Preface

This volume provides a comprehensive state-of-the-art overview of a series of advanced trends and concepts that have recently been proposed in the area of green information technologies engineering (green IT engineering) as well as of design and development methodologies for models and complex system architectures and their intelligent components. These new research directions have attracted much attention in recent years and are considered to be very promising.

All the contributions included in the volume have their roots in the authors' presentations, and vivid discussions that have followed the presentations, at a series of workshop and seminars, held within the international TEMPUS-project GreenCo project in the UK, Italy, Portugal, Sweden, and the Ukraine, during 2013–2015 and at the 1st–5th Workshops on Green and Safe Computing (GreenSCom) held in Russia, Slovakia, and the Ukraine.

The main purpose of this volume is to present a systematic exposition of research on principles, models, components, and complex systems (software and the PLC-based systems, and networks and IT-infrastructures) and a description of industry- and society-oriented aspects of the green IT engineering. The green IT engineering is a special kind of engineering based on energy-saving and efficient information technologies. It is represented in a form of services focused on the improvement of energy efficiency, safety, and environmental performance of industrial processes and products.

The book aims at motivating researchers and engineers representing different IT domains, and also graduate and Ph.D. students, and "postdocs," to explore and pay attention to an acute need for the promotion and propagation of green values in the analysis and solutions of complex problems that are relevant to the society and national economy.

A chapter-oriented structure has been adopted for this book following a "vertical view" of the green IT, from hardware (CPU and FPGA) and software components to complex industrial systems. The chapters are prepared according to a general paradigm and unified scheme of content, and step by step describe elements of a green IT engineering taxonomy by logically adding new values and proposals.

In terms of the structure, the 15 chapters of the book are grouped into five parts: (1) Methodology and Principles of Green IT Engineering for Complex Systems, (2) Green Components and Programmable Systems, (3) Green Internet Computing, Cloud and Communication Systems, (4) Modeling and Assessment of Green Computer Systems and Infrastructures, and (5) Green PLC-Based Systems for Industry Applications.

The chapters have been intended to provide an easy to follow, comprehensive introduction to the topics that are addressed, including the most relevant references, so that anyone interested in them can start the study by being able to easily find an introduction to the topic through these references. At the same time, all of them correspond to different aspects of the work in progress being carried out by various research groups throughout the world and, therefore, provide information on the state of the art of some of these topics, challenges, and perspectives.

Part I, "Methodology and Principles of Green IT Engineering for Complex Systems," includes three contributions. The first, "Concepts of Green IT Engineering: Taxonomy, Principles and Implementation," by V. Kharchenko and O. Illiashenko, summarizes concepts and provides a taxonomy of the green IT engineering. Main challenges and solutions regarding applications of energy-saving IT-based components and systems as well as principles of development and implementation for green computing are analyzed and discussed. The deliverables of the TEMPUS-project GreenCo are described.

I. Shostak, M. Danova, and Y. Kuznetsova, in "Foresight-Research for Green IT Engineering Development," study the basic principles and development directions of the green IT engineering, as well as ecological research in the software industry. A generalized procedure for foresight project implementation is proposed to determine scientific–technical development directions and perspectives of the green IT engineering using the proposed information technology. The authors propose a new approach to the construction of a foresight-type technology system model in the form of a two-level hierarchical system consisting of the functional and methodological levels. As a formal basis, methods of bibliometrics and scientometrics (calculation of the number of publications, an analysis of citations), multi-criterion decision-making problems (t-ordering, Pareto optimality), and patent analysis (trace analysis of the dynamics of inventive activity) are chosen. The result of the foresight-research implementation will be a number of priorities for the development of the green IT engineering.

In "Green IT Engineering in the View of Resource-Based Approach," J. Drozd, A. Drozd and S. Antoshchuk consider the development of the green IT engineering from the point of view of a resource-based approach which analyzes the integration of an artificial world created by a human being into the natural world (NW). The solution is based on the attainment of a certain throughput, trustworthiness, and the investment in resources: models, methods, and means. The throughput is aimed at receiving the maximum return from resources and the trustworthiness—at a harmonization with the NW. Resources structured under parallelism and fuzziness of the NW show in the development process three levels: replication, diversification, and autonomy. They are serviced by methods improving the throughput, trustworthiness, and access to resources, respectively. Green technologies as a model occupy the autonomy level. The models and methods used belong to the level of diversification. Means are built with the replication of operational elements. The authors discuss the methods of multiple effect and its focusing on the parameters which are important for the green technology that is based on increasing a level of resource development.

Part II, "Green Components and Programmable Systems," includes three contributions. In the first, "Green Logic: Models, Methods, Algorithms," S. Tyurin and A. Kamenskih investigate the green computing systems as energy-aware or energy-efficient and naturally reliable computing systems. A combination of these approaches gives many advantages for applied computing systems but estimations for them should be done very carefully. Delay-insensitive circuits occupy an important role in the design of the green hardware, but reliability improvement techniques of delay-insensitive circuits should be further investigated. The authors propose new indexes for estimating the efficiency of computing systems which can help developers to perform complex estimations of computing systems operating in a wide ranges of supply voltage and temperatures. The semi-modularity and the synthesis technique of fault-tolerant delay-insensitive circuits is discussed in this chapter.

In "Energy-Efficient Scheduling for Portable Computers as Bi-criteria Optimization," I. Turkin and A. Vdovitchenko consider the main problem of portable computers, that is a short duration of operation of the device in the standalone mode, while ensuring the quality of service, i.e., a subjective user satisfaction. There is no single way of measuring the subjective user satisfaction as the current quality of service requirements are in conflict with the requirements to ensure uptime portable computers. A power consumption model of a portable computer is presented as a 3-level power graph. The developed model of the multitasking system's scheduling in a portable computer battery life is based on the assumption that the problem under consideration belongs to the soft real-time class. The synthesis of schedule's multitasking system in a portable computer battery life is carried out by solving a bicriteria optimization problem by deriving the Pareto-optimal solutions. These criteria include the minimum penalty for the decline in the quality of service and the maximum battery life with the current profile of power consumption. For experimental investigation of the power consumption, PCMark-7 and Microsoft Joulemeter were used. As a result of the experiments, it has been found that during the operation on portable computers the minimum and maximum energy levels differ by more than 2 times. A time transition to a low- or high-voltage processor, respectively, can lead to a twofold increase in the battery life.

D. Maevsky, E. Maevskaya and E. Stetsuyk, in "Evaluating the RAM Energy Consumption at the Stage of Software Development," propose a new method of absolute value estimation of the computer energy consumption while running performing. The evaluation is done on the basis of the program source code and can help to choose the optimal solution from the viewpoint of energy saving at the software development stage. The method is based on the indication of energy consumption by the computer Random Access Memory (RAM) depending upon how intensive the RAM is used by the software. The method for determining the estimated computer power consumption based on assembler source code is proposed based on the two proposed mathematical models which allow to create a green software with the control of a degree of being "green" on all stages of its development.

Part III "Green Internet Computing, Cloud and Communication Systems" includes three contributions. In the first one, "Impact of the Internet Resources Structure on Energy Consumption while Searching for Information," by V. Dubovoi and O. Moskvin, a new model of the effect of the Internet resources structure impact on the energy efficiency of information search and the state of the art of search engines energy consumption, characteristics of hypertext systems, and search engines are presented. Moreover, a model of the relationship between the hypertext characteristics and the number of information search steps is developed. For this purpose, the impact of the hypertext structure on the number of steps while searching for relevant and pertinent information and the impact of the number of steps on the energy consumption are studied. As a result, approaches for the optimization of hypertext structure in the conditions of uncertainty are formulated. A simulation model makes it possible to test the adequacy of the developed model of the effect of the structure of distributed hypertext systems on the energy efficiency of information search.

A. Iqbal, C. Pattinson, and A.-L. Kor, in "Introducing Controlling Features in Cloud Environment by Using SNMP," discuss the deployment Simple Network Management Protocol (SNMP) for the monitoring and control of a type 1 hypervisor (in a cloud environment). This is followed by the customization of the MIB and net-snmp with Agent X to provide more SNMP management features. The work provides results of a rigorous physical experimentation involving the SNMP monitoring and management for the type I hypervisor Xen. The research results allow load balancing in the cloud environment during peak hours leading to a reduced power consumption helping the green IT cause.

In "Efficient Error Detection and Correction in Block Data Transmission," N.G. Bardis proposes a collection of techniques for correcting transmission burst errors in data transmitted over signal channels suffering from strong electromagnetic interference, such as those encountered in distributed and embedded systems. Efficiency is achieved by separating the error detection from the correction process and using different codes for each case. The proposed error control techniques are based on simple mathematical operations and are suitable for implementation in the FPGA devices. Therefore, it makes it possible to replace energy-demanding retransmission operations, including the overheads they entail with energy-efficient local error correction calculations. The techniques employed are shown to be more efficient than the existing ones, according to criteria that are relevant to current applications. These techniques reduce the need for error recovery by retransmission and hence the environmental effect of data transmission in terms of energy consumption and electromagnetic emissions.

Part IV "Modeling and Assessment of Green Computer Systems and Infrastructures" includes three contributions. In the first one, D. Basile, F.D. Giandomenico, and S. Gnesi in "Model-Based Evaluation of Energy Saving Systems" focus on a stochastic model-based approach as a support of the analysis of energy-saving systems, in combination with other non-functional properties, such as reliability, safety, and availability. The authors discuss general guidelines for building a model-based framework to analyze critical cyber-physical systems in which an efficient energy consumption is required, while assuring imposed levels of resilience. Also, an overview of the most commonly employed methodologies and tools for the model-based analysis is provided, and an extensive literature is provided as pointers to relevant research activities performed on this attractive topic over the last decades. Finally, in order to illustrate the proposed framework, a case study in the railway domain is shown. By adopting the Stochastic Activity Network formalism, the framework is instantiated to analyze effective trade-offs between the energy consumption and satisfaction of other dependability-related requirements.

In "MSS Models of Smart Grids with Multi-level Degradation and Recovery," E. Brezhnev, H. Fesenko, V. Kharchenko, V. Levashenko, and E. Zaitseva discuss the digital substations (DS) of a smart grid that are complex multi-component maintained systems consisting of a lot of hardware and software components. Failures of the components cause functional and parametric degradation of the substations. According to the DS structure, the reliability-block diagram, the structure function, and the Direct Partial Logical Derivatives (DPLDs) for the RMSS "electronic transformers—merging unit" are considered. The principal condition of the DPLD application in reliability analysis is the representation of a system under consideration by a structure function. The authors consider the calculation of some of these measures and their criticality for the analysis of the electronic transformers—merging unit. The structure function of this unit is based on the operation conditions of this system (unit).

Ye. Bodyanskiy, O. Vynokurova, I. Pliss and D. Peleshko, in "Hybrid Adaptive Systems of Computational Intelligence and Their On-line Learning for Green IT in Energy Management Tasks," consider a crucial problem of intelligent energy management which arises in the context of an intensively developed science direction, the Green IT. A hybrid neuro-neo-fuzzy system and its high-speed learning algorithm are proposed. This system can be used for online prediction of essentially nonstationary nonlinear chaotic and stochastic time series which describe electrical load producing and consuming processes. The considered hybrid adaptive system of computational intelligence has some advantages over the conventional artificial neural networks and neuro-fuzzy systems. The proposed hybrid neuro-neo-fuzzy prediction system provides a high-quality load prediction that is very important for the power systems.

Part V "Green PLC-Based Systems for Industry Applications" includes three contributions. The first one, Y. Kondratenko, O.V. Korobko and O.V. Kozlov, "PLC-Based Systems for Data Acquisition and Supervisory Control of Environment-Friendly Energy-Saving Technologies," presents the development of PLC-based systems for data acquisition and supervisory control of environment-friendly energy-saving complex high-tech technologies. The functional structure and main components of the PLC-based SCADA systems for environment-friendly energy-saving technological processes are given. The examples of SCADA applications in the design of the PLC-based systems for the monitoring and automatic control of (a) ecopyrogenesis (EPG) and (b) thermoacoustic technological processes are presented. The authors consider the criteria of energy and economic efficiency of the EPG technological process. The functional structures, software, and hardware implementations as well as multi-level human–machine interfaces of the developed PLC-based systems for data acquisition and supervisory control are shown. A considerable attention is given to particular qualities of the computation of technological parameters of the ecopyrogenesis and thermoacoustic processes by the proposed SCADA systems. The developed PLC-based SCADA systems provide: (1) a significant increase of values of the energy and economic efficiency criteria of the EPG and TAD complexes, (2) a high precision control of both technological processes, (3) monitoring of current technological parameters using the indirect methods for the measurement of parameters and identification, and (4) automatic control with high values of quality indicators and optimal parameters.

In "Assessment of Energy Consumption for Safety-Related PLC-Based Systems," V. Sklyar, O. Odarushchenko, E. Bulba, R. Horbenko, A. Ivasyuk, and D. Kotov describe an approach to measure the energy consumption of programmable components (MCU, FPGA, etc.) which are a core of the Programmable Logic Controller (PLC). An analysis of dependence of energy consumption on the type of programmable components as well as on features of software gives a road map for the implementation of energy efficiency measures to make the PLCs "greener." A special toolset named GreenCo Controller has been designed, implemented, and tested for the above-proposed solution. The architecture designed includes the following components: a commercially available motherboard (Arduino UNO) programmed with software to perform data processing with respect to the measurement of energy consumption of the target board-shield (GreenCo board); a GreenCo board on the basis of Microchip dsPIC30F3011 MCU programmed with different types of application software as a subject of energy consumption investigation; a software monitor for a PC desktop using the GUI of the GreenCo Controller mentioned. "Green" features of the PLC are analyzed after that formal optimization problems against the "energy consumption level/safety level" criterion. Such problems can be solved using dynamic programming. The concept and design of the GreenCo Controller are described. Some suggestions for a further research on the GreenCo Controller are proposed as a conclusion.

Finally, in A. Shamraev, E. Shamraeva, A. Dovbnya, A. Kovalenko, O. Ilyunin, "Green Microcontrollers in Control Systems for Magnetic Elements of Linear Electron Accelerators," a new approach to the design of industrial control systems is presented which is based on the application of "green" microcontrollers (with a low power consumption) used in complex real-time control systems. A wide range of capabilities of modern microcontroller peripheral units makes it possible to implement a system with a wide functionality based on a single microcontroller chip. The authors describe the order of connection of microcontroller pins which reduces noise influence on the results of signal processing. As an example, the proposed approach is considered in the context of development of a power supply control system for magnetic elements of linear electron accelerators.

The papers selected for this book provide a broad and comprehensive overview of some of the most up-to-date and relevant problems in the area of green IT engineering and the approaches and techniques that relevant research groups within this area propose, develop, advocate, and—finally—use for the solution of real world problems. We would like to express our appreciation to all authors for their contributions as well as to reviewers for their timely and interesting comments and suggestions. We certainly look forward to working with all contributors again.

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