MORPHOLOGICAL COMPUTING AND COGNITIVE AGENCY

TOPIC

Morphological computing, at its core, entails that the morphology (shape + material properties) of an agent (a living organism or a machine) enables and constrains its possible (physical and social) interactions with the environment as well as its development, including its growth and reconfiguration (1). The role of such computation in cognitive systems includes the off-loading of control onto the body and its interaction with the environment thus enabling flexible and adaptive behavior (2-6). In a more general sense, cognitive agency instantiated by the interaction processes of morphological structures in networks of networks of cognitive agents from cells to organisms and societies is a basis of understanding of embodiment of cognition on variety of levels of (self-)organisation of physical matter from its basic physical structures via chemistry and biology with life itself as cognitive process. (1)

Embodied cognition approach holds that cognition is grounded in environmental interactions in the world (e.g. Wilson 2002) and is invisible in classical symbolic representation accounts of cognitive function, which is modeled on human "thinking" or "mentality". However, modern computational perspectives on cognition such as natural computation (including info-computationalism) account for embodiment whereby cognitive processes are considered to emerge from interactions in the world (cf. 7-11).

In this symposium we bring together perspectives on morphological computation and embodied cognition and encourage open and constructive debate on the perceived differences in the various perspectives on constructivist and computationalist accounts of cognition, and specifically embodied cognition.

SPEAKER ABSTRACTS

Lorenzo Magnani

Eco-Cognitive Computationalism From "Mimetic Minds" to Morphology-Based Enhancement of "Mimetic Bodies"

Eco-cognitive computationalism sees computation as active in physical entities suitably transformed so that data can be encoded and decoded to obtain fruitful results. When physical computation is seen in the perspective of the ecology of cognition it is easy to understand Turing's ideas concerning the emergence of information, cognition, and computation in organic, inorganic, and artefactual agents. Turing's speculations on how the so-called "unorganized brains" are transformed in organized "machineries" are very important. Brains are of course continuous systems that can be treated as discrete systems able to perform "discrete" computations, so that we can describe the possible states of these brains as a discrete set, with the motion occurring by jumping from one state to another. Turing clearly says: "The cortex of an infant is an unorganized machinery, which can be organized by suitable interference training. The organization might result in the modification of the machine into a universal machine or something like it. […] This picture of the cortex as an unorganized machinery is very satisfactory from the point of view of evolution and genetics" (Turing, Intelligent machinery, 1948). This intellectual perspective first of all clearly depicts the evolutionary emergence of information, meaning, and of the first rudimentary forms of cognition, as the result of a complex interplay and simultaneous coevolution, in time, of the states of brain/mind, body, and external environment. At the same time it furnishes the conceptual framework able to show how thanks to an imitation of the above process the subsequent invention of the Universal Practical Computing Machine is achieved, as the externalization of computational capacities in those artefactual physical entities that compute for some human or artefactual agents: those computers that in this perspective offered by Turing I called "mimetic minds". It is in this framework that we can limpidly see that the recent emphasis on the simplification of cognitive and motor tasks generated in organic agents by morphological aspects implies - in robotics - the need not only of further computational mimesis of the related performances - when possible - but also the construction of appropriate "mimetic bodies" able to render the accompanied computation simpler, according to a general appeal to the "simplexity" of animal embodied cognition.

Tom Ziemke

The Role of Morphology in Intentional Agency and Social Interaction

The role of morphological 'computation' in embodied cognition is usually addressed from the perspective of individual agents, i.e. how do an agent's bodily materials, movements, etc. contribute to its cognitive processes. But the body of course also plays a crucial role in many social interactions, not least the communication/recognition of intentions between interacting agents. The talk how this affects human-machine interactions in cases where the interacting agents' morphologies are radically different (e.g. people interacting with cars) as well as cases where morphologies have superficial similarities (e.g. human-humanoid interaction), but the underlying bodily processes are fundamentally different.

Jordi Vallverdu

(Un-)Biasing the Morphologies of Affect for HRI Purposes

1. From Bodies to Bodies

One fundamental aspect of Human-Robot Interactions is the role of the morphologies of both humans and machines. Basically, humans are naturalistically oriented towards the social interaction with other humans, as wrote Aristotle in his classic *Politics*: "Man is by nature a social animal; an individual who is unsocial naturally and not accidentally is either beneath our notice or more than human. Society is something that precedes the individual. Anyone who either cannot lead the common life or is so self-sufficient as not to need to, and therefore does not partake of society, is either a beast or a god". Considering it as the long result of an evolutionary process, we can find the several cognitive mechanisms make possible these processes (Adolphs, 2003; Bechtel, 2001; Frith & Frith, 2007; Lieberman, 2012). Some of them, like constantly face-looking patterns allow some biased, like pareidolia or the faces convey primal information for our social life, which make possible to see faces into toasts, rocks or forests (Kato & Mugitani, 2015; Liu et al., 2014).

The constant analysis of morphological aspects is related to mating (Jaffé & Moritz, 2010; Wade, 2010), fly-or-fight responses (Bubic, von Cramon, & Schubotz, 2010), social coordination (Lieberman, 2000) or emotional interaction(Casacuberta & Vallverdú, 2015). This affects primarily the visual (Cavanagh, 2011) and metacognitive processes related to it (Kirsh, 2005), but must be understood as a multidimensional processes which involves several senses. Finally, there is also the influence of cultural values into basic informational sensory processes, as shows the cultural psychologist (Nisbet, 2003).

Taking into account that fact that human morphologies run a social role, and that affection or emotion are fundamental aspects of the eco-cognitive and social processes, I want to remark some important aspects fundamental to be taken into account during the design of good HRI systems and environments.

2. Moral Morphologies as Social Prejudices or Cognitive Bias?

Although 19th Century psychomorphologists or physiognomists like Cesare Lombroso were wrong about the causal relationship between face shape and (usually wrong) moral behaviour, the truth is that human beings tend to correlate some morphologies with moral and/or emotional content (Mazzarello, 2011; Stepanova & Strube, 2009). Here, bad guys are usually dark, angry, with some deformity or extreme trait (big nose, big ears, small head,...), weird cinematic body movement,…like we can find in most of popular cinema and Walt Disney's villains characters(Gould, 2008). Obviously there are not only biologically determined aspects related to this process, but the role of cultural values must not be undervalued:

Beyond the debates between continuous and categorical models of human caption of emotions, the outstanding fact is that morphology affects how we define the emotional output or even main character of an agent (Martinez & Du, 2012). Therefore, the morphology of the robot is one among a long list of *emotional affordances* I've described elsewhere in previous research (Vallverdu & Trovato, 2016), but at the same time the morphology has an outstanding role because determines a long set of related characteristics of the agent.

3. Emotional Morphologies for HRI

According to the previous data it is obvious that besides of considering the functional design of a robot, several socio-cognitive aspects related to their morphology must be taken into account: gender (Slepian, Weisbuch, Adams, & Ambady, 2011), related language semantics (Gendron, Lindquist, Barsalou, & Barrett, 2012), social context (Hertwig & Herzog, 2009; McHugh, McDonnell, O'Sullivan, & Newell, 2010), body gestures/cinematic (Castellano, Villalba, & Camurri, 2007), among a long list. It is very important for example, that most of previous studies have been related to visual and linguistic HRI interactions, while others extremely important, like touch or olfactory have been almost neglected, basically due to the high complexity of these processes. These aspects are not only basic for a more deep relationship between humans and robots in classic domains (service, military, industrial, care), but also for new ones (like the taboo one of sexual robotics (Levy, 2007), surely one the niches with great expected revenues and implementation according current data on sexual surfing and related interests through the Web and Social Networks). As a conclusion of this section, I must to affirm that the study of the emotional affective aspects embedded into robot morphologies arises as a multidisciplinary research as well as a multidimensional process that goes beyond the basic description of size, shape, colour or texture, requiring more variables: temperature, cinematic speed, temporal flow and adjustment to a naturalistic emotional gestures dynamics, among other ones.

4. The Challenge of Dynamically Augmented Morphologies: Transhumanism or Adaptable robotics.

There is a final idea to be discussed here: human agents are starting to modify severely their cognitive and bodily limits (up to date just as a repairing/prosthetic process or as fashionable gadgets) and this process will modify severely how the natural analysis of morphological phenomenology is performed. At the same time, we can find robots into the market with variable morphologies (combining biped walking with four-legged translation or even wheels; with adjustable body characteristics), something that can confuse the human interacting with the robot. While we do not have a clear control of current morphological aspects involved into HRI, a new set of challenges is in front of us.

Ron Chrisley

Roles for morphology in computation

The morphological aspects of a system are the shape, geometry, placement and compliance properties of that system. On the rather permissive construal of computation as transformations of information, a correspondingly permissive notion of morphological computation can be defined: cases of information transformation performed by the morphological aspects of a system. This raises the question of what morphological computation might look like under different, less inclusive accounts of computation, such as the view that computation is essentially semantic. I investigate the possibilities for morphological computation under a particular version of the semantic view. First, I make a distinction between two kinds of role a given aspect might play in computations that a system performs: foreground role and background role. The foreground role of a computational system includes such things as rules, state, algorithm, program, bits, data, etc. But these can only function as foreground by virtue of other, background aspects of the same system: the aspects that enable the foreground to be brought forth, made stable/reidentifiable, and to have semantically coherent causal effect. I propose that this foreground/background distinction cross-cuts the morphological/non-morphological distinction. Specifically, morphological aspects of a system may play either role.

Marcin Milkowski

Is morphological computation special?

In my talk, I want to argue against the claim that morphological computation is in some sense special, or different from other kinds of physical computation. By drawing on previous work of (Müller and Hoffmann 2017), I show that some purported forms of morphological computation do not count as computational, and these that do, are just computational in the mechanistic sense (Piccinini 2015; Miłkowski 2013). In particular, Piccinini's account has the same condition that makes the first purported class of morphology facilitating control non-computational because of the usability condition he defends. Then I turn to recent claims defended by Karl Friston (2011), who hypothesizes that agents' morphology is the model of the environment and that bodies are literally models of environment. I will argue that these claims are confused just like some claims about morphological computation criticized by Muller and Hoffmann.

Marcin Schroeder

Computing with Nature†

Natural and morphological forms of computing have diverse conceptualizations. This paper presents an alternative view on morphological computing based on a slightly generalized form of a Turing machine in which one-way action of head on tape is replaced by mutual interaction. This generalized (symmetric) Turing machine can serve as a component of a multi-level complex computing system in much closer analogy to living objects which tend to form systems of very high level of complexity (with levels starting at molecular level, through cellular one to organismal level, or possibly to the level of population or eco-system.

Erik Billing

When elephants play chess: Relations between reactive, embodied, and symbolic views of intelligence.

John Spencer

Models at play: Using dynamic field theory to understand looking and learning in dyadic interactions

Although cognitive and social development are often studied in isolation, many researchers have demonstrated convincingly that cognition and the social environment are inseparable components of development. For instance, the social context plays a crucial role in many facets of cognitive development. Critically, the mechanisms by which social interactions impact cognitive development remain poorly understood. Here, we present a dynamic field model that elucidates the neural and behavioral mechanisms by which social interactions contribute to developmental changes in cognition and *how these influences are reciprocal in nature*.

The goal of our work is to understand the mechanisms by which parental responsiveness impacts the social and cognitive development of term and preterm infants. We present an autonomous dynamic field model that looks about its environment containing multiple virtual objects. This neural system encodes and forms memories for the objects being looked at and captures the looking and memory formation abilities of typically developing and preterm infants *and* adults. We present several simulation experiments in which a parent model *and* preterm infant model share the same virtual world. We illustrate that a simple Hebbian learning process within the neural and behavioral systems of the parent and infant models is responsible for changes in how the infant model performs in a memory task and how the models learn to interact with each other.

References

1. Dodig-Crnkovic G., The Info-computational Nature of Morphological Computing, in Müller V. C. (ed.), Theory and Philosophy of Artificial Intelligence (SAPERE; Berlin: Springer), 2012. (Selected contributions from PT-AI conference @ACT) pp. 59-68
2. Hauser, H and Füchslin. R.M. and Nakajima, K. "Morphological Computation – The Physical Body as Computational Resource"in e-book on "Opinions and Outlooks on Morphological Computation", Chapter 20, ISBN 978-3-033-04515-6, 2014, – http://tinyurl.com/pjvey43

3. Pfeifer, R. and Bongard J. "How the body shapes the way we think: a new view of intelligence"MIT press, 2006.
4. Nakajima, Kohei, Helmut Hauser, Tao Li, and Rolf Pfeifer. "Information processing via physical soft body"*Scientific Reports 5* (2015) Article number: 10487, doi:10.1038/srep10487 http://www.nature.com/srep/2015/150527/srep10487/full/srep10487.html
5. Hauser, H.; Ijspeert, A.; Füchslin, R.; Pfeifer, R. & Maass, W."Towards a theoretical foundation for morphological computation with compliant bodies" *Biological Cybernetics, Springer Berlin / Heidelberg,* 2011, *105*, 355-370 http://www.springerlink.com/content/j236312507300638/
6. McEvoy, M. A., and N. Correll. "Materials that couple sensing, actuation, computation, and communication."Science6228 (2015): 1261689.
7. Scheutz, M. (2002) Computationalism: The next generation. In: Computationalism: New Directions. MIT Press 517-524
8. Chrisley, R. (2009) Synthetic Phenomenology. International Journal of Machine Consciousness, 1 (1). pp. 53-70.
9. Dodig-Crnkovic G. and Müller V., A Dialogue Concerning Two World Systems: Info-Computational vs. Mechanistic. Book chapter in: INFORMATION AND COMPUTATION , World Scientific Publishing Co. Series in Information Studies. Editors: G Dodig-Crnkovic and M Burgin, 2011. http://arxiv.org/abs/0910.5001 2009
10. Milkowski M. (2013) Explaining the Computational Mind, MIT Press.
11. Schroeder, M.J., Vallverdú, J., (2015) Situated Phenomenology and Biological Systems: Eastern and Western Synthesis, Progress in Biophysics and Molecular Biology doi:10.1016/j.pbiomolbio.2015.06.019.