and it emphasizes the importance of access to education through ICT.
The strategy "Romania of Education, Romania of Research" establishes the need for directing education towards eight key skills "required for personal development and knowledge economy", including the acquisition and development of "digital literacy", and also insists on the need to digitize the curriculum.

The strategy "Education and Research for Knowledge Society" sets not only infrastructure-related commitments ("providing all schools with computers connected to the Internet and educational software able to raise the teaching and learning quality"), but also students' acquisition of digital skills and the need for "teachers' lifelong training in blended learning mode", as well.

The existence of such needs is supported by data and studies. Eurostat shows that the ability to use a computer and the Internet are still very low in Romania. In 2012 (the latest data available), only 13% of the population was able to carry out 3 or 4 tasks on the Internet (out of 6 tested tasks) and 17% carried out 3-4 computer-specific tasks (out of 6), Romania being the last of the 31 countries surveyed (compared to the EU 27 average – of 25% and 27% respectively).

The study "Survey of Schools: ICT in Education" ordered by the European Commission shows that Romanian teachers' computer literacy (especially in secondary education) is below the European average.

Regarding the teacher's role in the web age, one may say without any doubt that this is in a continuous transformation process. By the nature of their job, the teacher should mediate and facilitate student's knowledge and training, but without neglecting aspects such as: students' developing critical thinking, increasing communication and networking with peers, and working collaboratively.

If we were to overlap all these issues with web features, we can see that they are compatible, to a large extent. In other words, through technology, applications and web services the instruction process may benefit from the basic elements characterising education, namely: users' interaction and communication, sharing and cooperation established between multiple users, and the information and training processes, as well.

Therefore, to maximize these benefits during the educational process the teacher must know, get acquainted to and be able to exploit web applications, services and technologies. Whether wikis, blogs, podcasts, social networking, bookmarking tools, labelling or social annotation sites, information syndicating processes, specialized search-engines, widgets/ gadgets and so on, they can be extremely useful to teachers in training students.

The major problem which prevents generalization of using these tools by teachers in the educational process is the lack of adequate time for appropriate training. With few exceptions, which are not characteristic for Romanian education, teachers (regardless of the subject they teach) do not receive help from qualified and authorized persons in preparing and using these tools. Therefore, the workload of a teacher should be huge, detrimental to his/her other tasks. Equally true is the fact that, the benefits and satisfaction are worth, so that teachers should not miss the opportunities arisen in lifelong learning.

A teacher in the current era must understand that the student is in the centre of the instruction process, and he/she, as a teacher, should facilitate all these and create an educational environment for the student to be able to access applications, services and current technologies appropriate for the educational process. The teacher's role is also to guide pupils and students, to encourage them to get engaged in conversations, whether virtual or real, both with peers and with teachers, the teacher-student role being thus often reversed. The teacher must therefore understand that he/she shall gain a lot from his/her students' learning experiences, and that they shall go together on this way of reducing physical boundaries of a classroom setting.

More than ever, teachers should guide the students in understanding and critically analysing the information content accessed, in terms of quality and accuracy, especially since the amount of information often grows uncontrollably.

Young people nowadays are using much of their free time to carry out online activities, such as: creating digital content (by posting on blogs, participating in social networks, etc.), communicating with friends/ colleagues/ family, looking for information or creating educational materials. Despite these digital skills and ICT-mediated communication or virtual activities for recreation and leisure, youth are quite poorly prepared when they need to use these skills for academic purposes. When they need to create educational material, gaps on selecting and synthesising the materials they have found are visible from the very first moment. Similarly, critical observation from a comparative perspective is another element that would ultimately lead to less satisfactory results.

2 Literature review

2.1 Clustering and k-means Algorithm

According to [2], clustering is the unsupervised classification of patterns (observations, data items, or feature vectors) into groups (clusters). Vaishali opined that clustering algorithms generate clusters having similarity between data objects based on some characteristics [5].

Clustering is extensively used in many areas such as pattern recognition, computer science, medical, machine learning. Jean Yan states that "formally cluster structure is represented as a set of subset C=C1,……..Ck of S, such that S=$\cup_{i=1}^{k}$ Ci and $C_i \cap$Cj=∅ for $i \neq j$. Consequently, instances in S belong to exactly one and only one subset". Clustering algorithms have been classified into hierarchical and partitional clustering algorithms. Hierarchical clustering algorithms create clusters based on some hierarchies. It is based on the idea of objects being more related to nearby objects farther away [2]. It can be top-down or bottom-up hierarchical clustering. The top-down approach is referred to as divisive while the bottom-up approach is known as agglomerative. The partitional clustering algorithms create various partitions and then evaluate them by some criterion. k-Means algorithm is one of most popular partitional clustering algorithm. It is a centroid-based algorithm in which each data point is placed in exactly one of the K non-overlapping clusters selected before the algorithm is run.

The k-Means algorithm works thus: given a set of d-dimensional training input vectors { x1, x2,.., xn }, the k-Means clustering algorithm partitions the n training examples into k sets of data points or clusters S = {S1, S2, …, Sk}, where k≤n, such that the within cluster sum of squares is minimised.

Generic k-means clustering Algorithms:

- Decide on the number of clusters, k.
- Initialize the k cluster centroids
- Assign the n data points to the nearest clusters.
- Update the centroid of each cluster using the data points therein.
- Repeat steps 3 and 4 until the changes in positions of centroids are zero

2.2 Decision Tree

It is a well known classification method that takes the form of tree structure and it is usually made up of:

- Testing node which holds the data for testing the condition
- Start node is the parent and usually top most node.
- Terminal node (leaf node): is the predicted class label
- Branches: represents results of a test made on an attribute.

Decision tree can be built using different methods, the first method developed was ID3 (Interactive, Dichotomiser) which later metamorphosed into C4.5 classifier. J48 classifier is an improved version of C4.5 decision tree classifier and has become a popular decision tree classifier. Classification and Regression Trees (CART) was later developed to handle binary trees. Thus, ID3, J48 and CART are basic methods of decision tree classification (Aman and Suruchi, 2011 [1]).

Decision trees are powerful and popular for both classification and prediction.

Decision tree algorithm proposed by Jiawei is presents further [4].

Algorithm

Parameters
Dataset T and its fields
Set of Attributes A
Selection Technique for the Attribute

Result
Tree Classifier

Procedure
1. A node is Created (call it E)
2. Check if all records R is in one group G and write node E as the last node in the that Group G
3. If $A = 0$(no attribute)

4. then write E as the last node
5. Use Selection technique for attributes on (R, A) to get the
   Best splitting condition
6. Write the condition on node E
7. Check if attribute is discrete and allows multiway split then
   It is not strictly binary tree
8. For all output O from splitting condition, divide the records and build the tree
9. Assign R $Set\ of\ all\ records\ in\ output\ O_0 =$
10. If $R_o = 0$then
11. Node E is attached with a leaf labelled with majority class R
12. Otherwise node E is attached with node obtained from
    Generate Decision Tree (R_o, A)
13. Next
14. Write E

3 Model specification and results

3.1 Input data

The survey is conducted on a representative sample of Romanian teachers. After the statistical processing of the collected data and after analysing the results derived from data processing, one shall establish the requirements for implementing the training programme for teachers in use of ICT in teaching. The research is also one of the landmarks which shall be used to assess the efficiency and impact of the training programme.

The research was conducted on a sample of 1,400 teachers. The extent of the sample satisfies one of the essential conditions for obtaining reliable results, namely the use of relatively large samples, which gives it representation at national level.

The method used to select study participants was random stratified sampling method, a very widely used method, leading to obtaining a sample under suitable conditions in terms of time and cost, relevant for the analysis of various groups of the surveyed population.

When determining the relevant population, one has taken into account to establish the assembly of individuals or organisations this research focuses on, and which its findings will be reflected on. Depending on the school level where the teachers in the target group work, the sample includes:

- Primary education teachers;
- Lower secondary school teachers;
- Higher secondary school teachers;
- Vocational education teachers;
- Higher education teachers.

The variables and indicators we have started from in drafting this instrument for data collection are:

- independent variables are identified by multiple choice questions (each with one possible answer):
  - identifying the respondent (question type: Information about respondents): the questionnaire enhances respondent's privacy; the respondent is identified by his/her name and surname initials;
  - occupation (type of institution) and experience (seniority): type of the institution where teachers carry out their professional activity;
  - environment (rural/ urban) where teachers carry out their professional activity;
  - gender of the surveyed teachers.

- **dependent variables** seek to test teachers' attitude towards their own professional status and their attitude towards continuous training, based on the following elements:
  - attitude towards their own professional status:

- teachers' satisfaction shown about their professional environment;
- perception on their own professional skills;
- attitude towards lifelong learning:
- teachers' conception of lifelong learning;
- frequency of accessing training courses;
- share of reasons for not participating in training;
- share of accessing training courses content;
- share of teachers' expectations towards future training areas;
- share of the need to develop professional skills;
- teachers' views on the expected features of training courses;
- teachers' views on the benefit of lifelong learning.

The extent to which respondents feel they need training to acquire and strengthen skills, in such areas as:

- knowledge and appropriate use of theoretical concepts related to ICT;
- designing educational content and assessment using specific ICT tools;
- knowledge and use of ICT tools;
- knowing and implementing teaching strategies enabling the effective use of ICT tools and teaching resources in the educational process;
- using basic functionalities specific to word processing programs;
- using basic functionalities specific to spreadsheet programs;
- using basic functionalities specific to presentations editing programs;
- using search programs to access the information available in the virtual environment and communicating by e-mail;
- knowing and getting acquainted with the operating mode of ICT tools providing facilities for converting teaching materials in accessible formats for various types of deficiencies experienced by disabled students.

These are multiple-choice questions, ranging from "to a very great extent" (value 5) up to "to a very small extent" (value 1).

3.2 Model definition

Clustering is a technique for extracting information from unlabelled data. Data Clustering is unsupervised and statistical data analysis technique. It is used to classify the same data into a homogeneous group. It is used to operate on a large data-set to discover hidden pattern and relationship helps to make decision quickly and efficiently. In a word, Cluster analysis is used to segment a large set of data into subsets called clusters.

Our model is built in several steps. In the first step, pre-processing data step, input data are normalized in order to be ready for processing. Then, we use divisive hierarchical clustering in order to obtain the optimum number of clusters.

Normalized input data and the optimum number of clusters are used by k-means algorithm. This algorithm is one of the simplest unsupervised learning algorithms that solve the clustering problem. The procedure follows a simple and easy way to classify a given data set through a certain number of clusters (assume k clusters) fixed apriori. The main idea is to define k centers, one for each cluster. These centers should be placed in a cunning way because of different location causes different result. So, the better choice is to place them as much as possible far away from each other. The next step is to take each point belonging to a given data set and associate it to the nearest center.

3.3 Model implementation

We chose RapidMiner (RM) for implementation of our model [6]. The main reasons which recommend RapidMiner for our model implementation are:

- Is one of the most powerful open-source systems for data mining.
- It includes a large collection of modular operators for design and processing of complex data mining problems
- Knowledge and data miner processes are represented by means of tree-operators. The leaves of the tree correspond to the simplest steps from the modelled process; the interior nods correspond to the abstract steps and the root to the whole process.
- For each operator are defined the input and output data and many settings parameters.
- All RapidMiner processes are described using XML
- It has a user friendly interface.
- It supports a flexible arrangement/rearrangement of operators
- It allows data import from a lot of formats (Excel, CSV, XML, Access, AML, ARFF, XRFF, SPSS, Stata, Sparse, DBase, C4.5, etc.)
- Offers many types of output data visualization thereby proving a easier understanding and interpretation of the results.

For the hierarchical clustering we use TopDownClustering operator. KMeans operator solve the non-hierarchical clustering task offering as output data the clusters. The representation of the clustering solution as a decision tree is realized using DecisionTree operator.
The implemented processes and the practical results are presented in the next section.

3.4 Practical results

First process is used in order to obtain the optimum number of clusters. It use an import operator named ReadExcel which reads an ExampleSet from the specified Excel file. The NominalToNumerical operator is used for pre-processing data named which changes the type of selected non-numeric attributes to a numeric type.

The TopDownClustering operator is used for hierarchical clustering and performs top down clustering by applying the inner flat clustering scheme recursively. Top down clustering is a strategy of hierarchical clustering. The result of this operator is a hierarchical cluster model.
The chains of the process is presented in figure 1.

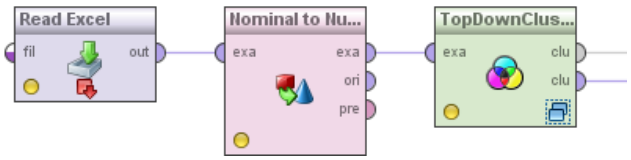

Figure 1. Top-down clustering

Second process is a combination of clustering and decision tree and is used to obtain the representation of the model. The chain of the process use KMeans operator which performs clustering using the *k-means* algorithm. This operator contains a parameter which specifies the number of clusters to form. The input value for this parameter is the value obtained in the first process.

The ChangeAttributeRole operator is used to change the role of one or more attributes. The Role of an attribute reflects the part played by that attribute in an ExampleSet. Changing the role of an attribute may change the part played by that attribute in a process. One attribute can have exactly one role. The target role for out attribute is label.

The final operator in our chain is DecisionTree. This operator generates a decision tree for classification of both nominal and numerical data. A decision tree is a tree-like graph or model. It is more like an inverted tree because it has its root at the top and it grows downwards. This representation of the data has the advantage compared with other approaches of being meaningful and easy to interpret.

The chains of the process is presented in figure 2.

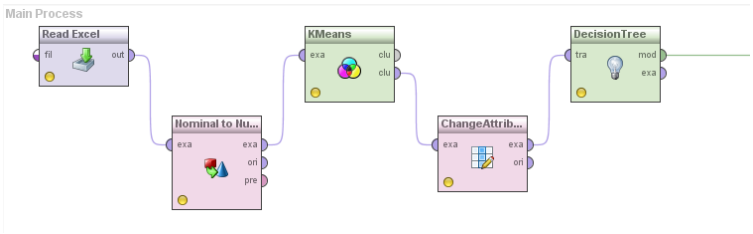

Figure 2. Non-hierarchical process

The clusters obtained using the process presented in figure 2 are show in figure 3.

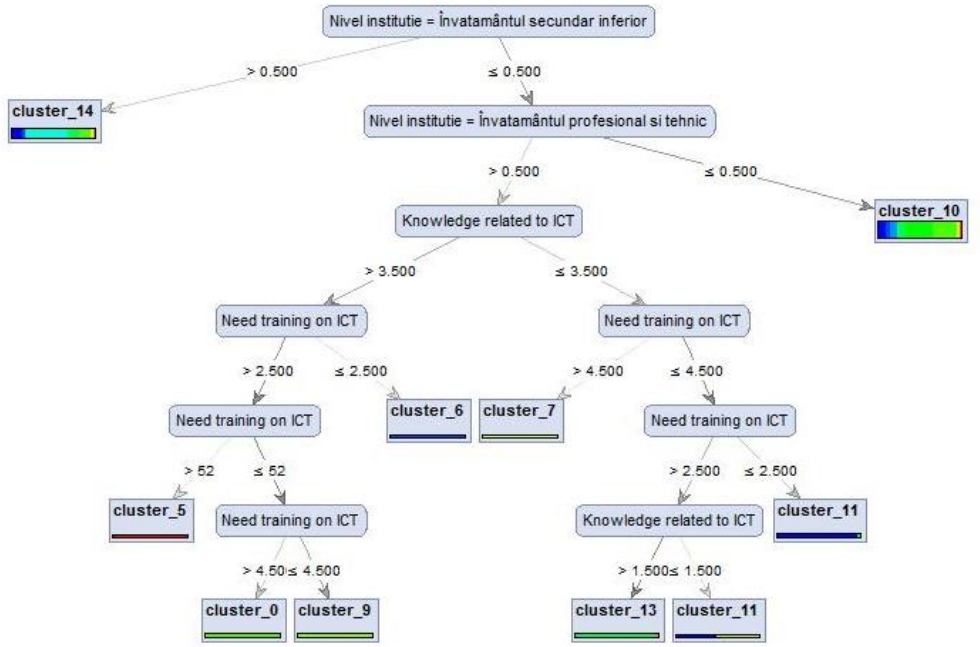

Figure 3. Decision Tree

These clusters help in the selection process in order to create the study groups and to adjust the level courses for each group.

It is suggested that, in establishing the course topics, one should take into consideration such objectives as: focusing on the learner; distributed resources by integrating electronic libraries and multimedia materials; open-minded, reusable learning objects making up adaptive training routes, virtual learning environments; computer assisted collaborative learning, social e-learning, social networking, asynchronous learning networks; simulations, educational computer games.

By attending the course, trainees should be shaped such attitudes as: the principle of equitable access of all students to information resources and technology; the adaptability to the information technology (development) needs and requirements; the use of interactive/ modern teaching methods; bringing virtual environment in the classroom space.

4 Conclusions

The course is recommended to provide information on: the use of ICT tools to streamline both teachers' own activity and the activity of their students; the information features (classification by source, validity, memory consumption, and the eventuality of changing and exchanging information), stressing that there should not be lost sight of, on one hand, the beneficiary-teacher, as a training participant and, on the other hand, the beneficiary-pupil/student, as the beneficiary of educational services offered by the trainees.

In designing the course topics, it is recommended to take into account that, at the end of the course, all participants should be able to use information technologies in their lessons, create digital resources to use in class, and use ICT technology for information and documentation.

In establishing the training methodology and strategies, one must take into account that most of the Romanian teachers are not sufficiently skilled to be enabled to know and get acquainted with the operating mode of ICT tools providing facilities for converting teaching materials in accessible formats for various types of deficiencies experienced by disabled students; to use basic functionalities specific to presentation editing programs; to use search programs to access the information available in the virtual environment and communicate by electronic mail; to know and use ICT tools; to use basic functionalities specific to word processing programs; to use basic functionalities specific to spreadsheet programs.

The course should be designed to facilitate access to technology and information channels and meet teachers' needs, such as: using search programmes to access the information available in the virtual environment and communicating by electronic mail, getting acquainted with digital devices and resources, as educational tools (both for learning and personal development.

Within this training programme, it is recommended to aim at: fostering attendees' creativity, structured thinking ability and interactivity. This training programme should also facilitate: collecting, analysing and interpreting data and information; taking into consideration individual differences and learning progress; use and maintenance of specialized educational software. Some of the key concepts within the course are recommended to be information, efficiency and applicability.

At the end of the training programme, the teacher's psychosocial portrait, as a training participant, should have the following features: to know when, how and where to use technology in his/her lesson, the teacher must know the basic hardware and software operations, and web resources suitable to the subject they teach, he/she should develop ICT based learning environments - to search, analyse and assess information - he/she should creatively and effectively use ICT tools.

The surveyed teachers consider they need training to acquire/ strengthen skills in using ICT tools to streamline both their own activity and the activity of their students. It follows that the approach of the course must be focused, on one hand, on the beneficiary-teacher, as a training participant and, on the other hand, on the beneficiary-pupil/ student, as the beneficiary of educational services offered by the trainees. The recommendation resulted from this situation is not to lose sight of the indirect recipient of the courses offered by this project: the pupil/ student.

This information, drawn from the study, allows us to establish as potential targets, which shall turn into skills, several needs clearly highlighted by the surveyed teachers: frequent use of information technologies in lessons, creating digital resources for classes, use of ICT for information and documentation.

References

[1] Aman Kumar Sharma, Suruchi Sahni, "A Comparative Study of Classification Algorithms for Spam Email Data Analysis", IJCSE, Vol. 3, No. 5, 2011, pp. 1890-1895

[2] A.K. Jain, M.N. Murty and P.J. Flynn,(1999)."Data Clustering: A Review". ACM Computing Surveys, Vol. 31, No. 3.

[3] Jean Yan,(2013). "Big Data, Bigger Opportunities- Data.gov's roles: Promote, lead, contribute, and collaborate in the era of big data". Retrieved from http://www.meritalk.com/pdfs/bdx/bdxwhitepaper-090413.pdf on 14 July 2015.

[4] Jiawei H., Micheline K., and Jian P. (2011)"Data mining: Concept and Techniques" 3rd edition, Elsevier,
[5] Vaishali R. Patel1 and Rupa G. Mehta, (2011). "Impact of Outlier Removal and Normalization Approach in Modified k-Means Clustering Algorithm". IJCSI International Journal of Computer Science Issues, Vol. 8, Issue 5, No 2, September 2011 ISSN (Online): 1694-0814
[6] I. Mierswa, M. Wurst, R. Klinkenberg, M. Scholz, T. Euler, Yale (now: RapidMiner): Rapid Prototyping for Complex Data Mining Tasks, Proceedings of the ACM SIGKDD International Conference on Knowledge Discovery and Data Mining (KDD 2006), 2006.

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Evaluation of the computational complexity of some hash functions

Olga Korol, Mykhailo Dorokhov

Abstract

The paper analyzes the computational complexity of the software implementation of cryptographic algorithms used in communication systems. A method of forming a cascade control codes of integrity and authenticity of data based on the algorithm UMAC with the final stage cryptographically strong hash function strictly on the basis of universal modular transformations algorithms MASH-1 and MFSH-2 has been proposed. Improved algorithm allows provide high collisional properties of strictly universal hashing, low computational complexity in the processing of large volumes of data and provide high safety performance at the level of modern means of provable resistance cryptographic protection. The resulting estimates of the specific computational complexity of forming MAC show that with increasing length of the processed information data for a fixed level of security specific computational complexity is reduced. For a high level of resistance (128 bits), the same result occurs for data blocks of 2^{15} bytes. For check the reliability of hashing algorithms be used the test suite NIST STS on a particular method study the statistical properties of hash functions. The analysis of the test results showed that the proposed algorithm can provide high-level security of modern provable resistance cryptographic protection.

1 Introduction

Studies have shown that using of hash key multilayer circuits allows you to build effective mechanisms for monitoring the integrity and authenticity of information in telecommunication systems and networks. However, the known multilayer structures (for example, the algorithm UMAC) together with the high speed and the cryptographic strength of the layer by applying a cryptographic transformation (using symmetric block cipher) lose properties of universal hashing, which leads to deterioration of the properties of the collision generated message authentication codes. Proposed in [1, 4, 5] universal hashing method using modular transformations algorithms MASH-1 and MASH-2 allows formation of authenticators (hashes) to provide the required parameter of stability.

The aim is to analyze the computational complexity of some hashing algorithms used in communication systems based on an assessment of time and speed performance processor bandwidth, a comparative evaluation of the computational complexity of the improved algorithm, UMAC, using as substrate pseudorandom algorithms modular transformations MASH-1 and MASH-2 and the statistical based security package NIST STS.

2 Analysis of computational complexity of some hashing algorithms.

For comparison of key hashing schemes in terms of durability and performance is customary to use the unit cpb, where cpb (cycles per byte) - specifies the number of processor cycles required for processing one byte of input information. The complexity of the algorithm is calculated according to the formula

$$Per = Utl * CPU\_clock / Rate \quad (1)$$

where *Utl* - utilization of the processor's core, CPU utilization averaged over the time interval – on each segment, where Idle Thread is not running, the processor is considered employed by any real load. This counter – the sum of the CPU utilization by user, system, and during periods of inactivity (Idle + User + System utilization, the name may be different on different platforms). According to the fact that on most platforms there is a separate idle counter CPU, it is recommended to use the following formula to calculate the consumption of CPU

$$CPU\ Consumption = 100 - Idle\ CPU\ (\%) \quad (2)$$

Rate - possibility of carrying algorithm (byte / sec). To assess the capacity, measured in machine cycles per byte for processing messages of different length we should use cycle per byte, because it gives the opportunity to compare the efficiency between processors running at different speeds. To convert to bytes per second, you need to divide the processor cycles per second (Hz) for the transmitted frames per byte. For example, a processor with a clock speed of 1 GHz at 2.0 cycles per byte performs 1e9 / 2,0 = 0.5e9 bytes per second (500 MB / sec).
Example of the values in terms of durability and performance of one of the algorithms contestants of NIST competition to a national standard hash algorithm SHA-3 is shown in Table. 1. Bits given by security categories of block cipher resistance: 80, 112, 128, 192, 256 [7].

Table 1 Durability and performance parameters of hashing algorithm Blake

Hashing algorithms	Security level *Sec* [біт]	Utilization of kernel, *Utl* (%)	Throughput *Rate* (байт/сек)	Complexity of the algorithm, *Per* (cpb)
Hash (Blake-224)	80, 112, 128, 192	56	19286741	61,5
Hash (Blake-256)	80, 112, 128, 192, 256	56	19192519	62,0
Hash (Blake-384)	80, 112, 128, 192, 256	56	15610497	76,0

Analysis of the table shows that the increase in resistance of the algorithm leads to increasing in complexity.

3 Comparative evaluation of the computational complexity of the improved algorithm UMAC

In developed an improved method of forming control codes of integrity and authenticity of data the first layers is proposed to implement the conversion to traditional high-speed algorithm, UMAC, but cryptographically weak universal hashing schemes, the last layer is proposed to implement using the developed safe (cryptographically strong) strictly universal hashing scheme based on modular transformations.
Formally, the proposed scheme of cascade formation control codes of integrity and authenticity of data presented in Fig. 1.

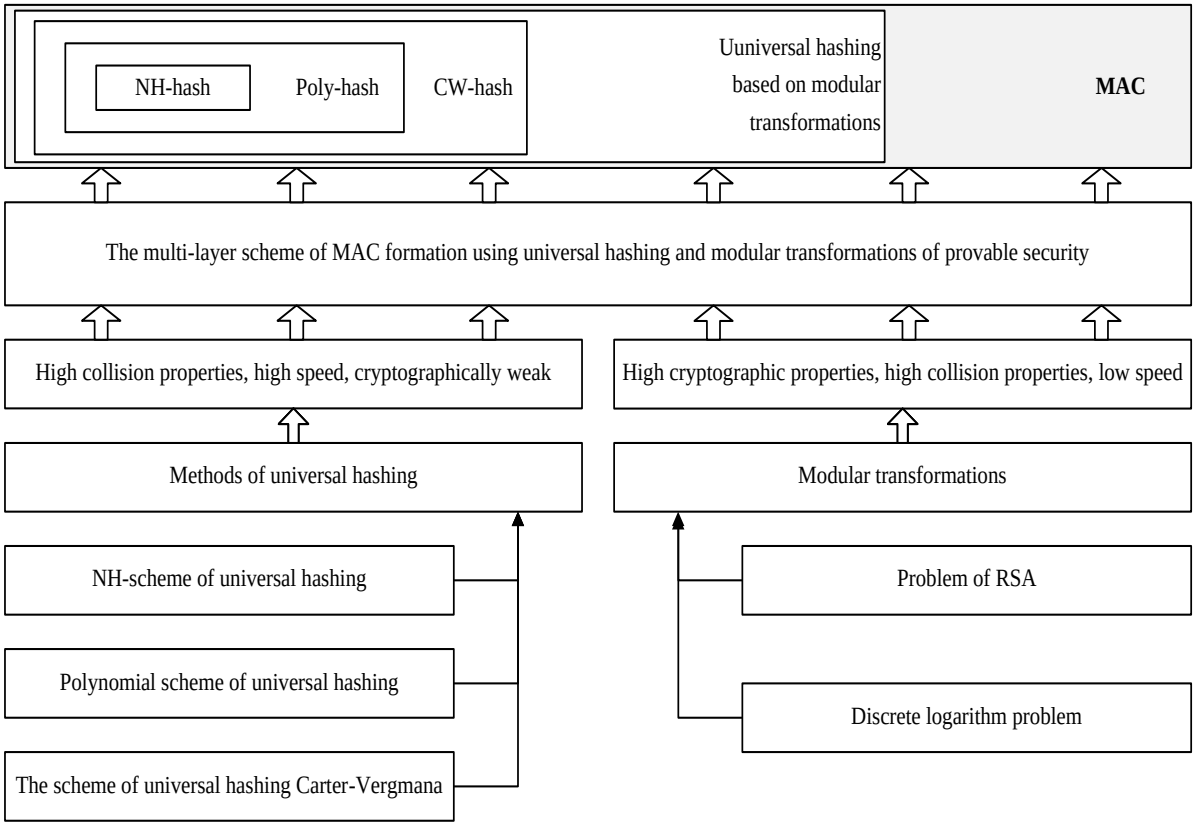

Fig. 1. - Improved scheme of cascade formation of control codes integrity and authenticity of data using modular transformations

For comparison with other schemes in terms of the hash key durability and performance can take the following assumptions. Let one multiplication operation on numbers, of 2^m order requires $\left\lceil \frac{m}{L} \right\rceil$ bitwise addition modulo two (XOR), where L - processor 's digit capacity of the computer system,

$|x|$ - rounded to the nearest integer x. This assumption is most often used when evaluating the complexity of the implementation of cryptographic algorithms [2, 3]. In this case, the assessment of $\left|\frac{m}{L}\right|$ gives an approximate number of cycles of L-bit processor required for the implementation of the multiplication of numbers, which bit length does not exceed from m. At the same time, hashing using modular transformations processing $m/8$ bytes of information data immediately.

Tables 2 and 3 show the results of comparative studies of practical realization of algorithms depending on the number of operations and logical structure of hashing schemes.

Table 2 The number of logical operations in the practice of hashing algorithms

Algorithm	Logical operations									
	AND	OR	XOR	ROTR	SHR	+	ROLs	NOT	MOD	MUL
MD-5	-	-	-	-	-	960	256	-	-	-
RIPEMD-128	-	-	-	-	-	396	128	-	-	-
RIMEMD-160	-	-	-	-	-	650	320	-	-	-
SHA-1	400	240	320	-	-	320	160	-	-	-
SHA-256	320	-	448	384	-	448	-	64	-	-
SHA-384	400	-	560	480	-	560	-	80	-	-
SHA-512	400	-	560	480	-	560	-	80	-	-
MASH1	-	6	4	-	6	1	1	-	6	5
MASH2	-	6	4	-	6	1	1	-	6	260

$\|$ – concatenation, + – addition, *and* – bitwise «AND», *or* – bitwise «OR», *xor* – excluding «OR», *shr* – Shift Right, *rotr* – (Rotate Right) , *ROLs* – cyclic shift to the left by s positions

Table 3 The number of steps and cycles in hashing scheme

Algorithm	Quantity of steps	Number of rounds r	Number of steps in round s	Different constants for each algorithm
MD-	64	4	16	Step
RIPEMD-128	64	4	16	Round
RIMEMD-160	80	5	16	Round
SHA-1	80	4	20	Round
SHA-2 - 256	64	1	64	Step
SHA-2 - 384	80	1	80	Step
SHA-2 - 512	80	1	80	Step

Table. 4 shows the results of comparative studies of the performance of key hashing schemes for fixed safety parameter. Parameter of speed is expressed in an amount of S cycles of 32-bit processor, required for generating one byte of output data. Safety parameter was recorded over the length of the secret key that should be hacked. For modular arithmetic's circuits is given the equivalent length of the key of block symmetric cryptographic algorithm.

Table 4 Estimation of the complexity of hashing algorithms in the number of S cycles of 32-bit processor on a single byte of data processed

Hashing function	Strength level (key length)	Number of rounds *S*
SHA-2 (512)	512	80
SHA-2 (256)	256	64
SHA-1	160	80
RIPEMD-160	160	160
MD5	128	64
Hashing based on modular arithmetic	80	512
	128	1536
	256	7680

The data presented in the Table. 4 show that the use of modular transformations for solving key hashing significantly increases the computational complexity, the performance of algorithms is reduced to 1-2 times. At the same time, developed key hashing schemes have provably resistant safety level (problem of finding the key hash or the inverse image is reduced to solving a certain theoretical and complex problems). In addition, in [1, 4, 5] it is proved that such authentication schemes satisfy the properties of universal hashing to ensure the highest collision characteristics generated by the MAC.
Let estimate the complexity of implementing an improved algorithm UMAC, if the volume of input data is increased.

At the heart of the developed scheme of formation of the MAC using modular transformations is the use of:

- On the first layers - high-speed universal hashing methods (NH-hashing, polynomial hashing, hashing Carter-Vergmana);
- On the last layer - safe strictly universal hash-based modular transformations. The use of a multi-layer structure can also significantly reduce the computational cost of the formation control codes integrity and authenticity of large data sets.

Let us explain the last thesis by the following arguments. Let the first layers of universal hash (as in the method prototype UMAC) are implemented using high-speed (but cryptographically weak) schemes Carter-Vergmana, polynomial structures and so on. (See. Fig. 1). Assume, that the complexity of such a transformation is equal to the complexity of the scheme UMAC, ie about 6 cycles per byte information data. In fact, this estimate is too high, as the most expensive in the scheme UMAC is the last layer of encryption, using the encryption algorithm AES. In other words, the evaluation in six cycles per byte of data to be processed is an estimation of the worst case, i.e. evaluation of the "top" [1, 4, 5]. Assume also that on the last stage of the cryptographic algorithm is used proposed scheme of provably resistant universal hash-based modular transformations instead AES (see. The model in Fig. 1). To assess the complexity of this final stage of formation of the MAC, data in Table 4 should be used. Then the resulting complexity as the number of CPU cycles per byte of data being processed has averaged score on all layers of the transformation in the proposed cascade structure of the calculation codes of controling the integrity and authenticity of data.

Since a major portion of the processed data is supplied only to the first conversion layers (see. The model in Fig. 1) and the last layer with modular cryptographic transformation is used only once for processing hash result for the previous layers of scheme, the resultant estimate of the complexity of large volumes of data to be processed strive for estimating the complexity of the scheme UMAC.
To confirm the above arguments Table. 5 shows a approximate estimation of the complexity of forming control codes of integrity and authenticity of data of proposed scheme using modular transformations.

Table 5 Estimation of the complexity of forming the MAC scheme in an amount of S cycles of 32-bit processor per byte of processed data

Strength level (key length)	Length of input data, bites									
	128	256	512	1024	2048	4096	8192	16384	32768	65536
80	518	262	134	70	38	22	14	10	8	7
128	–	–	1158	582	294	150	78	42	24	15
256	–	–	–	–	7206	3606	1806	906	456	231

The data presented in Table. 5, obtained by calculation by averaging the upper bounds on the complexity of universal hashing on the first layers of the transformations (6 cycles per byte) and evaluation of the complexity of modular transformations (using the round function of the tab. 4. A dash in the table. 5 bear the places in which to hashing Mapping (cryptographic layer) can not be performed. For example, the modular transformations for the level of resistance to an equivalent symmetric cipher key length of 128 bits should be implemented on the module length of not less than 3072 bits (see. Table. 4) that the input data of 256 bytes (2048 bits) of data is impossible. Analysis of the data in table. 5 confirms the above argument to reduce the complexity of the specific conversion (the amount of CPU cycles per byte of input data) with increasing length of the processed information data. In practice, this means that with increasing length of the blocks data, the suggested scheme of formation control codes integrity and authenticity on the computational complexity becomes equivalent to algorithms MD-5 and SHA-1 and SHA-2 algorithms, CBC MAC-Rijndael that is used today in network security protocols (including protocols IPsec).

Table. 6 shows a comparison of the computational complexity of some hash functions. Performance data to the proposed scheme for the MAC with modular transformations are for a minimum level of resistance (capacity of the set of key data of block symmetric cipher is equal to 280) and a sufficient level of resistance (for modular transformation is equivalent to the length of the block symmetric cipher key is 128 bits). Length of generated MAC is equal to 80 bits, and 128, respectively.

Table 6 Estimation of the complexity of forming the MAC with various schemes

Algorithm	Length of input data, bites					
	2048	4096	8192	16384	32768	65536
HMAC-MD5 (128 бит)	9	9	9	9	9	9
HMAC-RIPE-MD (160 бит)	27	27	27	27	27	27
HMAC-SHA-1 (160 бит)	25	25	25	25	25	25
HMAC-SHA-2 (512бит)	84	84	84	84	84	84
CBC MAC-Rijndael (128 бит)	26	26	26	26	26	26
CBC MAC-DES (64 бита)	62	62	62	62	62	62
Improved scheme of UMAS with modular transformations (80 bit)	38	22	14	10	8	7
Improved scheme of UMAS with modular transformations (128 bit)	294	150	78	42	24	15

For all the functions listed in Table. 6 (except for proposed using modular transformations) the complexity of the specific formation control codes integrity and authenticity of data does not depend on the volume of data to be processed (Table. 6 filled by data from the report of the competition NESSIE [2]). For an improved method UMAC using modular transformations specific complexity with increasing length of data to be processed is reduced. Thus, for high-level resistance (equivalent to the length of a symmetric cipher key block is 128 bits) even for blocks of 32768 bytes of data are comparable with the known and used in network security protocols MAC generated algorithm. For a minimum level of resistance (the cardinality of the key data block symmetric cipher is 280) The proposed scheme cascade

formation control codes integrity and authenticity of data using modular transformations is not inferior in speed used to date the formation of MAC algorithms in protocols network security, including the protocols IPsec for data packets of 2048 bytes

Thus, the research results show that the developed scheme of formation control codes integrity and authenticity of data using modular transformations enables high collisional properties of secure hashing. Furthermore, due to the multilayer structure hashing code there is significant reduce of the computational complexity and raising of the processing speed of information messages.

The obtained theoretical results can justify the practical recommendations on the use of the developed models and methods of forming the cascade control codes of integrity and authenticity of data to improve the security of telecommunication systems and networks.

To ensure the integrity and authenticity of data in telecommunications networks used manipulation detection code (MDC), message authentication codes (MAC). For example, a network security protocol IPSec control codes for generating the integrity and authenticity have mandatory ICV algorithms (to ensure compatibility of software from different manufacturers): HMAC-MD5, HMAC-SHA-1, as well as other (additional) algorithms, for example, DES-MAC. These mechanisms are applied by default to ensure the integrity and authenticity of data packets in all implementations of IPv6.

4 Assessment of the statistical security of hashing scheme based on NIST STS package

To test the stability of algorithms, hashing applicants use a set of tests NIST STS for certain research methodology of the statistical properties of hash functions [6].

For testing were taken the following parameters:

– test sequence length $n = 10^6$ bits;

– number of test-sequence $m = 100$;

– significance level $\alpha = 0{,}01$.

Thus, the volume of the test selection is:

– $N = 10^6 \times 100 = 10^8$ bits;

– number (q) for different lengths q = 189, so the statistical portrait of generator is 18900 values of probability P.

Test results of hashing algorithms are summarized in Table. 7.

Table 7 Results of tested hashing algorithms

Generator	The number of tests in which the testing have passed over 99% of sequences	The number of tests in which the testing have passed over 96% of sequences
BBS	134 (71%)	189 (100%)
FIPS 197	126 (67%)	189 (100%)
Blake	130 (69%)	189 (100%)
CubeHash	137 (73%)	189 (100%)
ECHO	139 (74%)	189 (100%)
Grostl	140 (75%)	189 (100%)
Keccak	134 (71%)	187 (98,94%)
MASH-1	101 (53%)	47 (24%)
MASH-2	126 (67%)	189 (100%)
MASH(EC)	141 (74%)	189 (100%)
UMAC 32	167 (88%)	189 (100%)
HMAC-SHA-256	134 (71%)	187 (98%)
EMAC	138 (73%)	189 (100%)
RIPEMD-160	129 (68%)	189 (100%)
UMAC+MASH-2	173 (91%)	189 (100%)

These results confirm the theoretical studies of resistance developed by the cascade method of hashing UMAC with the last layer as pseudorandom pad of modular transformations algorithms MASH-1 and MASH-2.

5 Conclusions

Based on the data shown in Table. 6, it can be argued that the developed scheme of forming a cascade control codes of integrity and authenticity of data using modular transformations is not inferior to the used in the protocols IPSec mechanisms by speed, while increasing the input sequence data provides a significant gain in speed of formation of the hash code. At the same time, the proposed scheme provides demonstrable proof security and conflict-level properties of strictly universal hashing. Since the protocol specification AH and ESP IPSec provides the use of new, more efficient algorithms of ICV, for the protection of data packets in communication networks is proposed the use of the developed models and methods of forming the cascade control codes of integrity and authenticity of data based on the modular transformations.

References

[1] Kuznetsov O.O. *Information security in information systems* / Kuznetsov O.O., Yevseyev S.P., O.G. Korol. - H .: Type. KhNUE, 2011. - 504 p.

[2] *Final report of European project number* IST-1999-12324, *named New European Schemes for Signatures, Integrity, and Encryption,* April 19, 2004 – Version 0.15 (beta), Springer-Verlag.

[3] *Cryptography and Network Security: Principles and Practice* / Stallings W. 1997. - 752

[4] Korol O.G. *Study methods Provision authenticity and integrity of data based on unilateral hash functions* // O.G. Korol, S.P. Evseev. Scientific and technical journal "Information Security". Special Issue (40). - 2008. - P. 50 - 55.

[5] Korol O.G. *Enhanced MAC algorithm based on the use of modular transformations* // O.G. Korol. "Radio Electronics, Computer Science, Control". № 1. - 2015. - P. 60 - 67.

[6] *Statistical testing technique NIST STS and mathematical proofs tests*. - Kharkiv: Institut information technology. - 2004. - 62 p.

[7] *Status Report on the First Round of the SHA-3 Cryptographic Hash Algorithm Competitionhttp* Andrew Regenscheid, Ray Perlner, Shu-jen Chang, John Kelsey.

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A continuous reformulation of the quadratic unconstrained binary optimization problem

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Abstract

In this paper we consider the Quadratic Unconstrained Binary Optimization (QUBO) Problem. Using a suitable function and penalty parameter we can reformulate the original QUBO problem as a continuous program. It is shown that the problem of large size can be reduced to two constraints. A new convex formulation is then proposed.

1 Introduction

In this paper we consider the quadratic unconstrained binary optimization (QUBO) problem:

$$\left.\begin{aligned} f(x) = x^T Qx + c^T x = \sum_{i=1}^{n}\sum_{j=1}^{n} q_{ij} x_i x_j + \sum_{i=1}^{n} c_i x_i \to \min \\ \text{subject to } x_i \in \{0,1\}, \forall i = 1,2,\ldots,n, \end{aligned}\right\} \quad (1)$$

where Q is a $n \times n$ real symmetric matrix, but not necessarily positive semidefinite, c is a constant vector: $c = (c_1, c_2, \ldots, c_n)^T \in \Re^n$ and x is an n-vector of binary variables: $x \in \{0,1\}^n$. The superscript "T" indicates transposition. $\Re^n$ is the Euclidean space of n-dimensional column vectors with the inner product $x^T y = \sum_{i=1}^{n} x_i y_i$ and $\Re$ denote the set of real numbers.

The problem considered by quadratic programming (1) occurs in different applications [1], [2], [3]. There are several problems of decisions whose modeling is reduced to the binary quadratic optimization. Such problems are frequently found in *Operations Research,* in *Graph Theory,* in *Economic Science* and in other areas [4], [5]. The QUBO problem is a problem of combinatorial optimization and is well known as *NP – hard* [6] and so, is difficult to solve. For example, the well studied *max-cut problem* is a problem of QUBO.

There were developed and proposed different methods of solving and various relaxation techniques of the considered problem:

- Semidefinite Relaxation [7]
- Lagrangian Relaxations [7]
- Linearization Techniques [8], [9]
- Convex – programming Relaxation [10], [11], [12], [13]
- Heuristic Methods [4], [14].

The simplest relaxation technique is the continuous relaxation that consists in replacing the discrete conditions $x_i \in \{0,1\}, i = 1,2,\ldots,n$ with continuous constraints $0 \le x_i \le 1$ for all $i = 1,2,\ldots,n$.

In the present paper are considered some representations of the binary set $\{0,1\}^n$ by means of which continuous reformulations for the QUBO problem could be obtained. But there are many large dimension problems at practical applications which are intractable.

This paper is organized as follows: in Section 2 we extend a well-known result on representation the constraints $x_i \in \{0,1\}, i = 1,2,\ldots,n$; in the third Section we show how one can considerably

reduce a big number of simple constraints $0 \le x_i \le 1, i = 1,2,\ldots,n,$ to only two convex constraints. In Section 4, by means of penalization parameters, the initial problem is reduced to a known problem in literature - *DC problem*.

2 Continuous Reformulation of QUBO Problem

The QUBO problem can be transformed into a continuous optimization problem, represented the binary set $\{0,1\}^n$ through inequations system:

$$\left.\begin{array}{l} p(x) \le 0, \\ 0 \le x \le e, \end{array}\right\} \tag{2}$$

where $e = (1,1,\cdots,1)^T$ is the vector, all components of which are equal to one and $p(x): \Re^n \to \Re$ is a continuous function that checks the inequality and the equality:

$$\left.\begin{array}{l} p(x) \ge 0, \forall x \in [0,1]^n, \\ p(x) = 0 \text{ and } \text{ if and only if } x \in \{0,1\}^n. \end{array}\right\} \tag{3}$$

Acting as $p(x)$ with the above properties (3) has been proposed and used the concave functions [15], [16]:

$$p(x) = \sum_{i=1}^{n} x_i (1 - x_i) = x^T (e - x)$$

or

$$p(x) = \sum_{i=1}^{n} \min(x_i, 1 - x_i) .$$

There is infinity of such functions. In what follows, we would propose three other continuous functions with similar features.
Let the function

$$p(u) = (1-u)|1-u| + u|u| - (1-2u)^2 = \begin{cases} 2u(1-2u), \text{if } u \le 0, \\ 2u(1-u), \text{if } 0 \le u \le 1, \\ 2u(3-2u) - 2, \text{if } u \ge 1. \end{cases} \tag{4}$$

Function $p(u)$ is a concave function, continuously differentiable to derivatives:

$$p'(u) = \begin{cases} 2(1-4u), \text{if } u \le 0, \\ 2(1-2u), \text{if } 0 \le u \le 1, \\ 2(3-3u) - 2, \text{if } u \ge 1. \end{cases}$$

It is found easily that the function

$$p_1(x) = \sum_{i=1}^{n} \left[(1-x_i)|1-x_i| + x_i|x_i| - (1-2x_i)^2 \right] \tag{5}$$

has the required properties.
Another function would be

$$p(u) = 1 - |2u - 1| = \begin{cases} 2u, \text{if } u \le \dfrac{1}{2}, \\ 2(1-u), \text{if } u \ge \dfrac{1}{2}, \end{cases} \tag{6}$$

which generates the function

$$p_2(x) = \sum_{i=1}^{n} \left[(1 - |2x_i - 1| \right]. \tag{7}$$

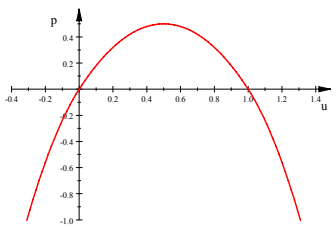
We bring another example of a function $p(u)$ that is twice continuously differentiable but is not concave on the interval $[0,1]$:

$$p(u) = -|2u-1|^3 + 3u^2 - 3u + 1 = \begin{cases} u(8u^2 - 9u), \text{if } u \le \frac{1}{2}, \\ -8u^3 + 15u^2 - 9u + 2, \text{if } u \ge \frac{1}{2}. \end{cases} \quad (8)$$

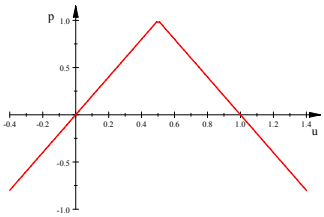
which generates the function

$$p_3(x) = \sum_{i=1}^{n} \left[-|2x_i - 1|^3 + 3x_i^2 - 3x_i + 1 \right]. \quad (9)$$

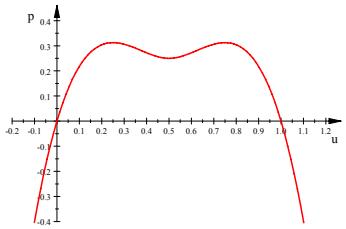
Graphs functions (4), (6) and (8) are presented below (Fig. 1):



$p_1(u) = (1-u)|1-u| + u|u| - (1-2u)^2$



$p_2(u) = 1 - |2u-1|$



$p_3(u) = -|2u-1|^3 + 3u^2 - 3u + 1$

Fig. 1.The graphs of $p_1(u)$, $p_1(u)$ and $p_3(u)$.

Using the functions (5), (7) or (9), quadratic programming problem (1) can be representing in the equivalent form:

$$\left.\begin{array}{ll} f(x) = x^T Qx + c^T x \to \min \\ \text{subject to} & p_1(x) \le 0, \\ \text{or} & p_2(x) \le 0, \\ \text{or} & p_3(x) \le 0, \\ \text{and} & 0 \le x \le e. \end{array}\right\} \quad (10)$$

We mentioned that $p_s(x) = 0$, $s = 1, s = 2$ or $s = 3$ for any $0 \le x_i \le 1$, $i = 1,2,\ldots,n$.

3 Reducing the Number of Constraints

The problem (10) includes 2*n* simple constraints:

$$\left.\begin{array}{l} x_i \ge 0, i = 1,2,\ldots,n, \\ x_i \le 1, i = 1,2,\ldots,n. \end{array}\right\}$$

For sufficiently large *n* there are some major problems in solving the problem (10).
In what follows we will show how we can reduce these *2n* simple restriction to only two convex constraints.
The constraint $u \ge 0$ is equivalent to inequation $\gamma_1(u) \le 0$ or with the inequation $\gamma_2(u) \le 0$, and the constraint $u \le 1$ is equivalent to $\gamma_3(u) \le 0$ or with $\gamma_4(u) \le 0$ where

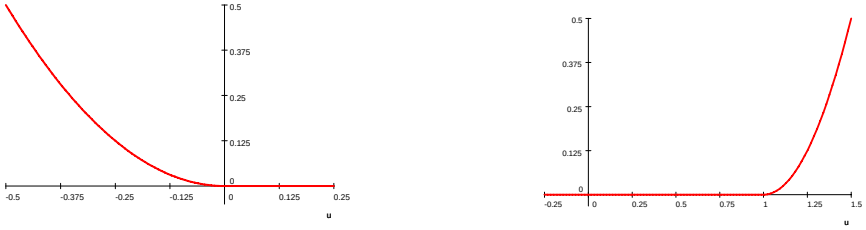
$$\gamma_1(u) = u^2 - u|u| = \begin{cases} 2u^2, \text{if } u \le 0, \\ 0, \text{if } u \ge 0, \end{cases}$$

$$\gamma_2(u) = -u + |u| = \begin{cases} -2u, \text{if } u \le 0, \\ 0, \text{if } u \ge 0, \end{cases}$$

$$\gamma_3(u) = (1-u)^2 - (1-u)|1-u| = \begin{cases} 0, \text{if } u \le 1, \\ 2(1-u)^2, \text{if } u \ge 1, \end{cases}$$

$$\gamma_4(u) = -1 + u + |1-u| = \begin{cases} 0, \text{if } u \le 1, \\ 2(-1+u), \text{if } u \ge 1. \end{cases}$$

The functions $\gamma_1(u),\ \gamma_2(u),\gamma_3(u)$ and $\gamma_4(u)$ are convex functions for $\forall u \in \Re$, for example, $\gamma_1(u)$ and $\gamma_3(u)$ look like that (Fig. 2):



$$\gamma_1(u) = u^2 - u|u| \qquad \gamma_3(u) = (1-u)^2 - (1-u)|1-u|$$

Fig. 2.The graphs of $\gamma_1(u)$ and $\gamma_2(u)$

As $x_i^2 - x_i|x_i| \geq 0$ and $-x_i + |x_i| \geq 0$ for $\forall x_i \in \Re$ the restrictions $x_i \geq 0, i = 1,2,\ldots,n$ are equivalent to the constraint $\varphi_1(x) \leq 0$ or $\varphi_2(x) \leq 0$, where

$$\begin{aligned} \varphi_1(x) &= \sum_{i=1}^{n} \left[x_i^2 - x_i|x_i| \right], \\ \varphi_2(x) &= \sum_{i=1}^{n} \left[-x_i + |x_i| \right]. \end{aligned} \tag{11}$$

Similarly it is determined that the conditions $x_i \leq 1, i = 1,2,\ldots,n$ are equivalent to the convex constraint $g_1(x) \leq 0$ or $g_2(x) \leq 0$, where

$$\begin{aligned} g_1(x) &= \sum_{i=1}^{n} \left[(1-x_i)^2 - (1-x_i)|1-x_i| \right], \\ g_2(x) &= \sum_{i=1}^{n} \left[-1 + x_i + |1-x_i| \right]. \end{aligned} \tag{12}$$

The functions $\varphi_1(x)$, $\varphi_2(x)$, $g_1(x)$ and $g_2(x)$ are convex and determines convex set. For example, for $n = 2$ the functions $\varphi_1(x)$ and $g_1(x)$ are as follows (see Fig. 3):

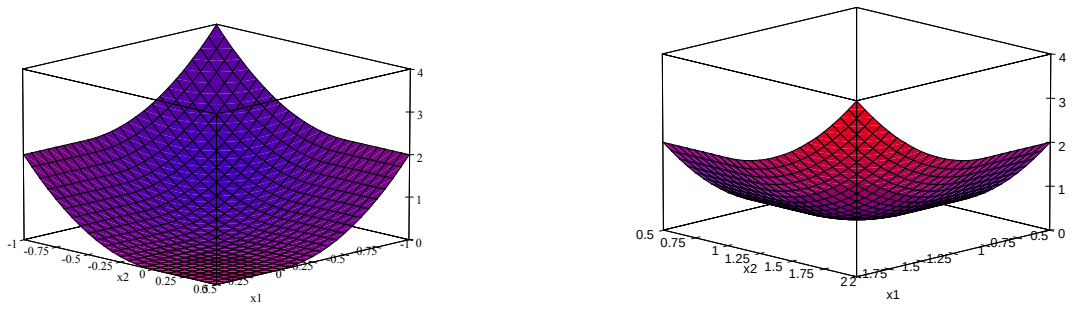


Fig. 3. The graphs of $\varphi_1(x)$ and $\varphi_1(x)$ $g_1(x)$

So the problem (10) which has (2*n*+1) constrains can be reduced to a problem of optimization only with three constrains:

$$\left.\begin{aligned} &f(x) = x^T Q x + c^T x \to \min \\ &\text{subject to } p_1(x) \leq 0, \\ &\qquad\qquad \varphi_1(x) \leq 0, \\ &\qquad\qquad g_1(x) \leq 0, \end{aligned}\right\} \tag{13}$$

or

$$\left.\begin{array}{l} f(x) = x^T Qx + c^T x \to \min \\ \text{subject to } p_2(x) \le 0, \\ \qquad\qquad \varphi_2(x) \le 0, \\ \qquad\qquad g_2(x) \le 0, \end{array}\right\}, \tag{14}$$

where the convex functions $\varphi_1(x)$, $\varphi_2(x)$, $g_1(x)$, $g_2(x)$ are determined by the formulas (11) and (12), while the concave functions $p_1(x)$ and $p_2(x)$ by formulas (5) and respectively (7).

4 Reduction to a DC problem

In problems (13) and (14) the constraints $p_1(x) \le 0$ or $p_2(x) \le 0$ are difficult as they represent non-convex sets. One way to ease the solution of problems (13) and (14) is to penalize these constraints. This can be carried out in such a way: Let us consider the optimization problem obtained from the problem (13):

$$\left.\begin{array}{l} \widetilde{f}(x) = x^T Qx + c^T x - \tau\, p_1(x) \to \min \\ \text{subject to} \\ \qquad\qquad \varphi_1(x) \le 0, \\ \qquad\qquad g_1(x) \le 0, \end{array}\right\} \tag{15}$$

where $\tau > 0$ is a sufficiently large positive number (parameter penalty). If the matrix Q is positive semidefinite then the function $\widetilde{f}(x)$ is represented as the difference of two convex functions and thus the problem (15) becomes a DC (*Difference of Convex Functions*) Programming [17], [18]. It could be found a τ_0 so that for $\forall \tau \ge \tau_0$ the problems (13) and (15) have the same optimal solutions. To solve such problems (15) can be used with success DC Algorithm [18].

5 Conclusions

In this work we are interested in the resolution of quadratic optimization problem in variable binary 0-1.The main idea is to transform QUBO problem into a new problem of optimization with only two convex constraints. The objective function $f(x)$ is reformulated a new function $\widetilde{f}(x)$, convex and equal to $f(x)$ for any admissible solutions QUBO problem. The results obtained with this approach are promising. On all convex functions that we considered $p_1(x)$, $\varphi_1(x)$ and $g_1(x)$ to have been very effective.

References

[1] L. A. Wolsey. *Integer Programming*, Wiley- Interscience, 1998.

[2] C.A. Floudas and V. Visweswaran. *Quadratic Optimization*. In "Handbook of Optimization", R. Horst, P. M. Pardalos (eds), Kluwer Academic Publishers, Dordrecht/ Boston/ Condon, 217-270,1995.

[3] A. Billionnet.*Quadratic 0-1 Bibliography.* http://cedric.cnam.fr/fichiers/RC611.pdf

[4] P.L. Hammer (Ivănescu), S. Rudeanu. *Boolean Methods in Operation Research and Related Areas.* Springer Berlin Heidelberg. 2014. 331 p. (reprint of the 1st edition 1968).

[5] A. Boros, P. L. Hammer. *Pseudo-Boolean Optimization.* Discrete Applied Mathematics. Vol. 123, 155-225, 2002.

[6] M. Garey, D.Johnson. *Computers and Intractibility: A Guide to the Theory of NP-Completeness.* W.H. Freeman & Company, 1979.

[7] C. Lemarechal and F. Qustry. *Semidefinite Relaxation and Lagrangian Duality whith Application to Combinatorial Optimization.* Research Report N. 3710, INRIA Rhone-Alpes, France, 1999.

[8] H. D. Sherali and W. P. Adams. *A Reformulation – Linearization Technique for Solving Discrete and Continuous Nonconvex Problems.* Kluwer Academic Publishers,, Norwell, MA, 1999.

[9] W. P. Adams, R. Forrester and F. Glover. *Comparisons and Enhancement Strategies for Linearizing Mixed 0-1 Quadratic Programms.* Discrete Optimization. **1(2):** 99-120, 2004.
[10] S. Poljak and H. Wolkowics. *Convex Relaxations of (0,1) Quadratic Programming.* Mathematics of Operations Research, V. 20, 550-561.
[11] P. L. Hammer and A. A. Rubin. *Some Remark on Quadratic Programming with 0-1 Variables*. RAIRO, **3:**, 67-79, 1970.
[12] A. Billonnet and S. Elloumi. *Using a Mixed Integer Quadratic Programming Solver for the Unconstrained Quadratic 0-1 Problem*. Mathematical Programming, Published online, 2006.
[13] M. W. Carter. *The Indefinite Zero-One Quadratic Problem.* Discrete Applied Mathematics, **7:,**23-44, 1984.
[14] J. E. Beasley. *Heuristics Algorithms for the Unconstrained Binary Quadratic Programming Problem.* 1998. http://mscmga.ms.ic.ac.uk/jeb/jeb.html.
[15] Le Thi Hoai An, Tao Pham Dinh, T. Huynh Van Ngai. *Exact Penalty Techniques in DC Programming.* SIAM Conference on Optimization, 2005.
[16] Le Thi Hoai An, Tao Pham Dinh. *A Continuous Approach for Globally Solving Mixed Integer Programming*. Sixth SIAM Conference on Optimization. Georgia, USA, Atlante, May 10-12, 1999.
[17] R. Host, N. V. Thoai. *DC Programming: Overview.* Journal of Optimization and Applications, 105 (1): 1-43, 1999. http://link.springer.com/article/10.1023%2FA%3A1021765131316#page-2
[18] Le Thi Hoai An, Tao Pham Dinh. *The DC (Difference of Convex Functions) Programming and DCA Revisited with DC Models of Real World Nonconvex Optimization Problems.* Annals of Operations Research, 133 (1), 23-46, 2005. http://link.springer.com/article/10.1007%2Fs10479-004-5022-1.

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Contributions to the diagnosis of kinematic chain components operation by analyzing the electric current and temperature of the driving engine

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Abstract

The analysis of the electric current and temperature can constitute a very valuable instrument in any monitoring program of the operating status of the kinematic chain components of an equipment and gives to maintenance department the possibility to choose the moment of an intervention; as a direct result it reduces the costs by planning the downtime period (for repairs) in favorable moments. The analysis of electric current and temperature is based on the fact that the engine can be regarded essentially as a transmitter. By installing an electric current sensor we can observe the electric current fluctuations of the engine. It is important to understand the limitations of using this type of analysis, imposed by the load conditions, when the engine is insufficiently loaded, and it is important to take all the logistic measures to obtain correct data which allow to evaluate the evolution of the engine parameters. Taking into consideration the load at which the engine is operating when the analysis of the electric current and temperature is made, we can monitor the results that appear during normal loading conditions of the equipment. Having in mind that in this case the engines can be tested remotely, from the control panel, the risk of making measurements in dangerous and inaccessible areas is eliminated right from the beginning. The results will be materialized in increased confidence in the accuracy of monitoring and will give the possibility of early recommendations for the maintenance department, leading to the amortization of the investment required to implement the research (the analysis of electric current and temperature) into an equipment.

Keywords: motor current, maintenance, transducer current, monitoring.

Introduction

The research performed till the present moment shows that up to 20% of the electric motors used in industry have various defects, such as: defects of the rotor, the rotor bars cracked or broken and the eccentricity of the rotor. A motor can also induce in the windings a current five or six times higher than the current absorbed, which can create a number of problems at startup. Nowadays there are effective techniques of maintenance to predict the critical faults of the electric machines in order to prevent their damage and the production disruption.Based on this research, this paper proposes to take

over some technical data used for the maintenance of the electric motors, for analyzing the behavior of the components of a machine-tool kinematic chain.

1. Electric current analysis

The analysis of the operation of kinematic chain components by studying the parameters of the current is the part of novelty that proposes to analyze the information collected from the main driving motor of an equipment though the agency of a transducer, an acquisition board and LabVIEW software in order to determine the necessary maintenance and to make a decision without having to interrupt the production. This method is used concomitantly with the thermal analysis to confirm the diagnosis of the key machinery in the production chain. The analysis of electric current is based on the fact that the engine can be regarded as a transducer. By installing a current transducer it is possible to determine the fluctuations of electric current in the motor. In this way the equipment can be tested remotely, from the control panel, from the office or from a cell phone, eliminating the risks of performing measurements in dangerous or inaccessible areas of the production chain. A current signal generated from the electric motor is a perfect sinusoid at 50 Hz. During operation, several harmonics will be found in the signal measured, so the real signal will include several peaks, including those incurred in the line frequency and its harmonics. This is the specific spectrum of the engine. Analyzing these harmonics according to signal amplification and processing allows to identify the poor operation of the elements of a kinematic chain. The research shows that when there is a high resistance (for example: the improper operation of an element of the kinematic chain) there are changes of the electric current value. This information helps to determine the input current modulation. Knowing this information allows determining the presence and evaluating the operation level of the kinematic chain.

2. Detection of faults

When conducting research work on electric current analysis, it is necessary to observe-determine if the engine is loaded at least 65%, so that the research findings be eloquent. In order to have a determination of maximum efficiency, it is necessary to read the amperage at idle running before starting the actual analysis. The equipment proposed to be monitored are part of industrial installations and technological flows that require variable working conditions. In order to carry out conclusively this research it is necessary to choose the most appropriate moment to retrieve the information in the operation of the system-kinematic chain.

In this situation, one can determine the performances of the motors and carry out effective monitoring of their history, even when the system has variable working parameters, provided that the load is large enough. As long as the load is large enough, we can correctly assess the system condition if we have sufficient data to outline the evolution of the machinery over time. When the system is loaded below 65%, the accumulated information leads us to the decision to install other equipment with proper characteristics for production needs.

As highlighted by the research conducted so far, the demodulated current spectrum is one of the most valuable results achieved within the techniques and technologies of predictive maintenance. Modulation occurs when the signal of low frequency increases and merges with the signal of high frequency, creating another signal. Thus, the dominant peak appears at the carrier frequency and most of the spectrum information is lost because of the background noise. Demodulation is the process of

removing the spectrum carrier frequency. In this case, the carrier frequency is the fundamental frequency of the power line used, namely 50 Hz. After removing the carrier frequency, only the frequencies due to load repetitive variations remain in the demodulated spectrum. In the electric current demodulated spectrum one can identify the fault frequencies (malfunction) and establish the evolution trend of the peaks occurred at these frequencies.
Thus the engine from which we take over the information will act as a permanently installed transducer. However we should take into account the comparison of the determined spectrum with a reference spectrum, measured when the equipment is in perfect running condition and operates at optimum parameters and also the comparison of the spectra of identical kinematic chains – equipment working in the same conditions. When registering the statistical and historical data, we have more indications on setting the alarm level for different types of equipment. In this context, the peaks occurred at low frequencies are lost in the background noise. In this case, the signal demodulation becomes very important. By eliminating the line frequency (50 Hz) from the spectrum, one can identify (presence of peaks) the frequencies characteristic to possible mechanical faults.

3. Fault monitoring system of a kinematic chain based on current footprint method

The analytical modeling of the engine before starting the monitoring is needed as a basis for the analysis conducted to highlight the effects of the faults of broken rotor bar type on engine performances. The technical environment enables the modeling and simulation in steady state conditions and in transient conditions of engine operation, without and with defects of the kinematic chain elements, by highlighting the influence of the defect on engine parameters: current, torque, rotational speed, temperature.
The engine should be checked first because the presence of the broken bars makes the value of the phase currents and of the electromagnetic torque to decrease in the same time with the increase of the broken bars number [4]. The relative variation of the current through the rotor bars highlights that a significant increase of the rotor current occurs in the bar next to the affected bar[5]. When all possible defects have been eliminated from the motor it is possible to start the monitoring of the kinematic chain. Normally, the recording is made for the 3 phases of the motor but in order to simplify implementation and to reduce the cost of development, the parameters monitoring will be made for a single phase of the electric motor (in the case of this research). Monitoring the variation of supply voltage is necessary for neglecting the possible errors occurred because of the incorrect variation thereof. The improper variation of the electric current enables the detection of malfunction of equipment kinematic chain elements as a result of the problems encountered with the electric motor.
It has been developed a system built for monitoring the operating parameters of electric motors and for highlighting a malfunction of a kinematic chain (Fig.3). The system includes a data acquisition module represented by a platform NI - DAQ, 6251 (Fig. 2), connected to a computer via USB port, an extension module that contains specific sensors for measuring the values of parameters and a LabVIEW software application for processing and representation of the information recorded by the acquisition module[1].

Figure 1. Burg Wächter device[7] for temperature direct measurement

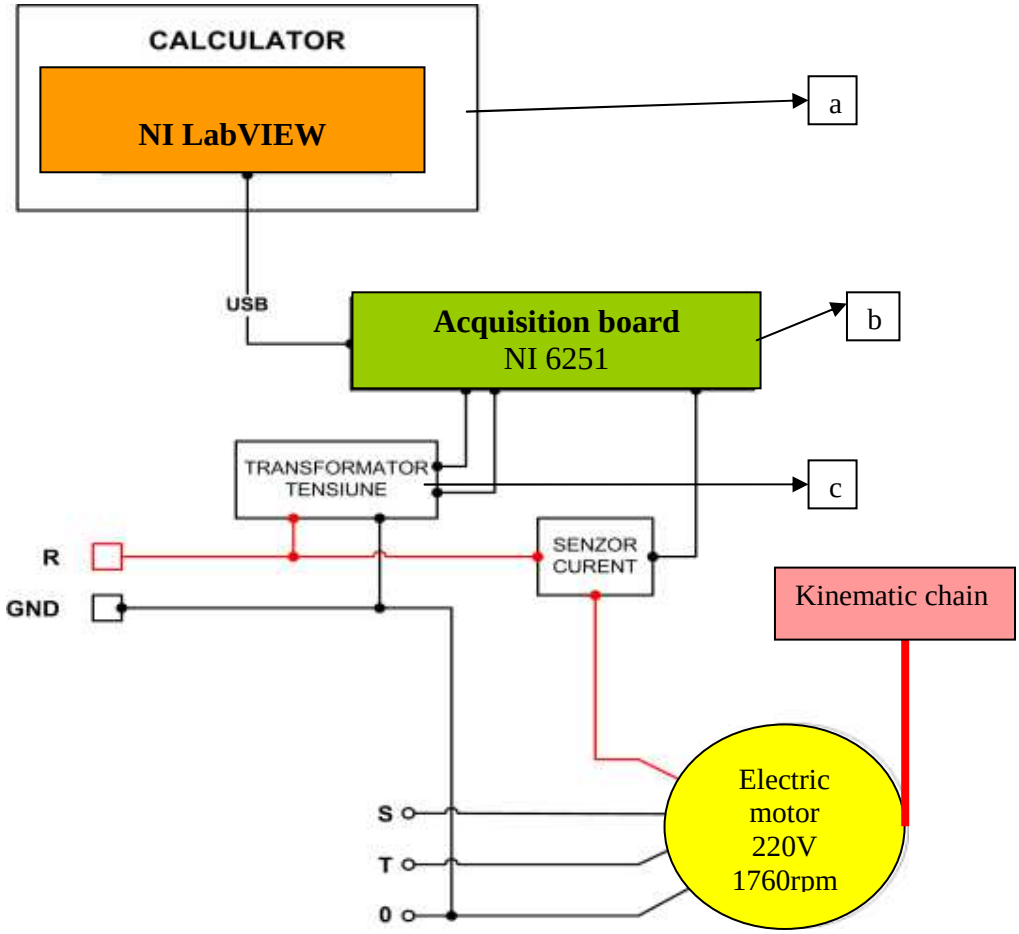

Figure 2. Monitoring system of the kinematic chain parameters

(a. LabVIEW software, b. NI 6251 acquisition board, c. Voltage transformer,)

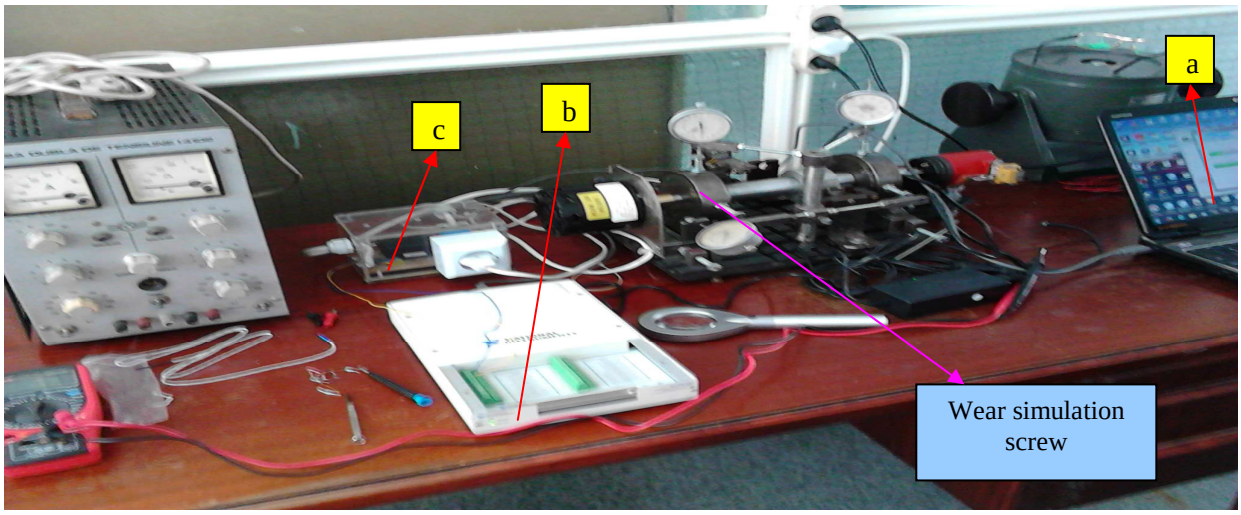

Figure 3. Experimental stand for kinematic chain monitoring

LabVIEW software application will perform the necessary processing of the electric current parameters for proper viewing of these ones and will allow their storage for subsequent viewings in the form of electronic files.
The LabVIEW software installed in the data acquisition module allows to record information regarding input voltage and the current used during the operation of the motor to be tested [1].
The monitoring system enables both the storage of the information recorded by the acquisition module and the viewing of the recorded information in graphical form. The graphical representation allows us to determine any malfunction of kinematic chain elements by detecting the points of sinusoidal signals alteration, representative for the input voltage and of the current used during the running of the equipment.
Information referring to the date and time of the test, the name of the test performed and a minimum description shall be saved for each test performed on the equipment.
While conducting the test, the power supply of the electric motor can be turned on or off and also the monitoring process can be started or stopped. The acquisition board records information specific to testing only during the period when the monitoring system is turned on. During the test carrying out, the recorded information can be viewed in graphical form (Fig. 4).

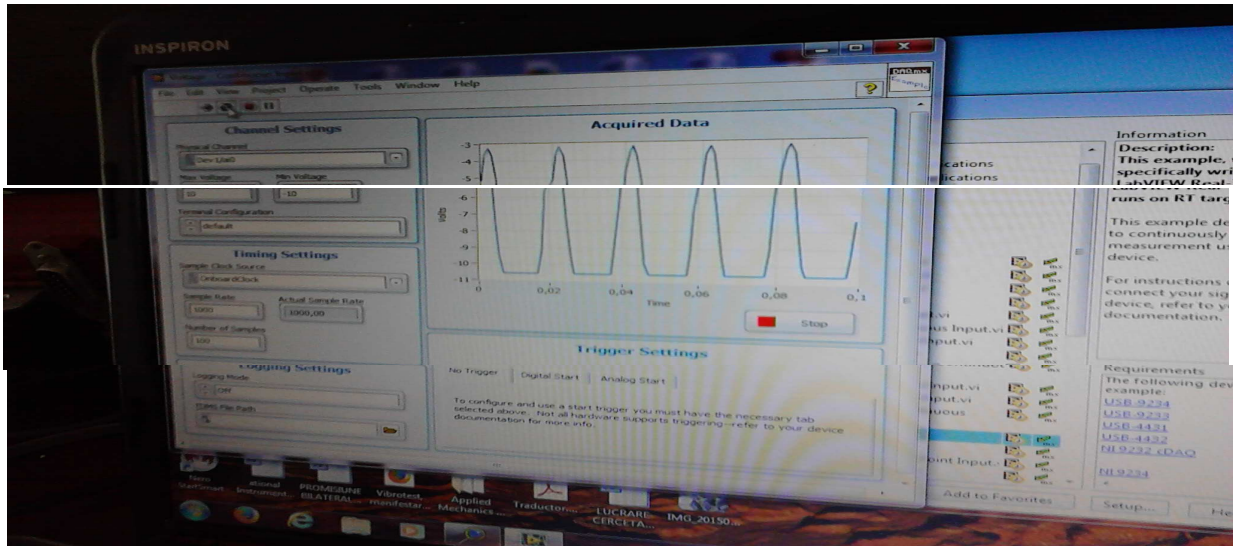

Figure 4. Monitoring of electric signal

The specific information of the tests performed can be viewed in the same way. A proper diagnosis, applied to any type of kinematic chain, requires a good theoretical foundation. By using simulation instruments, one can outline the effects caused by faults on the performances of the electric motor and can establish diagnosis indicators to identify and locate the defects occurred in the kinematic chain elements [2].
The analysis based on numerical methods enables the observation of changes in electric and temperature parameters (with device, Fig.1) as a result of the wear/failure process, without the need of shutdown or experimentation in laboratories. The main idea is to understand the electric, thermal and mechanical behavior of the electric motor transmitted by the elements of a kinematic chain in good condition or under wear [3].

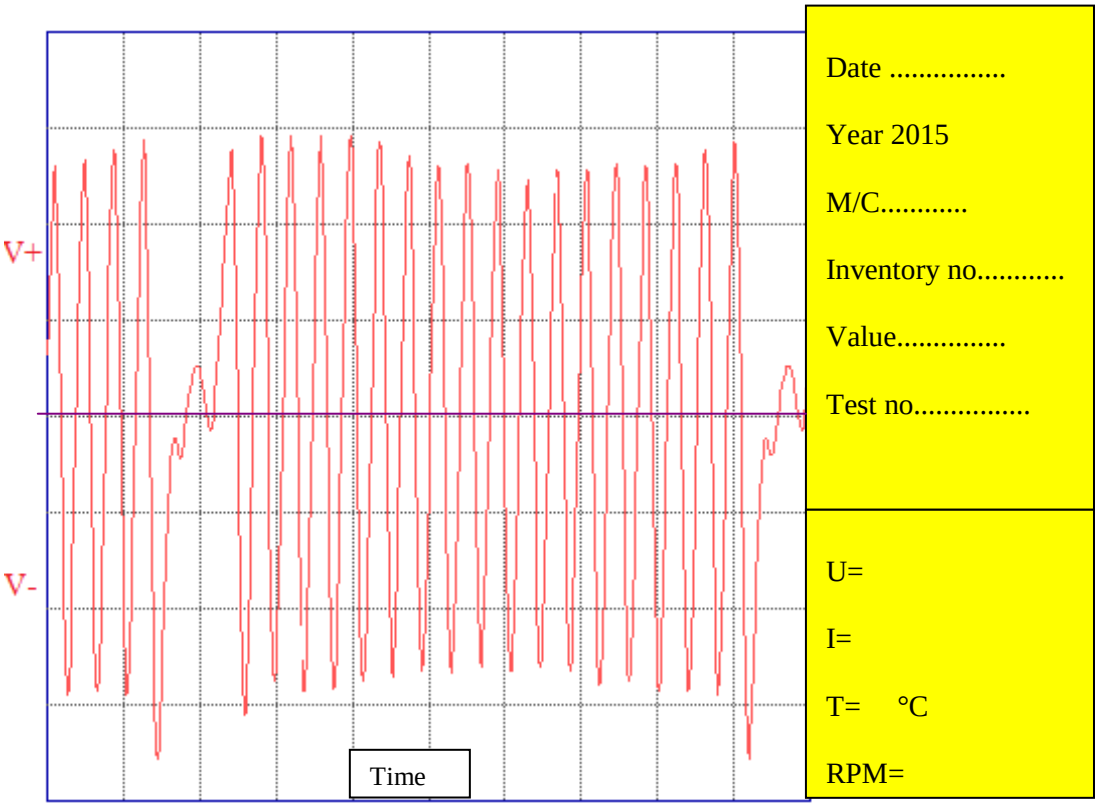

Figure 5. Variation over time of the signal recorded at a normally operating kinematic chain

The curves obtained have been analyzed and compared to the calibration curves of the device.
The shape of the curves obtained indicates:
□a constant amplitude of the displayed signal, corresponding to the type of sample –kinematic chain without defect;
□□increase of signal amplitude accompanied by a deformation that corresponds to a worn out element in the kinematic chain.

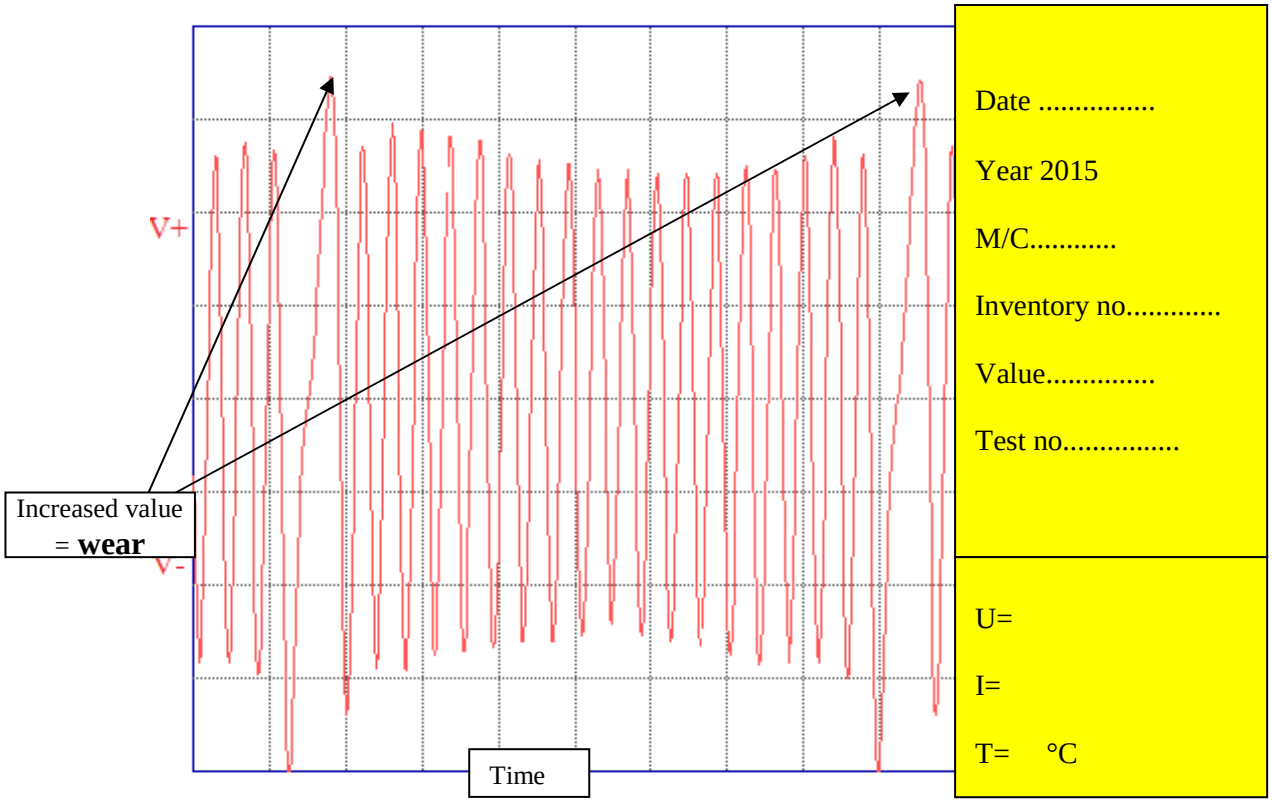

Figure 5. Variation over time of the signal recorded at kinematic chain with abnormal operation (screw displacement by 1.5 mm for wear simulation)

Table 1. Voltage during normal operation and wear simulation with screw displacement by 1.5 mm

No.	**U /V/normal**	**U/V/1.5mm**	**Time/min**	**N1** RPM	**N2** RPM	**T1** °C	**T2** °C
1	5	5.9	1	1760	1720	24	25
2	4.9	5.85	2	1758	1718	24.5	28.3
3	4.95	6	3	1768	1718	24.5	29.2
4	4.98	5.97	4	1757	1719	24.7	30.6

The parameters of the electric motors (rated current and power consumption) can be indicators of wear of kinematic chain elements when the motor is running normally (Fig.5). Following the tests, one can notice that the rated current and the voltage increase in the same time with the wear of the elements of a kinematic chain (simulated by the displacement of the screw by 1.5 mm); also, the motor power and rotational speed decrease and the temperature of the bearing increases [6].Using this information we can maintain the performances of the electric motor within the acceptable limits imposed by standards; the determination of the kinematic chain elements wear and of the failure rate can be achieved by identifying the sources and the causes produced by each element of this one.

5. Conclusions

In conclusion, the analysis of electric current is a research paper that provides an efficient way for a program to monitor the equipment operating status. However the research also highlights the limits of using this type of analysis, imposed by the load conditions, when the motor is insufficiently loaded; it is necessary to take all technical measures required for obtaining repeatable data, allowing the evaluation over time of the behavior of equipment kinematic line. Considering the load at which the engine operates, while making the research on the electric current analysis we can also check the results that we anticipated by using this method. The outcomes of this research lead to higher levels of confidence in the accuracy of the decision to be made and transmitted in due time to the maintenance team, enabling finally the possibility of amortization of the current analysis implementation in the shortest period.

References

[1] L. Arsenoiu, T. Savu, A. Szuder, *Fundamentals of LabVIEW programming*, Printech, Bucharest 1999.

[2] S. K. Ahamed, S. Karmakar, M. Mitra, and S. Sengupta, "*Diagnosis of induction motor faults due to broken rotor bar and rotor mass unbalance through discrete wavelet transform of starting current at no-load*," Journal of Electrical Systems, vol. 6, no. 3, pp. 442–456, 2010.

[3] M. D. Calin, L. Mariut, and E. Helerea, "*On the testing procedure of electrical machines used in automotive*," in Proceedings of The 5th International Conference on Interdisciplina-rity in Education, ICIE 2010, Tallinn, Estonia, 2010, pp. 277–280.

[4] A. Ciobanu, "*Online diagnosis system for the induction motor*", Magazine of the Creativity and Invention Doctoral School, vol. 3, pp. 1–5, 2011.

[5] M. M. Filip, "*Optimizing electrical machines manufacturing technologies to increase efficiency and effectiveness*," Thesis, „Transilvania" University of Brașov, Brașov, Romania, 2010.

[6] Glen A. Mazur "*From basic testing to advanced diagnosis* - Fluke Corporations"

[7] Burg Wächter temperature measuring equipment , http://www.bricoshop.ro/echipamente-de-masura-si-control-unelte-de-masura.

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Developing Internet of Thinks- based environment smart sensing network using model view controller

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Abstract

The paper is a part of environment smart sensing, framed into Internet of Thinks. Based on the fact that the sensor network is dynamically changing its configuration, the storing, preprocessing and processing of the data are changeable in time by user, and the viewing and reporting also need to be changed quite often, an independent approach need to be implemented for each three part of the system. Model- View- Controller (MVC) is the technique we are experiencing in our application. In this three layer architecture, after the initialization of the MVC, we are testing real time meaning in sensor network, we updates different processing applications on the server side, for querying optimization, and we are measuring the user interaction with view which calls a specified controller action. We also measure and test how the controller updates the models and how the view is refreshed for two different kind of smart sensors. By combining XML- based technologies with JavaScript Object Notation (json), we have imagined a scenario with multiple file input control with one type list stored in the XML file, instead of creating multiple properties, one for each control. By using one model builder that updates the property with the values by json serialization, there is a way of independent update of the processing functions on the server side.

1 Introduction

The research summarized in this paper is dedicated to the management of a municipal landfill monitoring. The monitoring system consists in a reliable network of smart sensors that takes measurements from the underground lands, and surroundings air, sends data over the network to a processing system database. The measured parameters for soil are: temperature and humidity, pH, Nitrate, Calcium, Iodide, Conductivity (Salinity), Dissolved Oxygen, and Chloride. For the air we measure: CO, CO2, NO2, O3, CH4, H2S, NH3, C4H10, and H2. For the measurement implementation, we are using electronic active devices, which are calibrated in labs and in site, based on the national specific regulations, and local Environment Agreement technically elaborated for a specific purpose. The in site calibration is annually re- calibrated. The data is collected into a web database.

At this moment they are some processing programs running on the server- side, which are open to changes, but they are some programs which are secured, and any changes might be done only according to the general (security requirements) and specific regulations (sensors' data interpretation). For the general management purpose, we designed a control interface of the sensors (sensor status, lifetime, sampling time changing). For the data management we have designed real time, history and alert representations. All this application facilities are able to be used independently, or in Google map's services.

The major related conclusion is that all the hardware software components are continuously and independently changed.

1.1 The specific of the database systems for smart sensors- based measuring systems

Since years of '90, when the researchers defined as "federated database systems" the databases where the data has been manipulated as different formats, protocols, and query languages, where they were identified different ways of representing a and storing the data, where the table decompositions may vary, column names may be different, data encoding schemes may also vary, with, or without similar semantics.
Referring to the smart sensors, data across constituent databases may be different but related, that way there is necessary to design semantic heterogeneity. In this case, the data structures are different according to the sampling rules in the process of measurements in one side, and database design rules on the other side.

1.2 Municipal waste landfill underground and air contamination

Because of landfill location (very close with populated areas, important rivers) the paper proposes a networked smart measurement pollution. The major related specificities are: large landfill surroundings- the area covered by the monitoring system is much larger then landfill area, very depending by the landforms and integrated valleys and rivers; strong and close link between landfill and air and water.
The landfill gas composition is methane, carbon dioxide, nitrogen, oxygen, and hydrogen, pungent odors (hydrogen sulfide, H2S), volatile organic compounds, ground–level ozone (smog), benzene, toluene, ethyl benzene, and vinyl chloride.

1.3 Specifics of the real time environment sensors measurements

Communication is based on 1-wire protocol ([1]), ([2]) and it is used for communication between measuring device and active sensors. The protocol is very simple, and for parameters measurements there is a demand to check if the data transmission is right. Detection of the pollution gases is achieved by measuring the sensing resistor RS during operation, according to the sensor's datasheet ([3]). The sensor is based on resistance variance in the presence of small concentrations of measuring gases. The sensor’s resistance in air, as well as its sensitivity, can vary between different units, so it is recommended to calibrate each one of them before finally inserting them in the application. The self- compensation consists in: gain error, non-linear transfer curve, offset error, hysteresis error, and gain variation with temperature / time. For instance, the check-sum for temperature and humidity (according to the datasheets) should be:

- Check sum=8 bit integral RH data+8 bit decimal RH data+8 bit integral T data+8 bit decimal T data. Example: measuring device has received 40 bits data from RHT03 as

0000 0010 1000 1100 0000 0001 0101 1111 1110 1110

- 16 bits RH data 16 bits T data check sum. Check sum=0000 0010+1000 1100+0000 0001+0101 1111=1110 1110

RH= (0000 0010 1000 1100)/10=65.2%RH; T=(0000 0001 0101 1111)/10=35.1^{o}C
When highest bit of temperature is 1, it means the temperature is below 0 degree Celsius. Example: 1000 0000 0110 0101, T= - 10.1 ^{o}C
To get data from the first sensor module (temperature and humidity) we declare parameters to be read as (including calibration process according with datasheets):

```
Vfloat temp = myDHT22.getTemperatureC();
temp = (temp*9/5) + 32 - 1; //calibrate here
float humidity = myDHT22.getHumidity();oid main()
```

where, myDHT22 is the specific library. Then, if the values have to be used as strings, the conversion method is:

```
String temp_string = dtostrf(temp*100, 4, 0, s);
String humidity_string = dtostrf(humidity*100, 4, 0, s);
```

In order to figure out the independency of the devices which are running for measuring and submitting the data to the web database, next we shown the structure of the site implementation devices. Measuring is done through two different devices (measuring device) and gateway (measuring and transferring data from the measuring network to the Internet).

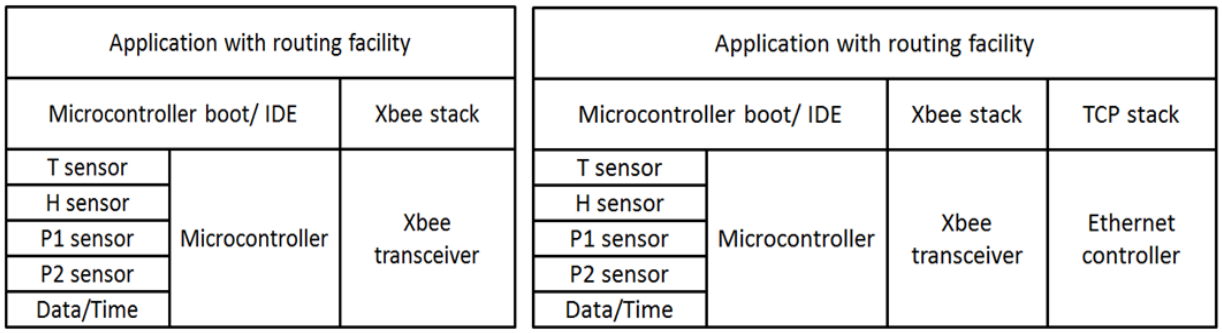

Figure 1. The software model for measuring, and gateway device

For both implementations, some logic level preparations must be done. Because, we need two serial ports, and because only one is hardware accessible, the other one have to created software. On the other hand, the measuring devices have to be proper configured.

1.4 Time scheduling model for software design

Time scheduling is related to measuring process demands not with software design. The local microcontroller has many additional tasks to do- it has to ensure that the data is sent to the database. The shown approach is also used for data storing locally (in the SD card). For that reason, it has to manage local data recording with sending data to the database. Based on these aspects, we have defined the Gantt diagram of the major tasks.

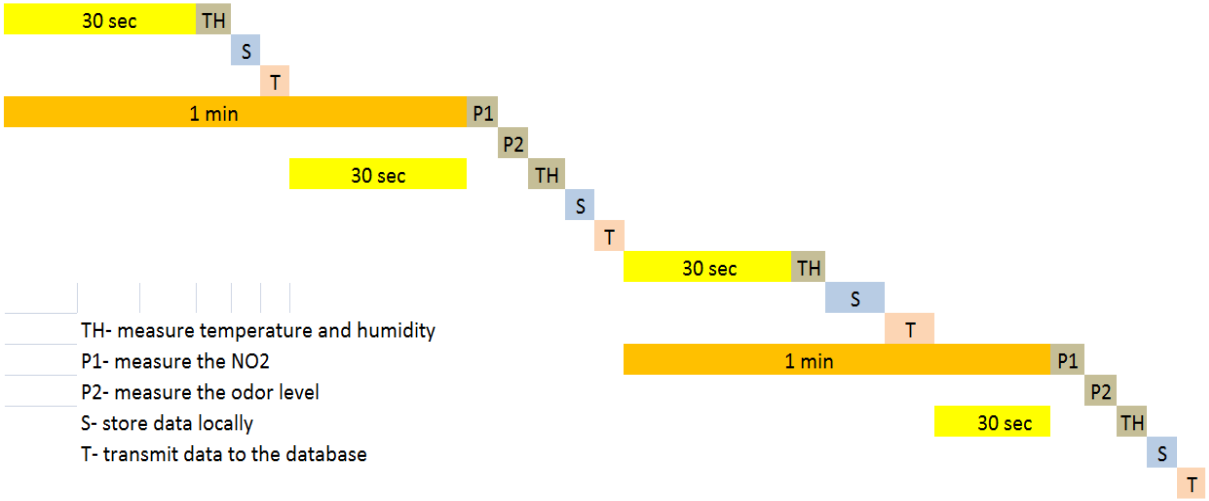

Figure 2 Two sensor measurement cycle with measuring, local storing, and transmiting tasks

The storing process is arranged as follow: T,H,P1,P2,T,H,ENTER. The sending data to the database is shown in next pseudo code:

```
if cycle== 1 minute/2
      use insert1.php
if cycle == 1 minute
      use insert2.php
```

Each 30 seconds data is sent through a php file. At 30 seconds, insert1.php sends only T and H, in one table. At 1 minute, insert2.php sends T, H in one table, and P1, P2 in the second table.

1.5 Premises for using model view controller technique for smart sensor software design

They are few premises which made possible to develop smart sensing systems- as major purpose of developing smart sensor networks. One of them is the huge switch between computing systems and distributed computing in one side, and the way of implementing the concept of big data [4]- as a structured documents and applications, [5]- as a result. Another premise is supported by the progress of computing devices and technologies [6]. As far as any device became connected to the web with a very low cost solution, we understand how easy became also to integrate the transduction element part together on one silicon chip. Since 1996 researchers proposed to integrate into LSVI devices functions like sensing element, signal conditioning electronic and controller/processor that support some intelligence in a single package [7]. One more, when the portability over different types of processors became real fact, the architecture of such device was meet in all vendors and software designers major tasks.

2 Application architecture design

The application architecture, based on the required tasks is shown next:

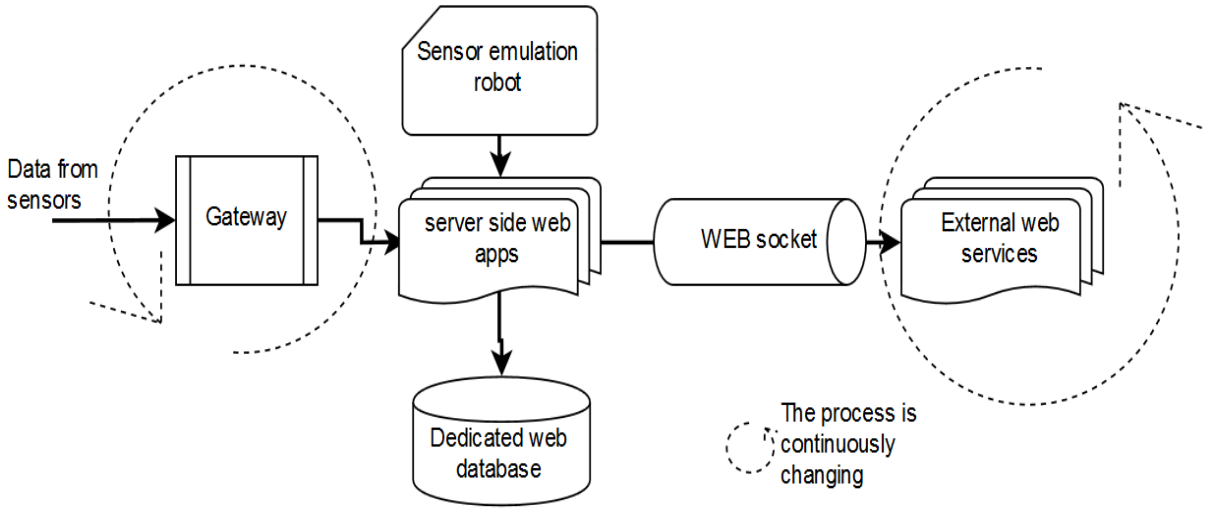

Figure 3 The designed software architecture, according to the required specifications. All block diagrams and models are designed with web resources ([8])

As it could be seen here, first designing constrains are related to the fact that, independently, the data which is coming from the site is not homogeneous, and the external services which are called (like Google map) are also working independently, and different versions means for our application continuous adaptations.
In two layer web application architecture, our application has to be continuously adapted.

2.1 Data coming application framework design

In order to design the application framework and its architecture, next we show the measuring sensor model.
As it could be seen in the figure 4, through the fusion process block, we accept different types of data, different sampling time, and in order to optimise the database design and exploitation, there

is required a strong data processing phase, before sending data through the gateway, to the database.

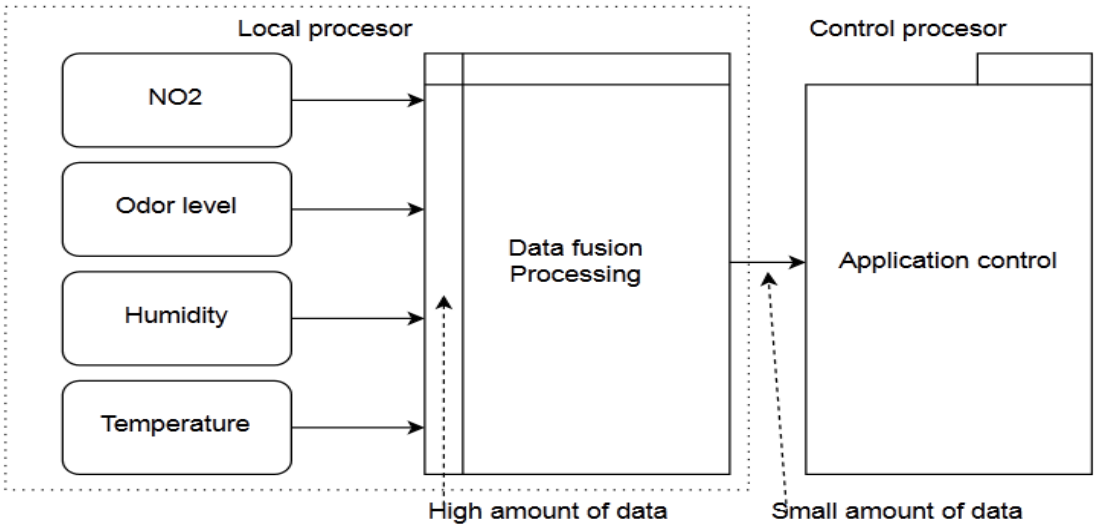

Figure 4 The designed architecture of data gathering device

2.2 Server side applications framework design

As far the application has to be continuously adapted when it interacts with both parts, one solution is to approach the design through model- view- controller (MVC) technique. All dedicated literature ([9], [10]) defines this technique like in figure 5:

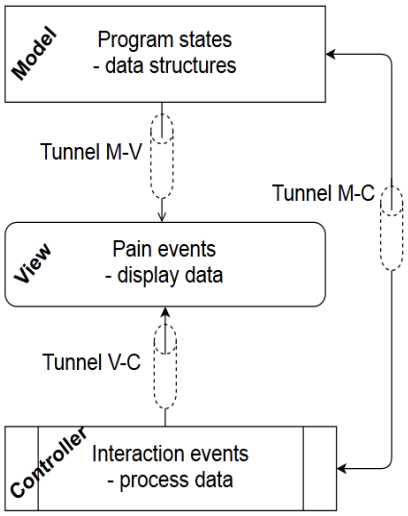

Figure 5 Adapted model-view-controller diagram

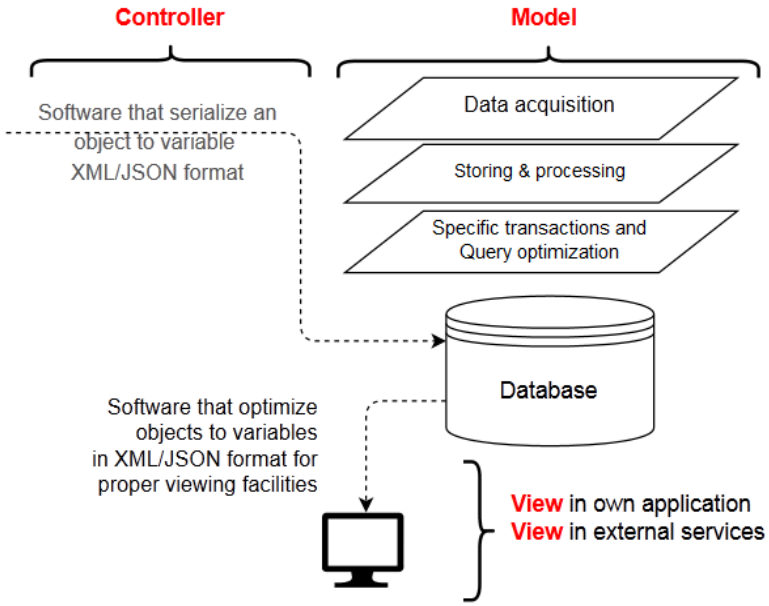

Figure 6 Extended model with storing and processing functions

Because in many cases, the user (human of intelligent device) when produce data interact directly with the controller, we could say that in such structure any block architecture interact with all the others (figure 5). We insist in this pre-required designing condition because if we extend the MVC to the data gathering, the model becomes more complicated (figure 6). From the software point of

view, data acquisition function means heterogeneous data gathering, then the other two functions (processing and storing) are able to store properly the refreshed data to the database.
By running the application designed in this architecture, we are able to optimize some parts without taking care of how other application components react to this changes, simply by serializing data using common techniques like XML, and temporary formatting data in json templates until de controller adapt requirements according to the designed model.

2.3 View framework design

In order to understand to simple mechanism of the work we proposed an working algorithm of interaction between the four parts (including here also the user) which is shown in figure 7. Here, a simple interaction is explained. First, the model, view and controller are initialized at application start-up. This phase is not interfering with smart sensor start-up because after powering-up the sensor it will proceed with authentication, joining to the network, and first data sending sequence. The view displays sensors symbols to the user by reading data sent by the model. The user interacts with the view (e.g. presses a button) which calls a specified controller action. The controller updates the model in some way, than the view is refreshed (fetching the updated data from the model).

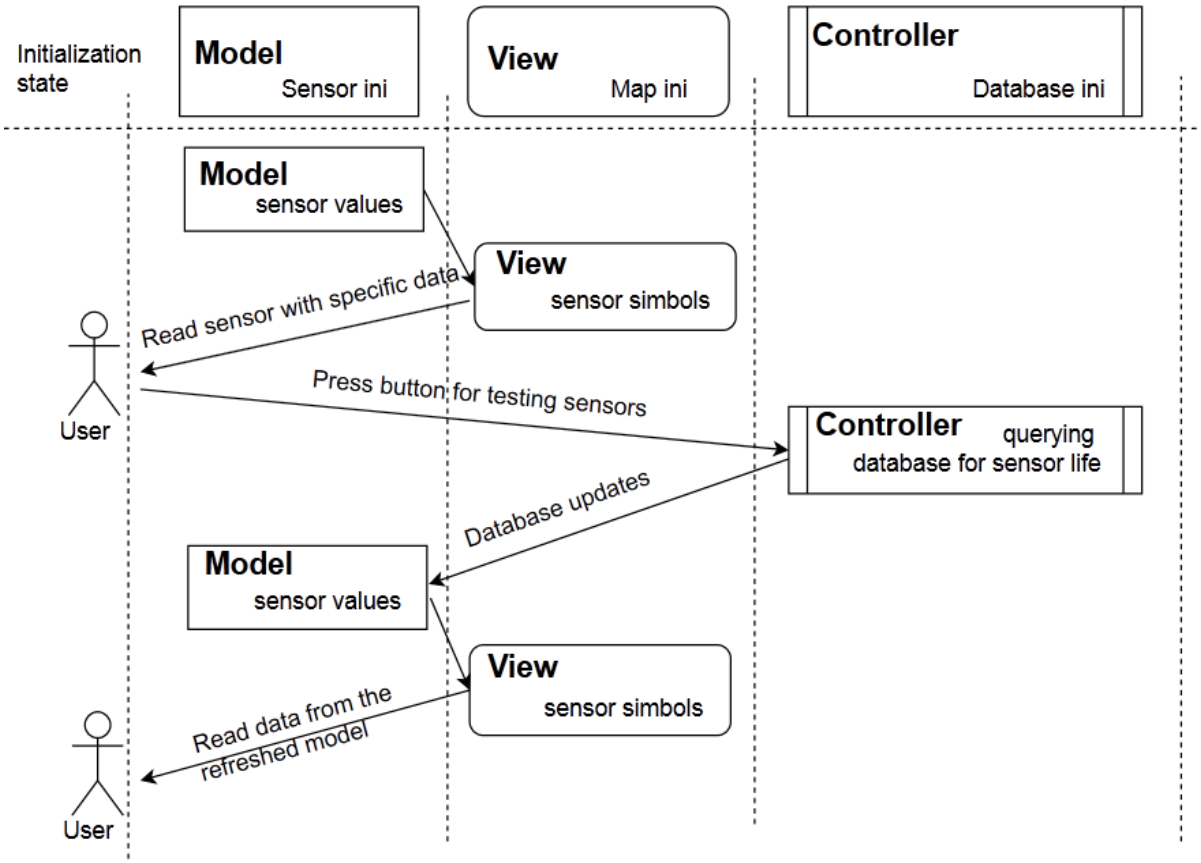

Figure 7 The specific designed algortihm for application management at client side

Based on this approach, the architecture of the designed application looks like in figure 8.
The used technologies for implementation are: PhP, MySQL, Ajax, and widgets from jQuery, with Linux servers. The major tests have been related to: user authentication, database connecting, new sensors value coming, own application accessing, external services use.

For an easy database management, we have proposed data storage into tables associated with parameters. Figure 9 shows how the data storage is implemented, in interaction with the controller (dynamic query that serialize data) and the model for viewing (php file).

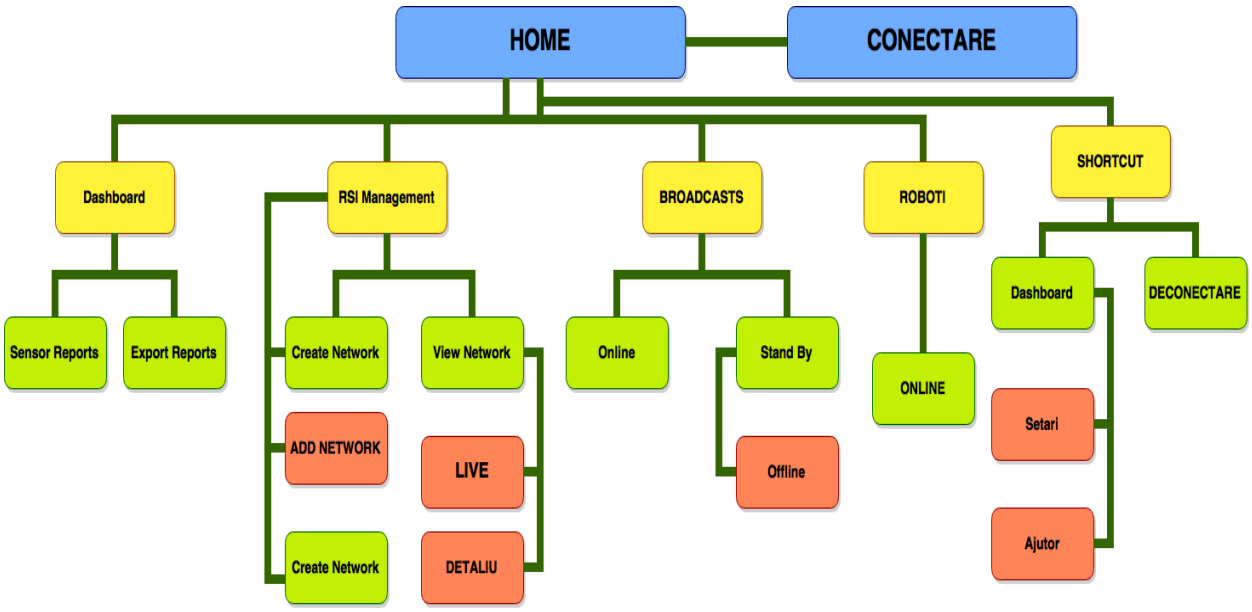

Figure 8. The application map of the designed architecture

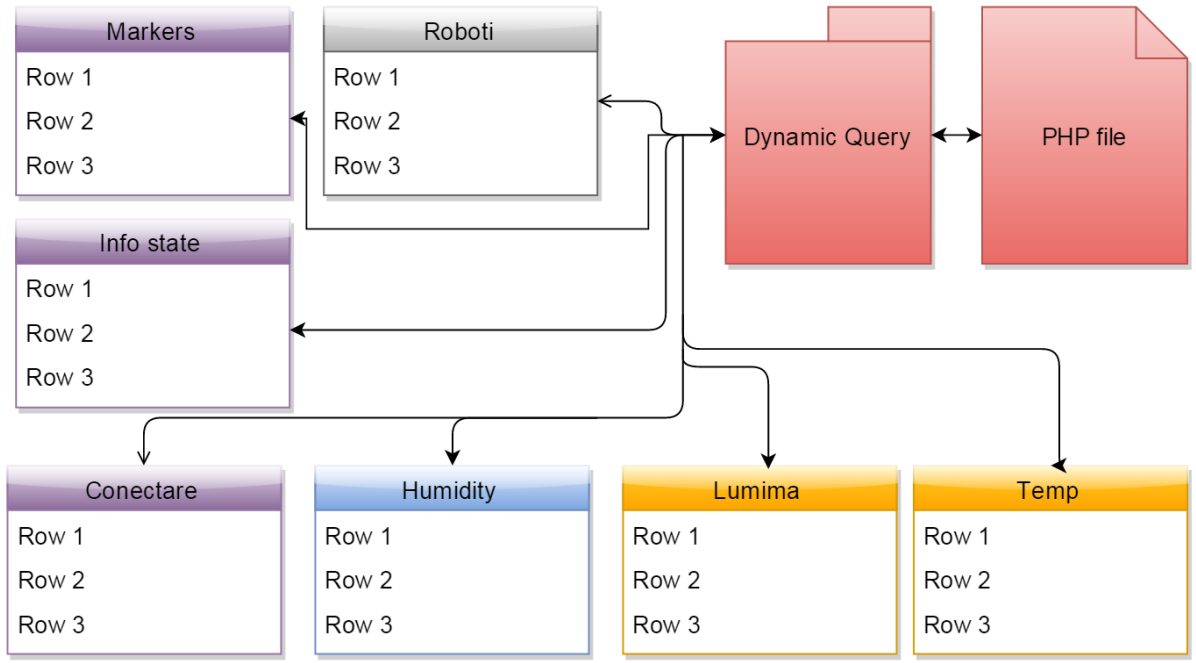

Figure 9 Sensors data in stored in dedicated table for each paramater, all values labeled with data and time

As it could be seen in figures 3, 7, and 9, by using own application models, the controller lets the different parts of the application to behave in own properties: the gateway will refresh the ports with own programmed parameters, then will push data to the database according to the server's privileges; the data is processed on the server when the files are invoked; the user, on the view side will wait until the controller will process the demanded actions, and the external services (Google map) will have own refresh time (5 seconds) and will process the dedicated scripts.

2.4 Designing socket model for external services

The structured communication between database and hetero data is made with XML file, which includes PHP code to collect simplify data ([12], [13]). The XML file will permit to be accessed by exterior application and fill up with data. In Google map service data is collected through markers. One example is shown next:

```
<markers>
<marker id="1" name="&amp;" address="not sepcific" temp="36.50" humy="&lt;u>Dezactivata&lt;/u>"
sun="&lt;u>Dezactivata&lt;/u>" lat="46.105194" lng="23.521086" status="activ" />
</markers>
```

The external service is invoked into:

```
<div id="map" class="map_arrange"></div>
```

Where an empty markup map from Google is loaded and it is waiting for markups:

```
google.maps.event.addDomListener(window, 'load', load);
```

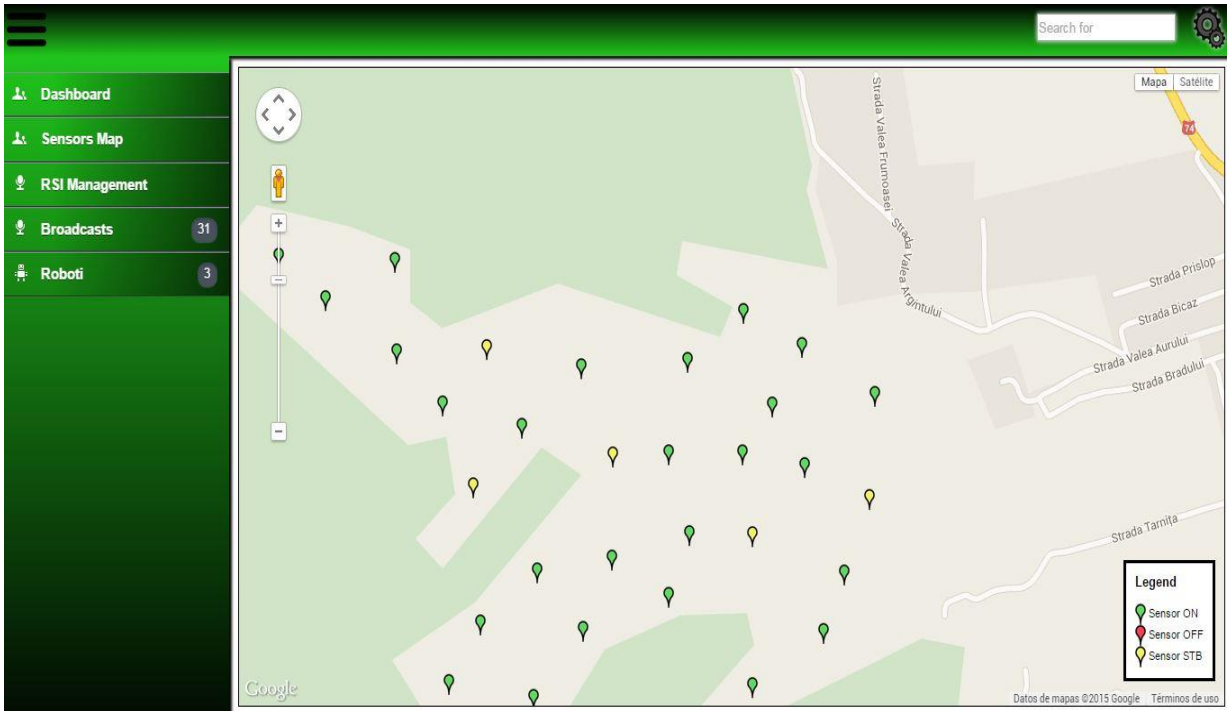

Figure 10 The front end of the application when external service is used to view the data

When this action is invoked, the PHP file will generate an XML from database with defined specified data. In order to get XML file, the XML process is made by the function *processXML(data)* with a single parameter.

```
function processXML(data) {
      var xml = data.responseXML;
      var markers = xml.documentElement.getElementsByTagName("marker");
      //clear markers before you start drawing new ones
      resetMarkers(markersArray);
      for (var i = 0; i < markers.length; i++) {
        var id = markers[i].getAttribute("id");
        var name = markers[i].getAttribute("name");
        var address = markers[i].getAttribute("address");
        var temp = markers[i].getAttribute("temp");
```

```
……
        var point = new google.maps.LatLng(
            parseFloat(markers[i].getAttribute("lat")), parseFloat(markers[i].getAttribute("lng")));
            //make a quick command button for temp.
        var menu = '<div align="left"><p></p><p>Temperatur&#259: '+temp+'&deg; C</p><p>Umiditate:
'+humy +'</p><p>Odor level &#259: '+sun +'</p><p>Via&#355&#259: 66%</p>'+
      '<div   onclick="senzoropt('+id+',\''+status+'\')"   id=""   class="button-style-info-iw"><p>Set&#259ri
Senzor '+ id+'</p></div></div>';
        var html = menu;
        var icon = customIcons[status] || {};
        var marker = new google.maps.Marker({
          map: map,
          position: point,
          icon: icon.icon
          });
          markersArray.push(marker);
          bindInfoWindow(marker, map, infoWindow, html);

      }
          setTimeout(function() {
             downloadUrl("inc/genfile_xml.php", processXML);
          }, 5000);
}
```

Every point from the map is a markup, which you can see it in xml file. The result looks like in figure 10.

3 Testing. Results

3.1 Working with XML and JSON formats in MVC

On the designed model let's analyse the JSON structure (data is in name/value pairs, data is separated by commas, curly braces hold objects, square brackets hold arrays) of the measuring sensor model:

```
{
  "name": "xxxxxxxx",  "id": "xxxx",  "isAlive": "true",  "batery": "value",
  "data":  { "year": "xxxx",  "month": "xx",  "day": "xx"  },
  "time":  { "hour": "xx",  "min": "xx", "sec": "xx",  "milisec": "xxx"  },
  "description":  {  "firstfield": "xxxxxxxx",  "secondfield": "xxxxxxxx",  "thirdfield": "xxxxxxxx"  },
  "values":
    [
    { "type": "humidity", "value": "xxxx.xx"  }, { "type": "temperature", "value": "xxxx.xx" },
    { "type": "NO2", "value": "xxxx.xx" }, { "type": "Odor level", "value": "xxxx.xx" }
    ],
}
```

This is quite similar structure with XML. As we know, the definitions in the XML Information Set specification are meant to be used in other specifications that need to refer to the information in a well-formed XML document. So they are some significant differences: the complexity of the structured controllers, the portability of the files, the possibility to store data according to the specific measuring sampling rules, and the position independent. Next they are two other JSON samples:

```
"time":  { "hour": "10",  "min": "22", "sec": "16",  "milisec": "315"  },
"values":  [ { "type": "humidity", "value": "44.00"  }, { "type": "temperature", "value": "34.15" },
   { "type": "presure", "value": "800.00" },  { "type": "so2", "value": "5.00" }    ],
….
"time":  { "hour": "10",  "min": "22", "sec": "33",  "milisec": "315"  },
"values":   [ { "type": "humidity", "value": "44.00"  }, { "type": "so2", "value": "5.00" }    ],
```

As a data oriented technique, the JSON is used closed with controller for heterogeneous data. The array of values is parsed when received, then, if they are available values according to the types of measuring parameters, the parser will store data into different tables, without inserting value "0" at each sampling period. The sample code shows how to parse JSON data in our application:

```
<p id="341"></p>
<script>
…
obj = JSON.parse(text);
document.getElementById("341").innerHTML =
obj.values[i].humidity + " " + obj.values[i].temperature + " " + obj.values[i].presure + " " +
obj.values[i].so2;
</script>
```

For data capturing , a simple PHP code is written ([13], [14]).

3.2 Smart sensors evaluation in the MVC technique approach

The main evaluation parameter for sensor proper working is the time delay between data refreshing. At this level of processing we are not taking into account lost, or uncompleted received packets because we are using XBee device in API mode ([11] [12]), where only packets that fulfils data integrity are considered.
In these conditions, the behaviours of the 10 XBee devices are explained in next two figures. This is the typical test we are running (10). First figure (11) shows that after 4-5 frames, each XBee device "learn" the way of data sending- after 5 frames the time delay is uniform increasing (from one XBee device to another) up to 5 seconds.

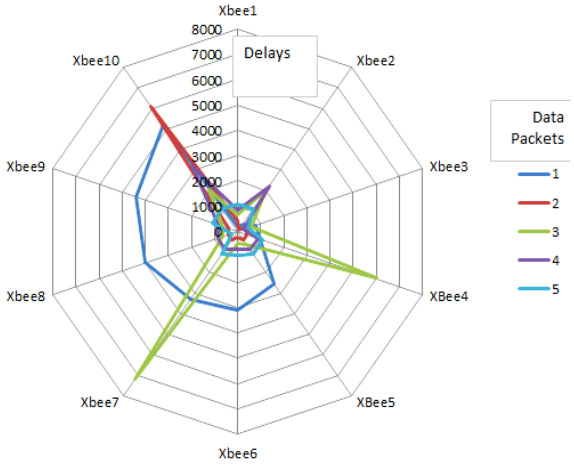

Figure 11 Delay evaluation at start-up of the sensor network

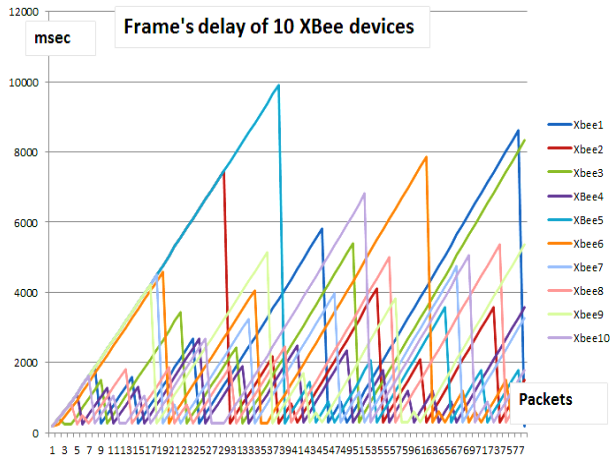

Figure 12 Measured delay during the netwrk testing

The second figure (12) shows records for long time delay in data packets reception process.
After the first 5 packets, the data is received from all 10 XBee devices (there not a gap into a device data transmission). The highest delay is below 10 seconds. The XBee number 5 shows the highest delay (not the farthest device), that means that in the established mesh network, there is a shorter way of data sending (possible because of radio propagation or perturbation conditions).
As it could be seen, there is interaction between application components.

3.3 Viewers evaluation as parts of MVC

The application is designed to work and switch automatically between own application and external services. This is possible because the two implementations are treated as different clients of the same application with the same management facilities. Ones the hardware implementation

is finished, the network viewing can be established in two ways- in own (local) application and Google Service.
In local application, the sensors are listed for collective and individual configuring and accessing. Independently by the option, each sensor is listed with own status (Online, Stand By or Offline). Then each sensor (figure 13) can be accessed for configuration (by checking, we activate some measuring parameters- in sensor 20 we activate temperature and humidity sensing) for real time data displaying, or for history of values.

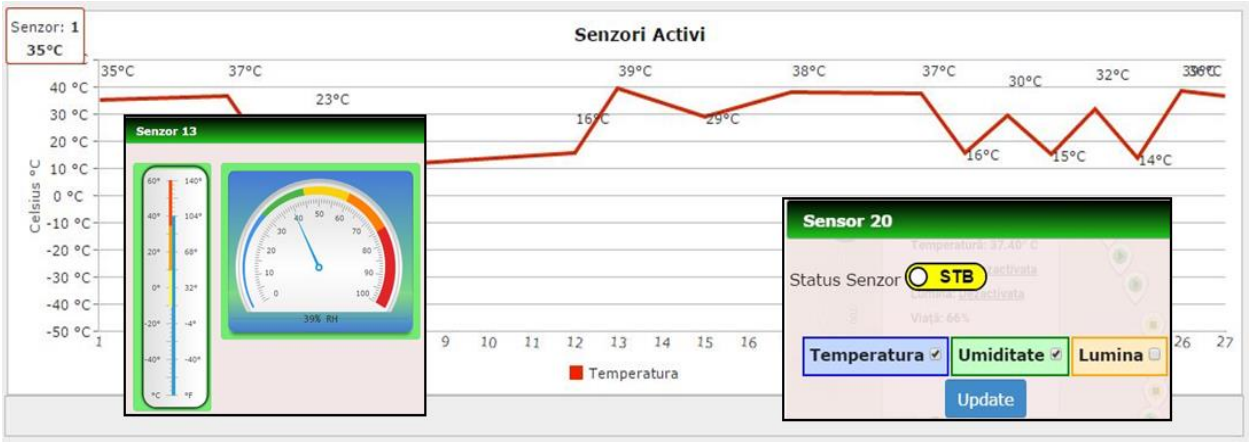

Figure 13 Captured screen for viewing facilities for sensor configuration (sensor 20), realtime viewing (sensor 11) and history values for sensor 1

For accessing data in Google map, we load the object as a child through main menu (figure 10). The screen capture shows the application frame that loaded the Google map with the geographically visualization of the installed sensors.
The application loads over a new layer with the specific legend (the most significant status information- ON, OFF, Standby). On the other hand, we have supplied with information the fast viewing facility of the Google map. By accessing the map "thumbtack" that represents a sensor, the provided information is shown 10 seconds.

Figure 14 Captured screen with the most significant sensor information

The figure 14 tells (as a public profile) to the user that the temperature and light sensors are not active, the humidity value is 33%, and the "life" of the sensor is 66% (the accumulator's capacity is 66% from the nominal energy value). If we react on the "Setari Senzor 2", the frame application switches to the own application for listing, configuring the sensors from the network, as presented in first part of this section (see figure 13).
The sensor's values history is also available. Depending by the user options, graph, or histogram option can be used.

4 Conclusions

During application tests we were always focused on fails probabilities when changes are done in different parts of the hardware/software architecture.
By using the dedicated communication protocol, the maximum obtained delay in 5 minutes for two successive measurements in the area with an electricity high voltage network. By self-testing facilities of the sensors, any fail in measurements is forecasted, then easy detected through the sensors' specific protocol, and stored in the database.
The second major research task have been devoted to test for using a communication reliable system, by using an ultra-low power transceiver controlled by a dedicated application. The optimized application ensures information link in any condition, with an acceptable time delay. The recorded results prove an acceptable delay limit (less than seconds) which offer the possibility of adding as many transmission devices are necessary. The Zigbee protocol accepts 264 64-bits device addresses, but limitations are related to network forming and specific transmission delay.
During tests, some measuring adjustments have been required because we intended to reduce the communication time, as a major problem in networked smart sensors. According to Niquist data acquisition condition, the minimal sampling frequency limit is 3 x 150 Hz= 450Hz- or one sample at each 2.2 milliseconds. If we want to take 10 samples for each oscilation dirrection, it means that the sampling period is 0.22 milliseconds (4.545 kHz sampling frequency). In upper estimations, in any case (8/ 16 bytes) there is a cover limit in communication transfer (8333/4545 in reading phase, and 10526/4545 in writing process). There is a time window of 0.22 milliseconds which can be used for another process task First, there is a need to speed up the data transfer in this bus. Usually, it is done by improving the standard transfer frequency (from 100 kHz to 400 kHz) and bus length (from 32 bytes to 64 bytes). Most of the 8 bits microcontrollers allow these changes. During changing tests, no conflicts or unacceptable time delay were observed in working with the database.
In the last conclusions idea, the present paper has been dedicated to design an upper level monitoring and decision making system, which has the main role to respond properly to changes demand, to ensure a satisfactory level of data management coming from de network, and over the web-based application. The implemented hardware software solution for the municipal landfills management covers a large land surface, through reliable networked sensors systems.

References

[1] xxx 1-Wire® Communication with PIC® Microcontroller datasheet, (2015)
[2] xxx AVR318: Dallas 1-Wire® master datasheet, (2015)
[3] xxx (MiCS – 2710) NO2 Sensor datasheet, (2015)
[4] Chun-Wei Tsai, Chin-Feng Lai, Han-Chieh Chao, Athanasios V. Vasilakos, Big data analytics: a survey, http://www.journalofbigdata.com/content, visited in June 2015,
[5] Patrick Schwerdtfeger, Webify Your Business, Internet Marketing Secrets for the Self-Employed, ISBN 978-0-557-04901-1, Wiley, 2009
[6] Erlendur Kristjansson, Portability of the 32 bits microcontrollers' platforms as IoT support, Microchip Technology report, www.microchip.com, visited in March 2015.
[7] J. M. Giachino, "Smart sensors," Sensors and actuators, 10(1986) 239-248.
[8] xxx www.draw.io, (2015).
[9] Trygve Reenskaug, James Coplien, The DCI Architecture: A New Vision of Object-Oriented Programming, http://www.artima.com/articles/dci_vision.html, visited in June 2015
[10] Atanas (Nasko) Rountev, Model-View-Controller (MVC). Design Pattern, http://web.cse.ohio-state.edu, visited in June 2015
[11] http://www.libelium.com/, visited in March 2015

[12] Dr. Ovidiu Vermesan, Dr. Peter Friess, EU, Belgium Internet of Things: Converging Technologies for Smart Environments and Integrated Ecosystems, ISBN: 978-87-92982-96-4 (E-Book), © 2013 River Publishers, PO box 1657
[13] https://www.google.com/webmasters/tools/home?hl=ro, last visited in March 2015
[14] Mircea Risteiu, Ioan Ileana, A redundant solution for collective residences inflammable gas leaking monitoring using ultra-low power transmission system and automatic control, AQTR 2014 978-1-4799-3732-5 ©2014 IEEE

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Ownership tracking with dynamic identification of watermark patterns

Dana Simian, Ralf Fabian

Abstract

The demand of adaptation in marking digital content for later author identification has become of huge interest given that nowadays it has become easier than ever to acquire and copy multimedia content. The paper focuses on visual content based owner or author identification applicable to digital images. It builds on a survey of techniques designed for minimal image quality loss. The techniques employed are chosen to reduce tempering visual delight of an image and making inserted information hardly detectable or removable. We propose an architecture for a system intended to provide digital watermarking services with automatic ownership tracking. The main issue in this endeavour is to overcome pattern degradation if the host image has been altered. To address this problem we apply a neural network based classifier. The more classifier design implies generating an initial training data set upon known transformations. Robustness of the implemented watermarking method was tested against common image processing operations.

1 Introduction

Digital recorded information has one main advantage and drawback at the same time: it can be copied without any kind of degradation in quality. If it is copyright protected material the content owner is forced to seek out for new technologies to protect his rights. Digital Watermarking technology protects the content even after or during transferring by placing information in the visual content itself that is never removed under normal conditions. Visually perceivable markings in form of text or other graphical elements are easily identified and can be modified with image editing applications. By design, unlike the printed visible watermark, a digital watermark usually remains invisible to viewers. As tool, it is adequate to identify the source and authorized consumer of an image or document. Three attributes distinguish watermarking form other techniques that deal with information hiding and protection like Cryptography or Steganography: *imperceptible* for an observer, *inseparable* from the content and *experience the same transformations* as their container.

Digital images are commonly stored and processed in the spatial domain and frequency domain. The spatial domain refers to the pixel amount composing an image and the processing involves here only those pixels directly, whereas in the frequency domain, high-frequency components correspond to edges and low-frequency components to interior regions of an object. Hence, visual content based operations might benefit from transforming an image from spatial to frequency domain.

Digital watermarking techniques are considered promising techniques for multimedia authentication. Among these, semi-fragile watermarking allows acceptable content preserving against manipulations such as common image processing like: blurring, low-pass filtering, median filtering, salt and peppers noise and lossy compression [3].

The paper focuses on visual content based owner or author identification applicable to digital images, using watermarking techniques. Digital watermarking is in essence digital code embedded into host data. Based on this scheme, various methods are developed for working in the spatial or frequency domain [3], 5, 7]. In the spatial domain, embedding techniques make use of changing the gray levels of pixels to insert supplementary data into a host image. These techniques, e.g. LSB method, are easy to implement but don't resist well on processing operations and might significantly degrade image quality. On the other hand, in the frequency domain, information is embedded in coefficients of the transformed image. Nevertheless, visual quality could suffer too, on high amount of inserted data. Common transforms include: discrete cosine transform (DCT), discrete Fourier transform (DFT) and discrete wavelet transform (DWT) [3][6], 7, 8]. A system based on Watson's perceptual model is proposed in **Error! Reference source not found.**.

The watermark system chosen for the application and described here is based on the frequency domain to achieve embedding in the visual content itself by exploiting peculiarities of human vision. To avoid the distortion of the chrominance quality, the focus is on the luminance component to perform embedding on. Sensitivity for luminance difference is high in middle rage frequency and decreases in low and high frequency range. Low frequency components are more robust and visually sensitive than the high frequency once. If a low frequency component is modulated, it will cause the more seriously distortions, but it has higher ability to resist tempering than the high frequency component. Hence, the technique applied here will embed watermark information in frequency domain whereas all components of the watermark will not equally perceptible.

In Section 2 we present the formulas for finding the DCT. Mathematical preliminaries used in this section are adapted and inspired from [2][1]. The details of our watermarking technique are presented in the Section 3. In Section 4 we propose architecture for a system intended to provide digital watermarking services with automatic ownership tracking. The main issue in this endeavour is to overcome pattern degradation if the host image has been altered. Experimental results that validate our proposed watermarking approach are presented in Section 5. They have been obtained using the system described in Section 4.

.2. Mathematical preliminaries. Discrete Cosine Transform (DCT)

The discrete cosine transform (DCT) allows the representation of an image as a sum of sinusoids of varying magnitudes and frequencies. DCT is a special case of Fourier transform, because instead of complex values, it uses only the real part of the transform. One specific property of DCT is exploited for images, namely, that most of the visually significant information is concentrated in just a few DCT coefficients, while the others are negligible small. This permits addressing image composition with respect to visual quality. That is why DCT is the heart of lossy image compression techniques, like the JPEG standard.

Like the Fourier Transform, the DCT provides a one-to-one mapping from spatial to frequency domain. Thus, to get back the original image, one simply has to take the inverse transform (IDCT) of the transformed image.

2.1 Bidimensional dimensional DCT (2D DCT)

An image of size MxN in the spatial domain can be represented in bidimensional manner, as a function $f(x,y)$, $0 \le x \le M$, $0 \le y \le N$ in the spatial domain. The corresponding image $C(u,v)$, in the frequency domain is given by the bidimensional discrete cosine transform (2D DCT):

$$C(u,v)=\alpha(u)\alpha(v)\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}f(x,y)\cos\left(\frac{(2x+1)u\pi}{2M}\right)\cos\left(\frac{(2y+1)v\pi}{2N}\right),\ 0\le u\le M-1, 0\le v\le N-1,$$

$$\alpha(k)=\begin{cases}\sqrt{1/K}, if\ k=0\\ \sqrt{2/K}, if\ 1\le k\le K\end{cases}$$ and $K=M$ if $k=u$ and $K=N$ if $k=u$.

The values $C(u,v)$ are called DCT coefficients. We can observe that all samples of f contribute to the coefficient.

The bidimensional discrete cosine transform (2D DCT) is a direct extension of the 1D DCT. Since the DCT is an invertible transform, its inverse, 2D IDCT, is given by:

$$f(x,y)=\sum_{u=0}^{M-1}\sum_{v=0}^{N-1}\alpha(u)\alpha(v)C(u,v)\cos\left(\frac{(2x+1)u\pi}{2M}\right)\cos\left(\frac{(2y+1)v\pi}{2N}\right),\ 0\le x\le M-1, 0\le y\le N-1.$$

2.2 DCT transformation matrix

The image $f(x,y)$ can be seen as a matrix A of size MxN and the inverse equation can be interpreted as meaning that any matrix A can be written as sum of M*N functions, called basic functions, of the form:

$$\alpha(u)\alpha(v)\cos\left(\frac{(2x+1)u\pi}{2M}\right)\cos\left(\frac{(2y+1)v\pi}{2N}\right),\ 0\le u\le M-1, 0\le v\le N-1$$

Without restricting the generality, in the following we will work only in the case $M=N$.

From a computational perspective, in order to reduce the amount of cosine functions, a more efficient attempt to compute a 2D DCT is using a MxM transformation matrix T of the form:

$$T_{i,j}=\begin{cases}\sqrt{\frac{1}{M}}, if\ i=0\\ \sqrt{\frac{1}{M}}\cos\left(\frac{(2i+1)j\pi}{2M}\right), if\ i>0\end{cases}$$

The matrix T is named the DCT transformation matrix and it is an orthogonal matrix. If A is an initial pixel matrix MxM, then T*A produces a MxM matrix whose columns contain the one-dimensional DCT of the columns from A. Hence, the 2D DCT is defined by the matrix product $C=T*A*T'$ and the 2D IDCT by $A=T'*C*A$.

The DCT coefficients typically represent the same information in a more compact form that can be stored in fewer bits. Moreover, purposely losing precision in the DCT domain is much less noticeable than losing the same amount of information in the spatial domain. Modern lossy image compression techniques use this as primary basis of operation. The JPEG standard relies on the block DCT domain and applies quantization according to step sizes.

3. The proposed watermark's embedding–extraction method

The aim of this section is to present a watermarking technique to add binary pattern to digital images. The method operates in the frequency domain, embedding a pseudo-random sequence of numbers in a selected set of DCT coefficients.

A digital image is divided into MxM square sized disjoint pixel blocks, i.e. 8x8, 16x16 etc. Each of these blocks is then transformed into the DCT domain and contains MxM DCT coefficients organized by frequency range, like in Figure 1. This transform tends to concentrates the image energy in the low-frequency coefficients of each block.

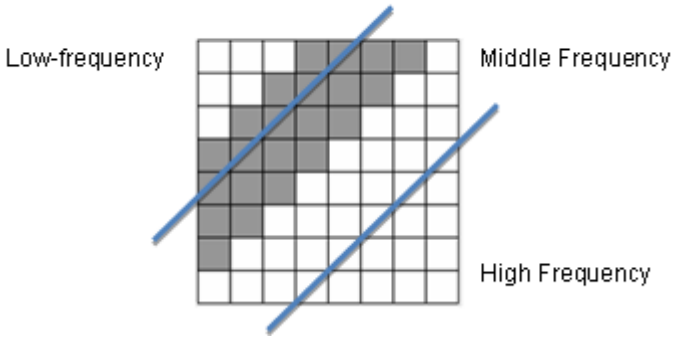

Figure 1. Frequencies organized in a DCT block.

To ensure watermark invisibility by exploiting the masking characteristics of the Human Visual System, data is stored in the more important frequency components. That is, from every DCT coefficient block, only a number of *K* middle frequency coefficients are selected for watermark embedding. The selected coefficients are shown marked grey in Figure 1.

By inserting the watermark in the low frequency coefficients, overall visual quality of the original image would be significantly affected. On the other hand, if inserted in high frequency coefficient, the visual quality of the image will not be as much affected, but the watermark is not that robust to processing, e.g. lossy compression.

We consider only small square matrixes *M*x*M* of small sizes, 4X4, 8X8, 16X16. A graphical view of 64 basic functions corresponding to an 8x8 block of an image is illustrated in Figure 2c). It can be easily seen that frequencies increase from left to right and form top to bottom.

(a) *(b)* *(c)*

Figure 2. (a) Lena test image. (b) Visual inspection of image (a) in the 2D DCT transform domain. (c) Basic functions of an 8x8 block.

After the entire watermark has been embedded, the IDCT is computed to obtain the watermarked version of the initial image in the spatial domain.

The proposed method uses Quantization index modulations (QIM) and performs a blind watermarking. For recovering only embedding settings are necessary, a reference image is not needed. The strategy is to associate watermark bit information with parity bits of DCT coefficients. Quantization step serves for hiding information by quantizing image data in the spatial or DCT domain.

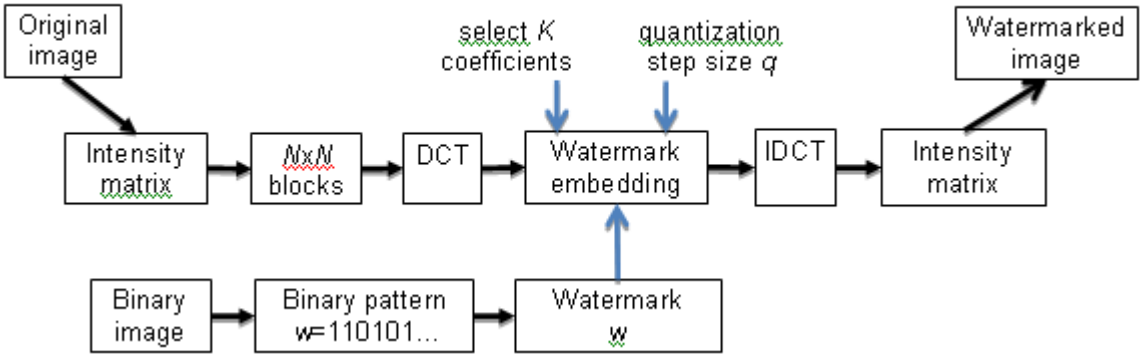

Figure 3. Block diagram of quantization based embedding procedure

3.1 Embedding

The watermarking embedding process complies with the following steps:

1. Partition the original image into square blocks of *NxN* pixels.
2. Apply 2D-DCT transform to all blocks from step 1, resulting in *NxN* size DCT coefficient blocks.
3. Transform the binary watermark w image of size $A \times B$ into a binary row vector w of size $P = A \times B$.
4. Select a DCT block and scan in zig-zag order (see Section 3.3).
5. Select a number of *K* coefficients from the current DCT block for embedding.
6. Embed a watermark bit $w(i)$ into each selected DCT coefficient by rounding its value to an even or odd quantization level *q*. Rounding to an even quantization level embeds a "0" bit, while rounding to an odd quantization level embeds a "1" bit. The new value of the DCT coefficient is calculated according to the following equation:

$$C_{u,v}^{w} = \left\lfloor \frac{C_{u,v}}{q} \right\rfloor q + \frac{q}{2} w(i) \operatorname{sgn}\left(C_{u,v} - \left\lfloor \frac{C_{u,v}}{q} \right\rfloor q \right)$$

   Where $C_{u,v}$ is the original DCT coefficient before embedding, u, v are the raw and column index, *q* is the quantisation step and $\operatorname{sgn}(x)$ is the signum function of *x*.
7. Repeat steps 4-6 for the next blocks until all bits of w are embedded.
8. If redundant embedding is requested, repeat L times the embedding of w through multiple steps 4-7.
9. Computed the 2D Inverse Discrete Cosine Transform (2D-IDCT) for each block to obtain the watermarked image in the spatial domain.

Redundant embedding watermarking is applied in order to increase the robustness of the watermarking systems [3]. In a case of an image distortion not all coefficients are affected equally. Therefore the watermark is redundantly embedded across several coefficients.

3.2 Extraction

To extract the watermarked information out of an image, a reverse process to the one used to embed is applied. Recovering or detecting the embedded watermark can be performed in blind or non-blind manner, depending on the embedding strategy employed. If blind, then no reference image must be present at extraction, else, both reference and embedded image are necessary to search for differences, where data is probably embedded. In our embedding-extraction method we chose a blind recovering method.

The block diagram of the watermark extractor is shown in Figure 4. With this method the embedded sequence is extracted without comparing to the original image.

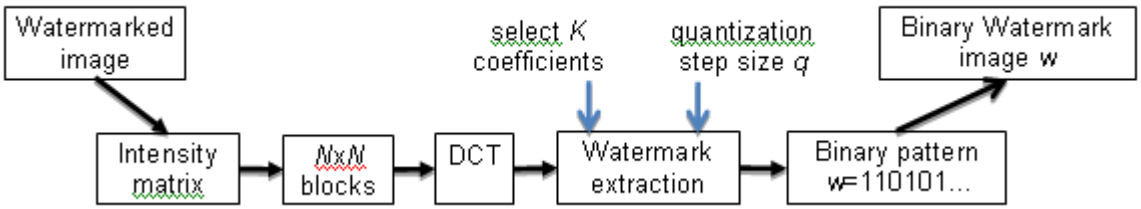

Figure 4. Block diagram of extraction procedure

The steps of the extraction process are:

1. Partition the watermarked image into square blocks of *NxN* pixels.
2. Apply 2D-DCT transform to all blocks from Step 1, resulting in *NxN* size DCT coefficient blocks.
3. Select a DCT block and scan in zig-zag order (see Section 3.3).
4. Select the same number of *K* coefficients from every DCT block used in the embedding process.
5. Extract one watermark bit from each coefficient selected in Step 4 by applying the equation:

   $w'(i) = \mathrm{mod}\,2\left(round\left(\frac{C^{w}_{u,v}}{q/2} \right) \right)$, where $C^{w}_{u,v}$ is DCT coefficient with embedded watermark data, *u,v* are the raw and column index, *q* is the quantisation step and $w'(i)$ is the extracted watermark bit.

6. Repeat steps 3-6 for the next blocks until all bits of w' are extracted.
7. Transform the resulting vector back to a binary image of size $A \times B$.

In case of redundant embedding, step 6 is preceded by one step that includes a decision function to identify the extracted bit:

From every block *i*, of DCT coefficients extract a sequence $w_i(j)$ of *L* bits, one bit from every DCT coefficient, and use the following decision function to determine the watermark bit extracted:

$$w(j) = \begin{cases} 0, if \sum_{i=0}^{L} w_i(j) \le \frac{L}{2}, \; j = 0,1,...,P-1. \\ 1, otherwise \end{cases}$$

P is the length of the watermark pattern; *L* is the number of pixels where the same watermark bit was inserted.

3.3 Zig-Zag scanning order

By traversing a DCT block in zig-zag order, low frequency coefficients are placed in top of a vector. In Figure 5 is shown how a *NxN* sized square matrix gets transformed into one dimensional array of length *NxN*.

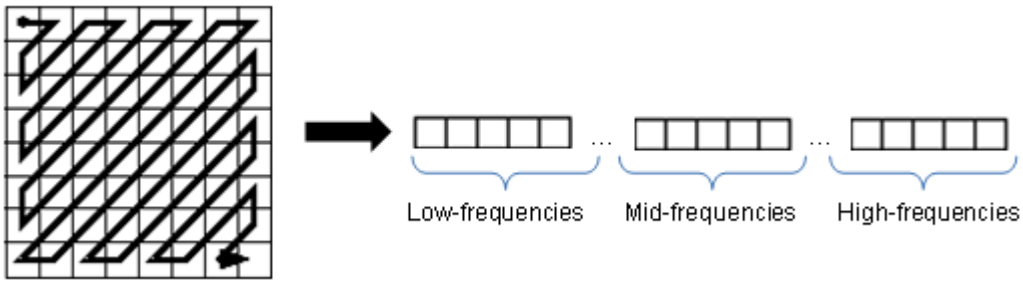

Figure 5. Zig-zag transformation of a DCT block

4. Experimental results

For benchmarking purpose, the results presented here are related to two test images that reached large popularity not only in image processing and computer vision fields. They are depicted in Figure 6, known as Lena and Cameraman. Experiments were conducted on different color and monochrome images. Results presented here are strictly related to the samples form Figure 6. Both images have a size of 512x512 pixels. One gray image is considered because the watermarking methods work with luminance information form pixels and therefore visual quality is influenced in very similar manner.

Figure 6. Test images known as (a) Lena, (b) Cameraman

Watermark bit embedding is done into blocks of 16x16 DCT coefficients. Hence, for 1 bit per block, the watermark payload has to be 512x512/256 =1024 bits. For demonstration propose, the binary image chosen as watermark information, presented in Figure 7, has a size of 64x64 (4096 bits), meaning a total payload of 4 bits per block.

Figure 7. Binary watermark test pattern.

In order to increase reliability of watermark preservation in the host image data, redundant embedding was tested. This strategy simply increases the number of bits inserted in a DCT block by duplicating the watermark bits.

To be useful in an image processing application a watermark embedding technique has to embed watermarks that survive normal processing including lossy compression, digital-analogue conversions, printing and scanning, format conversions etc.

The robustness of the implemented watermarking method was tested against common image processing operations, called attacks:

a) No processing applied;
b) Blurring using blocks of 3x3 pixels;
c) Exponential contrast modification;
d) Brightness increased by an amount of 50;
e) Brightness decreased by an amount of -50;
f) Gamma contrast modification with 1.6;
g) Gamma contrast modification with 0.6;
h) Linear contrast with 0.5;
i) Linear contrast with 1.2;
j) Adding “salt and pepper” noise with density d=0,5%;
k) Resize;
l) Rotate.

The extracted watermark images are listed in Table 1. Row letters correspond to each operation from the list above. Columns represent different redundancy factors.

Experimental results show that the watermark is robust to several processing techniques and distortions.

	1	2	3	4	6	8	10
a)							
b)							
c)							
d)							
e)							

	1	2	3	4	6	8	10
f)							
g)							
h)							
i)							
j)							
k)							
l)							

Table 1. Extracted watermark patterns for different attacks and different redundancy factors.

From an information security perspective it is highly important to detect an existing watermark or any kind of operation meant for altering or eliminating him. It is not impossible for watermarks or modified signals to remain undetected (false negative) or to be detected when they do not exist (false positive).

5. Ownership tracking system

In order to perform automate identification of watermark patterns we design an ownership tracking system. An image of the watermark identification using this system is presented in Figure 8. The dynamic authentication is based on a neural classifier with back propagation neural network. From an architectural view the system incorporates four processing steps:

a) Image pre-processing
b) Training/testing set construction
c) Classifier training
d) Performance evaluation

The image pre-processing is realized using a specially designed tool, allowing to apply common processing operation (blurring, brightness, different contrasts, salt and pepper effect, rotate, resize). For supervised learning the training/testing sets are obtained as results of generated attacks (as those presented in Section 4, Table 1). The more challenging classifier design implies building an initial training data set upon known transformations.

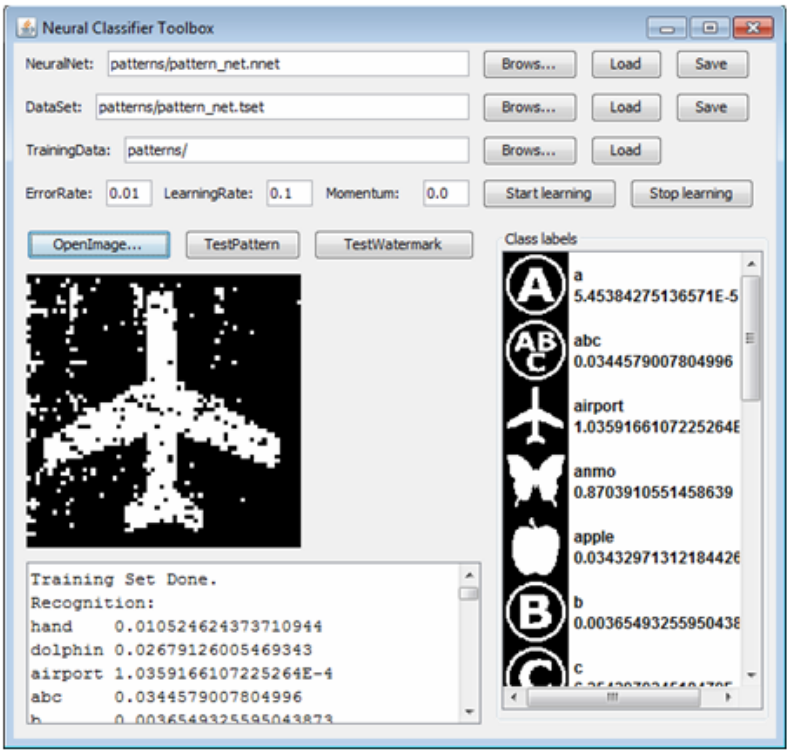

Figure 8. Screen capture from the Ownership tracking system.

Automatic identification also provides an identification rate and correlation between the identified watermark and the original one. (see Figure 9).

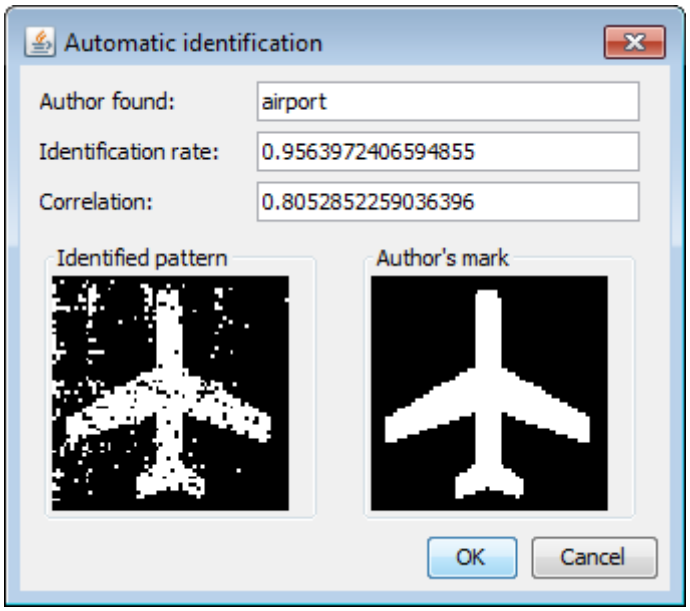

Figure 9. Automatic identification with the proposed Ownership tracking system.

A detailed presentation of the developed Ownership tracking system is outside the scope of this paper and will be subject of a future scientific presentation.

6. Conclusions and further directions of study

The watermarking method presented in this paper was tested against a series of attacks meant to determine the robustness for ownership tracking and verifications. All practical results are obtained by embedded in DCT coefficients of middle frequency. Low frequency coefficients make the watermark more resistant but lower the image quality, on the other hand, high frequency coefficients do not lower image quality but make the technique more vulnerable to attacks.

Quantisation step size and redundancy level are another two parameters that affect image quality and consequently watermark robustness. Since an acceptable balance has to be established at least between these three values, we are looking forward to developing an approach that allows dynamically finding best settings for any image based only on the visual particularities.

The results presented in this paper are part of an on-going research aimed at identifying best practice for providing secure and reliable tools of multimedia ownership tracking or identification. A strong emphasis is on the side of providing highly visual content adaptive methods that can be easily automatized with and integrated in classical pattern recognition.

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References

[1] John C. Russ, *The Image Processing Handbook*, Fifth Edition, CRC Press, 2007.

[2] R.C. Gonzalez, R.E. Woods, *Digital Image Processing*, Second Edition, Addison-Wesley Publishing, 2001.

[3] Ingemar J. Cox, Matthew L. Miller, Jeffrey A. Bloom, Jessica Fridrich, Ton Kalker, *Digital Watermarking and Steganography*, Second Edition, Morgan Kaufmann Publishers, 2008.

[4] Q Li, I. J. Cox, Using perceptual models to improve fidelity and provide resistance to valumetric scaling for quantization index modulation watermarking, *IEEE Transactions On Information Forensics and Security*, vol. 2, no. 2, 127–139, June 2007.

[5] H. Y. Huang, C. H. Fan, W. H. Hsu, An effective watermark embedding algorithm for high jpeg compression, *Proceedings of Machine Vision Applications*, 256-259, May. 2007.

[6] Frank Y. Shih, *Image Processing and Pattern Recognition: Fundamentals and Techniques*, Wiley-IEEE Press, 2010.

[7] N. M. Charkari, M. A. Z. Chahooki, A robust high capacity watermarking based on DCT and spread spectrum, *Proceedings of IEEE International Symposium on Signal Processing and Information Technology*, 194–197, 2007.

[8] Xiaojun Qi, Xing Xin, A quantization-based semi-fragile watermarking scheme for image content authentication, *Journal of Visual Communication and Image Representation*, vol. 22, 187-200, 2011.

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Interactive virtual world for games

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Abstract

The aim of this paper is to present a system that implements virtual world technology in the gaming design. The main idea was to develop, with a lower price, an environment which the user can explore and interact with. We have built a system that makes use of virtual reality glasses to project realistic surroundings where the player uses a controller designed by us in order to interact with the world. This system represents a first step in creating a new platform for users as well as for developers.

Keywords: virtual world, game, programming

1 Introduction

The concept of virtual reality (VR) refers to the computer simulation of the reality and the artificial creation of sensory experiences. The idea of VR and some prototypes first appeared in the 50's but the technology at the time was not powerful enough to sustain a stabile virtual world [3]. The recent breakthroughs in processor power and screen resolutions gave the possibility to develop devices able to create viable virtual experiences. VR technology can be implemented in many fields like healthcare, education, aeronautics, military, entertainment, etc. and can bring forth benefits [3, 6]. Virtual reality can also be used to present information that cannot be comprehended otherwise [5].
In the virtual environment systems the actors are a human operator, a computer and a human-machine interface [1, 2]. The human-machine interface is multimodal, the human actor is immersed in the computer-generated environment and the reality is perceived in three dimensions [1]. There are many software for creating VR, but most of them are dedicated to professional users, require expensive devices and are not free [11, 12].

The aim of this paper is to design a system that implements VR technology in the gaming design. The main idea was to develop, with a lower price, an environment which the user can explore and interact with. A 3D visual display is the output of the user interface, while the interaction is done through manipulation and navigation.
We created a virtual 360° open world which can be explored with the help of a VR headset. The headset immerses the user in the virtual world while the movements of the user as well as its interaction with the environment are controlled using a virtual rifle designed by ourselves. The rifle acts as a controller through which the user controls its actions.

For the beginning we created a frame for the virtual world. It is based on a simple map and contains landscapes such as mountains, a lake and a grassy field. The basic action of the user consists in controlling a character (a tank) with the help of the rifle as a controller. The rifle is meant to add to the realistic experience given by the virtual reality headset.

The paper is organized as follows. In Section 2 we present the technologies used to design and implement the virtual world. Section 3 is dedicated to the new input device: the virtual rifle (the controller). Details of implementation of our virtual VR platform can be found in Section 4. Section 5 reveals new directions of study for further development of our work.

2 Technologies

2.1 Unity

We developed the frame of our VR world using Unity, due to its features. Unity is a powerful game engine that allows developers to easily create 2D and 3D games [9]. The engine allows the creation of games from the simplest ones to the most extensive intricate ones developed by big companies.

Unity puts accent on the portability of its applications by supporting the following APIs: Direct3D on Windows Xbox 360; OpenGl on Mac, Windows and Linux. The engine provides game developers with a multitude of tools such as: automatic shadowing, object collisions or map creation.

2.2 Zeiss VR One

The immersion of the user in our virtual world is realized using a VR headset. There are many headsets from which to choose. A list of VR headsets can be found at [10]. Our choice was Zeiss VR One, a mobile and system-independent headset. It works via apps installed on smartphone devices. The main reason why we chose Zeiss VR was the fact that the headset was relatively cheap compared to others of the same quality available at the time. Another important reason was the fact that Zeiss provides a free SDK for developers in order to aid them in the creative process. The VR One SDK [13] is a SDK for Unity with the purpose of helping developers to create virtual reality apps for the VR. As of now it supports apps for mobile created with Unity3D for Android and IOS. The SDK splits the screen of the smartphone into two video feeds and applies a pre-distortion field along the edges so as not to create discomfort to the user. The SDK also uses the smartphone's sensors to track head-movement and reduce latency as much as possible [14, 15].

3 The controller

We felt that a keyboard or a joystick do not transmit the sensory/immersive feeling that we were looking for. Thus we created our own controller that simulates a rifle. It is based on the Arduino Leonardo board for data transmission and processing the signal from sensors. It uses an AT MEGA 32 microcontroller and has available 14 PWM pins and 8 ANOLOGIC pins. It has a 3V or 5 V power source.

The rifle is the device that controls the movements of your character (i.e. in fact of the user) as well as its interaction with the environment.

The rifle can work in two ways: analogical and digital. In the analogical form you move the target on the screen at the exact position. In the digital form you only transmit in which direction the rifle is moved.

The controller is not represented by just the device; it is the whole system with two parts: the Rifle and the AIM library.

3.3.1 The Rifle

The first part, the rifle itself is intended more for the general user. You simply plug in the rifle and it acts as your input device. In Fig.1. are presented the components of the Rifle in early stages of construction [4].

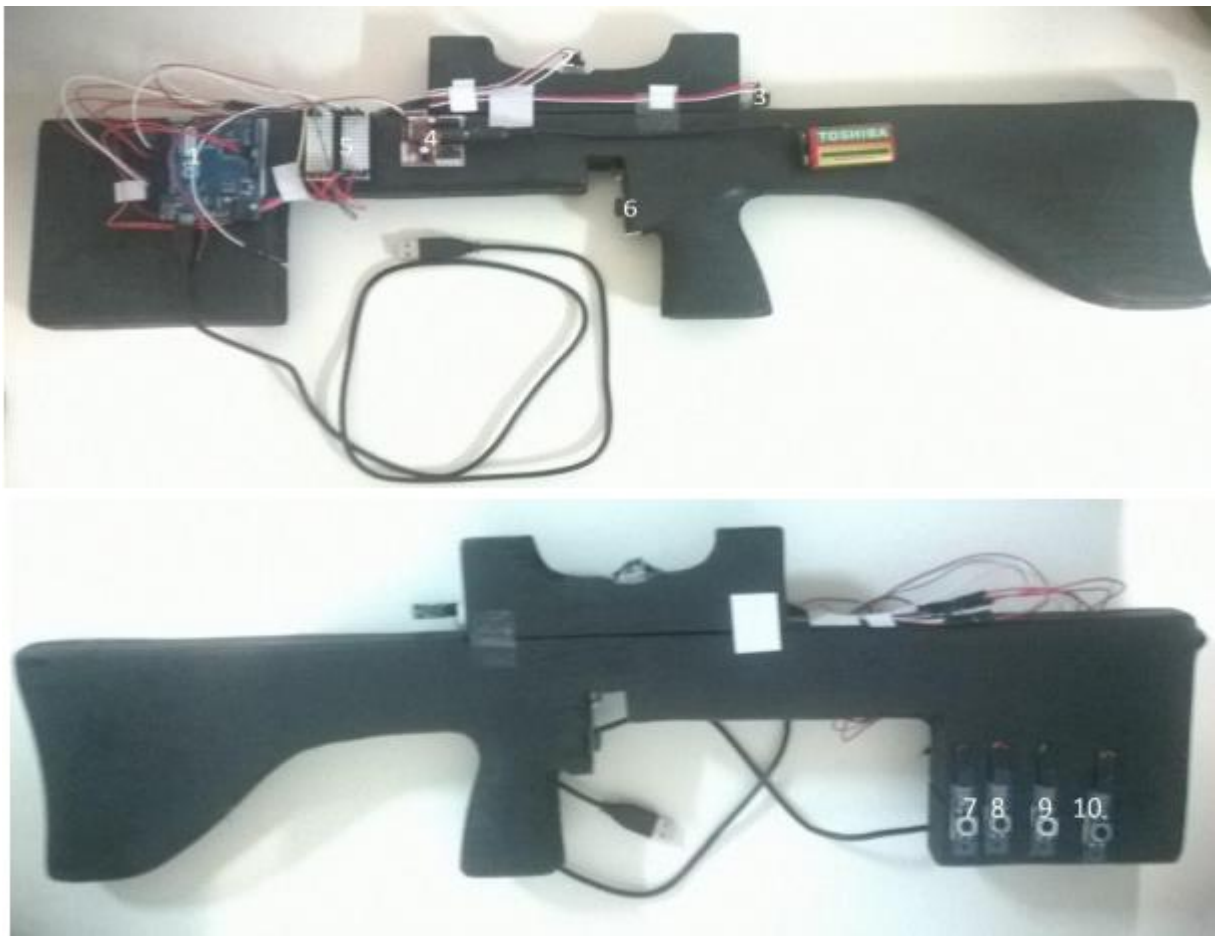

Fig. 1 - Rifle's main components: 1. Arduino board; 2. IMU sensor; 3. Proximity sensor; 4. Power supply ; 5. Breadboard; 6 - 10. Buttons.

Arduino is an open source kit composed of a program and a single board microcontroller [7]. Arduino platform is based on the C and C++ programming language. Arduino Leonardo board is based on the AT Mega microcontroller and it is capable of controlling the mouse and keyboard whit a set of libraries called Mouse and Keyboard [8].

We used the IMU sensor Pololu MinIMU-9, with 9 degree of freedom. It returns the exact orientation of the device to the user. It is equipped with an accelerometer, a magnetometer and a gyroscope, all three having 3 axes of orientation.

The proximity sensor is an infrared based sensor detecting if an object blocks the ray of light at distances of 2 to 10 cm.

The power supply ensures that the energy is provided in the range of 3 to 5 Volts.

The breadboard is a wire connection pad.

The buttons have a brick from, i.e. they are some sort of plug and play ready to use. The button 6 is used to shoot. The other four buttons control the movements. They replicate the W, A, S, D keys used for forward, left, back and right.

The inertial sensor (IMU sensor) returns to Arduino board the two axes coordinates: the X axis, given by magnetometer reading the North and the Y axis given by accelerometer [4]. Using these two axes coordinates we have developed a formula which converts the position of the sensor into the target cursor on the screen. Our formula reveals a linear dependence of them.

In order to use the setup the controller needs to be connected to the smartphone via a OTG cable. The battery has to be connected and the voltage regulator must be turned on. Controller calibration in the virtual reality world is made by keeping the rifle aligned with the headset in a

comfortable position and pressing the first button placed on the handle of the controller (button 6 from Fig. 1).

3.3.2 The AIM Library

The second part of the controller is the AIM Library. This library is written in C#. This part of the project is intended for the developers. It realizes the connection between Arduino and the code that you are writing to create the application that will use the Rifle.
The library has two main uses: one is intended to receive values from the proximity sensor and the buttons and the other one is intended to set the actions that take place when you press any of the buttons set on the rifle. Using the AIM library you can change the buttons and proximity sensor configuration giving them any value that you want.

4 Implementation

As stated earlier our desire was to create a simple frame for a virtual reality platform onto which we can add further development. Our present simple frame is used in order to get users accustomed with the new controller as well as with the virtual reality world. In order to achieve this we designed first a simple map in such a way that the user has no other alternative but to steer a tank downhill while he explores the map. For improving the user's dexterity in handling the rifle we stacked red boxes which the user can aim and shoot at. The game's goal is to hit the red boxes with the tank's cannon while exploring new parts of the map. What separates this game from others is the fact that you are actually inside the game and the way you move and shot is transmitted from the controller that resembles a rifle.
In order to create the terrain we used the terrain builder that Unity offers. The character was imported as an asset but we modified it so that it suited our needs. A screenshot from the game design process is presented in Fig. 2.

Fig. 2. – Image from the game design using Unity

The scripts that control the character were written by us in C#. At the moment the only options that the user has are to explore the map, test his accuracy by shooting the boxes and get used with our setup.

The script that controls the tank movement is given bellow:

```
        // Update is called once per frame
        void Update()
        {
            //Sound playing when a button is pressed to move the tank
            if (Input.GetKey(KeyCode.W)|| Input.GetKey(KeyCode.A) || Input.GetKey(KeyCode.D) ||
Input.GetKey(KeyCode.S))
            {
                if (!Source.isPlaying)
                Source.Play();
            }
            else
            {
                Source.Stop();
            }
            //Rotate the body of the tank
            transform.Rotate(new Vector3(0, Input.GetAxis("Horizontal") * RotationSpeed * Time.deltaTime,
0));
            //Accelerating tank
            Vector3 forward = Input.GetAxis("Vertical") * transform.TransformDirection(Vector3.forward) *
MoveSpeed;
            cc.Move(forward * Time.deltaTime);

            //gravity actioning
            cc.SimpleMove(Physics.gravity);
        }
```

The split screen provided by the SDK is shown in Fig. 3.

Fig. 3. The split screen provided by the SDK

Other virtual worlds can be built on top of this frame by adding maps and by implementing more interactive actions.

5...Conclusions and further directions of study

By using Unity, which is a free game engine (up to a point), with the Zeiss VR One and a smartphone we created an open VR platform frame that can be accessed by many people relatively cheaply. Our frame enables further developments by adding new maps and actions of the users in the 3D environment provided by the game. More elaborate and interactive virtual worlds can be obtained starting from our frame. A further goal is to construct new controllers capable to improve the user experience in a VR world. In the future we intend to enrich the educational content of the games realized using our VR platform, developing actions that teach concepts or ideas to the user while they are playing the game.

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References

[1] Nathaniel I. Durlach, Anne S. Mavor, Editors, Virtual *Reality. Scientific and Technological Challenges* The National Academies Press, 1995.
[2] Roy S. Kalawsky, *Science of Virtual Reality and Virtual Environments,* Addison-Wesley Pub (Sd); 2nd edition, 2004.
[3] Matjaz Mihelj, Domen Novak, Samo Beguš, *Virtual Reality Technology and Applications,* Springer Science + Bussiness Media, Dordrecht, 2014.
[4] Robert Sandica, Marius Toma, Dana Simian, *AIM - Kit for app* development, Imagination, Creativity, Design, Development - Proceedings of the International Students Conference on Informatics, ICDD 2015, Sibiu, Romania, „Lucian Blaga" University Press, pp. 142-147, 2015.
[5] Alan Wexelblat (Editor), *Virtual Reality: Applications and Explorations,* Academic Press Professional, 1993.
[6] Applications Of Virtual Reality - *http://www.vrs.org.uk/virtual-reality-applications/*
[7] Arduino description - *http://www.arduino.cc/*
[8] Arduino Leonardo board picture and description - *http://www.arduino.cc/en/Main/ArduinoBoardLeonardo*
[9] Unity homepage - *https://unity3d.com/*
[10] Virtual Reality headset with review - *www.aliexpress.com/*
[11] Virtual Reality Software, Augmented Reality, 3D Visualization, Knowledge Transfer, Training – *www.eonreality.com/*
[12] Virtual Reality Software - *www.worldviz.com/virtual-reality*
[13] VR One SDK - *https://bitbucket.org/vrone/unity3d/src/3c7395473a371ff755f89715a36ee532427c780d#markdown-header-what-is-the-vr-one-sdk*
[14] Zeiss VR One homepage - *http://zeissvrone.tumblr.com/*
[15] Zeiss VR One - Information – *https://vronecontest.zeiss.com/index.php?controller=pages&view=about_vr*

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Generating a CTL model checker using an attribute grammar

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Abstract

The attribute grammars are presented as a formal approach for model checkers development. Our aim is to design a CTL model checker from a context-free grammar which generates the language of the CTL formulas. An attribute grammar may be informally defined as a context-free grammar that has been extended with set of attributes and a collection of evaluation rules. We are using a CTL attribute grammar for specifying an operational semantics of the language of the CTL formulas by defining a translation into the language which describes the set of nodes from the CTL model where the corresponding CTL formulas are satisfied. We provide a formal definition for an attribute grammar used as input for Another Tool for Language Recognition (ANTLR) to generate an algebraic compiler. Also, is presented the technique of implementing the semantic actions in ANTLR, which is the concept of connection between attribute evaluation in the grammar that generates the language of CTL formulas and algebraic compiler implementation that represents the CTL model checker.

1 Introduction

The process of verification of a CTL model requires defining a specification which is represented by a CTL formula, and then determining whether or not that specification it is satisfied in the model.

Such a specification is performed using the CTL formulas language, which is based on well-established syntactic rules.

Verification of a CTL formula involves a translation of it, from the language in which it was defined to the language over the set of states of the model. The result of this translation will be the set of states that satisfy the given formula in the checked CTL model.

Most often the designing a translator is difficult to achieve and require significant efforts for construction and maintenance.

There are now specialized tools that generate the full code required using a grammar specification of the source language.

Traditionally, the tools used for the two phases of the translation of the text, *lexical analysis* and *syntactic analysis* were LEX *(A Lexical Analyzer Generator)* and YACC ***(Y**et **A**nother **C**ompiler **C**ompiler),* or their GNU equivalent, FLEX, BISON, BYACC/J. The disadvantage of the tools LEX and YACC respectively FLEX and BISON is that they only generate *C* code and that code is not always easily understood by the user (complexity induced by the nature of analyzers they generate).

BYACC / J is able to generate Java code, but supported semantic actions are rudimentary.

A high-performance analyzer generator is ANTLR [1] ***(An**other **T**ool for **L**anguage **R**ecognition),* capable of generating C ++, C #, Java or Python code and represents the instrument used in this article. We will use Java as the target language into which will be developed our own CTL model checker tool.

The original contribution of our approach consists in development of the CTL model checker tool by designing an ANTLR attribute grammar upon which is then generated, using ANTLR, the entire model checker tool.

The evaluation of a CTL formula is done by automatic activation of the semantic actions associated with production rules in the process of walking the Abstract Syntax Tree (AST) built into the process of syntactic analysis of the respective CTL formula, supplied as input for CTL model checker tool.

2 The CTL model

A model is defined as a Kripke structure $M=(S, Rel, P:S\rightarrow 2^{AP})$ where S is a finite sets of states also called nodes, $Rel \subseteq S\times S$ is a transition relation denoting a set of directed edges, and P is a labelling function that defines for each state $s \in S$ the set $P(s)$ of all atomic propositions from AP that are valid in s. The transition relation Rel is left-total, i.e., $\forall\, s \in S\ \exists\, s' \in S$ such that $(s,s') \in Rel$.

For each $s \in S$, the notation $succ(s)=\{s' \in S\ |(s,s') \in Rel\}$ is used to denote the set of successors of s. From definition of Rel, each state from S must have at least one successor, that is $\forall s \in S$, $succ(s)\neq\varnothing$. A path in M is an infinite sequence of states $(s_0,s_1, s_2,...)$ such that $\forall i, i\geq 0$, we have $(s_i,s_{i+1}) \in Rel$.

We use $s' \in succ(s)$ to denote that there is a relation (s, s') in Rel. The labelling function P maps for each state $s \in S$ the set $P(s)$ of all atomic propositions from AP that are valid in s [2].

We use the function $P':AP\rightarrow 2^S$, which associates each atomic proposition with the set of states labeled with that atomic proposition, such that $P'(ap)=\{s \in S \mid ap \in P(s)\},\ \forall\, ap \in AP$.

3 CTL syntax and semantics

A CTL formula has the following syntax given in Backus-Naur Form (BNF) [2]:

$\varphi :: true|false|ap|(\neg\ \varphi_1)|\ \varphi_1 \wedge \varphi_2|\ \varphi_1 \vee \varphi_2|\ \varphi_1 \Rightarrow \varphi_2|\ AX\ \varphi_1|\ EX\ \varphi_1|\ AG\ \varphi_1|\ EG\ \varphi_1|\ AF\ \varphi_1|\ EF\ \varphi_1|\varphi_1 AU \varphi_2|\ \varphi_1 EU \varphi_2,\ \forall ap \in AP$.

A CTL specification is interpreted over Kripke structures. The set of all paths through a Kripke structure is assumed to correspond to the set of all possible computations of a system. CTL logic is branching-time logic, meaning that its formulas are interpreted over all paths beginning in a given state (an initial state) of the Kripke structure.

A CTL formula encodes properties that can occur along a particular temporal path as well as to the set of all possible paths. The CTL syntax include several operators for describing temporal properties of systems: *A* (for all paths), *E* (there is a path), *X* (at the next moment), *F* (in future), *G* (always) and *U* (until)

Syntactically, *CTL* formulas are divided into three categories:

- those whose outermost operator, if any, is not a temporal operator;
- those whose outermost operator is a temporal operator (*X* (next), *U* (until), *F* (eventually) or *G* (always)) prefixed with the existential path quantifier *E*, and
- those whose outermost operator is a temporal operator prefixed with the universal path quantifier *A*.

4 Formal specification of the CTL model checker tool

A CTL model checker tool consists of an algebraic compiler $\mathcal{C}_{MC}:L_{ctl}\rightarrow L_M$ where the source language is the language of CTL formulas and the target language is the language that describes the sets of nodes (states) of CTL models (represented by Kripke structures) in that these formulas are satisfied.

The effective building of the algebraic compiler requires the implementation of a procedure for calculating the generalized homomorphism which uniquely associates to any syntactic construction of the source language a syntactic construction of the target language [3].

The algebraic compiler $\mathcal{C}_{MC}$ translates a CTL formula to the set of nodes S' of a given model M, over which the *CTL* formula is satisfied. Therefore, $\mathcal{C}_{MC}(f)=S'$ where f is the CTL formula to be verified and $S'=\{s \in S \mid (M,s) \models f\}$.

In other words, the algebraic compiler receives as input syntactic constructions of the source language $w \in L_{ctl}$ which then it maps to syntactic constructions of the target language $\mathcal{C}_{MC}(w) \in L_M$.

$\mathcal{C}_{MC}$ is generated from the specifications that define the model checker as a generalized homomorphism between the algebra of CTL formulas and the algebra of the set of states of the model [4]. When the homomorphism is evaluated using as input an object of the source algebra (a CTL formula), the *derived operations* are evaluated to generate the target image of the respective formula into destination algebra, the obtained result being the set of states in which formula is satisfied.

In general, a derived operation is a computation associated with an operation of the source language and specified using syntactic constructions of the target language. Often, the operations and the elements provided by the target language algebra are not expressive enough to specify the correct translation which should be performed by the algebraic compiler.

For each function name *op* from the operator scheme of algebras of the source language L_{ctl} is created a specification rule as a pair $(op, d_{MC}(op))$, where $d_{MC}(op)$ denote the derived operation in the syntax algebra of the target language L_M through which are constructed the target images of constructions created in the source language by the *op*.

We note with O_{ctl} the finite set of names of the operators of the language L_{ctl}, and we have $O_{ctl} = \{\top, \bot, \neg, \wedge, \vee, \rightarrow, AX, EX, AU, EU, EF, AF, EG, AG\}$.

The set of pairs $\{ op, d_{MC}(op)) \mid op \in O_{ctl} \}$ represents the *compiler specification* that can be used to generate a compiler that will associate the words from the syntax algebra of the source language L_{ctl} with words from the syntax algebra of the target language L_M.

Implementation of the algebraic compiler $\mathcal{C}_{MC}: L_{ctl} \rightarrow L_M$ which represents the CTL model checker and practical performs the checking of the CTL formulas, can be described by the following recursive function:

```
function C_MC (f ∈ L_ctl)  {
     if (A_L (f)) {
          if ( f = true)  return S;
          else if (f = false) return ∅;
          else return P'(f);
     }
     else if (A_S(f)= (op, (f_1,…, f_n)))
          return d_MC(op) ( C_MC (f_1), ... , C_MC(f_n))
     else return error;
}
```

Fig. 1: The algebraic compiler as recursive function

For formula f, the function $\mathcal{A}_{\mathcal{L}}$ determines if it belongs to the set of generators of the L_{ctl} language. If $f \in \{\top, \bot\} \cup \{ap \mid ap \in AP\}$, $\mathcal{A}_{\mathcal{L}}(f)$ returns ***true,*** else the function returns ***false.*** $\mathcal{A}_S$ is a mechanism that determines the operation and subformulas which were used to create the formula f.

The components $\mathcal{A}_{\mathcal{L}}$ şi $\mathcal{A}_S$ of the algebraic compiler $\mathcal{C}_{MC}$ can be implemented by a lexical analyzer respectively by a parser.

The lexical analyser $\mathcal{A}_{\mathcal{L}}$ should identify the lexical atoms represented by atomic sentences correctly constructed, according to a regular grammar that generates the specification language of atomic propositions.

The parser $\mathcal{A}_S$ determines whether the formula used as input for the CTL model checker is properly constructed and belongs to the language of CTL formulas whose syntax is described using the formalism of context-free grammars.

The parser $\mathcal{A}_S$ builds the derivation tree (parsing tree) of the formula into the respective grammar and thus it can determine for any sub-formula of the given formula which is the operation and sub-formulas used in its construction.

For the implementation of our own CTL model checker, we exploited the technological resources provided by the ANTLR system, which enables writing the derivative operations in the native language in which the whole algebraic compiler was generated (Java, C#, etc.).

To achieve the $\mathcal{C}_{MC}$ compiler, we designed the following grammar that generates the L_{ctl} language (grammar of CTL expressions) and we used ANTLR to generate automatically the components $\mathcal{A}_L$ and $\mathcal{A}_S$ on the basis of this grammar.

```
grammar CTL;

options {backtrack=true;}

@header {
   package ctl;
   import java.util.HashMap;
   import org.antlr.runtime.*;
   import java.util.HashSet;
   import java.util.Iterator;
   import org.graphstream.graph.*;
   import org.graphstream.graph.implementations.*;
   }

@lexer::header {package ctl;}

ctlFormula
  :     e1=implExpr 'au' e2=implExpr
  |     e1=implExpr 'eu' e2=implExpr
  |     'ax' e=implExpr
  |     'ex' e=implExpr
  |     'af' e=implExpr
  |     'ef' e=implExpr
  |     'ag' e=implExpr
  |     'eg' e=implExpr
  |     e=implExpr ;

implExpr
  :     e1=orExpr ( '=>' e2=orExpr  )* ;

orExpr
  :     e1=andExpr ( 'or' e2=andExpr )* ;

andExpr
  :     e1=notExpr ( 'and' e2=notExpr  )* ;

notExpr
  :     'not'  e=atomExp
  |     e=atomExp ;


atomExp
  :     '(' f=ctlFormula ')'
  |     AP
```

```
  |     'true'
  |     'false' ;

AP  :
('a'..'z'|'A'..'Z'|'0'..'9'|'!'|'~'|'_'|''|'$'|'%'|'&'|'*'|'?'|'|
         '|'/'|'{'|'}'|'['|']'|'^')+ ;

NEWLINE:'\r'? '\n' ;
WS  :   (' '|'\t')+ {skip();} ;
```

Fig. 2: The grammar of the CTL formulas language

It is noted that the precedence of CTL operators is explicitly encoded by the structure of production rules.

Grammar does not contain the code necessary to implement derivative operations associated with CTL operators.

From the grammar specification is observed that each CTL operator $op \in O_{ctl}$ has associated a production rule.

If for the production rule r we note by $op(r) \in O_{ctl}$ the CTL operator for which was defined the production r, a concise specification of the algebraic compiler $\mathcal{C}_{MC}$ is given by the set $\{\langle r, d_{MC}(op(r)) \rangle | r \in P_G\}$, where $d_{MC}(op(r))$ represents the derivative operation corresponding to the production rule r.

In the ANTLR terminology, for $d_{MC}(op(r))$ we will use the term "*semantic action attached to the production r*".

Evaluation of CTL formulas will be accomplished through implementation of the derivative operations as actions attached to the production rules. Such action can be called *semantic action*, because if by example such action is attached to the production:

$$v \to v_1 v_2 ... v_n$$

the role of respective action is to calculate the semantic value of derivation subtree having root v, ie of CTL subformula that can be built from the derivation of nonterminal v.

In order to implement the compiler $\mathcal{C}_{MC}: L_{ctl} \to L_M$ described in figure 1, we will transform the CTL grammar into an attribute grammar, by augmenting its production rules with semantic actions.

We present in the following a formal description of attribute grammars and the concrete use of such a grammar in implementation of the CTL model checker using ANTLR.

5 Verification of CTL models through attribute grammars

An attribute grammar is a context-free grammar augmented with attributes and semantic rules.

Each symbol (terminal or non-terminal) of an attribute grammar has associated a set (possibly empty) of attributes.

Each attribute has a range of possible values.

Let $G=(N,T_G,P_G,S_0)$ a context free grammar, where N is the set of non-terminal symbols, T_G – the set of terminal symbols, P_G – the set of production rules and S_0 - the start symbol of the grammar .

We denote by $G_A=(N,T_G,P_G,S_0,A,as)$ an attribute grammar built on grammar G by its augmenting with attributes *(A)* and semantic rules (actions) *(as)*. A production $p \in P_G$ is of the form: $X_0 \to X_1 X_2 ... X_{n_p}$ where $n_p \geq 1$, $X_0 \in N$ şi $X_k \in N \cup T_G$ for $1 \leq k \leq n_p$. The derivation tree of a sequence from the language generated by the grammar has the following properties:

- Each leaf node is labelled with a terminal symbol from the set T_G;

- Each inner node *t* corresponds to a production $p \in P_G$, and if the production is of the form $X_0 \to X_1 X_2 ... X_{n_p}$, with the meaning of the symbols described above, then *t* is labelled with the symbol X_0 and has n_p child nodes labelled with $X_1, X_2, ..., X_{n_p}$ from the left to the right.

For any non-terminal symbol $X \in N$ attributes can be divided into:
- *Synthesized attributes* if their values are computed using attributes of child nodes. We denote by *S(X)* the set of synthesized attributes of non-terminal *X*.
- *Inherited attributes* if their values are computed using the values of attributes attached to the parent or siblings nodes. The set of inherited attributes of non-terminal *X* is denoted by *M(X).*

The set of all attributes of non-terminal *X* is denoted by *A(X)* and is equal to:

$$A(X) = S(X) \cup M(X)$$

With these notations, the set of attributes of the grammar G_A is defined as:

$$A = \bigcup_{X \in N} A(X)$$

Considering the set of production rules of the form $P_G = \{p_1, \ldots, p_n\}$, with $n \geq 1$, we denote by $as(j) = \{action_j^{i_1}(), ..., action_j^{i_j}()\}$ the set of semantic actions attached to the production p_j, for each $j \in \{1, \ldots, n\}$. With these notations, the set of semantic actions of the grammar G_A is defined as:

$$as = \bigcup_{1 \leq j \leq n} as(j)$$

The values of all attributes of grammar symbols that appear in the derivation tree of a sequence from the language generated by the grammar are determined by the semantic actions associated with productions of the grammar that are involved in the process of derivation of the respective sequence.

These values are effectively calculated in the process of analysis, through invoking the semantic actions by the parser, generally at the moment of recognition of the next production rule used in the derivation process.

The attribute grammar used in the implementation of the CTL model checker will be denoted by G_A^{CTL} and has the following features:

- $A(X) = S(X), \forall X \in N$ – all attributes are *synthesized attributes*;
- $|A(X)| = 1, \forall X \in N$ – any non-terminal symbol *X* has a single attribute, denoted by $a(X)$.
- $|as(j)| = 1$, for each $j \in \{1, \ldots, n\}$ – each production rule has attached a single semantic action, $as(j) = \{action_j()\}$
- We consider that CTL model is given in the form of a Kripke structure: $M=(S, Rel, P:S \to 2^{AP})$, and the CTL attribute grammar corresponding to the model *M* is: $G_{A,M}^{CTL} = (N, T_G, P_G, S_0, A, as)$. Then $AP \subseteq T_G$ (the atomic propositions are terminal symbols of the attributive grammar). Each atomic proposition $ap \in AP$ has associated a single attribute denoted by $a(ap)$, such as $|A(ap)| = 1 \; \forall ap \in AP \subseteq T_G$. The set of attributes of the CTL grammar is extended to:

$$A = (\bigcup_{X \in N} A(X)) \cup (\bigcup_{ap \in T_G} A(ap)) = (\bigcup_{x \in N} \{a(X)\}) \cup (\bigcup_{ap \in T_G} \{a(ap)\})$$

Also, each atomic proposition $ap \in AP \subseteq T_G$ has associated the semantic action $action_{ap}()$ with the purpose of calculating the value of attribute $a(ap)$. The set of semantic actions of the CTL attribute grammar becomes:

$$as = (\bigcup_{1 \le j \le n} \{action_j()\}) \cup (\bigcup_{ap \in T_G} \{action_{ap}()\})$$

- For any symbol $x \in N \cup AP \cup \{true, false\}$, we denote by $v(x)$ the value of attribute $a(x)$ and we have $v(x) \subseteq S$ (the value of the respective attribute is a subset of the set of states of the model *M*).
- The evaluation of the attributes of the non-terminal symbols is context-dependent: if for rewriting of symbol $X \in N$ was used the production i_X, then the value of attribute of non-terminal X in the respective context is:

$$v(X) = action_{i_X}()$$

- The evaluation of terminal symbols is context-free:
  $v(ap) = action_{ap}() = \{s \in S \mid ap \in P(s)\} \; \forall \; ap \in AP \subseteq T_G$, $v(true) = S$ and $v(false) = \varnothing$.

Because often the model *M* is implicit, we write G_A^{CTL} instead of $G_{A,M}^{CTL}$.

A CTL formula *f* is syntactically correct if and only if there is derivation:

$$ctlFormula \overset{*}{\Rightarrow} f$$

where we suppose that *ctlFormula* = S_0 (the start symbol of the G_A^{CTL} grammar). The derivation tree of the formula *f* has its border composed by terminal symbols that appear in the formula *f*.

We consider that derivation $ctlFormula \overset{*}{\Rightarrow} f$ has a length *k*. Then there is the succession of direct derivations $f_0 \overset{i_1}{\Rightarrow} f_1 \overset{i_2}{\Rightarrow} f_2 \ldots \overset{i_k}{\Rightarrow} f_k$, where f_0 = *ctlFormula*, f_k = *f* and i_l represents the number of production rule involved in the direct derivation *l*, where $l \in \{1, ..., k\}$.

If we note by $action_j()$ the name of the semantic action attached to the production $j \in \{1, ..., n\}$, the parser will call, at the same time with building the tree analysis of the formula *f*, the semantic actions attached to production rules from the derivation:

$$ctlFormula \overset{*}{\Rightarrow} f$$

in the following order:

$$action_{i_1}(),\ action_{i_2}(),\ \ldots,\ action_{i_k}().$$

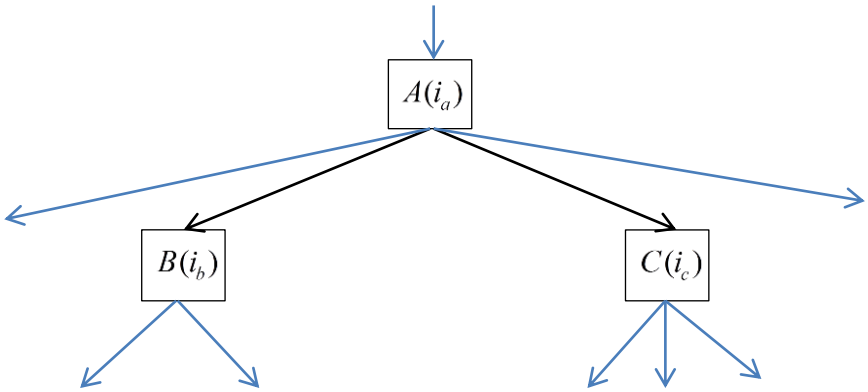

Fig. 3: A syntax subtree for the formula *f*

Assuming that in figure 3 is represented a subtree of the derivation tree built for the formula *f*, where *A*, *B*, *C* are non-terminals of the grammar and i_a, i_b, i_c are the numbers of the production rules used in rewriting of the respective non-terminals, the function $action_{i_a}()$ will contain calls of actions $action_{i_b}()$ and respectively $action_{i_c}()$. An action will return without a call to another action only when it is attached to a terminal symbol. In this case, the respective action carries out the evaluation of that symbol.

In the case of the CTL model $M=(S,Rel,P:S\rightarrow 2^{AP})$, for the symbol *true* will be returned the whole set of states, *S*. For *false* will be returned the empty set $\varnothing$, and for some symbol *ap* from the set *AP* will be returned the set of states $\{s \in S \mid ap \in P(s)\}$.

For a given formula $f \in L_{ctl}$, in the function $\mathcal{C}_{MC}(f)$ the parser $\mathcal{A}_S$ identifies the first production of grammar used in derivation:

$$X_0 \overset{*}{\Rightarrow} f$$

Assuming that production is *r:* $X_0 = t_0 X_1 t_1 X_2 ... X_n t_n$, $\mathcal{C}_{MC}(f)$ will call the derived operation associated with production *r*, $d_{MC}(op(r))$, and will store the result in the meta-variable $\$set$, as follows:

$$\$set = d_{MC}(op(r))\ (\$a_1.set\ ,\ldots\ \$a_n.set)$$

where $\$a_i.set$ are semantic evaluation of non-terminals X_i, $1 \le i \le n$, by which rewriting are obtained the subformulas $f_1,\ldots, f_n$ of *f*. These evaluations are performed recursively, and we have:

$$\$a_i.set = \mathcal{C}_{MC}(f_i),\ 1 \le i \le n$$

If we denote by $G=(N,T_G,P_G,S_0)$ the context-free grammar that generates the CTL formulas language, with production set in the form of $P_G = \{p_1, \ldots, p_n\}$, $n \ge 1$, a concise specification of the compiler $\mathcal{C}_{MC}$ is given by the set of pairs $\{\langle p_i,\ d_{MC}(op(p_i))\rangle \mid 1 \le i \le n\}$, where $d_{MC}(op(p_i))$ is the *derived operation* corresponding to the production p_i and $op(p_i)$ is the CTL operator for which was defined the production p_i, $1 \le i \le n$.

Automatic generation of the CTL model checker from the above specification is accomplished in ANTLR by building an attribute grammar $G_{A,M}^{CTL} = (N,T_G,P_G,S_0,A,as)$ in the meta-description language of ANTLR grammars, with the following properties:

- The grammar productions are those specified in the Section 4.
- Attributes associated to the generators of language L_{ctl} have the following values:

$$v(ap) = action_{ap}() = P'(ap), \forall\, ap \in AP \subseteq T_G$$
$$v(true) = action_{true}() = S$$
$$v(false) = action_{false}() = \varnothing$$

- For production p_i: $X_0 = t_0 X_1 t_1 ... X_n t_n$, the attribute value of non-terminal X_0 is calculated as:

  $$v(X_0) = action_i() = d_{MC}(op(p_i))\ (v(X_1),...,v(X_n)).$$

  Using the notational descriptions of the meta-description language used in specification of the ANTLR attribute gramars, equality becomes:

  $\$set = d_{MC}(op(p_i))\ (\$a_1.set\ ,\ldots\ \$a_n.set)$.

The components $\mathcal{A}_{\mathcal{L}}$, $\mathcal{A}_S$ of the algebraic compiler are automatically generated by ANTLR, using as input the unique file containing the definition of the grammar $G^{CTL}_{A,M}$.

In the ANTLR grammar, the meta-variables of form \$*set* are used to store the attribute values of grammars symbols ($N \cup T_G$). At the time of construction of the derivation tree, for meta-variables that appear in the definition of a semantic action attached to a production used in the derivation process, ANTLR generates code to invoke the semantic actions of productions used in rewriting of non-terminals appearing in the right member of the corresponding production.

The role of semantic actions associated with the production rules of the ANTLR grammar is to calculate and return the attribute values of non-terminal symbols from the left member of respective productions (nonterminals rewrited by these productions).

For example, for the rule *atomExp*:

```
atomExp returns [HashSet set]
:
…
;
```

the generated code has the following form (simplified):

```
public HashSet atomExp () throws RecognitionException
{
      HashSet set = null;    // Return value, referenced in
      ...                    // the definition file of grammar
      return set;            // by $set
}
```

Verification of the given formula *f* involves the building of the derivation $ctlFormula \overset{*}{\Rightarrow} f$ (and hence the corresponding derivation tree) and ends when is returned the attribute value of the start symbol of the grammar $v(ctlFormula) \subseteq S$, which represents the set of all states from *S* which satisfy the formula *f* in the given model M.

Implementing a model checker based on an attributive grammar requires a detailed description of its semantic actions.

In figure 4 is presented the formal definition of the derivative operation $d_{MC}(AG)$.

In our approach, the implementation of the CTL temporal operators is based on two functions $pre_\forall$, $pre_\exists : 2^S \rightarrow 2^S$, defined as:

$$pre_\forall(Z) = \{s \in S \mid succ(s) \subseteq Z\}, \quad \text{respectively}$$
$$pre_\exists(Z) = \{s \in S \mid succ(s) \cap Z \neq \phi\}, \forall Z \subseteq S,$$

where *succ(s)={s'∈S|(s,s')∈Rel}* represents the set of successor states of the state *s* in M.

The functions $pre_\forall, pre_\exists$ are implemented in Java code, specifications being included in the single definition file of the CTL grammar.

The advantage of this solution is that entire algebraic compiler code is generated in a single step without the need for previous pre-processing.

The semantic action of production corresponding to the *AG* operator implements the derivative operation $d_{MC}(AG)$. The function $pre_\forall()$ is dependent on the verified CTL model, so that the model must be accessible to the algebraic compiler when verifying a CTL formula, in the form of internal data structures required by the call $pre_\forall(Z')$.

The argument of the derived operation, $*set1*, represents the calculated image (satisfaction set) of CTL sub-formula to which is applied the AG operator.

The value returned by the semantic action is stored in the variable $*set* to be propagated in the analysis / evaluation process of the CTL formula for which the process of verification was launched:

$$\$set = d_{MC}(AG)\ (\$set_1).$$

```
ctlFormula: $set → 'ag' implExpr: $set1
{  Set Z, Z';
         Z:=∅; Z':= $set1;
         while (¬(Z=Z')) {
            Z:=Z'; Z':=Z'∩ pre∀(Z');
         }
   $set :=Z';
}
```

Fig. 4: The formal definition of the derivative operation $d_{MC}(AG)$

For the CTL operator *AG*, the corresponding *action* included in our ANTLR grammar of CTL language is detailed in figure 5.

```
private HashSet PreAll(HashSet Z) {
  HashSet rez = new HashSet();
  for (Node n1 : model) {
    Iterator<Edge> it =
    n1.getLeavingEdgeIterator();
    HashSet succ = new HashSet();
    while (it.hasNext()) {
       Edge e = it.next();
       Node n2 = e.getTargetNode();
       succ.add(n2.getIndex());
    }
    if (Z.containsAll(succ)) {
       rez.add(n1.getIndex());
    }
  }
  return rez;
}

ctlFormula returns [HashSet set]
@init { }
: 'ag' e=implExpr {
    HashSet rez = new HashSet();
    HashSet rez1 = new HashSet($e.set);
    while (!rez.equals(rez1)) {
       rez.clear();
```

```
        rez.addAll(rez1);
         HashSet tmp = PreAll(rez1);
        rez1.retainAll(tmp);
    }
    $set = rez1;
}
```

Fig. 5: Implementation of the *AG* operator in ANTLR

6 Example

It is noted that for some CTL formula *f*, the syntactic analysis is top-down but evaluation of the formula is at the end of successive function calls using a stack of execution, so it is made in a bottom-up fashion.

The evaluation of the formula *f* is practically accomplished by walking the derivation tree in a bottom-up manner, starting from the leaves and eventually going to the root of the tree.

In each intermediate node, the semantic evaluation of the child nodes are used to compute the semantic value of CTL subformula associated with that intermediate node. The calculation algorithm is determined by the semantic of the CTL operator that appears in the rule of rewriting the non-terminal corresponding to the respective intermediate node.

For the model described in the figure 6:

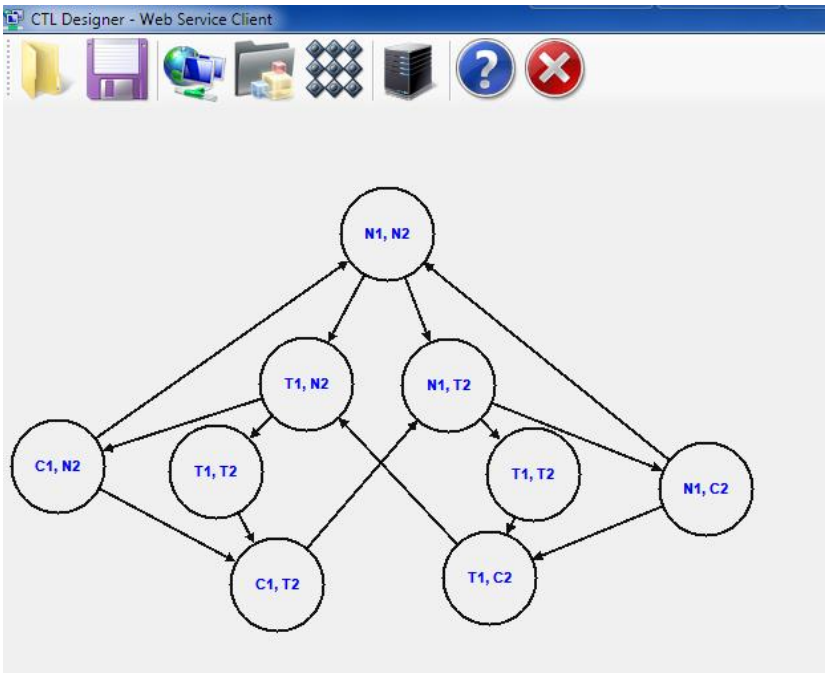

Fig. 6: The CTL model of mutual exclusion of two processes, build with CTL Designer

the parse tree constructed when analyzing the formula *ag (not (C1 and C2))* is presented in figure 7, generated using ANTLRWorks [5]:

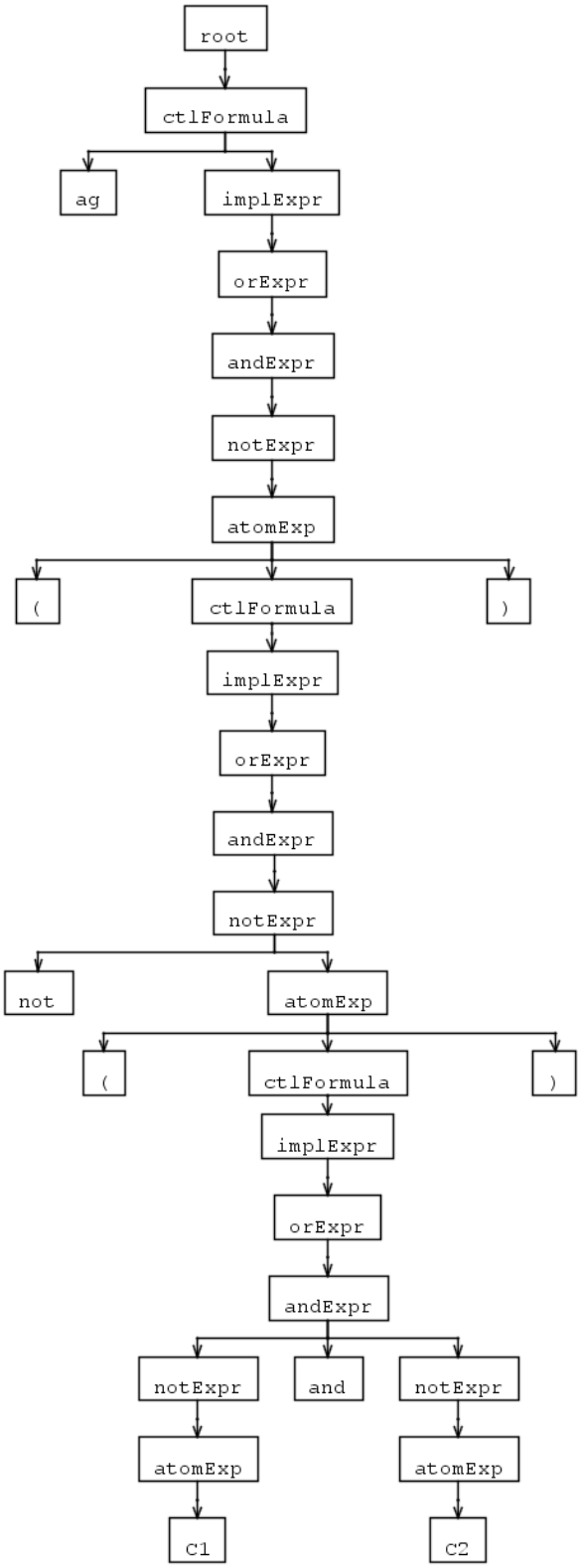

Fig. 7: The parse tree for formula *ag (not (C1 and C2))*

The evaluation of the verified formula is made bottom-up, as we can see from the output of our CTL model checker:

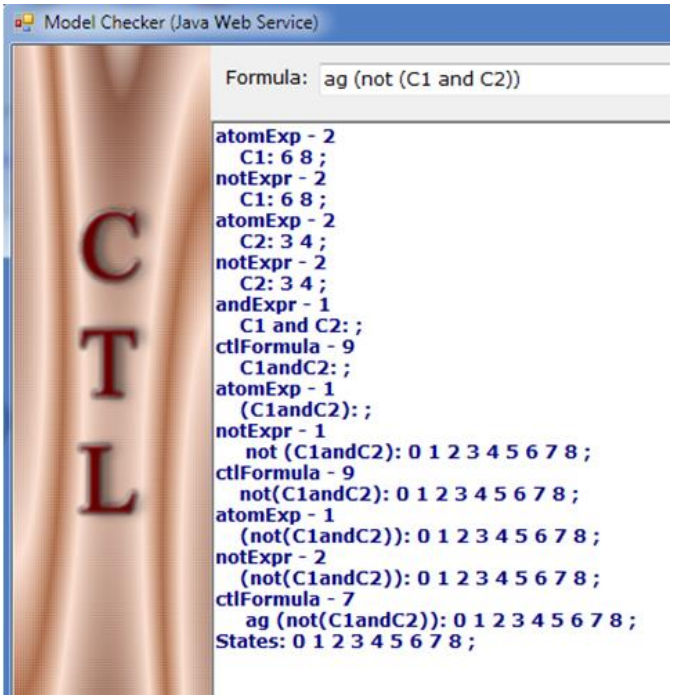

Fig. 8: Verification of formula *ag (not (C1 and C2))* in CTL Designer [6]

7 Conclusions

We enumerate some of the arguments that recommend the utilization of the ANTLR attribute grammars in implementing model checker tools:

- The verified model can be encoded and accessed by classes of objects in the chosen target language (C++, Java, C#, Objective C, Python) directly in the attribute grammar specification file.
- For the implementation of the semantic actions in ANTLR, we can exploit the full power of an advanced programming language (Java, C #, etc.).
- We can specify multiple target languages to generate the model checker tool, and the semantic actions can be implemented by efficient code, taking into account the features of the chosen language.
- The proposed methodology has a generic character since it can be applied to generate model checkers for different temporal logics (CTL, ATL, LTL, etc.).

As future work, we will investigate an alternative approach to generate a CTL model checker using the concept of labelled stratified graph (LSG) [7].

We intend to use the concept of accepted structured path [8] over a stratified graph in order to build a parser for the language of CTL formulas. Also, the inference process [9] developed in a stratified graph can be used to implement a model checker: a CTL formula is transposed in a labelled graph in order to construct inferences based on the given representations, providing as result the set of states where the given CTL formula is satisfied.

References

[1] Terence Parr. *The Definitive ANTLR Reference: Building Domain-Specific Languages*. Version: 2007-3-20.
[2] M. Huth and M. Ryan. *Logic in Computer Science: Modelling and Reasoning about Systems*, Cambridge University Press, pages 1–405, 2000.
[3] E.V. Wyk. *Specificaion Languages in Algebraic Compiler*. CitiSeerX, pages 1–38, 2000.

[4] T. Rus, E. Van Wyk and T. Halverson. *Generating model checkers from algebraic specifications*. Springer, Formal Methods în System Design. Vol. 20, Issue 3, pages 249–284, 2002.
[5] Jean Bovet. *ANTLRWorks: The ANTLR GUI Development Environment*, http://www.antlr.org/works/index.html
[6] L. F. Cacovean, F. Stoica, *WebCheck – ATL/CTL model checker tool*, http://use-it.ro
[7] Daniela Dănciulescu, *Formal Languages Generation in Systems of Knowledge Representation based on Stratified Graphs*, INFORMATICA 2015, vol. 26, no. 3, pp. 407-417, ISSN 0868-4952 (2015)
[8] Daniela Dănciulescu, Mihaela Colhon, *Splitting the structured paths in stratified graphs. Application in Natural Language Generation*, Analele Ştiinţifice ale Universităţii Ovidius Constanţa, Seria Matematică, vol. 22, no. 2, pp.59-69, ISSN: 1224-1784 (2014)
[9] Daniela Dănciulescu, *Systems Of Knowledge Representation Based On Stratified Graphs And Their Inference Process*, 9th International Conference of Applied Mathematics, Abstracts and Pre-Proceedings, Baia Mare 25-28 September (2013)

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