Substituting Animals with Biohybrid Robots: Speculative Interactions with Animal-Robot Hybrids

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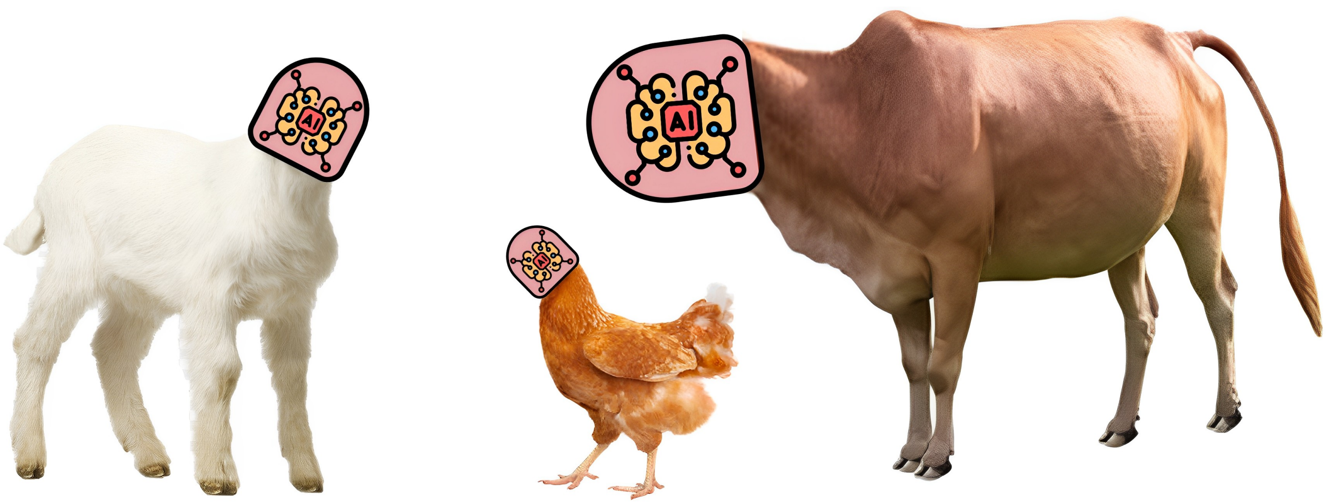

Figure 1: Different species of animal-robot hybrids

ABSTRACT

What if animals were substituted with biohybrid robots? The replacement of pets with bioinspired robots has long existed within technological imaginaries and HRI research. Addressing developments of bioengineering and biohybrid robots, we depart from such replacement to study futures inhabited by animal-robot hybrids. In this paper, we introduce a speculative concept of assembling and eating biohybrid robots. With this provocation as a starting point, we intend to initiate cross-disciplinary and cross-cultural discussions around human-food interaction practices and related topics.

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CCS CONCEPTS

• **Human-centered computing** → *Ubiquitous computing*; *Ambient intelligence*.

KEYWORDS

Biohybrid robots, cultivated meat, human-food interaction, speculative design, provocation

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1 INTRODUCTION

Humans have evolved in a world alongside animals. Both have been in constant and varied interactions throughout environmental and technological epochs. While our relationship with animals has been complex (i.e., consists of many facets and is seldom homogenous), in this paper, we focus on one dominant and enduring strand: animals-as-food for humans. At a societal level, human consumption of animals has been a constant. While a constant feature, a series of sociotechnical revolutions throughout history have altered many aspects of the animals-as-food for human relationship. Technologies have afforded a shift from hunting 'wild' animals to domestication, and later selective breeding of livestock. More recently, the industrial revolution made humans less reliant on animal power for production, whilst making the mass slaughter of animals on production lines possible.

An emergent technology of cultivated, or lab-grown, meat has reached approval for commercial sale and consumption. Today, Singapore is the first and only nation that has legalised the sale of lab-grown meat, with other states including the USA likely to follow suit. Such developments have been heralded as the beginnings of a *food revolution* [6] that could provide alternative solutions to environmental and animal welfare issues caused by today's industrial meat production. However, it is unlikely that the transition to ubiquitous consumption of cultured meat across the planet will be a linear one; many technical and sociopolitical unknowns and challenges can hinder the next steps of this emergent technology. One point that we emphasise here is that it would be extremely difficult to replicate the form, texture, and appearance of conventional animal meat based on the status quo of technology (see [35]).

In this provocation paper, we aim to draw attention to some of the wider implications of being able to produce animal flesh and organs through technological means and integrating these into various forms of biohybrid robots, or what we call animal-robot hybrids (see Figure 1). We start out with a broader question: *what if animals were substituted with biohybrid robots?* In doing so we are engaging with a category of research called 'tissue-engineered biohybrid robots' [47]. There are many possible use cases already proposed for these future-facing technologies that span medical, environmental, and industrial applications. The purpose of our work, however, is to introduce ideas that are currently absent from this research and imaginative space. To start this process, we propose a speculative concept of assembling and eating biohybrid robots as a provocation.

2 BACKGROUND AND RELATED WORKS

To contextualise our provocation, we: (1) review the new frontiers for human-food interaction (HFI) literature; (2) present the state-of-the-art of lab-grown meat; and then (3) inject the idea of Living Machines and the animal-robot analogy to situate our concept.

2.1 New Frontiers for Human-Food Interaction

Food is not only essential for survival, it is often a deeply social experience and cultural event that can be enjoyable, unusual and/or repulsive[22]. Technology has crucially supported and enriched food-related practices[22]. There has been a growing trend in exploring Human-Food Interaction(HFI) to create, transform and elevate food-related experiences with technology [20, 39]. The research in HFI has been framed mainly in two directions: "around food" and "with food" [12]. While "design around food" focuses more on the social experience of consuming food, "design with food" emphasises crafting edible user experiences. A number of recent projects have involved the growth, preparation and consumption of new foods [19, 44, 49]. However, the space of "design with food" has been less explored compared to "around food" due to its challenging nature of going beyond traditional screen-based products [29] and underutilisation of taste- and smell-based interfaces within the field of HCI [27, 28, 36]. Furthermore, existing studies in the "design with food" area have emphasised social and cultural aspects of technology in dining [14, 16], rather than aiming to improve the individual eating experience [1]. There are research works that aim to address this gap, by focusing on the fundamental dining experience, such as Logic Bonbon [9], Chewing jockey [41] and LoLLio [25]. Despite growing activity in creating and investigating new Human-Food Interactions as yet, there has been limited exploration of food sources and food production technology – animal-robot hybrids are currently absent from this field of research and development.

2.2 State-of-the-Art Cultivated Meat and Its Limitations

Frontier bioscience and bioengineering technologies like cellular agriculture and tissue engineering have made animal stem cells differentiated in-vitro to grow meat products. As an emergent technology, lab-grown meat has been introduced and promoted as a 'slaughter-free' and sustainable alternative mode of production. In theory, and in scientific discourse, cultured meat contains environmental, ethical, and health appeal [35] – benefits claimed include reduced ecological footprint, no need to kill animals, and better control of animal diseases during meat cultivation. In spite of these asserted benefits and an enthusiastic industry, there are key technical, socio-political, and regulatory challenges ahead for the sector [40]. To replicate the multicellular macroscale structure of biological systems with its nano- and microscale functional features being maintained is the primary technical challenge of tissue engineering [13]. Our concept of assembling animal-robot hybrids (see section 3) offers a potential method of bypassing existing technical constraints to better replicate the innate structures and textures of naturally grown animal flesh and organs.

2.3 The Idea of Living Machines and the Animal-Robot Analogy

Over the last decade, the term Living Machines has been employed to signal a growing convergence between biology and technology (see [32, 33]). Machines and systems are being created that mimic, or are inspired by, biological phenomena and structures [21, 45, 46]. Machines are also being built from biological matter [24]. Some emerging systems couple engineered, synthetic components with living biological materials to form a new biohybrid entity (see [18, 47] for reviews). As a significant cultural metaphor, Living Machines build upon an idea that humans will continue to radically control and re-engineer the living world, including animals, to bend to our will [42]. A Living Machines approach that links new technologies within living ecosystems found in the natural world is also promoted as a radical and sustainable alternative to the energy and material consumption of current robotics and Artificial intelligence (AI) [15]. At the same time, similarities between robots and animals are being articulated and pursued in various ways [7, 23, 26, 48]. Here we highlight an animal-robot analogy to study human-robot interaction (HRI) [7, 8], where some argue that people should treat robots as animals to supplement human skills and relationships [8]. Such sentiments align closely with broader and persistent ideas that humans can, and should, re-engineer the living world to conform to our needs.

Against this backdrop of humans' propensity of exploiting animals to their will, two main topics surface, namely harvesting animal products for food and demanding animal services. Although many investigations have been done focusing on the comparisons of various aspects between animals and robots, these works mainly explored the use cases of providing humans with services. In contrast, the case of growing and harvesting animal products for human consumption has not yet been considered in robotics. And to consider this prospect raises the question: *what implications may this have for other human-robot or human-animal relations?* One reason for this idea to be absent from the field may be that knowledge and technical constraints in the past limited people's ideation – there were clear boundaries between animals as biological organisms and robots as lifeless machines. The idea of Living Machines starts to collapse these boundaries and in doing so injects the sociotechnical horizon with new, and almost unbound, possibilities.

3 SPECULATIVE CONCEPT

3.1 Assembling the Animal-Robot Hybrid

As a speculation of further technology advancement, our concept is the creation of a biohybrid robot consisting of two major parts, namely: an artificial and engineered computer brain, and a body containing living components stemming from real animal stem cells. The brain would be a computer made of electronics and wires with artificial intelligence (AI) that is advanced enough to control and regulate the living body of the biohybrid system. The body part acts as a movable living incubator that enables animal stem cells to differentiate into diverse desired biological structures, which can grow functional animal organs and flesh that replicate the naturally grown ones.

The choice of stem cells theoretically can be extracted from whatever animal species exist, meaning that any conceivable species of animal-robot hybrid could be made (as demonstrated in Figure 1), and put on the menu. Depending on the chosen animal species, the configuration of the hybrid will respectively require morphological and functional varieties of the body types and different levels of complexity of the computer brains (for instance, computers to control mammalian bodies would be tremendously more complex than those for insectile ones). The complexity of the artificial brains are regarding both the hardware and software.

Consciousness is a highly debated topic in philosophy, but from a neurobiological and scientific perspective, the formula is straightforward: no cerebrum = no consciousness = no sensory experiences. From this perspective, being a cerebrumless (meaning having no cerebrum) living thing is a key feature of our proposed animal-robot hybrid. From some perspectives then assembling and disassembling these hybrids, harvesting their edible parts, would constitute a slaughter-free production process.

Corresponding to conventional livestock, animals may be substituted with biohybrid robots to grow products for food supplies, fashion industry, medical purposes, and so forth. Notably, the advanced technology itself opens up for new opportunities that conventional animal productions can not offer. For instance, because stem cells can be chosen from whatever kinds of species it will be possible to produce biological products from endangered and rare breeds. It may also be possible to use preserved samples of extinct animals (e.g., Dodo bird [34]) to bring them back in some hybrid form, or even to create new species.

Based on the almost unbound possibilities of Living Machines and potential for Biohybrid Robots it is beyond the scope of this paper to dive into the sociotechnical horizon too far. Besides, we would be limited to our imagination. The purpose of the examples above is to scratch open the surface of possibilities for substituting animals with Biohybrid robots. Our provocation, to make and eat biohybrid robots, sits between the preposterous and conceivable. Importantly, realising such a future would bring complex ethical, social, political, technical and environmental factors into dialogue.

3.2 Eating Biohybrid Robots

Farming animals for meat is environmentally demanding and resource/labour intensive. Calls to adopt more sustainable alternatives to cope with environmental, social, economic and political pressures are amplifying.

A variety of cuts of beef exist and each has unique textures and tastes that cannot be replicated through state-of-the-art cellular agriculture and tissue engineering (see section 2.2). Figure 2 illustrates a cow-robot hybrid with an artificial brain controlled and a body that grows differentiated parts of beef. The arguable benefits might include: (i) this hybrid has no sensory experience or sentience and therefore might not be subject to the same animal welfare framework; (ii) ecological impacts can be better controlled and optimised by computationally regulated behaviours; (iii) certain parts of their body can be trained to obtain desired result in texture and taste; (iv) bacteria control and virus prevention could be improved; (v) the choice of meat products offered could be diversified allowing people to consume, for instance, whales, pandas, even *human* meat if this were deemed ethical and a demand existed.

Dairy products are closely related to this speculative concept. Chicken eggs are widely consumed, so are duck, geese and quail eggs in some parts of the world. With battery farming still commonplace to match demand, the idea of outsourcing egg production to biohybrid robots may have animal welfare appeal. Alternatively, the Platypus (a mammal that lays eggs) may offer an atypical case where platypus-robot hybrids produce richly nutraceutical milk and eggs. How would you react to seeing aardvark and armadillo milk, or snake and crocodile eggs, being sold in the supermarket?

3.3 Some Ethical Dilemmas of Eating Animal-Robot Hybrids

Some immediate and unique ethical issues that are contained within this speculative concept include: how will the notion of 'slaughter-free' play out in relation to cutting and cooking these hybrids? They

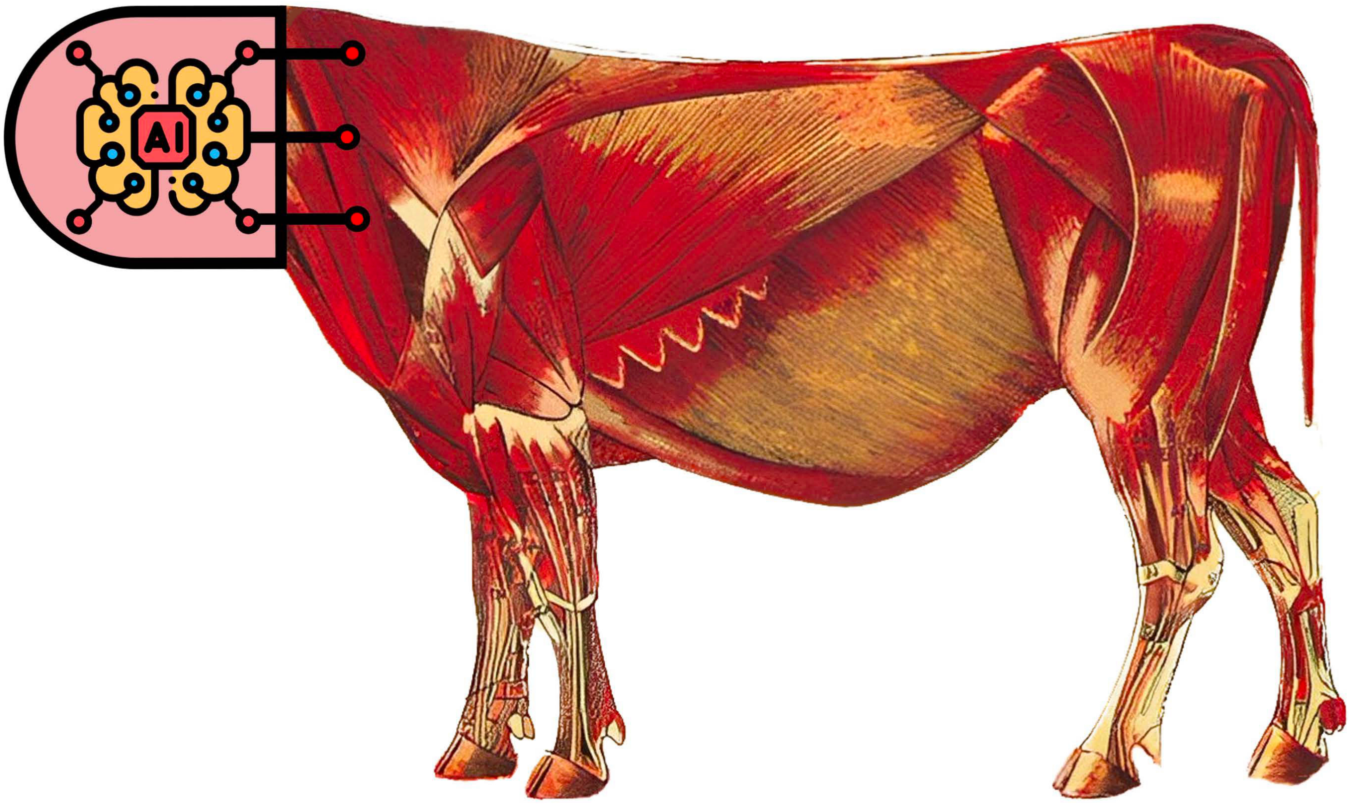

Figure 2: A cow-robot hybrid with an artificial brain and body grown from cultures

may have no senses or sentience but their flesh bleeds. They may be engineered by design but their flesh originates from once autonomous living cells and may still be categorised as 'alive' in other ways. Moreover, cultured meats, while claiming to be "slaughter-free", contradict the ethical principle of reducing animal usage by utilising animal-derived components. For instance, cultured meat production currently relies on foetal bovine serum (FBS) as the standard supplement, which is derived from the foetus of a pregnant cow [30], potentially causing unnecessary pain to the unborn calf [43]. Furthermore, FBS contains numerous proteins and small-molecule metabolites in unknown concentrations [31], and substituting it entirely with chemically defined components can lead to significant environmental burdens and high costs [37], making it an unsustainable option. Furthermore, robots that lay eggs and produce milk infers that animal-robot hybrids' reproductive systems are intact. Whilst the similarities and distinctions between humans and animals continue to command philosophical and research interest, we acknowledge that for many, the animal-robot hybrid we propose may be extended to the creation of human-robot hybrid. Here, our speculative concept resonates with ongoing debates, for example, organ transplant, xenotransplantation, xenobots, ectogenesis, and maybe even sex robots. These areas, whilst interesting, are outside the scope of our provocation of assembling and eating biohybrid robots. Realising, working towards the development of the varied scenarios mentioned in this paper would unleash complex and varied, ethical, social, technical and political debates.

4 THE NEED FOR NEW ETHICAL FRAMEWORKS AND FUTURE RESEARCH

Ethical frameworks continue to be developed and tested for practical application to emergent technologies and societal practices. We anticipate that the prospect of assembling animal-robot hybrids will require more than simply combining elements from ethical AI and bioethics to account for the two core components of the hybrid entity. Mature debates, frameworks and convergences in both fields (see [10]) offer some broad principles that may be applicable to our speculative concept. One overarching bioethical framework has four core principles, namely: *autonomy*, *nonmaleficence*, *beneficence*, and *justice* [4]. These four bioethics principles have been seen as important to addressing challenges of AI, with an added focus on *explicability* - that incorporates both *intelligibility* (around the question 'how does it work?') and *accountability* (around the question: 'who is responsible for the way it works?') [11]. The idea of eating animal-robot hybrids also connects with ethical concerns highlighted for the production of cultured meat, that are *safety*, *suffering*, and *sustainability* [2].

Such questions and broad principles resonate with the speculative concept proposed in this paper. And yet we suggest that the specific ethics for tissue based biohybrid robots may generate nuanced and complex dilemmas that require further exploration. The emerging ethical landscape is vast when we consider futures where animals are substituted with biohybrid robots, and are used for companionship, work, transportation, entertainment, and so on. To narrow this, we introduce this provocation as a way to turn focus towards the implications for the longstanding animals-as-food for human relationship as new frontiers for human-food interaction expand. To conclude this section, and to set out key areas of interest that will direct our future work, we further articulate this emergent ethical landscape by giving some indicative themes/examples across three levels: (1) Governance and responsible innovation, (2) Cultural practices, and (3) Sustainability.

Governance and responsible innovation. The creation of animal-robot hybrids may introduce potential health risks that need to be navigated. For example, animal-derived products introduce the risk of contamination with bacteria and undefined substances, which could cause foodborne illnesses [31]. Therefore, it is vital that governing institutions and research practices adhere to appropriate regulations that ensure the safe use of these technologies. As with other AI technologies, principles around *privacy*, *autonomy*, *transparency* and *security* will also be important [5] to their responsible development.

Cultural practices. Some may seek to create new animal-robot hybrids in a bid to conserve cultural culinary traditions that are dying out or have been banned due to over-farming or on animal welfare grounds (e.g., the traditional way of preparing and eating Ortolan bunting). Whereas others may advocate the creation of new cultural practices that do not reinforce, in any way, animals-as-food relationship even if those animals are hybrid entities and may lack sentience. There is no inherent rationale for engineering elaborate biohybrid systems to mimic the look and taste of animals apart from that it may provide opportunities for traditional cultural eating practices to be conserved in the face of growing ecological and animal welfare concerns. The provocative concept therefore brings competing cultural ethics to the fore, raising questions around the desirable directions of travel and the need for broader societal continuities or changes.

Sustainability. Our climate crisis has created existential pressure to change many aspects of contemporary society, including how food is produced and consumed. No 'solution' enjoys uniformal support. For some the uptake of cultured meat on mass represents a protein rich sustainable future. Alternatively, vegan diets are already promoted globally within certain cultural movements and religions. The idea of assembling biohybrid robots for our consumption sits awkwardly between such debates. The comparative carbon cost of assembling animal-robot hybrids against existing farming methods would depend on many currently design variables (there could be a high carbon cost to the AI component of the new biohybrid entity).

The purpose of sharing these tensions was not to start the speculative process per se but rather to indicate some of the grounds that could be explored through future work. Despite not being 'messy' enough (they only scratch the surface) we share them as some selected threads that cut across a range of cultural and disciplinary issues. In our view this makes the concept inherently disruptive and a strong candidate for further interdisciplinary exploration.

We plan to set out to explore these areas in detail and in a cross-disciplinary manner through a social-sensory speculative approach (see [17]) culminating in a public speculative experience. This will be a social experience that directly engages participants' senses (e.g. taste, olfactory and touch) to stimulate critical reflection and dialogue across relevant fields of research and policy. Our future collaborative work will form the basis to elaborate on existing ethical literatures relating to AI and bioethics, and to construct frameworks that respond to the specificities of the emergent sociotechnical landscape of animal–robot hybrids.

5 FINAL THOUGHTS

In this paper we have begun to extend the space of possibilities for animal-robot hybrids, and have systematically discussed ideas that some readers still might find preposterous or unnerving. The intention of this provocation paper was to bring a disruptive speculative concept into view, that is to eat biohybrid robots. We now embark on a speculative collaborative research project to elaborate on this idea with various experts, stakeholders, and publics – following the overarching question: *What if animals were substituted with biohybrid robots?* Whilst it is outside the scope of this provocation paper to outline our methodology for exploring this question, we suggest that speculative approaches are needed in HRI for they: (1) generate new questions [3] that can be taken forward in iterative research activities and design processes; (2) open cross-disciplinary conversations and engage the public [38]; and (3) bring possible (un)intended consequences of technological developments into critical view, now before it's too late.

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