(Un)sustainable structural coupling – a testimony for snail intelligence

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Abstract

The current artificial intelligence paradigm, where exponential scaling of data and computation leads to an increase in functionality and application, requires exponential demand in energy usage, data storage and raw materials for computing components. We compare this dynamic of resource dependence and depletion of AI systems to population dynamics of a snail, the symbol of the degrowth movement. Juxtaposing both phenomena as autopoietic systems within a structural coupling with their environment we identify the difference between sustainable and unsustainable coupling, meaning the ability to sustain itself over time. Due to an absence of negative feedback loops for AI systems, with resources ultimately limited, we identify the state of current AI systems and resources as unsustainably coupled. As AI systems are currently in a process of homogenization in form and function, we call for exploring alternative ways of being for AI systems, for example inspired by the sustainable dynamics of snails within their ecosystem.

Introduction

Even though artificial intelligence (AI) finds itself increasingly in an applied and thus societal, economic, ecological and political setting, artificial life research has much to offer for alternative explorations of AI. With current wicked problems such as climate change, exceeded planetary boundaries (such as biogeochemical flows, freshwater change) and technological acceleration, AI is a two-sided technology as on one hand it may have potential for making processes deemed necessary more efficient, but on the other hand requires high amounts of energy, scarce and difficult to reach raw materials, data storage, manual labour and has a potential to increase inequality (Deranty & Corbin, 2022; Richardson et al., 2023; Vries, 2023).

In this extended abstract we frame AI within the current Western socio-economic system of capitalism, with a high demand for finite resources and where AIs might be seen as capital or as tools to increase capital (Berman, 1992). As we project that private and public funding for AI innovation and deployment continues, and thus resources will remain being used for this, we assume a continuation of current research leading to societies where humans and AIs become more intertwined, either as co-operative AI, human-AI hybrids or fully autonomous AI beings.

A radically differently vision of the future is researched by the degrowth or post-growth movement, which broadly speaking advocates for an alternative economy and societies that prioritize social and ecological well-being instead of corporate profits, over-production and excess consumption (Engler et al., 2024). It puts an emphasis on the expansion of the biophysical basis of society and the evidence that the global economy encounters biophysical constraints to further growth (Crownshaw et al., 2019). As a relatively new and upcoming technology, the position of AI in a post-growth society is yet undetermined and has not been extensively researched yet. For inspiration we will use the symbol of the movement, the snail, which represents an alternative kind of economy, but has also been used in different contexts, such as de-accelerationism, self-limiting growth and conservation ecology (*Good Infinity*, 2019; Rosa, 2010; Werner, 2017).

To compare these two dynamics, we examine the snail within its ecosystem and AI systems within society as autopoietic systems, creating a structural coupling between itself and their environment. Autopoietic systems are sustaining over time through a closed process of self-maintenance through external conditions: they have originally been studied in a biological context, but have also been applied in fields such as economics, sociology and organization theory (Bruin, 2022; Rammelt & van Schie, 2016; Varela et al., 1974). By comparing the interactions of snail and AI with their environment, we identify the difference between the sustainable and unsustainable coupling.

Snail growth and (un)sustainable coupling

The common periwinkle *Littorina littorea* has a specific coupling between their environment, shell morphology and growth rate (Kemp & Bertness, 1984). If a snail grows in a dense population, their growth rate is lower and their shells become elongated and thicker, leaving less room for an increased body size. However, if they grow in a sparse population their growth rate is higher and their shell become more globose but thinner, allowing a higher body size. This process can be described as structural coupling: there is feedback from the autopoietic system to the input layer, with either a positive or negative feedback loop that ends with the system and the medium becoming coordinated (Figure 1). Here, structural coupling between the snail population and their environment is an example of sustainable structural coupling: once resources become scarce in the population, snail size and growth rate become diminished, leaving time for regeneration of the resource pool and minimizing intra-population competition. This is in contrast with what we call unsustainable coupling, when there is no negative feedback between the system and the environment, leading to depletion of the resources and the system collapsing. We can find an example of this in biofiltration techniques, where microorganisms are placed in an environment containing toxins. In the beginning, the bacteria feed on their rich diet and grow their population without inhibition, however, as there is no negative feedback once the toxins have been eaten the resources are depleted and the population collapses (Pachaiappan et al., n.d.). Let us analyze AI and compare it to the sustainable structural coupling of the snail.

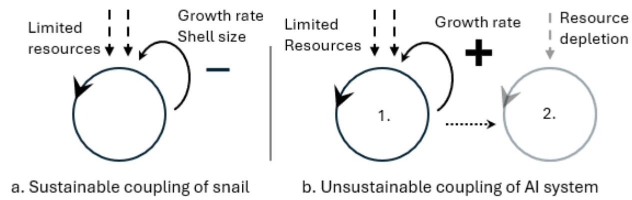

Figure 1: The difference between sustainable and unsustainable structural coupling is in this case the presence of a negative feedback loop. Dashed arrows indicated resources from the surrounding feeding the autopoietic system, solid arrow indicates either negative (-) or positive (+) feedback of the autopoietic system based on its environment.

AI as an autopoietic system

We can describe artificial intelligence as a self-maintaining autopoietic system, originating from an abstract concept, through imagination, science fiction and scattered services used by people, towards the physical systems that are becoming increasingly intertwined with human everyday lives and might affect the way we shape our work, minds and environment (Bruno, 2022).

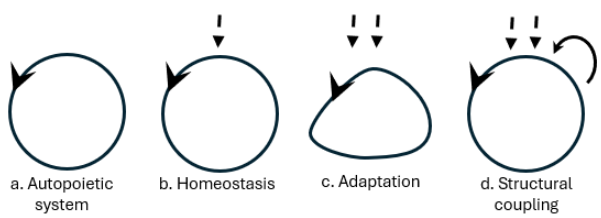

Figure 2: Different ways of how an autopoietic system can interact with or by the environment. Dashed arrows indicate resources, input or dependencies of the system. The solid arrow represents a feedback loop from the autopoietic system.

Instead of food resources, this autopoietic system in its current form receives datasets, raw materials for components such as GPUs, energy, improvements from research and usage by consumers and citizens (Figure 2). Some autopoietic concepts:
Homeostasis: characterized by a fixed point representing the ideal static state for the AI system from which it will not move, or slightly fluctuate from. This can be viewed as distinct fixed examples of AI, such as a random forest algorithm, requiring resources such as datasets (input arrow in figure 2).
Adaptation: a process where a certain AI model or system gains more attention or research through funding or interest, where over time a different AI concept, algorithm or system emerges. This process is not permanent, and the AI system either moves to homeostasis, or structural coupling. There is an increased interactional input from the environment, seen as a drive of innovation, but there is not yet a structural influence of the AI system on the biophysical underpinnings of society.
Structural coupling: AI systems, such as large language models, are being applied broadly in society, where its use directly or indirectly influences the biophysical underpinnings of the environment through a positive feedback loop by both reinforcing the further development and use of AI. This simultaneously increases the resources needed to sustain the AI system. Especially on computing and data resources the increase of their availability for AI is salient and persistent: a single company (Microsoft) alone aims to build 50 to 100 new datacenters each year for the foreseeable future. In more future directed visions where AI systems, -machines or -beings might be able to evolve and self-learn in novel ways, they will likely continue this incessant need for energy and raw materials that are inherently limited in supply. Here, we identify the main difference between the structural coupling scenario of the snail in comparison to AI systems, namely the lack of a negative feedback loop of the AI system reacting to the limited resources of the environment, which we would call *unsustainable structural coupling*. Where snails adapt their morphology to enhance the probability of survival of the population when resources become limited, AI systems are on a trajectory to ultimately deplete its resources due to exponential uptake, and thereby severely undermining its biophysical constraints thereby potentially damaging its societal environment.

Conclusion

Here, we described the difference between sustainable and unsustainable coupling of autopoietic systems. We look at AI as an autopoietic system that consumes resources, such as energy and GPUs, and produces services to its environment. This allows us to clearly understand various autopoietic stages of AI and then model the impact of AI in society as a phenomenon of unsustainable structural coupling, similar to cancer cells. Next, we take the snail as an example of sustainable structural coupling and compare it with AI and identify a lack of negative feedback loops responding to limited resources of the environment it depends upon in AI systems. AI does currently not face restrictions in resources to keep it stable as an autopoietic system other than those imposed by economic laws of supply and demand. There are possibly multiple ways to gain more sustainable structural coupling, naming legislation, more deliberate decision what AI will be used for (McQuillan, 2022). As AI is often developed within the framework of optimalization, automatization and isolated processed, characteristics fitting for capitalist societies, it is important to broaden the research vision towards alternative ways of being. Inspired by artificial life research, AI models could be developed more focused on 'snail-like' dynamics: slow, sustainable and stable and perhaps even promoting regeneration for their environment.

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