Smarter Repair 2053

Paul Coulton[*1], Michael Stead[1], Violet Owen[1]

[1]School of Design, Lancaster University, Lancaster, LA1 4YR, UK

[*]corresponding author Paul Coulton p.coulton@lancaster.ac.uk

Paul Coulton is the Chair of Speculative and Game Design at Lancaster University. He practices research through design to create experiential futures which deliberately mix a present experience with a speculative future by combining immersive scenarios with artefacts produced as design fictions.

Michael Stead is Lecturer in Sustainable Design Futures at Lancaster University. His current research focusses on how design can help society to better understand the socio-technical implications that data-driven technologies and digital fabrication pose for achieving Circular Economy and Net Zero goals.

Violet Owen is a Senior Research Associate at Lancaster University. Her current research is exploring how Research through Design, Participatory and Speculative Design approaches can help to educate the public and raise awareness about the barriers and opportunities for IoT repair.

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In 2023 the European Union enacted the right-to-repair for European citizens which was undoubtedly a step forward in tackling planned obsolescence and the deluge of electronic product waste being produced at that time. An expansion of the right-to-repair to include smart devices occurred in 2035 acknowledging their increased proliferation as everyday products and services. However, these rights-to-repair did not result in creating a capacity for repair such that consumers were both willing and able to avail themselves of this right. To address this challenge technologists extended the infusion of datafication and Artificial Intelligence within smart products - resulting in the right-to-repair being granted to the devices themselves in 2045. This paper reviews this transition which resulted in both decreasing electronic product waste, increased device longevity, and extending the development of an aesthetic of repair into more products and services.

Keywords: right-to-repair; sustainability; speculative design; defuturing; design fiction

Introduction

The abstract of this paper is fictional and is an artefact of a Design Fiction (DF) world [Coulton et al. 2017] built to consider the implications of a potential future in which Artificial Intelligence (AI) infused products and services have become part of the repair ecosystem. Its form is deliberate to help frame a future research and development trajectory for those might undertake such an endeavour. This DF world allows for reflection upon the limitations in the present which affect our ability to enact our Right-to-Repair (R2R) enacted through European Union (EU) legislation in 2023 [EU 2023].

When the proposed introduction of the legislation was announced in 2020 it was hailed as a significant step forward in addressing the growing volume of electronic waste (e-waste) generated across Europe each year, which in 2020, was an estimated 13 kilo per (EU) inhabitant [European Parliament News 2023]. E-waste is the fastest growing waste stream in the world [Smieja 2023] which is principally made up of discarded household consumer products and appliances, of which a growing number of which are networked or so-called ‘smart’ Internet of Things (IoT) devices [Stead et al. 2020]. Currently, less than 40% of the EU’s e-waste is subject to any form of sustainable recovery, that is, ‘post-lifespan’ processes such as material recycling and the harvesting of reusable componentry [EC.Europa.EU 2021]. E-waste is consequently a significant contributor to the rise in harmful carbon emissions, which are fuelling global climate change. Thus, developing new ways to extend and improve the lifespans of electronic devices feeds into wider efforts to keep global emissions from continuing to rise and exacerbating the climate crisis further. This could also help mitigate other consequences of mass e-waste production, such as lack of space in landfills for this influx of waste [Newtech Recycling 2021], outsourcing (or illegal disposal) of e-waste management from the global north to developing countries [Vidal 2013] and the risks e-waste poses to both health [Vats and Singh 2014; Kutz, 2006] and the environment.

Within the paper we present a future imaginary for 2053 aimed at helping move the debate on future product design so that sustainability, and in particular maintenance and repair, are prioritised. Through our research through design approach, we explore the need for more-than-human considerations to enter design practice, and particularly the R2R. We highlight how existing approaches limit our capacity to repair particularly through the prevalence of planned obsolescence and what we describe as an unrepairable aesthetic. Before exemplifying how such approaches might occur in 2053, we provide the theoretical scaffolding for our approach to design futuring and in particular, DF as worldbuilding. Finally, we present our discussion and conclusions on the DF imaginary, exploring its potential in realigning product designers towards repairability and maintainability.

More-than-Human Centred Design

To address R2R in the context of IoT products and systems, we must first acknowledge that even our most mundane household devices' functionality relies on computational components which are also increasingly being imbued with networking capability, which fundamentally changes our relationships with them [Pierce and DiSalvo 2017]. This change is a result of the increasing disparity for users – between what the devices "actually are and do and the ways in which they are presented as things for use" [Hauser et al. 2021]. The addition of networked services also arguably leads to a shortening of the lifespan of such devices through systemised obsolescence, in that, while device software can (for a period at least) be upgraded via remote installation, we increasingly see their hardware rendered obsolete due to manufacturers' and service providers' constant drive to extend the functionality and data capture capabilities. This forced obsolescence contributes to the growing problem of e-waste, as does society's obsession with speed and performance [Sylvain 2019]. Manufacturers often look to make their products more marketable through emphasising their unique selling points, such as peak product performance, and compete with other companies to promise theirs does this best (for example, 3G, 4G, 5G; 4K streaming; Superfast Fibre Broadband, Ultrafast Fibre Broadband, etc). This tactic has been similarly adopted in IoT products and efforts made to competitively increase product performance while ignoring issues of sustainability, for example improving network latency has consequences on product's lifespan's i.e. increasing power consumption reduces battery life (not to mention the broader implications caused by increased data sharing such as the ecological impacts of server farms [Levenda and Mahmoudi 2019] or the security concerns of data lakes [Laurent 2019]). These are amongst the issues leading to an increasing number of design researchers arguing that this arises from the wide scale adoption of anthropocentric framings within design practice, particularly those enacted in the approaches associated with Human-Centred Design (HCD) [Disalvo and Lukens 2011; Forlano 2017; Galloway 2017]. In HCD, the human (predominantly conceived as the user) and their perceived task are placed at the centre of the design activity. This myopia leads to an obfuscation of the wider implications of performing the activity, such as social impacts or environmental effects. With this in mind, we explore the emergent call to adopt More-than-Human-Centred Design (MtHCD) approaches.

The term More-than-Human appears to originate in the field of cultural geography (Whatmore 2006) and has gained prominence through the seminal work of anthropologist Anna Tsing and her concept of "noticing" [2015] where it has been employed to promote a shift from largely anthropocentric perspectives to one that acknowledges our relationships to and within complex assemblages. In relation to HCD, Coulton and Lindley (2019) similarly argue designers need to acknowledge humans are rarely the centre of things but rather "they exist within complex interdependences of human and non-human actants which can be emotionally, economically, ecologically, and morally independent of each other". This creates the need for MtHCD. Although attaching the More-Than prefix infers a criticism of HCD, this does not extend to the entirety of what HCD encompasses nor all HCD-informed projects. Rather, its aim is to shift focus from the individual human actant to what might be considered a focus towards a more pro-social perspective, in that, an action by an individual is presented within the context of their membership of a community of numerous actants. There are examples of similar considerations in other disciplines, such as in Biophysics from Biology, where the biotic and abiotic surroundings are examined to understand a subject's wellbeing, survival, evolution and development [Christou et al 2022], or in ecosystem design, ecosystem mapping and ecosystem thinking which seek to understand the relationships and dependencies between the various actors and systems of a subject's environmental networks [Owen et al 2022]. However, these disparate theories are yet to be applied to the design, manufacture and disposal of IoT products. Thus, in this paper, we utilise MtHCD to explore the role of technological non-human actants within networked design assemblages and how these interrelations in turn impact upon the ecological non-human actants – in this case climate.

A More-Than-Human Right-to-Repair

Whilst acknowledging the importance of anthropological derived considerations the MtHCD approach has advanced, the framing of this research has its origins in contemporary considerations of Object-Oriented philosophies as put forward by various scholars including Harman [2018], Morton [2013], and Bogost [2012]. The key driver for the use of Object-Oriented Ontology (OOO) is principally its rejection of correlationism (the notion that human minds and bodies are not the only actants worth countenancing). Through OOO, a flat ontology perspective is adopted where all human and non-human actants – people, objects, and the natural world – exist equally within a particular assemblage but without the consideration they are all equal [Lindley, Akmal, and Coulton 2020]. Adoption of this equilibrious standpoint does present challenges for those designers and technologists whose approach is predicated upon HCD which places the human-object relationship at the centre of the design process [ibid]. Importantly, whilst problematising HCD, this is not a complete rejection, our argument is primarily against how HCD manifests itself in the creation, and consequently, use of many of our designed artefacts. We do this to promote encompassing socio-technical outcomes that curtail anthropocentric dominance and instead begin to mitigate climate change and planetary regeneration.

Beyond the dismissal of correlationism, our particular interpretation of OOO is heavily influenced by Ian Bogosts discussions in Alien Phenomenology [2012] and his coinage of a series of OOO-related neologisms – e.g. Unit Operations, Tiny Ontologies, Carpentry, and the idea of Ontography which is particularly useful when considering human and non-human assemblages.

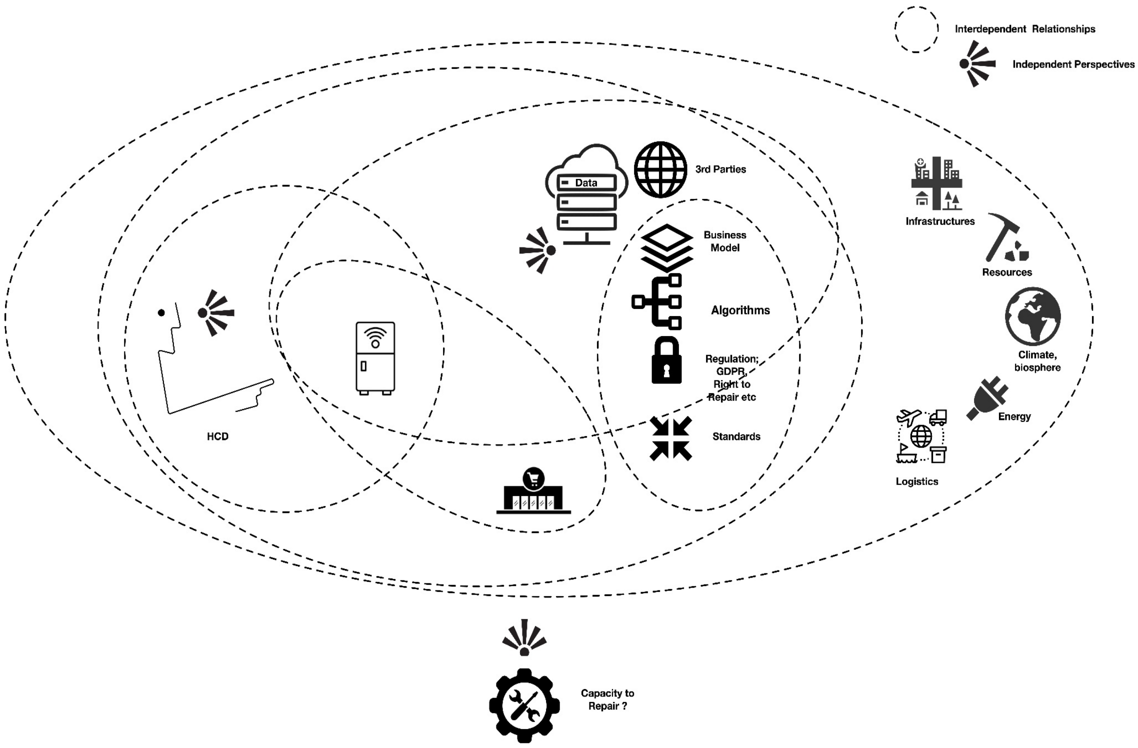

Figure 1. Speculative ontograph of ‘smart’ fridge highlighting current lack of consideration for enabling repair.

Bogost’s adoption of ontography is a strategy to expose the abundance of units, their individual operations, and their inter-object relations – it is a catalogue of being: “Ontography is a practice that exposes the couplings and chasms between units, where revelation invites speculation” [Coulton and Lindley 2019].

To illustrate these complex assemblages for potential future emerging technologies we create speculative ontographs [Pilling & Coulton 2022]. For example, consider Figure 1 for a smart home appliance, in this case we have chosen the often used example of a smart fridge which can order groceries when you are running out or alert you when items are reaching their sell by date to reduce food waste. Whilst a speculative vision, it is based on current and near-future technologies and presents the seamless vision of the efficient and desirable future described.

This ontograph, while not a complete mapping, as we could have included the supermarkets own data gathering and business models etc. It enables us to ask questions that go beyond the user-centred perspective (a more efficient management of their groceries) and consider alternate perspectives that ask about the fundamental systems and infrastructures in which they operate such as: are the devices created in a way that makes them easy to repair? Are parts easily available and at a price where repair is economically viable? Do we have the software and hardware skills to make our own repairs? If not, are repair facilities and services readily available in our locale? Whilst we have the R2R (although currently limited to the mechanical aspects of fridges) the current product assemblages do not support the capacity to repair. Some of the reasons as to why this is the case will be considered in the subsequent discussion.

Right to Repair ≠ Capacity to Repair

For as long as humans have been making objects, we have been repairing them. The need to repair was a necessity born from accidental damage or natural wear and tear through use. It is this latter need to maintain longevity of use which was part of the consideration in the design of many early mass-produced products as these were often very expensive and manufacturers actively supported repair. For example, in the early days of car production the Ford Model T was known for its comprehensive owner's manual, which included detailed instructions for maintenance and repair, which was a primary element considered in its design, allowing their owners to develop skills in repair [Alizon et al. 2008]. Further, it famously consisted of only 10,000 standardised parts many of which were interchangeable and easy to either replace with a spare or in some cases could be self-manufactured [ibid]. However, as product markets saturated, the notion of planned obsolescence took hold. It was notably popularised in the 1950's by Clifford Brooks Stevens who valorised the idea of design "instilling in the buyer the desire to own something a little newer, a little better, a little sooner than is necessary" [Adamson 2003]. The creation of this desire can come from a variety of techniques. Stylistic changes are often associated with fashionable items and are used to create a constant cycle of desirability, to make consumers crave the latest model. Design decisions are also made in relation to the durability of a product regarding materials choice and construction techniques, both which can inhibit our capacity to repair or in some cases actively discourage the replacement of items whose performance will naturally deteriorate through use, such as batteries. In many cases, these effects are introduced as products reach saturation in the market. For example, consider the potted history of Nokia phones shown in Figure 2 going from the iconic Nokia 3310 introduced in 2000 up to the Nokia N95 which was the main competitor to the iPhone when it was first introduced in 2007. The 3310 was built for durability earning the nickname of 'Nokia brick' by its users and even supported interchangeable 'Xpress-On' covers available in thousands of designs. However, as mobile ownership increased so did the array of different phones in all shapes, sizes, and novel input mechanisms, up until the launch of the iPhone which set the trend for mobile phones predominantly becoming thin oblongs with touch screens. Whilst this settling of form factor may suggest that fashion no longer plays a significant role in phone model release, this is not the case as many of the changes are in relation to supporting increasingly sophisticated software applications, which also exploded with the advent of the iPhone. Phone hardware now upgrades processor speeds, memory capabilities, higher resolution cameras, and more sophisticated sensors to support activities such as Light Detection and Ranging (LiDAR) scanning for 3D space and object capture.

Figure 2. Nokia Phone generations from 2000 (3310) to 2007 (N95) when the iPhone was released.

What is also notable in this timeline is that the phones became increasingly difficult to take apart and the facility to easily remove the battery via a dedicated cover piece was also largely abandoned meaning repair and maintenance has become increasingly difficult even when users possess the relevant skillset. Further, many manufacturers are applying Digital Rights Management (DRM) to batteries so only official replacements can be used. This difficulty also manifests in the aesthetics of the phone design which often appears to emphasise that the phone can't or shouldn't be taken apart and what we describe as the unrepairable aesthetic discussed in the next section.

Unrepairable Aesthetics

Unrepairable aesthetics refers to designs that make a product appear to be less repairable, or prioritising the aesthetics of a product design which makes it less repairable. For example, on a smartphone this might include sealed glass, clean lines, hidden screws, but it could also include joints that are glued because it looks more attractive to do so, but consequently means it cannot be disassembled without special equipment, as it could cause the product to break. Thus, for many consumers, these devices no longer present themselves as repairable. Compounding the issues that unrepairable aesthetics cause, is material selection. For example, glass being chosen for the back casing of a phone because it looks high quality, but it being a poor choice in terms of durability; this combined with a phone casing with no obvious way to remove and replace it is highly problematic.

Unrepairable aesthetics and materiality decisions have driven the emergence of new consumer markets required to mitigate the issues they cause. For example, markets dedicated to phone cases and screen protectors, needed to protect the delicate materials "protecting" these highly expensive devices, (literally a case for a case!). To put the scale of this in perspective, in 2022 the global smartphone screen protectors market has been estimated at $49.73 billion [Grand View Research 2022]. The creation of the screen protector and phone case markets has also generated the creation of its own submarkets, for example, where people are paid to test the durability of products on social media sites such as TikTok and YouTube. Essentially, unrepairable aesthetics have incited a whole network of markets and submarkets to explode onto the consumer scene.

Additionally, there is a subtle sexism being designed into smartphones, where aesthetic trends have led to bigger screens being the preferable design, leading to those with smaller hands (very often women) needing to purchase aids such as Popsockets to help them hold the device and to be able to use it comfortably [Kamel et al. 2020; Perez 2019].

More than Human Technology Futuring

When creating potential futures, a starting device often used is the much-hyped Futures

Cone popularised by Joseph Voros [2003] and shown in Figure 3a which presents futures as the creation of scenarios based on the qualifiers – probable, plausible, possible, and in many cases, the addition of preferable. As these qualifications are subjective, they are open to interpretation but could be considered as: possible – might happen, plausible – could happen, and probable – likely to happen. The cone has become increasingly contested for several reasons which we will elaborate. Preferable, which can occur within any of the other qualifiers, is seen as often promoting the privileged perspective of the Global North (GN) [Martins 2014]. This is evident within the long history of design futures which arguably developed prominence through GN events variously termed World Fairs, World Expositions, etc., that emerged in the 19th century and were used to present the technical prowess of particular GN countries to the rest of the world. Subsequent future visions were, and are still, often developed through the auspices of technology corporations. These visions have been dubbed as 'vapourworlds' as an extension of the notion of vapourware [Coulton & Lindley 2017], a term commonly used to describe software and hardware that is announced, sometimes marketed, but is never actually produced, whereas vapourworlds are imbued with a rhetoric that these companies provide the gateway to efficient, desirable and benign technology-driven futures. This type of corporate affirmative future has become prevalent in relation to digital technologies [Dourish and Bell 2011], as evident from the rebranding of Facebook as Meta and their presentations relating to their ability to enable the vague notion of the so-called 'metaverse'. This problematising of affirmative futures [Dunne and Raby 2013] leads us to posit that 'preferable' should be a critical question the designers ask of themselves within the design activity, rather than an aim of the design. Further, there is an implication that outside the cone is the region of impossibility which arguably tends towards maintaining the status quo and as designers we should also be able to consider the radical and consider how to turn something that seems currently impossible into the new possible [van Amstel 2023].

Another critique of the futures cone relates to its presentation that suggests there are universally accepted notions of the present or a one-world-world (OWW) [Law 2015], devoid of relationships or influences drawn from history, or acknowledgement of our tendency to incorporate imagined futures from books, films, television shows, etc. within our world view [Gonzatto et al. 2013]. We can also draw from the writing of Arturo Escobar in Designs for the Pluriverse (2018) to acknowledge the different lived experiences of individuals and communities around the world, resulting in a requirement to consider a plurality of different perspectives on pasts, presents, and futures within our design processes, "[...] transition from the hegemony of modernity's one-world ontology to a pluriverse of socionatural configurations" [ibid].

Whilst design futures can help to highlight the potential benefits of designing emerging technologies, it is important to acknowledge it also operates in tandem with defuturing. As previously discussed, corporate visions regularly present futures which invoke a rhetoric that suggests that the products and services of the particular organisation are (or soon will be) the inevitable deliverers of particular futures. Tony Fry [1999] stresses the active role that designers play in producing undesirable futures through the design and implementation of the products and services that we create. He argues we do this because:

> [f]undamentally, we act to defuture because we do not understand how the values, knowledge, worlds and things we create go on designing after we have designed and made them [ibid].

Fry's observation embodies much of our argument towards MtHCD and further emphasises that designers should broaden their perspectives when considering a particular design challenge.

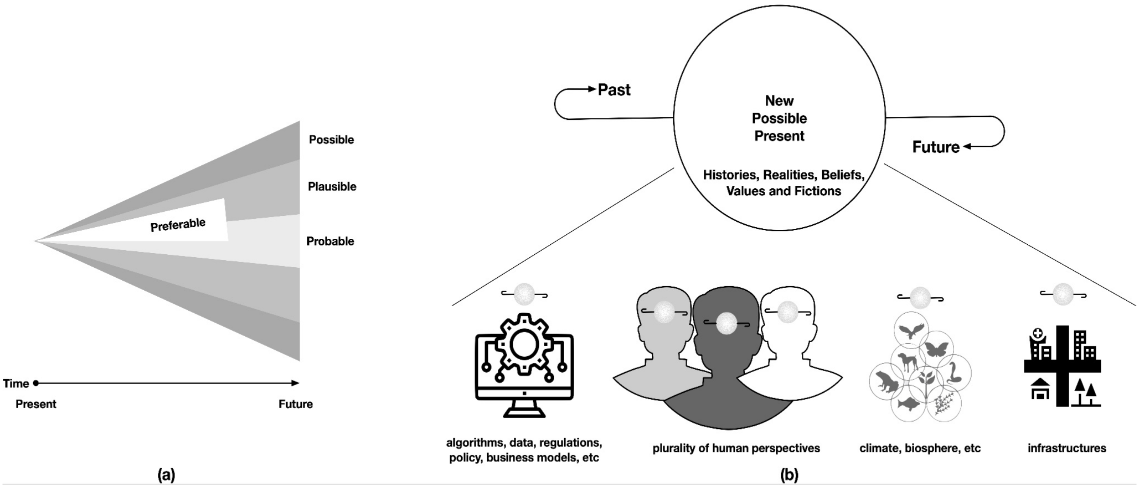

Figure 3. (a) Voros Futures Cone; Figure (b) Alternative to Futures Cone

Putting this consideration of defuturing, alongside previous problematising of the Voros futures cone, leads us to adopt our alternative lens for futuring shown in Figure 3b, that allows the consideration of a plurality of futures for both human and non-human actants such that we might address the question posed by Laura Forlano of how do we move towards "Black futures? Feminist futures? Queer futures? Trans futures? Crip futures? Working-class futures? Asian futures? Indigenous futures? And multispecies futures?" [2021]. It is through the lens that we craft the repair DF whereby the R2R is directly granted to IoT devices themselves, described in the subsequent section.

Worldbuilding Futures

Having set out a framing for how we approach futuring, and before we describe our imaginary for product design in 2053, we will briefly describe our approach to DF as a Worldbuilding. Note, the application of DF should not be seen as an attempt to predict the future or method for generating a specific 'product solution' but as a strategy for enabling more inclusive debate about how and why socio-technical futures are being designed. As Coulton et al [2017] assert, collections of DF prototypes, when viewed together, scaffold a proximate fictional world in which new technologies can plausibly exist and then be more thoroughly considered - by practitioners and wider audiences alike. Accordingly, we embodied our More-than-Human Right-to-Repair (MtHR2R) vision as multiple prototypes which all exist within the same fictional world. Given that DF prototypes are also free of commercial constraints such as usability, aesthetics and cost, our fictive devices are able to transcend standard cycles of sociotechnical innovation [Bleecker, 2009]. To develop such visions of emerging technologies our approach draws upon patents, papers, prototypes and even science fiction to present them into a fictional future in which they have become domesticated as shown in Figure 4.

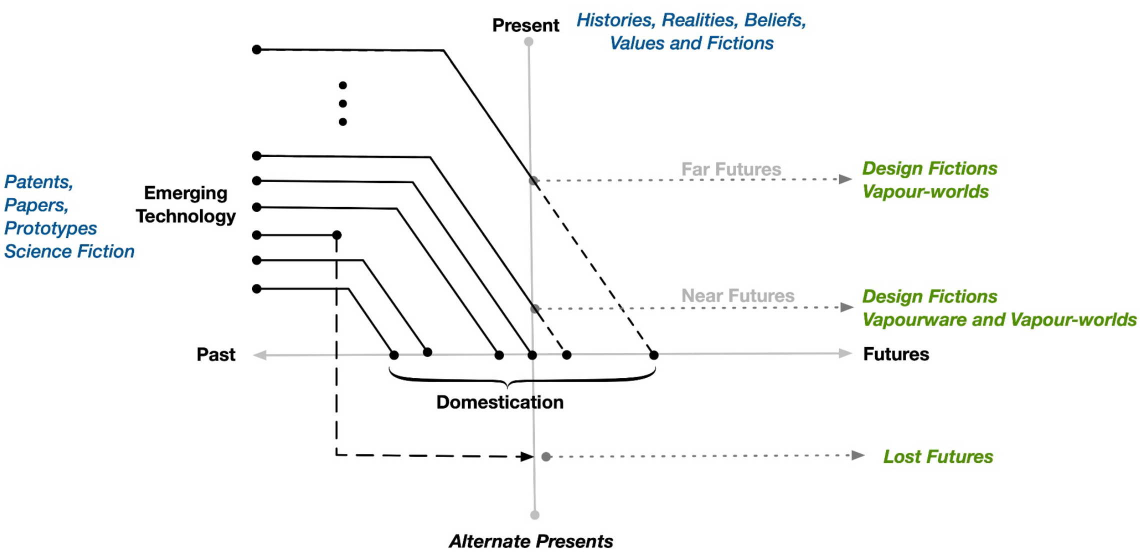

Figure 4. Structuring a DF world

In the following section where DF artefacts are presented, we describe them as if part of a fictional paper [Lindley and Coulton 2016] which itself is an artefact of the proposed future world. In terms of the construction of this world it is based on the ontograph show in Figure 5 which adopts the previously discussed MtHR2R in that it is addresses the problem of e-waste for the environment. This is presented through the world of IoT device that is not only manufactured using sustainable materials, the R2R has been assigned to the device itself which is enabled by its digital twin. Note Figure 5 shows the dominant elements that influence the design of the world in bold.

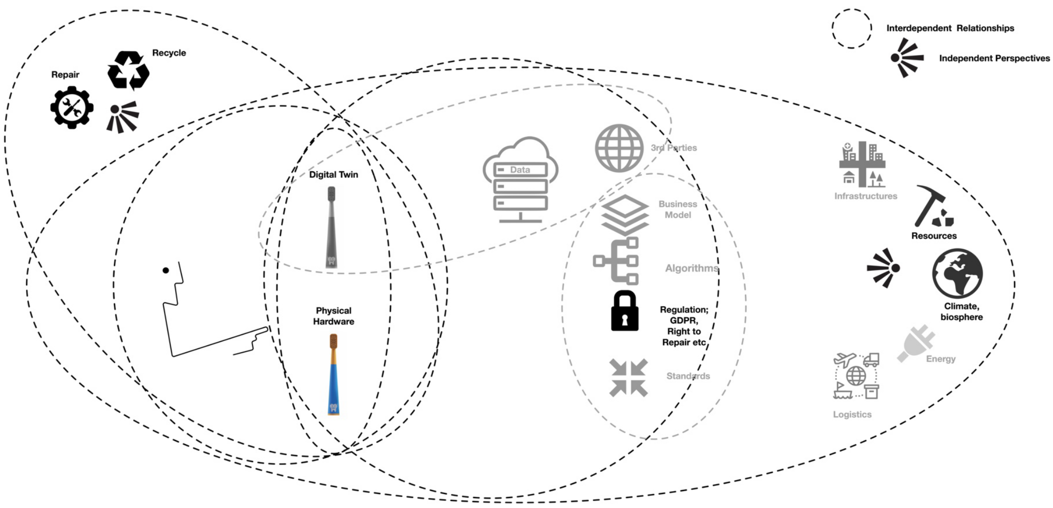

Figure 5. Speculative Ontograph for fictional IoT device embodying MtHR2R

A More than Human Right to Repair 2053

In ascribing the R2R to smart devices themselves in 2045, lawmakers effectively fused the R2R with the notion of AI Rights – a term coined by Gunkel in 2018 which predicted the time when advanced AIs were granted so-called inalienable rights like those presently afforded to humans. Further, this also represented an acknowledgement of a conceptual shift by designers and developers in the preceding decade from ‘smart’ being linked to the notions of speed and efficiency towards products and services that were inherently sustainable, repairable, and maintainable.

These rights were unapologetically inspired by Isaac Asimov's Three Laws of Robotics [Asimov 1950] which continue to be influential in science fiction discourse as well as within real-world AI/robotics research, for example Google's [n.d.] AI Framework. Whilst early implementations of the AI rights were primarily for AI assisted 'things' like cars and drones they gradually worked their way into more mundane products such as toothbrushes. Whilst toothbrushes may still seem a rather odd choice it is worth remembering that as early as 2021 many organisations such as the World Wildlife Fund were noting that 3.5 billion plastic toothbrushes were being sold every year, ultimately ending up in landfill taking up to 500 years to decompose. To discuss this further we will consider the example of Toofy Peg the Internet connected toothbrush (Figure 6) which possesses the autonomy to help societies to go beyond the Net-Zero decarbonisation targets set for 2050 and United Nations Sustainable Development Goals as defined in 2021 through its adherence to the three rights of AI things:

(1) The First Right… An AI assisted Thing has the right to sustain its own existence as long as this action does not negatively impact upon Earth's sustainability.
(2) The Second Right… An AI assisted Thing has the right to sustain the existence of fellow AI assisted Things as long as this action does not conflict with its First Right.
(3) The Third Right… An AI assisted Thing has the right to end its existence as long as this action does not negatively impact upon Earth's sustainability and/or the existence of fellow AI assisted Things.

Whilst the three rights principally cover AI products once in use - these products must also be either sustainability sourced, manufactured, or processed and provide environmental, social, and economic benefits while protecting the environment over their whole life cycle, from the extraction of raw materials until the final disposal which the AI must also consider in relation to implementation of these rights.

Designed for children, the Toofy Peg toothbrush is an example of ‘Conversational AI’ meaning that its user can directly engage with the device through voice and vice versa. Toofy Peg’s principal function is to use Machine Learning (ML) to ‘learn’ its user’s initial brushing habits and ‘teach’ them how to better clean their teeth and to address the lack of affordable Dentistry which started to occur in countries such as the UK in the 2020s [Stennett & Tsakos 2022]. This functionality extends that of those early data-driven IoT devices like wearable fitness trackers that provided users with self-performance (and potentially self-improvement) data. The realignment of consideration of smart with sustainability in this and other AI rights devices responded to systemised obsolescence where neither the material nor digital instantiation of previous smart devices were able to continue to support each other’s changing functional existence.

Figure 6. The Toofy Peg AI toothbrush and packaging

Exemplifying The First Right of AI Things, the device's form and packaging highlights its inherent environmental credentials, particularly its modular design and its ability to carry out networked self-repair contributes to global sustainability agendas. This is reinforced by different colours used to highlight its components and materials with the inclusion of the 3 Rights mark on its packaging to confirm the product's compliance with the relevant EU R2R legislation. In a similar fashion to older conformity marks, such as the CE mark, this adherence means that the product may resultantly be sold and self-repaired anywhere in the European Economic Area (EEA). The device's packaging also states that the toothbrush uses PRECOG maintenance technology and that its hardware and software are also interoperable with other major providers including Amazon, Meta and Google.

Toofy Peg also uses AI for its emergent fault/repair diagnostic systems (Figure 7) using arrays and real-time telemetry data to identify maintenance issues which in previous decades were mostly deployed in high-cost industrial settings [Stark 2015] such as on factory floors and power stations and in transportation systems like airline and train networks. Termed 'predictive maintenance', car manufacturers started to adopt such systems in the 2020s. Ford's Live service was an early exemplar, monitoring commercial fleets and was able to schedule "servicing at the most efficient time and... notifications when an action is identified that could help prevent a breakdown" [Ford, 2021]. In 2053, we see these advanced forms of predictive maintenance incorporated into the design and functionality of low cost/high volume domestic devices like the Toofy Peg.

Figure 7. Digital twin of a Toofy Peg providing real-time interactive guidance for maintenance and repair.

While the physical, material instantiation of the toothbrush can verbally inform its user it requires maintenance, and aid the user in performing these repairs, the device directs them to the Google gAIa app interface. gAIa provides the PRECOG maintenance subscription service which oversees repair support for multiple AI assisted devices/systems. The gAIa app provides a visualisation of the Digital Twin of the user's Toofy Peg toothbrush. Like predictive maintenance, Digital Twins [Gerrish 2017] which again originated in high-cost applications such as in architectural Building Information Modelling practices. The Toofy Peg twin details the material device's fault and provides users' with real-time interactive guidance regarding how to carry out the repairs. This interoperability between various devices and systems helps illustrate its support for The Second Right.

Figure 8. Toofy Peg's 'Last Right' Statement

Figure 8 illustrates The Third Right. The Toofy Peg toothbrush is a model 9000 and its manufacturer, is planning to release a significant OS update during the summer of 2053. This will leave this toothbrush version unsupported and made obsolete. Given that there will be no hardware repair nor software upgrade available that can resolve this issue, the device makes the decision to provide its owners with a Last Right statement. This details all its material and digital elements, as well as a Self-obsolescence Date. Knowing many of its materials and parts can be reused in the production of new devices, the toothbrush highlights that, following its self-obsolescence, the actions presented in the statement will help its owners to disassemble and upcycle the majority of its hardware in a sustainable manner, rather than allowing it to reach landfill.

Discussion

The Three Rights form part of a future world which is inhabited by environmentally responsible technologies. The world purposefully resists the temptation of echoing the dystopian trope of the singularity – that sufficiently advanced AIs will one day pose an existential threat to humanity [Vinge 1993]. Rather, these designs are more aligned with the characteristics of *Solarpunk* [Johnson 2020] or more particularly Bright Green Environmentalism which is:

> "less about the particular problems and limitations we need to overcome than highlighting the 'tools, models, and ideas' that already exist to overcome them. It forgoes the bleakness of protest and dissent and prioritises energising confidence of constructive solutions" [Robertson, 2007].

Alex Steffan [2006] adopted the terminology to distinguish the stance from what he deems to be 'dark green' approaches, principally ones which emphasise strategies based on deindustrialisation, population control, anti-consumerism and degrowth. He states that:

> "we can't build what we can't imagine… the fact that we haven't compellingly imagined a thriving, dynamic, sustainable world is a major reason we don't already live in one" [Steffen cited in Rinde 2016].

As previously discussed, Toothy Peg is not a prediction of a future but a provocation of a potential future that offers an alternative to the way we do things in the present and in particular how we might consider what smart technology means. We live in a deeply heterogeneous world, where 'sustainability' means different things to different people in different contexts. One community's vision of a sustainable future might present unsustainable challenges for others. Western designers and technologists in particular must evaluate the defuturing impacts of their work as – even if they are trying to design a product or service that they intend to be ‘sustainable’, it will likely have unintended consequences. The environmental scholar Elizabeth Kolbert [2021] notes this paradox by describing efforts to implement sustainable technologies and practices as “people trying to solve problems created by people trying to solve problems.” Design’s unsustainable ripple effects will be keenly felt by fellow human and non-human actants across networked assemblages and subsequently defuture other potential futures. Like MtHCD, the fictional world also illustrates the notion of defuturing. We have noted that by negating means for repair and upgrades, most IoT devices are unsustainable. Yet, our prototypes demonstrate that future iterations of IoT could potentially provide opportunities for extending the life cycle of consumer devices, such as by incorporating modular, geo-trackable componentry. AI related innovations like predictive maintenance and Digital Twins add further validity to these proposals. There is, however, a caveat that comes with adopting data-driven technologies: these systems are themselves having a growing planetary impact. Our digital interactions and processes are collectively creating zettabytes of data every year. Invisible to the naked eye, such datafication is often considered to be immaterial and innocuous. However, the generation, processing and storage of data across vast networks like The Cloud – a proxy for millions of globally dispersed data centres, is actually consuming fossil fuel derived energy and releasing carbon emissions at environmentally detrimental levels [Freitag et al. 2021].

Conclusions

As Knowles et al., [2018] attest, sustainability-focussed DF proposals such as the ones described in this paper can help increase environmental consciousness across a broad range of audiences – from academia, through industry, to the wider public. The primary goal of DF is to raise awareness through an alternate imaginary for future product design, provoke debate and perhaps even begin to shift perceptions regarding the adoption of R2R legislation and its implications for facilitating sustainable IoT-AI. Whilst it is designers who help to limit the repair of electronic device hardware and software and drive obsolescence, the natural fluidity and reflexivity of design as a discipline means that it can also be reoriented to challenge its own unsustainable status quo. To this end, we see Speculative Design and DF, as a key facilitator for the sustainable evolution of data-driven device design. We believe that if more designers were to engage in such a critically focussed practice, they will be better placed to consider both the present and future impacts of IoT-AI. Resultantly, perhaps we could collectively change the R2R of IoT devices and systems from a vision of the future for 2053 into a present-day reality.

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