

Preface

This book presents a conceptually original, oscillations-based paradigm aimed at the modeling of agents and their systems as coherent, stylized, neurodynamic processes. Putting into perspective the various pathways of research as they are interrelated, the book provides a philosophical underpinning, experimental background and some modeling tools. In this effort, some general fundamental design principles of the field-theoretical view of the oscillating agent are outlined, as well as of coherent economic or social systems in general.

The conceptual insights presented here are employed for the formulation of the main postulates and principles of the proposed Oscillation-Based Multi-Agent System (OSIMAS) simulation paradigm.¹ The OSIMAS provides a foundation for the creation of an oscillations-based social simulation research framework. It explores various stylized oscillating agent models (OAM), which can be further expanded to the multi-agent system (MAS) simulation model. For that reason, a canonical pervasive information field (PIF) and wave-like interaction models (WIM) are also employed.

Consequently, this study not only discusses the major conceptual assumptions of the proposed (OSIMAS) paradigm, but also presents an electroencephalography (EEG)-based experimental validation framework and some prior empirical results to validate or disprove the OSIMAS assumptions. Based on the conceptual, experimental and simulation findings, a modeling framework is constructed aimed at the prospective development of the proposed pioneering paradigm.² This book also systemizes some other studies and applications, which were most relevant to the work presented here.

However, this is a challenging multidisciplinary research area, which is only starting to evolve following recent technological advances. The major problem concerning these fundamental and applied research areas is related to the lack of a

¹The OSIMAS project's website is available at <http://osimas.ksu.lt>.

²The OSIMAS simulation platform and interactive models are available at <http://vlab.vva.lt>; for login, enter the username Guest and password guest555.

conceptual unifying theory, which could provide a bridge for a coherent research framework. The author hopes that this multidisciplinary book, via the unique conceptual, experimental and modeling framework, helps to bridge that gap.

In fact, in recent years there has been a noticeable surge of interest in the multidisciplinary areas, bridging the gaps between diverse fragmented research in terms of disciplines, methods, and scale. In this regard, multidisciplinary research is always packed with some element of risk, as it is very difficult to not only attempt to master a few research areas, but also to combine them so that one can propose certain experimental validation in an effort to resolve the long-standing fundamental issues confronting us in these areas of research, not only individually but also collectively. It is a delicate balancing act, especially when one is attempting to simultaneously address what appear to be related, but conflicting fundamental issues in such seemingly diverse disciplines as quantum mechanics, neuroscience, artificial intelligence, cognitive and behavioral sciences, etc.

Accordingly, the mainstay of this book is to systematically review and synthesize related fundamental, experimental and simulation approaches stemming from various multidisciplinary areas of research. Thorough analyses are performed using universal principles of field-based self-organization on various scales, starting from the micro level, i.e., quantum physics, where we can find a great number of theoretical and experimental studies suggesting that field-theoretical properties at the micro level occur not at the quantum level with subatomic or atomic particles, but also in the world of large molecules, the brain's neural networks, and presumably on the social scale too.

In fact, the proposition that the physical manifestation of consciousness is a bioelectromagnetic field (BEM) that exhibits wave-mechanical dynamics has profound implications for our understanding of the phenomenon of consciousness. Moreover, even our societies (the macro-world) can no longer be viewed as entities totally separate from the quantum effects taking place in the heads of a society's members. At least theoretically, we can acknowledge and arrive at the viewpoint that societies can also be understood as collective consciousness processes emerging from the coordinated behavior of the conscious and subconscious bioelectromagnetic brain fields of individual members of society. In this way, we can hypothetically admit that emergent social behavior could be at least partly associated with some coherent, collective, bioelectromagnetic brain field, characterized by some synchronous collective mind state processes and, therefore, can inherit some degree of field-like behavior.

By reflecting a subject's visceral connection to the world and to other people, research into collective brain activations may reveal the states of a subject that are evident in overt behavior, but are connected to collective mental states and are thus helpful for a more holistic understanding of a subject's conduct. We have to be aware that studying the mind-field basis of social cognition and interaction in terms of two- or multi-person neuroscience may shift the focus of traditional research into social communication from basic sensory functions in individual subjects toward the study of interconnected mind-fields.

From another perspective, social networks, digital services, and the network economy at large, are highly heterogeneous with many links and complex inter-relations. Uncoupled and indirect interactions among agents require the ability to affect and perceive information in a field-broadcasted context. In this sense, there is a need to look for ways to model the information network as a virtual information field, where each network node receives pervasive (broadcasted) information-field values. Such an approach is targeted to enforce indirect and uncoupled (contextual) interactions among agents in order to represent contextual broadcasted information in a form locally accessible and immediately usable by network agents. In this regard, there is a clear need to develop a collective mind-field paradigm capable of simulating some complex social cognitive and behavioral phenomena, such as collective states' temporal circadian rhythms, spatial clustering, herd effects, convergence effects, social networking, media and political campaigns impact on collective mind states, propaganda and information war effects on perception of threats, etc.

The implications of collective behavior modeling in the simulated agent-based social mediums play a paramount role in achieving a better understanding of the behavior of modern digitally interconnected economic systems. It provides a unique possibility to define some novel ways to manage the core individual and collective parameters, which impede or enable the observation of local and nonlocal emergent complex social phenomena. In a wider perspective, such modeling provides means to simulate and investigate various sensitivity, fragility, and contagion processes in different social mediums.

In this way, via agent states-related diffusion properties, we could investigate complex economic phenomena like the spread of stock market crashes, currency crises, speculative oscillations (bubbles and crashes), social unrest, recessionary effects, sovereign defaults, etc. All these effects are closely associated with social fragility, which is affected by and follows seasonal, production, political, business, financial, and other cycles. However, there is a long way to go and the author believes this manuscript can contribute in that way via some of the original conceptual insights, experimental frameworks and social simulation models provided.

The multidisciplinary OSIMAS paradigm, not only via some theoretical insights but also via an empirical and simulation framework, contributes to a new way for modeling the complex dynamics of individual and collective mind states, where emergent complex social behavior is understood as a consequence of coherent individual mind-field effects.

We hope that approaches based on the proposed research framework will help to reveal new frontiers of multidisciplinary research. However, we also admit that extended additional conceptual, experimental and simulation research needs to be done to examine, in detail, the issues and criteria that will help improve the OSIMAS paradigm and associated models. This could yield new knowledge and surprising perspectives, allowing a better understanding of social agents, their social organization principles, and corresponding simulation models of individual and collective behavioral patterns. In a way, this book with its presented pioneering

paradigm is just a beginning, which reveals a perspective of a vast new multidisciplinary research area.

Hence, because of its highly multidisciplinary nature, this book might be of interest to scholars in many disciplines, e.g., the artificial intelligence (AI) community, multi-agent systems (MAS) research, neuroscience and cognitive science, psychology, social and economic sciences, applied quantum physics, biological systems research, etc. Students from various disciplines may also find a lot of inspiring ideas here about some unconventional research topics.

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In general, the content of this book is organized so that the reader would first become familiar with the philosophical and conceptual ideas stemming from the great diversity of related research approaches. Afterwards it introduces the OSIMAS research conceptual framework, which proceeds with the experimental chapters that pertain to the neuroscience related EEG (electroencephalography) research of human brain oscillations in the form of brainwaves. Further chapters provide various OAM and MAS modeling setups, which culminate with some simulation results. At the end of the book, Appendixes A, B, C, and D review OSIMAS research approaches in the broader light of other related theories and models.

In fact, the structure of this book has been partly formed by a summation and adaptation of the earlier publications. Therefore, some chapters have their own line of thought and can be read separately from the rest of the book. However, all the chapters are closely related to the OSIMAS paradigm and follow its development in a chronological way.

Brief comments regarding the content are provided below, and the first synopsis chapter explains the multidisciplinary scope and major aims of the book in detail. It briefly introduces the related cross-disciplinary research approaches.

The second chapter mainly focuses on (i) identifying the general properties of information-based economic systems, (ii) ways to model the emergent and self-organizing features of social networks, and (iii) discussion on how to simulate complex economic systems using the field-based approach and multi-agent platforms. This chapter provides some ideas and examples on how, not only the communication mechanism, but also the social agents can be simulated as oscillating processes.

The third chapter starts from a review of a wide range of theories across various disciplines in search of some common field-like fundamental principles of coordination and self-organization existing on the quantum, cellular, and social levels. These findings outline some universal principles, which are further employed to formulate the main premises and postulates of the proposed OSIMAS simulation paradigm.

The fourth chapter not only comments on the major conceptual assumptions of the proposed OSIMAS paradigm, but also presents an EEG-based experimental validation framework and some empirical results to validate the major OSIMAS assumptions from the viewpoint of some baseline individual neurodynamics. In other words, here is presented the experimental neuroscience based research framework and some experimental evidences of the oscillatory nature of social agents as approximations of real humans. In this regard, we noticed from the neuroscience domain that basic mind states, which directly influence human behavior, can be characterized by the specific brainwave oscillations. For the experimental validation (or disproof) of the biologically inspired OSIMAS paradigm we have designed a framework of baseline individual and group-wide EEG-based experiments. Initial baseline individual tests of spectral cross-correlations of EEG-recorded brainwave patterns for some mental states have been provided in this chapter. Preliminary experimental results do not refute the main OSIMAS postulates.

The fifth chapter presents a simulation of human brain EEG signal dynamics using a refined coupled oscillator energy exchange model (COEEM). We have created the coupled oscillations-based COEEM model in order to establish a relationship between the experimentally measured EEG signal oscillations and the conceptually described oscillating agents in the OSIMAS paradigm. Investigation and further refinements of this biologically inspired experimental model helped to define the features of our constructed oscillating agent model (OAM) in the OSIMAS paradigm. Hence, the oscillation-based modeling of human brain EEG signals oscillations, using a refined Kuramoto model, not only directly demonstrates validity of the OSIMAS premises but also helps to specify the OAM, but also significantly contributes to EEG signals prognostication research, which is the major topic of this particular direction of neuroscience research.

The sixth chapter describes a conceptually novel modeling approach, based on quantum theory, to the basic human mind states as systems of coherent oscillation. The aim is to bridge the gap between fundamental theory, experimental observation, and the simulation of agents' mind states. The proposed quantum mechanics-based approach reveals possibilities of employing wave functions and

quantum operators for a stylized description of basic mind states and the transitions between them in the OAM. The basic mind states are defined using experimentally observed EEG spectra, i.e., brainwaves (delta, theta, alpha, beta, and gamma), which reveal the oscillatory nature of the agents' mind states. Such an approach provides an opportunity to model the dynamics of the basic mind states by employing stylized oscillation-based representations of the characteristic EEG power spectral density (PSD) distributions of the brainwaves observed in experiments.

In the seventh chapter, a description and some explanatory sources pertaining to the OAM are provided, which are an intrinsic part of the oscillations-based OSIMAS paradigm. This chapter presents the OAM simulation results of the basic mind states' (BMS) dynamics. The OAM models a social agent in terms of a set of basic mind-brain states and the transitions between them. The presented OAM model is based on the experimental EEG (electroencephalography) spectral power redistribution processes observed during the different mental states, stylized entropy/negentropy processes and internal energy dynamics. In this way, the OAM paves the way for a putative link between the conceptual oscillations-based OSIMAS framework and the empirically observed coherent bioelectromagnetic oscillations of ensembles of neurons in the brain (EEG spectra).

The eighth chapter deals with the multi-agent system (MAS) simulation setup and analysis of the obtained simulation results. The OAM-based MAS is essentially based on the OAM described in the seventh chapter. In general, the OAM-based MAS construction is aimed at simulating circadian group-wide, i.e., collective mind-brain states and the correspondingly emerging coherent and synergy phenomena. This chapter is aimed towards the simulation setup for a group of agents, which coordinate (synchronize) to some degree in their internal BMS processes not by using pair-to-pair interaction, but a field-like (mean field) coordination that pertains to (i) the common external circadian rhythms, and (ii) some basic collective synergy effects, which conserve the systems' total energy and decrease system's entropy. The OAM-based MAS simulation is oriented to reveal the basic conditions and parameters for the emergence of some coherent group-wide behaviors.

The ninth and tenth chapters were mostly contributed by prof. habil. Dr. Sarunas Raudys. In the ninth chapter, improved cellular mechanism based models of excitable media employed to mimic economic and financial investing units (agents) in rapidly changing environments are presented. We have used an AI-based approach to investigate excitation information propagation in artificial societies. We used a cellular mechanism approach, in which it is assumed that social media is composed of tens of thousands of community agents, where useful (innovative) information can be transmitted to the closest neighboring agents. The model's originality lies in its exploitation of the artificial neuron-based agent schema with a nonlinear activation function to determine the reaction delay, the refractory (agent recovery) period and the algorithms that define the mutual cooperation among the several excitable groups that comprise the agent population. This novel media model allows a methodical analysis of the propagation of temporal and spatial oscillations of several competing innovation/information signals in social media

and networks. Depending on the model parameters, we can obtain temporally or spatially oscillating chaotic, spiral, semi-regular, or regular agents' behaviors. The sum of the outputs of the groups of integrated agents fluctuates over time, similar to the observed oscillations in the financial time series.

In the tenth chapter, the spectral representation of the output time series allows classification of the agent groups and determination of the excitable model parameters. The latter fact inspired the creation of the spectra-based clustering of the financial time series. This chapter uses large-scale social media excitation wave-propagation model for the simulation of automated investment strategies. Some OAM, PIF, and WIM principles were integrated in the large-scale AI-based MAS modeling of agent states. The real-life applications use simple wave-like communication mechanism between agents. The spectral representation of the multidimensional time series allows specific features to be generated that are necessary for recognizing the type of chaos-generating model.

At the end of the book the reviewing Appendixes A, B, C, and D were kindly contributed by Prof. James F. Glazebrook. He has focused his attention on certain theories and concepts which are considered to be germane to the tasking mechanisms of the OSIMAS and OAM. These are common to a number of mainstream models of cognition, neurodynamics, and sociobiological/cultural systems. The main topics covered in these four appendixes are: (1) The Maturana–Varela theory of autopoiesis, leading to Varela's foundations for a theory of neurophenomenology, (2) Global Workspace Theory—a principal forerunner in modern theories of cognition, (3) Distributed and Embodied Cognition, (4) Several other approaches interrelated with (1–3) that may also be significant for the OSIMAS and OAM models.

Introducing the Oscillations Based Paradigm

The Simulation of Agents and Social Systems

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