A3 Afternoon Session 3: (25 min) Luisa Damiano and Pasquale Stano "General Lines, Routes and Perspectives of Wetware Embodied AI. From its Organizational Bases to a Glimpse on Social Chemical Robotics"

Supporting links: https://www.frontiersin.org/articles/10.3389/fbioe.2021.724023/full

Quick summary and Notes:

1. EAI aims to address the limitations of classical AI by emphasizing the importance of the body in cognitive processes. The text explains that Embodied AI (EAI) emerged approximately 30 years ago as a response to classical AI, which primarily focused on computational models. EAI aims to address the limitations of classical AI by emphasizing the importance of the body in cognitive processes.
2. EAI as a contemporary approach to AI that focuses on studying how the body (physical presence) of an intelligent agent influences cognition. It implies that traditional AI, which typically relies on computers and software, may not capture the full scope of cognitive processes as it doesn't consider the importance of the body. These models are designed to learn from their environment and perform cognitive tasks using their physical bodies, in contrast to traditional computers. **The goal of EAI is to create "complete" or "embodied" agents, which are essentially robots with physical bodies. These agents develop cognitive abilities through "emergent design," meaning that their intelligence arises from interactions between various organizational levels within their bodies. The authors' research program aligns with previous approaches in embracing the autopoietic characterization of biological organization, emphasizing its chemical nature. However, their approach differs significantly in that it aims to recreate this autopoietic organization synthetically, using wetware (chemical) implementations rather than hardware or software.**
3. Brain and Body Experiment (remember Stefano mentioned about it)
4. Body could be seen as something outside the nervous system that supports symbolic information processing and connects symbols with sensorimotor experiences.
5. **However, the EAI community is also engaged in building robots that are not guided by computers, and are capable of learning about their environments and accomplishing cognitive tasks only through their body**
6. Critics argue that EAI not only focuses on the mechanistic aspects of the body but also falls short in modeling the complex organization of the body, particularly how it continuously self-produces and sustains itself through metabolic processes.
7. **The criticisms argue that EAI's current approach primarily imitates the superficial aspects of the biological body, such as movements and anatomical features, while neglecting its fundamental aspect—the**

self-organizing and autonomous nature of biological organization.

8. **First: Synthetic Biology has been developing as a research direction since the 2000s, focusing on the chemical modeling of biological processes. It's positioned within the broader field known as the "sciences of the artificial."** Synthetic Biology (SB) is described as a branch of biology that takes inspiration from engineering principles. Its goal is to design and construct biological components or systems that do not naturally exist, with practical applications in mind. The references to Endy, Andrianantoandro, de Lorenzo, and Danchin suggest established figures in the field. SB is likened to AI and robotics in that it is often characterized as a cutting-edge field expected to shape the future, a notion supported by references to Morange, Peccoud, and Hockfield. This passage highlights the breadth of research in Synthetic Biology. It encompasses various aspects, including designing, optimizing, and minimizing biological components. SB also involves tasks such as modifying cell metabolism or regulatory networks, developing responsive molecular devices to manipulate cell behavior, integrating artificial subsystems/modules into cells, and extracting them for in vitro (outside the living organism) operations. The text highlights a recent milestone in SB research: the creation of a cell controlled by a fully synthetic genome that was custom-designed and synthesized for this purpose. This achievement illustrates the progress made in SB. In addition to ambitious endeavors like the creation of cells with synthetic genomes, SB also includes bottom-up approaches. These approaches align with AI's philosophy of understanding by building, and they involve constructing living or lifelike systems with minimal complexity through chemical means. One of the typical goals in SB is to model living cells and behaviors similar to life by starting from the ground up, essentially reconstructing cell models from scratch. References to Luisi and Schwille highlight key contributors to this line of research.
9. **Second: The second cornerstone involves integrating the theory of Autopoiesis, which is a theory about the self-organizing nature of living systems, into their SB approach to EAI.** The core idea of the authors' research plan is to introduce the concept of autopoietic organization into the experimental arena through a wetware-based approach. This approach involves studying natural cognitive processes synthetically by creating and experimenting with wetware (chemical) implementations of the autopoietic model of biological organization. The shift towards a wetware-based approach represents a fundamental departure from current robotic models. It is expected to lead to entirely new models that could reshape our understanding of life, cognition, and, over time, generate entirely new technologies. Wetware-based approaches leverage chemical networks that exist simultaneously in functional and structural spaces. These networks are designed to self-generate autopoietic and embodied "agents." The absence of a wetware-based approach in organizational AI suggests a need for intervention in this direction. It also has further 4 directions:
    1. One dimension involves the theoretical aspect, translating the

autopoietic theory of biological organization and related concepts into theoretical models that can be applied in wetware-based models using Synthetic Biology techniques. The questions raised in this dimension revolve around how to integrate the autopoietic concept of biological organization into wetware systems like artificial cells and how to explore fundamental biological phenomena, such as life and cognition, within synthetic chemical systems.

2. Another dimension focuses on the experimental aspect, aiming to develop a bottom-up Synthetic Biology toolbox suitable for constructing and experimentally exploring these new wetware-based AI models. In this dimension, research questions include identifying suitable material models for constructing minimal autopoietic systems and determining the developmental path from simpler models, such as autopoietic micelles or existing non-autopoietic synthetic cells, to systems that genuinely exhibit autopoietic organizational dynamics and AI capabilities.
3. The epistemological dimension is concerned with defining a set of epistemological criteria to assess the significance of organizational wetware models for advancing our scientific understanding of life and cognition.
4. The final dimension focuses on the practical application of autopoietic cognitive synthetic cell technologies.

Summary:
Embodied Artificial Intelligence (EAI) focuses on understanding cognition by considering the role of the body in cognitive processes. EAI ranges from robots that use their bodies for sensing and interaction to systems that learn and perform tasks without traditional computers. Critics argue that EAI often lacks depth in modeling the biological body's autonomous organization. This article proposes an innovative research approach to EAI that involves creating wetware (chemical) models of the biological body's organization. The authors draw on Synthetic Biology (SB) techniques, which engineer biological systems for practical purposes. SB can design entirely new biological systems or modify existing ones, often referred to as a "science of the new century." SB has both top-down and bottom-up approaches, the latter aligning with understanding-by-building principles seen in AI. The authors' approach combines SB's bottom-up techniques with the autopoietic theory of biological organization, focusing on chemical implementation. Their research involves theoretical modeling, experimental exploration, epistemological criteria development, and potential applications. This approach aims to provide insights into life, cognition, and new technologies by shifting from traditional robotics to wetware-based organizational AI.