Cognitive Science:
Recent Advances and Recurring Problems

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Introduction

This book is a survey of various topics pertaining to cognitive science and philosophy of mind, as presented in an international meeting held in the city of São Paulo, the *10th Brazilian International Meeting of Cognitive Science* (EBICC 2015).

Part I of the book brings eight chapters written by the invited speakers of the meeting, with topics ranging from brain connectivity, adaptive computation, and human visual system to issues in epistemology, theory of action, philosophy of mind, and friendship. Part II presents four chapters written is essay style, addressing topics discussed in some round tables at the conference, and one of them (chapter ten) features the paper chosen as the best student essay of the conference. These chapters cover subjects spanning from spike propagation neural networks, logical and geometrical aspects of cognition, the frame problem, to ethical issues in information technology. Part III contains eight chapters, each one about a topic with recurring questions in the field. They address problems in computer simulations in cognitive science, cognitive architectures, Bayesian statistical reasoning, deep learning, long-term synaptic plasticity, language and cognition, the mind-body problem, issues in semiotics, and in the history and philosophy of neuroscience.

The book is targeted for researchers, teachers and students, particularly those interested in the fields of cognitive science, artificial intelligence, and philosophy of mind, and also covers topics of relevance in linguistics, neuroscience, biology, psychology, physics, mathematics, and computer science.

Part I opens with the contribution of Maria Eunice Gonzalez, who discusses to what extent the concept of "autonomous action", applicable to human beings, can be extended to robots and machines. She examines some recent examples of adaptive self-organizing robots, and the dangers they might pose for human autonomy. The Complex Systems Paradigm is used as a theoretical guide for analyzing the emergent properties of the multiple-scale interactions between humans and autonomous learning machines.

In the second chapter, Fred Adams discusses the issue of "content externalism" in epistemology and philosophy of language. Externalism about mental content is the position that the content of an intentional state, such as a belief or a desire, does not only supervene on the intrinsic properties of a subject, but also depends on the subject's relation to the external environment. This is Adams' position, which is also called "broad content", and he defends content externalism from Gabriel Segal's attacks against it. After presenting Segal's views on "narrow content", especially his argument based on empty terms, such as "Santa Claus", Adams argues extensively that there is very slim support for narrow content. In his

radical externalist account, empty names and kind terms have no meaning because they have no bearers (objects or properties).

In chapter three, Claus Emmeche analyzes friendship as a social cognitive phenomenon, within a framework of multilevel organization, with different levels of embodied, extended and embedded cognition. Distinct levels of embodied cognition are identified as animate, anthropic and societal. Friendship is understood as involving "relational attention", which contains three aspects: self-disclosure, mutual knowledge, and joint attention (*sunaisthesis*). Friendship also involves thinking together, which expresses patience and empathy. The author has shown how philosophizing about friendship may be valuable for cognitive science.

In chapter four, Sofia Stein analyzes the mind-body problem from the perspective of neutral monism – the view that there are basic sense-data from which any object is constructed, as well as the self. Adopting a position close to science, involving a pragmatic stance and considerations from the philosophy of language, she concludes that neutral monism is in fact a good approach to the problem.

Dora Fix Ventura and coworkers discuss in chapter five some recent research findings arising from the exciting discovery made in 1998 that there is a third type of photosensitive cell in the human eye, a subset of retinal ganglion cells that contains the pigment melanopsin, maximally activated by blue light. Such cells initiate a non-image-forming visual pathway, responsible for pupillary light reflex, circadian rhythm of sleep and awakeness, mood, cognitive capacity, and playing a role in the image-forming system. The authors also review their original laboratory work exploring pupillary light reflex in patients with glaucoma and Leber's hereditary optic neuropathy.

Koichi Sameshima, with collaboration of Luiz A. Baccalá, presents in chapter six an overview of the experimental modeling of functional features of the brain, based on the analysis of correlations and causality present in electrophysiological data and functional measurements of brain activity. They point to the recent question of "how brain areas interact and integrate information (functional integration) during the enactment of cognitive tasks or over the genesis of behavior". They provide a historical and methodological review of the efforts that led to the analysis of brain connectivity, based on the use of a measure of "partial directed coherence", closely related to the temporal correlation measure known as "Granger causality". Finally, they make some remarks about the challenges posed by the recurring question of how the brain works, face the present state of the art in computational methods for analyzing huge amounts of data (Big Data) and the so-called conectome, arising from graph theoretical methods applied to small-world networks.

In chapter seven, Luiz A. Baccalá, with collaboration of Koichi Sameshima, reviews the concept of Granger causality, making clear how the associated "consistent prediction" improvement is different from usual definitions of causality, which require some physical linking mechanism or a criterion of intervention. The importance of such time series analysis is that it can uncover the directedness of multiple neural links underlying brain areas which show significant correlated activity.

João José Neto presents in chapter eight a thorough overview of the general computational strategies for simulating natural systems, with special consideration of the framework of adaptivity. This framework is implemented via rule-based devices of event-driven models, and adaptivity means that the set of rules can change over time in response to inputs. All the knowledge contained in the simulated phenomenon is encoded exclusively on the set of rules describing its operation. Learning thus amounts to the encoding of novel information into the database of rules. Adaptive procedures are therefore those that perform learning and forgetting.

Mariana Broens, João Moraes & Arturo Forner-Cordero discuss in chapter nine the internet of things, which includes the internet of robotic things. They characterize the phenomenon as a social affordance, describe the dissemination of this new social interaction, and explore some of its ethical implications.

Chapter ten, authored by Samuel Bellini-Leite, brings an overview of the frame problem in artificial intelligence, i.e. how an information processing system can deal in a relevant way with a changing environment. He lists twelve sub-instances of the problem, and argues that the "revisionist strategy" of taking these sub-instances seriously is the best path for cognitive science, a strategy that is consistent with a pluralist approach to the field, in which "all flowers may blossom".

Joao Kogler Jr. & Paulo Santos discuss, in chapter eleven, the geometrical and logical aspects of a cognitive agent, which distinguishes it from merely reactive and perceptive agents. What singles out the cognitive agent is the use of context-invariant information that breeds knowledge. In their approach, the perceptual system is formed by a chain of processes dealing with contextual information, beginning at the sensorial system and ending at the motor system. The perceptual chain is constrained not only at both extremities, but its transformations are geometrically connected with "holonomic" constraint propagation. On the other hand, the cognitive system comprises self-constrained processes that operate with learned transformations, so that the geometry of cognition is "non-holonomic". Shifting to the logical approach to the problem, "qualitative spatial reasoning" is unveiled in terms of "regional connection calculus", which describes how spatial regions are connected. The approach, as pointed by the authors, has not fared well with experimental data from cognitive psychology, which is expected since the formal approach is an abstraction from perception. Building

on suggestions from advantaged properties of representations, a formalism is proposed which represents qualitative location by partitioning the visual scene around an agent into sectors, and providing relations among them, so that they form a language capable of expressing the spatial organization of the scene.

In chapter twelve, João Ranhel, Emilio Del Moral & Márcio Lobo discuss in detail a spiking neural network model in which the spikes propagate with delays and entail the formation of neural cell assemblies that fire in synchrony, functioning as coincidence detectors. They show how the model implements logical functions, memory, plasticity, and decision-making, working with central pattern generators.

André Leclerc & William Pickering (chapter thirteen) discuss two different views in philosophy of language. The first part investigates the linguistic explanation of "meaning", and argues that the traditional approach based on disquotational truth conditions is insufficient for natural languages. The consideration of the intentions of the speaker is also insufficient, so one must include in the analysis *intuitive* truth conditions, in which the agent grasps immediately the speaker's expectations and plans. The second part of the paper discusses how linguistics has been explored from the perspective of complex systems theory. The notion of an emergent property is essential, and such an approach has been combined with the usage-base theory of linguistics, although it is not inconsistent with generativism.

Ivo Ibri, João Queiroz & Vinicius Romanini (chapter fourteen) explore different philosophical issues related to the semiotic theory of Charles Peirce. The first point made is that pragmatism is an indispensable framework for semiotics. Next, the semiotic theory of mind is presented as a variety of situated and distributed cognition, as a middle position between representationalism and its negation. Finally, Peirce's concept of information is analyzed, showing how cognition may be construed in terms of potential and actual information, leading to a concept of cognition understood as a general and pervasive feature of the intelligible Universe.

Alfredo Pereira Jr., Jonas Coelho & Osvaldo Pessoa Jr. (chapter fifteen) present three different monist views on the mind-body problem. "Triple-aspect monism" considers that there are three main phases of actualization of the potentialities in Nature: the physical, the informational, and the conscious. The "double-face view" assumes that conscious mind and brain are irreducible to each other, stressing not only that the conscious mind is dependent on the brain, but that changes in the brain are also dependent on the conscious mind. "Qualitative physicalism" adopts the mind-brain identity thesis, and defends the view that subjective qualia are actual physical attributes of some region of the brain.

Peter Claessens & João Sato (chapter sixteen) review probabilistic modeling in machine learning, arguing that Bayesian statistical inference is not only a

methodological tool for cognitive science, but might also be a theoretical description of the actual working of the brain. Still, Bayesian statistics should be complemented with other techniques. "Robot doctors" tend to be increasingly used, but the medical doctor should be able to understand how a decision was made by diagnostic support systems. The authors also point out the similarities between Deep Learning and the developmental stages of human beings.

Diego Zilio, Flávio Corrêa da Silva & Luciano Silva (chapter seventeen) explore different issues related to computational models of cognition. The first point made is that there is a significant difference between a computational model and an experimental model in biology and psychology: while the latter reproduce the mechanisms of the actual phenomenon being studied, the first only reproduces the behavior of the phenomenon. The paper also examines the distinction between deep artificial intelligence (AI), shallow (or biologically-inspired) AI, and mimicking AI, advocating an integration of the three approaches. As a case study, they present a probability calculus to be used in emotional user interfaces, based on algebraic semiotics.

In chapter eighteen, Loula, Lobo Netto Muñoz & Gudwin discuss fundamental questions concerning cognitive architectures, such as the definition of a "cognitive system", taken to be a system which aims at explicitly modeling human cognitive functions, including perception and action. Artificial intelligence that should not be called "cognitive" is also discussed. The importance of language for high-level performance of cognitive systems research is analyzed, and the frontiers of research in the field are explored.

Fábio Simões-de-Souza (chapter nineteen), in a short text that complements chapter twelve, summarizes the state of art of research on computer models of spike-timing-dependent plasticity, an important mechanism of long-term synaptic plasticity, essential for learning and memory.

Chapter twenty, by Rômulo Ferreira & Maria Inês Nogueira, closes the volume exploring issues in the history of neuroscience. In the first section of the paper, problems related to the formation and development of scientific concepts are examined, emphasizing how concepts such as "nervous cell" change with time. A distinction is drawn between concepts that have a clear referent from those that do not. In the second section, some methodological and philosophical issues of current research in neuroscience are examined.

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First and foremost, we thank Alex Krueger for his kind invitation for publishing, and for having encouraged us to elaborate a book with the proceedings of the 10th Brazilian International Meeting of Cognitive Science (EBICC 2015). We very much appreciated the experience of working with Vernon Press, and we thank their editorial staff, for the tireless effort provided throughout the months of preparation of the book. We particularly acknowledge the careful supervision, support and patience of Argiris Legatos, for whom we owe much of the success. And we also thank the cover designer for the excellent artwork.

The achievement of this book would not be materialized without the effort of the several authors that provided their contributions in updated form for this publication, and we thank and congratulate them for the excellent work.

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Many other people contributed for the success of the event, that lead to this book, and we apologize for not having acknowledged them nominally here, however we provided a full list of contributors at the EBICC 2015 web site (http://www.lsi.usp.br/ebicc-2015/).

Chapter 1

Autonomous action in complex mechanical systems: a real dilemma?

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Abstract

In this paper we investigate the relationship between human *autonomous actions* and activities performed by complex mechanical informational systems such as self-organizing autonomous robots. Ethical problems related to the contemporary rapid development of these kinds of systems will be addressed, with special emphasis on the usage of autonomous robots in human social environments. In this context, the general problem that will guide the present analysis can be characterized as follows: Is there any (in)compatibility between the concepts of human *autonomous action* and autonomous *mechanical agency*? We argue that the *paradigm of complexity*, which unites interdisciplinary research perspectives in the areas of Philosophy, Physics, Biology, Robotics, Complex Systems Science, and Cognitive Science, amongst others, offers a useful conceptual framework for analysis of the problem in question.

> *The reason why it may be wise to distrust the political judgment of scientists qua scientists is not primarily their lack of "character" – that they did not refuse to create atomic weapons – or their naiveté – that they did not understand that once these weapons were developed they would be the last to be consulted about their use – but precisely the fact that they move in a world where speech has lost its power. And whatever men do know or experience can make sense only to the extent that it can be spoken about. [...] Closer at hand and perhaps equally decisive is another no less threatening event. This is the advent of automation, which in a few decades probably will empty the factories and*

> *liberate mankind from its oldest and natural burden, the burden of labouring and the bondage to necessity [...].*
> (Hannah Arendt, [1958] 1998, p. 4)

1. Introduction

Can a complex informational system, such as a robot, act autonomously? Answers to this question reveal strong polarization between dualists and materialists, which has been growing for centuries. Thus, a negative answer would be immediately given to this question in the 17th century, supported by theological and philosophical traditions. This would be the case, for example, of the (mind/body) dualist Cartesian view, which attributes to the soul the ability to move a (mechanical) body. Since robots do not have a soul, they could not, in principle, act, and, much less, act autonomously. According to this view, the movement of automata should necessarily be dependent on the command of their human inventors.

Assuming that only humans could act autonomously, in contrast to animals/machines that move around propelled by external forces impinging on their physical systems, René Descartes argued that there would be two tests able to always distinguish a human being from other animals or machines: the test of language and the test of action.

In part V of the *Discourse on the method*, Descartes argues that:

> *[...] if any such machines had the organs and outward shape of a monkey or of some other animal that doesn't have reason, we couldn't tell that they didn't possess entirely the same nature as these animals; whereas if any such machines bore a resemblance to our bodies and imitated as many of our actions as was practically possible, we would still have two very sure signs that they were nevertheless not real men. (1) The first is that they could never use words or other constructed signs, as we do to declare our thoughts to others. We can easily conceive of a machine so constructed that it utters words, and even utters words that correspond to bodily actions that will cause a change in its organs [...]; but not that such a machine should produce different sequences of words so as to give an appropriately meaningful answer to*

> *whatever is said in its presence – which is something that the dullest of men can do.* (Descartes, [1637] 2007, part V, p. 22)

With respect to the test of action, he claims that:

> *[...] even though such machines might do some things as well as we do them, or perhaps even better, they would be bound to fail in others; and that would show us that they weren't acting through understanding but only from the disposition of their organs. For whereas reason is a universal instrument that can be used in all kinds of situations, these organs need some particular disposition for each particular action; hence it is practically impossible for a machine to have enough different organs to make it act in all the contingencies of life in the way our reason makes us act.* (Descartes, [1637] 2007, part V, p. 22)

Descartes stresses that we should not confuse speech or actions with the natural movements of physical systems whose organization might imitate human actions or speech; he claims that parrots, for example, can repeat words, but they cannot speak as humans in such a way that they would understand what they say in different situations. In the same way, he envisioned the possibility of the creation of automata that could imitate human actions, in specific circumstances, but that they would necessarily lack the ability to act diversely and adequately in response to different situations in life, as humans generally can, with the help of reason.

In short, Descartes' claim of the radical limitations in speech and action inherent to machines is grounded on his (mind/body) dualist presupposition of their lack of soul and reason, which are supposedly responsible for the exclusively human abilities. However, this dualist presupposition has been strongly rejected by materialists of different types. In the 18th century, Julien de La Mettrie, for example, in *L'homme machine* (1747), developed several arguments to support his hypothesis that humans are not different from machines: not only do they act mechanically, but they are themselves machines! As a radical materialist, he claimed that human thoughts, language, and actions result from the complex organization of matter.

La Mettrie's ([1747] 1912) arguments in defence of a mechanistic approach to human action, language, and mind in general, are not the object of the present investigation, but it is worth mentioning that they have been supported by contemporary researchers in the areas of Artificial Intelligence, Cognitive Science,

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