More-than-human Perspective on the Robomorphism Paradigm

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Figure 1: Illustration of our example of robmorphism during a pretend play activity of a child puppet with a robot shape.

ABSTRACT

This paper proposes a posthuman perspective of the robomorphism theory. We propose to define robomorphism as the attribution of robotlike traits to non-robotic entities. Such a definition embraces the centrality of robots in two aspects. First, by assuming the target of robomorphism is not necessarily a human. Second, by considering the notion of robomorphic traits as inherently crucial to establish the robomorphism paradigm. Embracing robots as relevant non-humans in the robomorphism paradigm constitutes the more-than-human perspective of the proposed approach. The contributions of this paper are threefold. First, we propose the robomorphism paradigm by defining it and its inherent concepts, such as robomorphisation and robomorphic. Second, we discuss the broader implications of the robomorphism theory to the research community of Human-Robot Interaction, raising important new challenges. Third, we created a preliminary inventory of robomorphic traits, which were collected from a speculative workshop activity in order to start answering one of the proposed open challenges.

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CCS CONCEPTS

• **Computing methodologies → Philosophical/theoretical foundations of artificial intelligence**; • **Computer systems organization → Robotics**.

KEYWORDS

robomorphism, robomorphic, posthumanism, more-than-human, robot-likeness, robot-like traits

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1 INTRODUCTION

Imagine that a child is playing with a puppet that has the shape of a robot (illustrated in Fig. 1). The puppet has two cubes, a bigger one with a smaller one on top of it, which has two circles and a line (resembling two eyes and a mouth). The puppet has two sleeves that can be manipulated by the puppeteer as arms. The child plays with the puppet (as a puppeteer) with unsteady straight and unidirectional movements, performing small breaks every time it changes the direction of the arm movements. To pretend that the puppet speaks, the child says "I. Am. A. Robot.", and each word sounds like a sentence as a long pause follows it.

The example above portrays a child in a pretend play in which the puppet is a robot. The child endowed the puppet with the capability to move and to speak, and employed an unsteady movement and voice. In other words, the child projected their knowledge and beliefs about robots into the puppet. We argue that this attribution of robotlike traits to a non-robotic entity can be defined as *robomorphism*. This paper proposes robomorphism as a broader paradigm, stemming from a posthuman perspective.

Robomorphism was recently defined by Schouten et al. as "the projection of robotlike qualities onto a human" [41]. Such definition stems from dehumanization theories supporting that the presence of mechanical qualities may decrease the sense of humanness we ascribe to a person [28]. This definition of robomorphism by Shouten et al. is inherently human-centred as it assumes the target of robomorphism is always a human and its latent process is related to (the lack of) human-like traits. Instead, we propose a new definition of robomorphism, significantly diverging from the previous one in two main aspects. First, by considering that those attributions may occur towards other entities beyond humans, specifically towards non-robotic entities. Second, by considering its latent process is related to robot-like traits. As a result, our proposed definition stems from posthuman theories and unveils a broader theoretical paradigm that is robot-centred.

Posthumanism represents a complex paradigm that challenges the boundaries between humans and other non-humans, i.e., animals, plants, machines or other things [6, 27, 39]. We follow a philosophy of posthumanism that abandons human subjectivity and instead considers the central role of non-humans alongside humans, also referred to as a critical posthumanism [7] or more-than-human [13]. Our proposed paradigm of robomorphism acknowledges the centrality of robots and their robot-like traits. Moreover, it does not assume robot-like traits constitute the opposite of human-like traits, embracing the entanglement between humans and robots in a more-than-human perspective [23].

We review in Sec. 2 the existing literature on more-than-human theories and methods in the fields of Human-Computer Interaction and Human-Robot Interaction. Sec. 3 dives into the main contribution of this paper proposing robomorphism as a paradigm, which opens a wide avenue towards the comprehension of *robomorphic* attributions and the *robomorphisation* process. For instance, when do we ascribe robotlike traits to other entities? How do robomorphic attributions materialize? Or why does the robomorphisation process occur in the first place?

Because robomorphism can be considered a broader explanatory paradigm, it raises several implications and challenges to the fields of Philosophy and Psychology, which are not addressed in this paper. Instead, our second contribution is a discussion of three major implications to the field of Human-Robot Interaction (Sec. 4), namely (1) understanding the *robotness* of robots, (2) challenging the current anthropocentrism in HRI, and (3) creating opportunities for more-than-human robotics.

Lastly, we argue that the backbones of the robomorphism paradigm lie in understanding the robot-like traits. Consequently, leveraging our broader definition, and considering its implications in Human-Robot Interaction, we did an exploratory data collection based on a speculative method (see Sec. 5) to start answering the question of: What are the characteristics and features that we associate with robots? As a result, the third and last contribution of this paper is a preliminary inventory of robomorphic traits (Sec. 6).

2 RELATED WORK

We will now review current state-of-the-art literature on more-than-human posthumanism, in the fields of Human-Computer Interaction (HCI) and Human-Robot Interaction (HRI).

2.1 More-than-human in HCI

In the field of HCI, more-than-human thinking has emerged as a potent area with vocabulary, methodologies, practices and examples of designs that adopt the approach [19, 22, 23, 25, 44]. Within these approaches, there is a shared commitment to better understand and work with the broader ecologies that computing is part of, accounting for, for example: birds [4], mushrooms [30], houseplants [44], bacteria [36] – but also entities such as materials [18, 31, 37], tools, machines [16, 17], and the agency they have in how technologies are created and lived with. As a subsection of the new methods and approaches, there has therefore been an active effort to get insight into the lifeworld's of nonhumans, through approaches such as noticing differently [32, 38, 47], taking a thing-perspective [24, 45], and co-habitation [42, 44]. Through this, more-than-human agencies and capacities have been explored, and the extent to which they are similar or equal to humans has come into question. For example, how to position the more-than-human (in the context of HRI for example, the concept of robot-citizenship [34]), and what the limits or risks are in how much we can understand from a human perspective or body [33].

Relatedly, the notion of anthropomorphism is challenging in a more-than-human context and needs to be considered with care. Cary Wolfe responds to a decision made by the Spanish Parliament in 2008 to grant basic rights to Great Apes, protecting them from harm [46]. The article further aims to understand to what extent we can see this decision as a satisfactory solution to the problematic ethical dimension of human relations with non-human animals. For example, by the granting of rights to Apes, which animals have become rendered rights-less? It unpacks how simply granting rights is still a human way of considering the non-human, imposing human structures and concepts that do not fit neatly in other contexts. Yet, taking the perspective of the more-than-human can also be generative of seeing things anew.

For example, Clarke and co-authors make use of animal masks on city tours to understand the urban environment anew from a multi-species point of view [11], Judith Dorrenbacher et. al. propose techno-mimesis [20] and describe the overcoming of anthropomorphism, and Oogjes and Wakkary follow the perspective of a thread through an illustration that includes fictional little hands, to better understand why a yarn from an e-textile project repeatedly tangled and knotted in the process [37]. These approaches show that anthropomorphizing can be generative for making sense of more-than-human capabilities. For example, new materialist theorist Jane Bennett turns to an interaction between two nonhuman entities: a flame burning a cotton plant [3]. As humans, we know that cotton has many creative capacities – it can be harvested and spun into yarn to weave soft and durable fabrics with, and it can be turned into a cotton swab. To other species, like worms, bugs, and birds, it offers different possibilities as a food source or material for nests. But for the flame, which perceives the world in its own distinct way, the cotton is only one thing: flame-able. Through this example, Bennett demonstrates how our blind spots of anthropomorphizing are demonstrative of our own capabilities (and the limits to it).

We see that the key to making such approaches work is to leverage the creative potential of understanding human-robot relations differently. We argue that speculative methods can be helpful to better understand a wider set of possible relations between humans and robots.

2.2 More-than-human in HRI

Human-centred approaches have yet dominated the field of Human-Robot Interaction. To our best knowledge, little attention had been given to more-than-human theories.

Among the few examples, we found the recent work by Boffi et al., who developed a robot that "want to to be a pollinator" [5]. The robot was deployed on a participatory action at a local farm with the mission of monitoring the biodiversity. Nevertheless, the robot would then engage in a speculative narrative of loving flowers and protecting flowers' pollinators. Such narrative was able to promote a reflexive discussion with the farmers on the problem of pollinators decline. The methodology by Boffi et al. recognises the multiple entanglements between humans, non humans and other natural elements, which the authors called the natureculture. The work generally embraces a relationality posthuman perspective of "thinking-with".

Similarly, we found the "Techno-Mimesis" methodology proposed by Dörrenbächer et al. [20]. It is a performative workshop method where participants are invited and prompted to take the robot's perspective, e.g. perceiving the world with a distance sensor, instead of using their vision. While traditional methods focus on discussing differences between humans and robots, which leads to a rational and distanced perspective, the "Techno-Mimesis" workshop invites participants to embody the robot in a playful approach. The authors argue their more-than-human methodology promotes a reflective and critical perspective in which people "become a robot".

DeFalco also wrote an essay on posthuman care, proposing how human care should be augmented cross-species [14]. More precisely, it is about exposing the hybridity of the organic and inorganic (e.g. robots) networks in care and in relationships. Her proposed concept sustain life in more-than-human worlds by encapsulating the improbable range of affects, energies, behaviours, attachments, dependencies, both visible and invisible.

Finally, the work by Lupetti et al. speculates on the idea of robot citizenship [34]. The authors reviewed possible approaches to implement robot citizenship and advocate for more understanding on the socio-relational perspective (i.e. more-than-human). Their paper also speculate on three different scenarios that highlight future challenges for the HRI community.

The current landscape of more-than-human methods applied to HRI demonstrates a preliminary but also promising perspective to rethink how to create social robots. Our paper proposes a new paradigm that is established on more-than-human theories where robots and their relation with humans become central.

3 ROBOMORPHISM PARADIGM

We propose a new paradigm on robomorphism. First of all, we assume a robot is "an autonomous system which exists in the physical world, can sense its environment, and can act on it to achieve some goals" [35]. To dive into the fundamental concepts of this paradigm, we will analyse the example of the child and the robot puppet, presented in Sec. 1 (see Fig.1). As previously mentioned, the child's attributions of robot-like traits to the puppet reveal their projection of knowledge and beliefs about how robots act and, therefore, constitutes an example of robomorphism. We can also highlight the actual puppet as another instance of robomorphism. The physical features of the puppet can be found in known robots. As a result, the design process of this puppet can also be pointed out as involving robomorphism. Our broader definition of the term robomorphism is as follows.

> **Robomorphism** is the attribution of robotlike traits to a non-robotic entity.

This definition holds two important considerations. First, the target of this action is a non-robotic entity. Contrary to a previous definition of robomorphism by Shouten et al. [41] proposing this attribution occurs only towards humans, we argue instead that it can also occur towards non-human targets. Non-robotic entities are any entities that are not robots, for instance, humans, animals, plants, objects, or gods. In the example above, the target of robomorphism is an object, i.e. the puppet. Other examples of robomorphism can be describing a person as performing a robot dance, or identifying a dog that is crawling and sweeping the floor of an apartment as a robotic vacuum cleaner.

The second consideration drawn from our definition of robomorphism is the centrality of robotlike traits. In all of the examples above, robomorphism always describes a projection or an attribution of traits associated with robots. For the first example of the child playing with the puppet, the robotlike traits were, for instance, the capability to move and the unsteadiness of the actual movement. For the examples of the puppet's design, one can identify the physical shape of the puppet with cubes as robotlike features. These traits are generally part of the broader characterisation of something as a robot. Due to the centrality of the robomorphic notion in the robomorphism paradigm, we also define this characterisation as follows.

> **Robomorphic** describes characteristics, features or qualities found in robotic entities.

3.1 What is (and is not) a robomorphic trait?

The word robomorphic is an adjective describing something that possesses robotlike traits. Robots are expected to be considered and perceived as robomorphic. From our initial example of the child playing with the puppet as a robot, we previously mentioned the capability to move and speak as robotlike traits. A follow-up question would be whether those traits are specific to the robomorphism paradigm, because moving, for instance, is a capability attributed to other species, such as humans and animals. And it could, therefore be also considered as a sign of animalism (or specifically anthropomorphism and zoomorphism, respectively), rather than robomorphism. A similar argument could be made towards the capability of speaking, which can be attributed to humans or other artificial entities, e.g. a smart speaker.

We claim that robomorphic features characterise the notion of a robot and, therefore, lead it to be recognised as such. We acknowledge some of the features can be unique to robots, compared to other entities, while some other characteristics can simultaneously belong to other entities. If we look at definitions of "robot" in dictionaries[1 2], the commonalities point to the fact that it (I) has a physical body in the real world, and it (II) moves/acts/actuates in the real world. A recent literature review also analysed previous definitions of a "social robot" [40], and identified five main qualities. Nevertheless, to the best of our knowledge, the extensive identification of robomorphic traits remains underexplored.

Another related question is whether all robomorphic traits are present in all robots. For instance comparing with human traits, such as friendliness and unfriendliness, we expect an extensive list of robomorphic traits to similarly include conflicting features, considering that different robots possess different traits. We would like to make an additional remark on the nature of the robomorphic traits. We foresee at least three types of robomorphic characteristics: physical-related, action-related, and interaction-related. More investigation should consider expanding the possible types of traits that characterise robots.

Lastly, robomorphic traits can also hold some inherent subjectivity of the actor. Considering the initial example again, we assume the child specifically chose the capabilities to move and to speak as it was her belief (from the robots she previously knew) that robots can generally possess these capabilities. If the child's projection of those capabilities came from her knowledge on another entity, then it would not be considered an example of robomorphism. Regarding the other robomorphic trait of unsteady movements, it is less ambiguous that the child was robomophising the puppet, i.e. attributing robotlike traits to it. Overall, some robomorphic traits might generalise more than others. In other words, some traits might be widely acknowledged as part of any robot characterisation, while other traits are subjectively derived from a specific knowledge base.

3.2 Who can robomorphise?

In the previous examples of robomophism, we presented how different non-robotic entities can be the target of robomorphism (i.e. puppet, human or dog). However, the actors or initiators of those robomorphic attributions in the previous examples were all human. We also speculate on the possibility that other entities can robomorphise a non-robotic entity, i.e. being the actor of the robomorphism. This notion leads to our last definition is on the concept of robomorphisation.

> **Robomorphisation** is the process(es) of attributing robotlike traits to non-robotic entities, and the result of that process(es) is robomorphism.

According to this definition, robomorphism is the result or consequence of a previous attribution of robomorphic traits. The actor or initiator of robomorphism is the one performing those process(es) involved during the projection of robomorphic traits. If the actor is a human, those processes are cognitive and may be conscious or unconscious. Similarly, if the actor is an artificial agent, those processes refer to computational programs that perform those inferences. Therefore, our definition allows the possibility of different entities as actors of robomorphisation and, therefore, of robomorphism.

3.3 What is the relation between robomorphism and other paradigms?

The robomorphism paradigm is not mutually exclusive with any other relatable paradigm. In other words, the target of robomorphism can simultaneously be the target of analogous paradigms. For instance, the puppet of our initial example can also be target of anthropomorphism [21], or even zoomorphism [2] as the physical shape of this toy includes two circles and a line, resembling the eyes and mouth of a human or an animal, respectively. It is, therefore, admissible that an entity possesses both robomorphic traits while also having anthropomorhic, zoomorphic or even mechanomorphic characteristics [9], just to name a few.

3.4 What is special about robots?

Robots are artificial agents that are physically embodied in the real world. They also have a certain degree of agency, considering the actions they (can) perform in that environment. Their intelligence and (partial) autonomy lead humans to attribute them an artificial intentionality [43, 48]. Additionally, their physical embodiment and physical presence strongly influence our perceptions of robots and the perspective-taking attributions we make [15, 29]. As a result, compared to other disembodied artificial entities, we argue the physicality of robots in the real world plays a crucial role in the robomorphisation process(es).

3.5 Open questions

Robomorphism opens a wide avenue towards the comprehension of robomorphic attributions and of the robomorphisation process(es). We finish this section with posing possible research questions that depart from our definition of the robomorphism paradigm. When do we ascribe robomorphic traits to other entities? How do robomorphic attributions materialize? Why does robomorphisation process occur in the first place?

[1] https://www.ldoceonline.com/dictionary/robot
[2] https://www.oxfordlearnersdictionaries.com/definition/english/robot

4 BROADER IMPLICATIONS OF THE ROBOMORPHISM PARADIGM TO HRI

The robomorphism paradigm characterises a phenomenon that does not occur towards robots, but rather towards the opposite of a robot. As a result, one can ask whether such phenomenon has implications for the research community of human-robot interaction.

First, the proposed posthuman perspective of robomorphism brings attention to a novel thing-centred perspective in robotics [10], specifically highlighting the possibility of a robot-centred perspective. A central notion while defining the robomorphism paradigm is the term "robomorphic", which characterises the possession of robotlike traits. This notion opens the possibility to identify what exactly characterises robots. We argue that a detailed inventory or characterisation of possible robomorphic traits is needed and can guide the research community on human-robot interaction to further understand what is considered a robot. And, philosophically, what conveys *robotness* to a robot?

A second important implication is the fact that the robomorphism paradigm can contribute to challenging the current anthropocentrism in the field of human-robot interaction [26, 49]. Challenging the current anthropocentric approaches in the field of HRI does not mean removing human-centred approaches from the landscape. It means instead shifting the focus to additionally consider the non-humans involved in the interactions. That distinction specifically describes the more-than-human school of thought within posthuman theories, i.e. by considering the relationality between humans and non-humans (rather than excluding the humans). In this case, we propose bringing attention and giving voice to the robot as a relevant non-human.

The third and last implication of the robomorphism paradigm is that is opens broad avenues to explore more-than-human robotics. This, in turn, will require further investigation proposing and developing novel (I) concepts, (II) methodologies, and (III) practices, drawing inspiration from a similar attempt in the field of HCI [12].

5 SPECULATIVE WORKSHOP

The current section describes the methodology we used to create the preliminary inventory of robomorphic traits, described in next section (Sec. 6). Our goal was to invite a diverse group participants to speculate on a new and unknown concept of "robomorphic thing". We wanted to encourage people to engage in a speculative activity, in which they knew upfront the concept being explored was not familiar to anyone.

We followed the Magic Machines Workshop proposed by Andersen and Wakkary [1]. This technique aims at leveraging personal visions of its participants towards a potential novel technological thing. It uses a 2-hour embodied process of making non-functional objects (or machines), embracing the personal emotional content of each individual democratically. Moreover, the timekeeping and material choices allow for a freedom of expression without any technological concerns or limitations.

Our choice for using the Magic Machines Workshop goes in line with the more-than-human perspective, leveraging the defamiliarisation involved in this technique. This section provides a detailed description of our methodology.

5.1 Participants

Participants were recruited from researcher's personal connections, ensuring a fair diversity of age, backgrounds, technology expertise, and robot's familiarity. A total of seven participants took part in the workshop session, four of them were female and their ages ranged between eighteen and thirty five. One participant completed highschool, two of them completed BSc, and four of them a MSc. Their expertise included Biomedical Engineering, Computer Science, Robotics Engineering, Marketing, Design, and Philosophy. Only two participants were familiar with robots, one of them works as designer in a robotics company and the other is pursuing PhD in Robotics Engineering.

5.2 Procedure

The procedure consists of an initial questionnaire, followed by the 2-hour Magic Machine Workshop with all the steps proposed in the original version [1]. The workshop was audio-recorded and video-recorded during the steps two and four. All participants signed the consent form to acknowledge their voluntary participation and the following data collection and analysis by the research team. A detailed breakdown of each step is provided below.

Initial Questionnaire: This step was done one day before the workshop. Participants were requested to complete an online questionnaire with demographic information about their background, expertise and age. We also asked the following open-ended question: "When you think of "robomorphic things", what are the five words/ideas that come to your mind?".

1. Introduction: The workshop commenced with a concise 5-minute introduction. Two researcher were present, one with the role of facilitator and another as assistant. The facilitator emphasised his responsibility in guiding the workshop's agenda and outlining each step. Meanwhile, the assistant's role was to capture photographs, videos and notes of all the session.

The facilitator then elucidated the workshop's scope and expectations, employing simple and easily understandable language to establish a social contract with the participants. The workshop's scope was to explore and define the novel concept of *"robomorphic"*.Furthermore, the facilitator communicated the expectations regarding participant contributions, encouraging open sharing of personal viewpoints, ideas, and contributions. It is important to highlight that participants were told this concept does not exist, nor it was ever defined in any dictionary, and that there were definitely no correct or wrong theories on this.

2. Prompt: The prompt phase, lasting for 10 minutes, aimed to immerse participants in the theme of robomorphic traits. Participants were asked to engage in an individual activity where they had to think or imagine something robomorphic, and to think about the sound/noise of that thing. The goal here was to stimulate the imagination of actions and behaviours rather than solely physical aspects of their imagined robomorphic thing. After a few minutes, participants were asked to reproduce the sound of their robomorphic thing to the audience using their own voices, body, or any nearby object.

Figure 2: Material kits and space: a. individual kit, b. shared kit, c. material making space

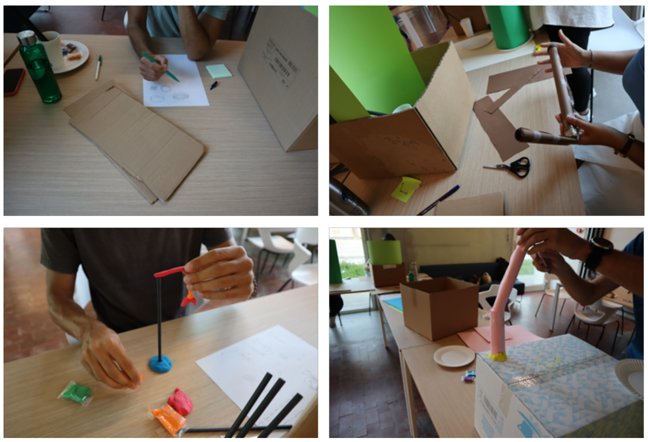

Figure 3: Making process using sketching, and assembling

3. Material making: During this phase, participants were tasked with individually crafting robomorphic things within a time frame of 30 minutes. The facilitator explicitly instructed participants to translate their mental conceptions of robomorphic thing into tangible, physical creations, i.e. their "magic machines".

Each participant was provided with a dedicated workspace for this activity (fig.2 c.), and an individual kit containing essential materials (fig.2 a.), including paper plates, paper cups, strings, coloured plasticine, and cardboard. Additionally, a shared table was set up with materials accessible to everyone (fig.2 b.), which included extra paper plates, coloured pens and pencils, scissors, post-it notes, glue, tape, as well as additional cardboard and paper sheets. Figure 3 illustrates the participants' creative process, using sketching, assembling and experimentation.

4. Presentation of Robomorphic Things: In this phase, participants were invited to show and describe their "robomorphic things" to whole the group. This marked the transition from the internal creative process to an external presentation action. Subsequently, the facilitator outlined the presentation guidelines step by step. Each participant, in turn, was asked to stand up and showcase their "robomorphic thing", describing its features, goals and showing how it works. Participants were also advised to not comment on each other presentations at this point. This phase encompassed a total duration of 40 minutes, divided between a reflective period (for presentation preparation) and the individual presentations themselves (took circa 2 minutes each). The assistant researcher video recorded all the presentations.

5. Group discussion: This phase extended for approximately 35 minutes and aimed to promote collective reflection on the notion of "robomorphic". The facilitator outlined the guidelines, emphasising that this was a collaborative activity in which all participants should engage in critical reflection and constructive discussion of each other's ideas. Participants were encouraged to identify both similarities and differences among the magic machines they created before and had the freedom to pose questions about specific machines. The facilitator intervened whenever needed to keep the speech fluid, by raising questions.

6. Documentation: This last step of the assistant facilitator involved adding to the workshop documentation a photograph of all the robomorphic things.It served as a symbolic conclusion to the session, during which the facilitator expressed gratitude to all participants for their time and valuable contributions.

6 INVENTORY OF ROBOMORPHIC TRAITS

The analysis of the workshop detailed in the previous section resulted in an inventory of robomorphic traits, based on participants' insights. We first transcribed the audio content and then followed a thematic analysis using an iterative inductive coding approach [8], which underwent review by two additional researchers.

Table 1 summarises the current inventory of robomorphic traits. This inventory is not an extensive list of all traits that characterise robots. Instead, it provides a starting point towards understanding what can be considered as a robomorphic trait. The traits are grouped into physical-related (i.e., traits associated to the shape, material, or form), action-related (i.e., traits associated to actions and capabilities) and interaction-related (i.e., traits associated to interaction and relationships with other entities).

This classification of the three types of robomorphic traits was inspired by participants answers to the initial questionnaire, which reflected these three dimensions. Specifically, the words they mentioned were related to the embodiment (e.g., "humanoid/machine man"; "robotic exoskeleton"; "robot-shaped object", "android robot", "eyes", "head", "metal", and "lights"), to the actions or behaviours (e.g., "superficial", "manipulated", "mechanised", "impersonal", and "without personality"), and to the interaction or purpose (e.g., "innovation", "future", "improvement", "human symbiosis", "uncanny valley", "sleep robot", "Greek mythology", and "replacement").

We will detail each of the robomorphic traits on Table 1 as follows, with some related quotes to give example and context.

6.1 Physical-related Robomorphic Traits

Body: Participants often referred to the physical embodiment of their robomorphic thing, acknowledging its tangible presence (*"has a physical body"*), which can take various forms (*"do not have a specific shape, because there are so many types."*). They also mentioned specific body parts, such as arms, heads, wheels, or engines (*"I made a hanger that has a robotic arm on top"*; *"What I imagined would have a head, but animals also have heads."*; *"it would have two wheels"*; *"regardless of whether it has a head or not, or an arm or not, it always has an engine. If they move, they have a motor"*). Geometrical solids were also mentioned to describe the shape (*"they are, in general, cylindrical.*)

Type	Robomorphic Traits
Physical-related	- Body - Dynamic shape
Action-related	- Autonomy - Goal-oriented - Movement - Mechanical movement - Sound - Perfection and replicability - Computational power
Interaction-related	- Change (or act on) the environment - Sociability to interact with humans

Table 1: Preliminary inventory of robomorphic traits based on one session of a workshop following the methods described in Sec. 5.

Dynamic Shape: They physical bodies can exhibit dynamic properties, adapting to specific functions or contexts. For instance, its shape may change to suit its purpose, such as folding or expanding, based on its needs. This adaptability can include folding mechanisms and the capacity to alter space occupation (*"they have a double wall so they can collapse inwards or outwards, depending on the need... its space occupation, is lower when it is square"*). This can also be used to adapt and expand pre-existent components such as bionic prosthesis (*"takes the form of something, for example the bionic arm when someone loses his arm... This is practically an articulated arm... are connected to tendons and nerves"*).

6.2 Action-related Robomorphic Traits

Autonomy: Participants considered autonomy a fundamental characteristic of a robomorphic thing, with varying degrees of independence from humans, or even sharing it with humans (*"...everything that then has a certain degree of autonomy can also become something robotic, and that has the shape of that..."*; *"...and humans give instructions and that robot does it autonomously."*)

Goal oriented: Participants perceived that robomorphic things are fundamentally designed with the aim of assisting humans in various contexts. Their primary function is to simplify human lives and fulfil specific objectives (*"...They serve to make our lives easier."*). It is also common to prioritise resource optimisation (*"Yes, basically it's about working on optimising resources."*).

Movement: Movement also plays a crucial role in the classification of robomorphic traits. It is required that robomorphic things exhibit diverse forms of movement: they can move around, typically using wheels, manipulate different parts of their body, or remain stationary. Furthermore, the association of movement with sound was identified as a critical aspect of action-related robomorphic traits. Combining sound with movement implies that the thing is engaged in a specific action, reinforcing its classification as a robot. (*"When you combine a sound with a mechanical movement, that is, it already implies that, perhaps, that robotic object is performing a certain action..."*).

Mechanical movement: They often do so in a consistent manner, such as maintaining a constant pace (*"...like a platform that moves at the same pace..."*). These movements are characterised by degrees of freedom distinct from those of humans. While robots may possess a broader range of motion along specific axes, they do not encompass all the degrees of freedom seen in living creatures. The description of non-fluid emphasised these distinctions, more mechanical movements that are indicative of robomorphic objects (*"This is a neck to rotate to see the other side"*); (*"...their movements are not fluid... Therefore, in this sense, they would be robomorphic objects."*; and *"...by the way they move, we realise that they are mechanical movements..."*) .

Sound: This robomorphic trait includes the sounds produced by the motors and robotic voices. Robot motor sounds were noted for their variability, ranging from non-constant (*"... the noise of the engines... a different and not constant noise."*), to more continuous and distinct sounds, like those of vacuum cleaners.

Furthermore, the association of sound with the function was highlighted through examples. The noise generated by its mechanical action, such as the noise of a cutting blade in a candy manufacturing store (*It's a robot that only cuts sweets and cakes. And the noise it makes is (SOUND) the noise of a blade. In other words, it's not even the engine; it's the noise of the blade cutting the cakes... Like, it would be like (SOUND) like a millefeuille, right? And that's the noise he makes with an arm. A sword like that..."*). Robomorphic voices were mentioned while describing artificial voices (e.g. text-to-speech) with qualities that distinguish them, often reminiscent of mechanical voices (*"(...) but in the past, there were voices, which we called robotic voices because they have a characteristic, it is difficult to describe what the characteristic is, but we identified it as a robotic voice."*).

However, it is worth noting that some participants did not necessarily associate robomorphic traits with any sound, suggesting that sound might not be an inherent feature of all robomorphic objects, and that differs from humans and animals (*"If this is a robomorphic object, why does it have to have a sound? And therefore, there may be no sound."*).

Perfection and replicability: Robomorphic traits are often associated with characteristics such as perfection and replicability. These behaviours are precisely repeatable, exceptionally accurate, and rely on rapid decision-making based on extensive data from sensors and past experiences (*"If something is too perfect or too smooth, we immediately say it looks like a robot."*; *"it is perfect in the sense that... It does not fail."*; *"If there is behaviour that is replicated or can be replicated, at any time, it is robomorphic behaviour."*).

Computational power: Participants also mentioned the robust computational capabilities (*"So, the robot is sometimes doing the process that we do, just with the biggest database it has..."*).

6.3 Interaction-related Robomorphic Traits

Change and act in the environment, Sociability: Robomorphic things are active agents in the physical world and, through their actions and environmental perception, they can be regarded as social partners or with social impact(*"...It's just a social partner."*; *"... a robot has to be able to interact with the physical world..."*).

6.4 Discussion on the Robomorphic Traits

We have distilled a preliminary and non-exhaustive inventory of robomorphic traits, i.e. characteristics, features and qualities found in robotic entities. We would now like to discuss five important considerations from the thematic analysis.

First, participants' notion of "robots" was crucial during the several activities of the workshop while they speculated on "robomorphic things". Even though the facilitators mentioned several times that a "robomorphic thing" could literally be anything, most participants kept their mental model of robots as central. They even interchangeability mention their "robomorphic invention" as a "robot". This consideration is in line with the more-than-human perspective we wanted to raise awareness about during the workshop. Additionally, it also corroborates the idea that robormorphic attributions are central in the robomorphism paradigm.

Second, different targets of robomorphic attributions were mentioned by participants. For instance, humans can have robotlike traits (*"Someone or something can have a robotic voice."*; *"There is also the concept of people behaving in a somewhat robotic way..."*; *"bionic prostheses, it is also a bit of a human being, no one calls it a robot becoming, moving towards being more robotic, literally, and not just robotic behaviour."*; *("The first thing I thought was people becoming robots."*. Similarly, objects can also be considered robomorphic (*"it's a doll in the shape of a robot, too, it doesn't need to be animated, you're right, ... it's just a doll with a robomorphic form"*). This is also aligned with the proposed more-than-human paradigm of robomorphism.

Third, during the group discussion, participants also started rambling if a robomorphic thing could simultaneously be anthropomorphic, and whether these terms were opposite or not. This conversation topic started upon the bionic arm example, and the specific/technical word "anthropomorphic" was brought by a robotics expert, which was followed by a clarification of the term by one facilitator (to ensure all participant knew its meaning). Interestingly, participants converged into an idea of mixed forms, specifying a thing can be characterised with both traits, and also that one term might overlap the other (*"But an anthropomorphic can also be a robomorphic, one is inside the other. The anthropomorphic can then be inside this robomorphic."*).

Fourth, participants draw attention for several human factors and purposes associated with the goals of the robots, mentioning that robots are designed by humans, and thus, their inspiration and features are inherently driven by a human perspective and subjectivity (*"But it's interesting that robots can also be anthropomorphic, the idea is that they do that, they replace, that is, they perform human actions."*).

Lastly, when describing robotlike traits, people commonly use the term "mechanistic" or related terms. Generally, the terms are used to describe lack fluidity, lack of expressiveness, or less emotionally expressive postures (*"...in this sense it could be associated with the term robomorphic, with a person, with the behaviour of a person who has a more mechanical, less expressive posture."*). However, it seems to be difficult for them to further explain the meaning they want to convey, as this notion may come associated with a sound or a gesture, which we found interesting.

6.5 Towards New Concepts and Methodologies in More-than-human Robotics

Our inventory of robomorphic traits constitutes a preliminary effort on scrutinising a new concept, i.e. "robomorphic". It also revealed a need to create a new vocabulary and further expand our knowledge, as drawn by the difficulty of participants to express the meaning of "mechanical". This emphasises how we lack terminology centred on the non-human aspects of a robot.

Regarding the methodologies, we would like to point out that we employed the Magic Machines technique for the speculative workshop as it allowed participants to defamiliarise with the "robomorphic" notion being explored, following a first step towards more-than-human approaches. However, this technique still holds a strong human perspective as participants assume the role of a human designer. It would be interesting to further use other methods, such as the "Techno-Mimesis" technique [20], in which humans assume a non-human role with non-human traits. This discussion point also reinforces that when applying a more-than-human perspective, it remains difficult to escape from a human view completely. Nevertheless, it generally paves the floor towards new methodologies in HRI [3, 10, 37].

7 CONCLUSION

This paper proposes a new posthuman paradigm on robomorphism, which refers to the attribution of robotlike traits to non-robotic entities. The contributions of this paper are threefold. First, we propose the robomorphism paradigm by defining it and its inherent concepts, such as robomorphisation and robomorphic. Second, we discuss the broader implications of the robomorphism paradigm to the research community of Human-Robot Interaction, raising new challenges to this scientific field. Third, we created a preliminary inventory of robomorphic traits, as an attempt to start answering to one of the open challenges of developing novel concepts within more-than-human robotics.

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