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Editorial

Contributions to the 2021 IS4SI Summit from the 13th International Workshop on Natural Computing (IWNC) †

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† Summary of the 13th International Workshop on Natural Computing (IWNC), IS4SI Summit 2021, online, 12–19 September 2021.

Abstract: This is an outline of contributions from the 13th International Workshop on Natural Computing (IWNC), which was one of the ten conferences of the 2021 Summit of the International Society for the Study of Information held online on 12–19 September 2021. Each of the ten conferences contributing to the summit had a 3–6 h block of plenary time with the program (usually invited lectures and panel discussions) intended for all participants of the Summit. Outside of the assigned plenary time, conferences had parallel programs of more specialized, technical, or focused presentations. All plenary events and some parallel internal events of the conferences federated into the summit were recorded. Links to several of these recordings and extended abstracts of all presentations are available at the IS4SI website. Five of the papers presented at the IWNC were submitted and accepted for publication in the Special Issue of *Proceedings*.

Keywords: natural computing; unconventional computing; information dynamics

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1. Introduction

This is an outline of contributions from the 13th International Workshop on Natural Computing (IWNC), which was one of the ten conferences of the 2021 Summit of the International Society for the Study of Information held online on 12–19 September 2021. Each of the ten conferences contributing to the summit had a 3–6 h block of plenary time with the program (usually invited lectures and panel discussions) intended for all participants of the summit. Outside the assigned plenary time, conferences had parallel programs of more specialized, technical, or focused presentations. All plenary events and some parallel internal events of the conferences federated into the summit were recorded, and many of these recordings have been edited and published on YouTube. Links to several of these recordings and extended abstracts of all presentations are available at the IS4SI website: https://summit-2021.is4si.org/ (accessed 8 March 2022). This summary is focused on the 13th International Workshop on Natural Computing (IWNC). It presents the subject and content of the conference. The Organizing Committee of the IWNC Conference was chaired by Marcin J. Schroeder (Global Learning Center, IEHE, Tohoku University, Sendai, Japan) and co-chaired by Masami Hagiya (Department of Information Science, Graduate School of Information Science and Technology University of Tokyo, Japan), Yasuhiro Suzuki (Graduate School of Informatics, Nagoya University at Nagoya, Japan), and Gordana Dodig-Crnkovic (Chalmers University of Technology and the University of Gothenburg, Gothenburg, Sweden).

2. The IWNC Conference

The series of conferences called International Workshops on Natural Computing, initiated in 2006, developed from its original focus on molecular computing. However, within the years following this original initiative, the topic of natural computing became one of the main topics of study in several disciplines. Natural processes or even life

itself started to be considered a form of information processing with characteristics of computing. On the other hand, information processing in natural systems became a source of inspiration for innovation in computer science, artificial intelligence, and engineering. Moreover, computer simulation became a common tool for the study of nature. The plan for the workshop was cancelled in 2020 due to the global outbreak of COVID-19. The workshop was implemented as an online contributing event of the cluster of conferences of the 2021 IS4SI Summit. This was a unique opportunity to engage in interactions and discussions with participants of multiple conferences of the summit.

Following this general trend of mutual interactions of disciplines, the 13th International Workshop on Natural Computing continued the IWNC series' already established tradition of devote its sessions to recent and future developments in research, practice, philosophical reflection, and creative activity in the intersections of nature, computing, information science, cognitive science, and the study of life and culture.

The workshop intended to bring together a very wide range of perspectives, including philosophical, scientific, and artistic viewpoints. There was an opportunity to present original and creative contributions without any restriction of disciplinary divisions or the level of advancement of research. Contributions from those at the beginning of their academic or intellectual career were as welcome as those from experienced professionals.

3. Invited Lectures

The IWNC included the following four invited lectures (all were in the plenary program for all participants of the summit), presented here with their abstracts.

"Computing with slime mould, plants, liquid marbles and fungi" by Andy Adamatzky (Unconventional Computing Lab, UWE, Bristol, UK).

The dynamics of any physical, chemical, and biological process can be interpreted as a computation. The interpretation per se might be non-trivial (but doable) because one must encode data and results as states of a system and control the trajectory of a system in its state space. One can make a computing device from any substrate. I will demonstrate this using examples of computing devices made from the slime mould *Physarumpolycephalum*, growing plant roots, the vascular system of a plant leaf, mycelium networks of fungi, and liquid marbles. The computing devices developed are based on the geometrical dynamics of a slime mould's protoplasmic network, the interaction of action potential-like impulses traveling along vasculates and mycelium networks, and collision-based computing of plant roots' tips and droplets of water coated by hydrophobic powder. Computer models and experimental laboratory prototypes of these computing devices are presented.

"Falling Up: The Paradox of Biological Complexity" by Terrence W. Deacon (UC Berkeley).

There is an unexpected twist in the evolution of the complexity of biological information. A survey of living complexities at many levels suggests that it is often a spontaneous *loss* of capacity, a *breakdown* of individuation, and *decreased* complexity at one level that serendipitously contributes to the emergence of a more complex collective integrity at a higher level of scale, such as from individual cells to multi-celled organisms like ourselves. This points to a critical *non*-Darwinian process that is the inverse of a progressive improvement of adaptation. I will provide evidence gleaned from a wide range of phenomena to demonstrate that evolutionary complexification often results from a tendency to simplify, to do less, to shift the burden elsewhere if possible. It is an expression of life's *least work principle*. Life just backs into ever more intricate webs of dependency as it explores ways to avoid work. Additionally, this web of interdependencies only becomes more entangled with time, producing a complexity ratchet. In particular, cases of hierarchic complexification may result from displacement or externalization of functional information onto some outside influence, whether environmental or social. This reduces the selection maintaining the corresponding intrinsically provided information, which consequently becomes susceptible to spontaneous degeneration. With its degeneration, there is increasing selection to maintain access to this extrinsic source. As a result, duplication, displacement, degeneration, and complementation can build recursively, level upon level, from molecular information

to organism adaptations to mental and social cognition. The result is that what we call 'information' tends to spontaneously complexity in depth, with higher levels dependent on and emergent from lower levels, thus making a single level concept of information increasingly inadequate for use in biology.

"Machines computing and learning?" by Genaro J. Mart'ınez (Artificial Life Robotics Laboratory, Escuela Superior de C´omputo, Instituto Polit´ecnico Nacional, Mexico and Unconventional Computing Lab, University of the West of England, Bristol, UK).

A recurrent subject in automata theory and computer science is an interesting problem about how machines are able to work, learn, and project complex behaviour. In this talk, I will particularly discuss how some cellular automata rules are able to simulate some computable systems from different interpretations; this is a problem of universality. These systems are able to produce and handle a huge number of information massively. In this context, an original problem conceptualized by John von Neumann from the 1940s is: How are primitive and unreliable organisms are able to yield reliable components? How could machines construct machines? In biological terms, it refers to the problem of self-reproduction and self-replication. In our laboratories, we implement these problems in physical robots, where some particular designs display computable systems assembled with modular robots, and other constructions display collective complex behaviour. Modular robots offer the opportunity to assemble and reconfigure every robot. In particular, a number of robots have been constructed by Cubelets to simulate Turing machines, Post machines, circuits, and non-trivial collective behaviour. It was discussed whether the machines learn and develop knowledge as a consequence of automation and information.

"Almost Disjoint Union of Boolean Algebras Appeared in Punch Line" by Yukio Pegio Gunji (Department of Intermedia Art and Science, School of Fundamental Science and Technology, Waseda University, Tokyo, Japan).

While humour is one of the most intriguing topics in human behaviour, there is little mathematical research with respect to the universal structure of humour. Recently, quantum psychology has attempted to describe how humour arises from uncertainty. Although quantum theory is a sufficient condition, it is not a necessary condition to describe humour. Instead of starting from quantum theory, we start from describing a sequence of humourous text in stand-up comedy. The relation between preceding and subsequent words is expressed as a binary relation, which leads to a lattice by rough-set approximation techniques. We here show that the binary relation found in stand-up comedies entails a lattice called the almost disjoint union of Boolean algebras, which is a general form of an orthomodular lattice. It implies that a quantum-like structure can be obtained even if we do not start from quantum theory. In a binary relation, cat is distinguished from non-cat in a focused context, i.e., there is no relation between cat and non-cat in a sub-relation. However, cat is mixed up with non-cat outside the focused context, i.e., there is a relation between cat and non-cat. The ambiguity of relation and no relation implies uncertainty with respect to indication. Since each element in a focused context is distinguished from all other elements, the context focused on is expressed as a diagonal relation. If there are two contexts, 2 by 2 and 3 by 3 in a 5 by 5 symmetrical relation, the 5 by 5 relation consists of 2 by 2 and 3 by 3 diagonal relations and relations between any other pairs outside the diagonal relations. Using a rough set lattice approximation, fixed points with respect to upper and lower approximation based on the binary relation entails a lattice. In the case of 2 by 2 and 3 by 3 diagonal relations, each diagonal relation entails Boolean algebra, and the relations between any other pairs outside the diagonal relations glue Boolean algebras at the top and bottom, and that entails an almost disjoint union of Boolean algebras. We here define the subjective probability for a lattice that satisfies that if $A \leq B$, then $P(A) \leq P(B)$. This probability reveals that the probability of an element appearing before the punch line is very low, and the probability of an element at the punch line is very high. It implies that tension in the audience increases before the punch line since the audience cannot understand the event that can rarely happen, and that the tension is relaxed and released at

the punch line since the audience faces the event that can frequently happen. Humour is here explained, based on a quantum-like structure, not starting from quantum theory.

4. Panel Discussion

The panel discussion "Natural Question about Natural Computing" moderated by Marcin J. Schroeder involved panellists Andy Adamatzky, Masami Hagiya, Genaro J. Mart´ınez, Kenichi Morita, and Yasuhiro Suzuki.

The moderator initiated the discussion by reformulating the question in the title into one that directly addressed the individual views of the panellists, who provided their own perspectives on natural computing. The following is the moderator's introduction.

The question about natural computing may be natural, but the attempt to answer it by providing a formal definition would be pointless. Definitions of concepts serve the purpose of closing them into an existing framework of concepts with an already established intention or meaning. Natural computing is an open idea that serves the opposite purpose, to transcend the currently dominating paradigm of computing. The qualifier "natural", which, for centuries, was a subject of philosophical disputes, is not used here in the restrictive sense. After all, its common sense negation "artificial" is associated with human skills or competencies, and there is no reason to consider these non-natural or at least inconsistent with human nature or human inborn capacities.

This conference is the 13th in the long series of International Workshops on Natural Computing, whose participants and contributors have diverse ways of understanding this subject. However, there was never a risk of mutual misunderstanding, and there is no such risk now. What was and is common and uniting in these diverse inquiries can be expressed as the search for dynamic processes involving information that have all or some characteristics of computing, but are different from it in the form and means of implementation, procedural description, intention, outcomes, etc. The adjective "natural" reflects the interest in natural processes studied in several different disciplines of science independently from any application in computing, but it did not exclude the interests in the dynamics of information in cultural, social contexts of human life. Just the opposite, natural computing is an attempt to bridge technological interests with natural aspects of information processing to transcend the limitations of computing, including the limitations of its present applications.

The panellists represent diverse directions of research and study within natural computing. I would like to ask them the question: "*Quo Vadis?*" (Where are you going?) Unlike in the scriptural origin of this question, this is not a call to return to Rome. It is a request for sharing with the audience panellists' vision of the direction and future of natural computing. This is a question about their motivation to pursue this path of inquiry. Finally, the panellists may choose to reflect on the more general question of the future of not only natural computing but computing in general.

5. Papers Accepted for Publication in Proceedings

"Information Processing by Selective Machines" by Mark Burgin (Department of Computer Science, University of California, Los Angeles (UCLA)) and Karthik Rajagopalan (Department of Computer Science, University of California, Los Angeles (UCLA)). The goal of this paper is the development of the novel automaton model of learning processes called a selective machine and to study the properties of these machines. The model is based on the analysis of the process of language acquisition by people, although it also reflects how learning processes occur in nature.

"Advancing Human Understanding with Deep Learning Go AI Engines" by Attila Egri-Nagy (Akita International University) and Antti Törmänen (Nihon Ki-In—Japan Go Association). This paper presents the idea of developing a system of the interface between AI and human intelligence that can assist us in understanding in a human way (based on explanation, causation, and narratives) the results obtained by neural networks through deep learning or other AI systems equipped with statistical procedures, which,

from the human point of view, function as black boxes. Following the tradition in AI, the focus is on a game of Go. The strategy of Go is a well-defined problem domain that is complex enough to provide solutions in other fields of knowledge too, where AI technology outperforms humans.

"The Natural, Artificial, and Social Domains of Intelligence: A Triune Approach" by Jorge Navarro (Grupo de Decisión Multicriterio Zaragoza (GDMZ), Faculty of Economics, University of Zaragoza) and Pedro C. Marijuán (Independent Scholar affiliated with the Bioinformation Group, Aragon Health Sciences Institute (IACS)). This paper presents a view of the important connections between the three main domains of intelligence, categorized as natural, artificial, and social. Its objective is to go beyond the stimulation of an interdisciplinary study of intelligence, as the insufficient recognition of these connections contributed in the past to the accumulation of issues in AI applications that can be resolved in this approach.

"Learning Computing from Nature: Reflection on the Klein Four-Group" by Marcin J. Schroeder (IEHE, Tohoku University, Sendai, Japan). The subject of this paper is information integration, considered by many authors as the key characteristic of the mechanism of consciousness, although the mechanism of integration remains unknown. Its mathematical model was given by the author in terms of the factorization of mathematical structures. This paper presents information integration as a mode of encoding information. The level of integration is reflected in the logic of encoding. The frequent occurrence of Klein's Four-Group in relevant contexts provides some clues about the integrating logic of encoding information.

"*Tactileology*: Understanding Tactile Communications as Algorithms" by Yasuhiro Suzuki (Graduate School of Informatics, Nagoya University at Nagoya, Japan). This paper is about the construction of a natural computing system based on the sense of touch. This natural computing system does not depend on the conventional methods of computer science. The computing consists of a computing entity and an algorithm that is defined as a list of instructions for solving a problem and a computing system as the act or process of calculating an answer or amount by using an algorithm.

6. Other Contributions to 13th IWNC

The following papers were presented at the conference, but they were not submitted for publication in *Proceedings*. Their extended abstracts are available on the website of the Summit: https://summit-2021.is4si.org/ (accessed 8 March 2022).

Igor Balaza, Koji Sawab, Tara Petrica "Evolution of functionality as the emergence of logical structures"
Alan B. Cerna-Gonz´alez, Genaro J. Mart´ınez, Andrew Adamatzky, Guanrong Chen "Tag Systems and their Spatial Dynamics with Cellular Automata"
Masami Hagiya "Three Models of Gellular Automata"
Katsunobu Imai "On sustainable self-explanatory executable document"
Kenichi Morita "Composing reversible computers in a reversible and conservative environment"

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