Rematerialising Digital Technologies Through Critical Making

Pedro Ferreira
ferreirapedro@protonmail.com
Universidade de Lisboa,
Faculdade de Belas-Artes,
Centro de Investigação
e de Estudos em Belas-Artes
(CIEBA), Largo da Academia
Nacional de Belas-Artes,
1249-058 Lisboa, Portugal

This article examines artistic practices that engage with digital technologies through a critical making methodology. Critical making is described as a hands-on practice that aims to merge critical thinking with making. This is a practice that focuses on the process of making and combines material experimentation with critical thinking about the effects of digital technologies. Critically-made artifacts in the artistic context have the potential to disrupt pre-established notions of art engaged with digital technologies as well as to challenge screen essentialism in artistic production and everyday life. In this paper, it is proposed that critically-made artifacts are a form of post-digital art based on hybridisation of digital and non-digital technologies. This turn in artistic practices engaged with digital technologies is seen as a way to rematerialise digital technologies unfolded in physical space as well as a critical reaction to the post-digital condition, where all aspects of daily life are circumscribed around digital technologies in computational societies.

1. The nature of critical making

Recent artistic practices engage with digital technologies critically and combine them with physical materials through hands-on making. These modes of artistic production can be described as critical making, as "a general descriptor for kinds of conceptual-material" (Ratto and Hertz 2019, 19) practices engaged with critique, digital technologies and non-digital materials. The key research questions of this paper are: (1) What is the nature of critical making as an artistic practice? (2) How is critical making distinguished from other forms of hands-on making? (3) How does critical making as an artistic practice relate to a form of post-digital art?

This paper aims to answer these questions by starting with an overview of the term critical making coined by scholar Matt Ratto (2011) who considers it an educational and pedagogical hands-on workshop. Further on, it analyses the perspective of scholar and artist Garnet Hertz (2016) in which critical making is taken beyond the scholarly domain, oriented toward makers and technology-oriented artists as a way to introduce critique to hands-on material practices of physical engagement with digital technologies. Following from this, critical making is distinguished from the maker movement and attempts to introduce a critical stance towards it. Critical making is further analysed in the context of the arts as hands-on material-conceptual experimentation with technologies that often result in hybrid installations that assemble non-digital and digital technologies. This potential of critically-made artifacts in the arts is examined in the art installation *Entanglements* (2021) by the collective ANNEX.

To conclude, the paper argues that critically-made artifacts in the context of the arts introduce a bifurcation from previous art engaged with digital technologies that focus solely on the technical possibilities of new media. As an alternative to new media art practices, critical making approaches digital technologies through a hands-on material engagement that attempts to convey both awareness of their technical operations and sociocultural consequences through a rematerialisation of digital technologies in physical space.

1.1 A brief introduction to critical making

The term critical making was introduced by the scholar Matt Ratto in 2008 to describe the "combination of critical thinking with hands-on making" (Hertz 2016). It intended to merge both "critical social reflection and making" as a pedagogical hands-on practice and "material engagements with technologies" (Hertz 2016). Initially, it was intended as a practice for scholars and students who work primarily in the realm of critical theory and abstraction, ideas, criticism, text, linguistics and individualism (Ratto and Hockema 2009). Making belongs to the physical and material domain, as embodied and hands-on practices often

community-oriented through the sharing of tools, spaces, knowledge and collaboration. Ratto and Garnet Hertz associate critical thinking with the Frankfurt School of Critical Theory and describe being critical as reflexive and hermeneutic or linked to the "goal 'to liberate human beings from the circumstances that enslave them'" (Horkheimer 1982, 244: Quoted in Ratto and Hertz 2019, 21). Following this latter definition of criticality, critical making aims "to reconnect our lived experiences with technologies to social and conceptual critique" (Ratto 2011, 253). As an attempt to combine both areas, critical making aims to merge the domains of critical theory and making as an effort to bridge the disconnect "between conceptual understandings of technological objects and our material experiences with them" (ibid.).

Consequently, the conception of critical making, as an academic and pedagogical workshop that merges criticality and making, is composed of three stages that do not have a fixed order.[1] One stage is dedicated to the literature review and the compilation of relevant concepts. Another stage engages in material prototypes through digital fabrication. In this stage, the development of prototyping "is used to extend knowledge and skills in relevant technical areas as well as to provide the means for conceptual exploration" (ibid.). And, finally, a recursive stage that requires a process of reconfiguration and reflection over the created artifacts to discover "alternative possibilities, and using them to express, critique, and extend relevant concepts, theories, and models" (ibid.). However, the focus of critical making is not merely on the resulting artifact, but rather on the sharing of "results and an ongoing critical analysis of materials, designs, constraints, and outcomes" (ibid.). In the words of Ratto, the goal of critical making is to make tangible the abstract realm of concepts and bring them closer to the body and not only to the brain, as a way "to make new connections between the lived space of the body and the conceptual space of scholarly knowledge" (Ratto 2011, 254).

1.2 Critical making as a process-oriented practice

Following Ratto's conception of critical making, it is also distinguished from critical design. Hertz explains that critical making is a "constructive process of making" instead of merely "building an artifact" (Hertz 2016). Hertz points out that regular methods for design "often produce systems that lack cultural richness, emotion, and human-oriented values," and similarly, engineering "often overemphasizes principles like efficiency and productivity that contributes to a consumer-oriented culture that overworks, overproduces, and overconsumes" (ibid.). While critical design is oriented to "building refined objects to generate critique of traditional industrial design" (ibid.), critical making is a "process-oriented and scholarship-oriented" workshop in which the final prototypes are considered traces of the making process (ibid.).

1. See more about the pedagogy of critical making in Ratto (2011) and Ratto and Hertz (2019).

In short, critical making highlights a hands-on process-oriented practice that emphasises critical thinking about technical devices and digital technologies. This is achieved through the process of making as collaborative, constructive and reflective action. To make a precise and defined object is not the ultimate goal. Instead of being oriented towards a fixed object-based practice, critical making is a process-oriented practice with an "emphasis on critique and expression rather than technical sophistication and function" (Ratto 2011, 253).

2. Re-politicising makers and technology-oriented artists

Extending Ratto's conception of critical making as part of the academic fields of social sciences and humanities, Hertz understands it as reaching beyond the scholarly domain. For him, the potential of critical making stems from the "perspective of hands-on technology development and studio practice—in *makers* becoming more critically engaged with their medium" (Hertz 2016). Critical making is directly aimed at the "builders of technology—whether hackers, engineers, industrial designers, or technology-oriented artists" (ibid.). From this point of view, the practice of critical making challenges makers to adopt a critical stance through tinkering and DIY practices engaged with physical computing, materials, digital technologies and other technical objects.

2.1 The maker movement

Following Hertz's perspective, critical making is a practice aimed at those who are immersed in building new technologies to take a "step back and reevaluate the assumptions and values being embedded into their technological designs" (Hertz 2016). This perspective on critical making has the potential to introduce to the maker movement a constructive critical engagement with technologies through the process of making, eventually prompting alternative technological imaginaries. Therefore, critical making challenges the maker movement, often perceived as a non-critical and leisure time practice popularised by Make magazine[2] through "subtracting critical engagement from the [making] process" (Ratto and Hertz 2019, 23). Dale Dougherty, the founder of Make magazine, "describes makers as enthusiasts who want to explore the possibilities of both new and old technology (Dougherty, 2012b: Quoted in Dufva 2018, 88). This view of the maker is seen from the European and North American context, which forked from hacker culture. This converted making into a popular de-politicised practice merged with traditional crafts and DIY practices accessible to any person with enough free time. In contrast to making as a leisure activity, seen from the European and North American contexts, in different contexts "making is driven by environmental and economic conditions of necessity, rather than leisure or profit-driven innovation" (Foote and Verhoeven 2019, 77),[3] similar to repair and other DIY cultures.

2. Make magazine popularised the term maker to "rebrand and sanitize the term 'hacker' to be more acceptable to the public, schools, and potential sponsors" (Ratto and Hertz 2019, 22).

137

3. For example, "Gambiarra" is a Brazilian expression related to improvised methods of making and solutions to solve a problem with any available material. Similarly, "Jugaad" derived from India "is described as a type of frugal innovation or a 'hack'" as a response "to problems with a creative solution, fix, or workaround" (Foote and Verhoeven 2019, 77).

4. Free/Libre Open-source Software (FLOSS) stands for "a set of practices for the distributed, collaborative creation of code that is made openly available through a reinterpretation of copyright law; it is also an ideologically charged mode of production and authorship that seeks to reorient power in light of participants' understanding of the moral and technical possibilities presented by the internet." (Dunbar-Hester 2020, 6).

5. Dufva defines creative coding not "only as an artistic medium or as a method to learn computer programming, but as a process through which one can comprehend and critique the surrounding digitalised world more clearly" (Dufva 2018, 12). It enables "experiential connection with the digital processes, providing [...] hands-on experiences and theoretical frameworks" (Dufva 2021, 272). Similarly, the scholar David M. Berry rejects the notion of "software immateriality" and argues for code "as a medium materialised into particular code-based devices" (Berry 2011, 10).

Making as promoted by Make magazine is criticised by the scholar Tomi Dufva as a "continuation of the neoliberal agenda" (Dufva 2018, 89). Without a critical perspective, making is merely another hobby and a "new commercial trend" (ibid., 90) for-profit driven where making takes a commercial path into building consumer commodities of handmade items within the creative industries and start-up culture. Therefore, critical making attempts to challenge this and introduce a "sense of criticality back into post-2010 maker culture: to un-sanitize, un-smooth and re-politicize it" (Hertz 2016).

Critical making and the maker movement explore and propel new forms of engagement with hardware and material expression together with FLOSS[4] and creative coding practices.[5] The choice of a tool or a medium for the creative process can be considered political expression. But, as Hertz rightly asks "after learning to use a 3D printer, making an LED blink or using an Arduino, then what?" (Hertz 2012). The next important step for critical digital making is to ask "questions about the design, purpose, and cultural value of created things [...] [in] the process of making" (Ratto and Hertz 2019, 23).

Dufva argues for another perspective of the maker as "a societal and political movement, closely tied to hacker culture and open software & hardware movement" (Dufva 2018, 90). It has proliferated through makerspaces, hackerspaces and FabLabs, as community-oriented places where tools and knowledge are shared (ibid., 89). Adding to this, as scholar Christina Dunbar-Hester writes, these spaces are not places for job market preparation but rather for community participation to "experience making as both politicized and distinct from capitalist production" (Dunbar-Hester 2020, 143).[6]

However, digital making is only made possible due to raw material extraction, labour and manufacturing of "cheap hardware from China [that] is costing someone else their health and soil" (Bogers and Chiappini 2019, 8). In other words, digital making and its affordable digital tools are only made possible in a globalised economy with established power relations, one that relies on the exploitation of workers and the environment. Critical making takes into consideration the previous aspects to introduce a more diversified critique of hacking and making which attempts to include not only class and labour critique but, too, the "transnational political economy of the material conditions that support Global north" (Dunbar-Hester 2020, 5). By challenging these material aspects, critical making differentiates from the pre-established maker movement as it aims to challenge the sociocultural consequences of digital technologies. In short, critical making attempts to re-introduce critique to makers as a form to engage with "sociocultural histories and futures, as well as the environmental and economical implications of digital machines" (Bogers and Chiappini 2019, 8).

2.2 Making as embodiment through hands-on approach

6. Dunbar-Hester writes that maker and hacker spaces are seen as sites of "[v]oluntaristic technology communities [and] are important sites because they are utopian spaces where people play and tinker not only with technical artifacts but with social reality, imagining social relations through participation in a third space outside work and home, though they are in dialogue and tension with labor market and domestic economies." (Dunbar-Hester 2020, 240)

Making includes a direct engagement with a different range of technologies, from affordable "new digital tools, such as 3D-printers or laser cutters or even biotechnology" and, too, an engagement with traditional handcraft practices (Dufva 2018, 89). Making is then understood not as a break with older forms of hands-on material practices for the sake of the new, as promoted by new media art or digital art practices, but an engagement with both "new" and "old" media through physical engagement and material experimentation that might include materials such as paper, textile, clay, wood, metal, glass, stone and even mass-produced objects or the repurposing of older media technologies.

Making and hacking, as hands-on approaches, "consists of the opening of both physical (machines) and abstract (software) products, by which a maker gets to know how the products or tools operate by way of doing by hand." (ibid., 94-95). In this sense, Dufva quotes the scholar Seija Kojonkoski-Rännäli who "relates making by hand to Heidegger's concept of making (bauen)" in which "making is not only an act of creating an artifact but that it also includes aspects of caretaking and belonging to the world the maker creates" (Kojonkoski-Rännäli, 1995: Quoted in Dufva 2018, 91). Therefore, making by hand is a form of "grasping of the world [...] a core function of being" (ibid.).[7] Similarly, the philosopher Bernard Stiegler describes the relation between "to make" and "to act" meaning "to *take* one's dreams with *enough force* for them to *become real*" (Stiegler 2016, 93). Stiegler relates crafting not only to "what makes or fabricates" but "to exteriorize something" which requires action and initiates "one or more new circuits of transindividuation"[8] (ibid.). Thus, making by hand is a way of caring, belonging and "personality transformation: by working materials, the maker remakes herself" (Nijenhuis 2019, 138). Making can thus be considered a "form of knowledge creation [that] predates intellectual comprehension" (Dufva 2018, 91). Critical making attempts then to add a sort of reflection and critique through the iterate process of hands-on making.

7. The scholar Seija Kojonkoski-Rännäli "uses the Greek term techne (tekhniké) [...] understood as a making by hand [...] it can also be interpreted as understanding and knowing [...] techne fuses knowing and doing into one: problem-solving and molding of the material, thinking and motor skills are closely combined" (Dufva 2018, 91).

In sum, making is understood as a form of embodiment through a direct intervention that approaches digital technologies from a material perspective. This can be seen as a way to grasp the disorienting environments of the post-digital condition, as "the messy state of media, arts and design *after* their digitisation" (Cramer 2014, 17). In other words, critical making entails a re-materialisation of digital technologies as an embodied experience accessible through a hands-on approach in physical space. Thus, critical making is a form of being in the world that engages through an iterative process with the materiality of digital technologies and critique that allows a deconstruction of the hidden values and mechanisms embedded in our everyday technical devices to expose their pervasivenes.

8. The concept of "transindividuation" is for Stieglers "the process of co-individuation within a preindividuated milieu and in which both the "I" and the "We" are transformed through one another. Transindividuation, then, is the basis for all social transformation and is therefore a way of addressing what happens within education" (Stiegler and Rogoff 2010).

3. Critical making and post-digital art

The curator Nora O. Murchú describes the critical maker as one who "engages with the material layer of digital technologies through prototyping to interpret and to intervene in the values embedded within them" (Murchú 2020, 168). Following this view of the critical maker, Dufva writes that by offering "a critical understanding of our everyday digital products, making can empower the user in the digital world" (Dufva 2018, 89). The artist engaged in critical making differs from merely technical-oriented artists. The critical maker probes technical objects with a critical and political attitude instead of merely relying on learning how to handle digital tools or computer programming to create artifacts. The critical maker is here understood not as a regular user who uses tools as intended, but rather, as a user who not only learns "how the tool works, but also to hack and reprogram the instrument" (ibid., 95). In this sense, through critical processes of hacking and making, makers manage to glimpse "inside the black box and make it their own" (ibid.).[9] These critical practices attempt to change power relations and enable artists to take control of their tools of production. On the one hand, this allows the artist to reconfigure and reinvent digital and non-digital tools and devices to fit their artistic purposes, instead of handling a product from its original design instrumentality. On the other hand, the artist becomes an empowered user "with an enhanced ability to parse the complexity of our sociotechnical world" (Ratto and Hertz 2019, 25). However, this empowerment is far from creating a direct and large sociocultural impact and is better viewed as micro-politics that consist in taking small steps towards questioning and disrupting the power relations imposed by Big Tech.

To this end, the critical maker questions the sociotechnical world from an ethical, critical and collective perspective that attempts to step away from capitalist exploitation of proprietary software and consumer-oriented digital tool or interfaces. A perspective that moves in-between digital and non-digital technologies and materials as well as online and offline modes of production. As such, the critical maker creates a kind of post-digital art that deviates from pre-established configurations of artistic production mediated through digital technologies.

3.1 Critically-made art

The maker acknowledges non-human agency in matter and in doing so the production of art engaged with digital technologies is taken from an embodied and collaborative perspective of human and non-human agents. In this way, critically-made art can be understood as based on new materialism philosophy,[10] openness,[11] diversity,[12] and hybridisation[13] of technologies. Critically-made objects introduce critique and re-evaluation of the impacts of digital technologies and might result in artifacts such as prototypes, case studies, hybrid installations

9. The abstraction layers of software and its inner logic and structures brought a "world [that] is difficult to grasp or understand when the user cannot see how the program is constructed […] [proprietary] software [becomes] a black box without any access" (Dufva 2018, 94).

10. New materialism is in general seen here as a reaction to the decrease involvement "of matter in the dominant Euro-Western tradition as a passive substance intrinsically devoid of meaning. […] new materialists routinely emphasize how matter is "alive," "lively," "vibrant," "dynamic," "agentive," and thus active" (Gamble et al. 2019, 111).

11. For a detailed analysis on openness and the maker movement see Saari et al. (2021).

12. See more on diversity and inclusion issues of open technology cultures in Dunbar-Hester (2020).

13. On neo-analogue hybrids and the repurposing of older media technologies see Ferreira and Ribas (2021).

14. Critically-made objects can be "documented online, exhibited in public art galleries, or published as case studies in academic papers—and can work to expose the hidden assumptions within the designed objects around us and be embedded in technological systems to a wide audience" (Hertz 2016).

and other non-installation formats.[14] The critically-made artifact unveils traces of hands-on material experimentation engaged with technologies and critique by debunking their infrastructures as well as challenges how digital technologies are perceived in everyday life. Critically-made art introduces new perceptions that unfold digital and non-digital materials through space as a form to grasp the sociocultural impacts brought by digitisation.

In the context of the arts, critical making bifurcates from established forms of new media art that focus solely on the virtual, simulation and abstract layers of code as a medium, or the zeros and ones. Critically-made art distances itself from the modernist paradigm of aesthetics pursued by new media arts, one that focuses solely on the technical possibilities and specificities of a medium. Instead of propagating the tradition of medium-based arts, critically-made art creates perceptions and affections that result in a sort of impure aesthetics, one that mixes and combines critique, hands-on material experimentation of non-digital and digital technologies. Consequently, this combination of technologies and different materials can be understood as hybridisation.

3.2 Post-digital hybridisation

Critically-made artifacts as hybridisation shift art from "an object with a fixed arrangement of meanings, material and aesthetic composition to one that is open and subject to continuous flux" (Murchú 2020, 166). As such, it has the potential to "alter everyday situations, objects and rules to build provocations that encourage a re-evaluation of technology in culture" (ibid.). This is here understood as a post-digital hybridisation, a form of post-digital art that critically combines non-digital and digital technologies, as entanglements of material assemblages that are reconfigurable and open-ended installations. This emerges in the artistic context engaged with digital technologies as a rejection of new media art and as a reaction to the post-digital condition where everyday life is pervaded by digital technologies that have become banal technical gadgets. Critically-made artifacts are then a form of post-digital art engaged in hybridisation across different materials as a tactic that unfolds and rematerialises digital media technologies through physical space. As a result, these artifacts challenge the dominance of screen-based art practices to approach digital technologies beyond screen essentialism.[15] By doing so, they expose both "the inner-workings and external influences to these systems, and their increasing authority in society" (Murchú 2020, 171). As Hertz puts it, critically-made artifacts instantly "hit like an emotional sledgehammer if thoughtfully implemented" (Hertz 2016). These artifacts trigger reflection of digital technologies' effects and render "a provocative, speculative, and rich vision of our technological future that avoids the clichés of consumerist-oriented industrial design." (ibid.). The perceptions generated by critically-made artifacts engage with post-digital hybridisation through material

15. Screen essentialism means to stay at the surface level of the screen and its image output where information is "disembedded from its material carrier" (Berry 2011, 36).

16. The philosopher Jane Bennet claims that there is a vitality in materiality, things have a force of their own, she calls it "thing-power." She writes that "Thing-power may thus be a good starting point for thinking beyond the life-matter binary, the dominant organizational principle of adult experience. The term's disadvantage, however, is that it also tends to overstate the thinginess or fixed stability of materiality, whereas my goal is to theorize a materiality that is as much force as entity, as much energy as matter, as much intensity as extension." (Bennet 2010, 20).

17. The collective ANNEX works within the fields of architecture, art, media theory, computer science and gaming, it is composed of Sven Anderson, Alan Butler, David Capener, Donal Lally, Clare Lyster and Fiona McDermott.

18. Further analysis of the artwork with a methodology other than the aesthetic experience would enable further understanding of the critical theory explored, collaborative aspects of the artists and hands-on processes of making as well as their social participation and engagement with the wider community.

19. Cloud computing is the dominant business model and infrastructure of information technologies on the internet.

assemblages that have a vibrant potential[16] to be affective where non-human forces transform human perceptions, affections and emotions through an art form that not only critiques or comments on digital technologies but presents a re-imagination of other possible material conditions and technological futures.

4. Entanglements

As an example of a critically-made artifact in the arts, it is now examined the art installation *Entanglements* (2021) created by the collective ANNEX,[17] recently presented at the festival Transmediale 2022 in Berlin, Germany. This artwork is chosen to illustrate the previous analysis of critically-made artifacts as post-digital hybridisation. The work is here analysed from the aesthetic experience perspective of an audience.[18] The installation *Entanglements* is considered as a critically-made audiovisual sculpture that creates a hybrid environment and radiates traces of its making and critique through the assemblage of several layers of physical materials. In the process of making, different materials related to information and communication technologies have been assembled, including digital and non-digital materials as well as sound and video in order to unmask the materiality of the cloud[19] and critique of their environmental impacts. In general, the work aims to "re-evaluate the utopian fantasy of digital communication and to reflect on how we live together through data infrastructure, today and into the future" (ANNEX 2021).

4.1 Grasping the cloud

Entanglements is a large-scale audiovisual sculpture (Fig. 1 and 2) that allows the audience to enter and experience it from within its circular formation relating to the campfire[20] and data infrastructures. The artwork assembles different materials, such as network burnt server-racks (Fig. 3), a web of ethernet cables, coals, fans and media, such as speakers, lights, live cameras and several vertical screens. This form of hybridisation combines the burnt server-racks stacked up high, entangled with cables linked to the servers to form a messy web, symbolic of the internet. Through a tactile and direct material engagement, the cloud infrastructure is deconstructed to grasp its materiality as well as to disclose its local and planetary ecological consequences.

Various screens are vertically displayed and show text generated by machine learning[21] over satellite thermal pictures and videos as well as real-time thermal video from the installation space. The aerial pictures show data centres in Ireland,[22] it is forecasted that by 2027 data centres in Ireland will consume 31% of the total electricity demand (ANNEX 2021). The viewer is reminded of the environmental consequences of data centres not only through the burnt server-racks but, too, by generated text on screens such as:

This intersection of human, technical, and social aspects of global systems of production, consumption, and waste treatment is, in important ways, one of the most dynamic and significant drivers of climate change, and it has been inextricably with the rise of another facet of capitalist production. (ANNEX 2021)

The installation is interconnected and controlled through software to generate the media playback and the composition which lasts about 20 minutes. It triggers sounds, lights, fans, screens and real-time video. It is embedded within a powerful soundscape of mechanical sounds as well as the sounds of birds, water and the sea. These sounds are from a grotto where the first transatlantic telegraph was placed in 1857 on Irish Valentina Island. The soundscape emanates from two large subwoofers, felt through the body, together with speakers located around the structure. It appears as though the sound triggers white LED lights that illuminate coals (Fig. 4). On the bottom of the structure and around it are fans that produce wind when triggered.
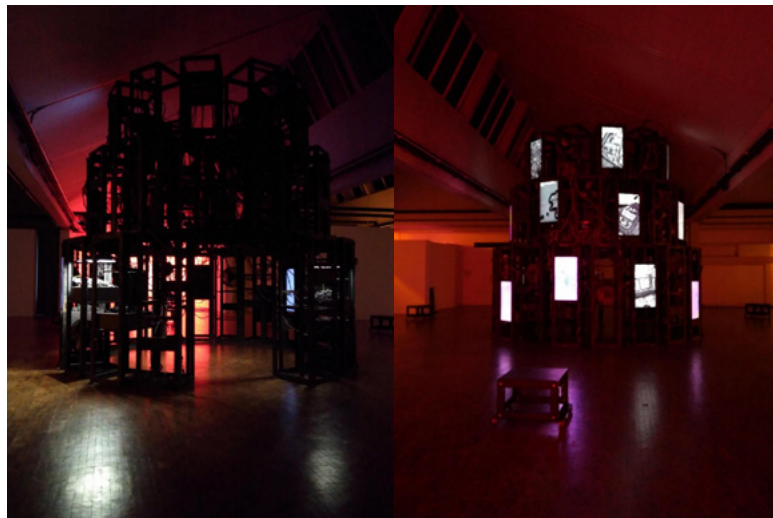
Fig. 3 and 4. *Entanglements* (2021), close-ups. Art installation at Transmediale 2022, Akademie der Künste, Berlin, Germany.

The artwork explores hybridisation of materials in physical space as a critical tactic to express concerns about the environmental impacts of information technologies and their ecological footprint with a focus on its drastic amount of energy consumption and heat generation in maintaining the networked world. The scholar Sean Cubitt writes that the production of the digital culture and the logistics of "digital equipment now uses at least as much energy as the airline industry" (Cubitt 2016, 102). And according to Greenpeace, information technology companies rely heavily on non-renewable energy sources, such as coal, to power cloud computing (Cook 2012). All this reminds one that to send an email, scroll on Facebook or reproduce a video on YouTube or "a virtual fire, such as Netflix's *Fireplace For Your Home*, creates real heat in its production" (ANNEX 2021) that adds to the carbon footprint of the online world.

The installation *Entanglements* unmasks the materiality of data infrastructures to deconstruct the data centre, the infrastructures dedicated to store, distribute and handle data as the basis of the networked society. The materiality of the cloud is emphasised through hybridisation as a tactic that assemblages technical objects that compose data centres to critique their energy consumption and residual heat associating the data centres with the production and distribution of energy infrastructures. As such, the work is here considered as a critically-made artifact that rematerialises the cloud and unfolds it physically and spatially through digital and non-digital materials. To conclude, the work affectively points out the growth of global data and its environmental impacts by unmasking the materiality of the cloud. This critique through material hybridisation challenges the popular imagination and marketisation of an immaterial digital culture that is marketed as "independent of material substrate, transportable on the vague and indeterminate channel of 'the Internet'" (Parikka 2013).

5. Conclusion

In this paper, the nature of critical making was analysed as a practice that emphasises critical thinking about technical devices through the making process. Inherent to critical making is a pedagogical component that aims to strengthen technical skill, incorporate critical theory about our sociotechnical world and promote awareness of STEAM[23] in education. Critical making can be distinguished from other forms of hands-on making as it re-politicises makers and has the potential to critically reconfigure the maker movement. This form of making differs from uncritical-making, leisure-making or forms of entrepreneurial-making. Thus, the critical maker is an artist engaged with technologies through critique and materials who deconstructs the inner mechanisms embedded in our everyday devices. Critical makers are politically and ethically engaged through hands-on making which creates community-oriented practices with the sharing of technical knowledge and a sense of social participation and belonging. These values and modes of artistic production are distinct from capitalist modes of production such as labour division, individualism, competition, disaffection and consumer-oriented commodities of artistic production.

The art installation *Entanglements* (2021) was examined to illustrate a practical example of a critically-made artifact in the context of the arts. The installation suggests hybridisation of digital and non-digital materials together with critique of the ecological footprint generated by data centres and their sustainability. These negative consequences of environmental pollution brought about by computational societies are part of a constellation of digital media materiality, which includes not only electricity production and consumption, but, too, mining, unfair labour conditions, planned obsolescence, e-waste and other residual effects from digital technologies.

It was argued that critical making rejects the new media art paradigm and is instead associated with a post-digital art practice critical about the consequences brought on by digital technologies. As a form of post-digital art, critical making engages both "new" and "old" media through physical engagement by hand and material experimentation. Thus, critical making provides a rematerialisation of digital technologies in physical space as embodied technical devices accessible to the hand. This artistic practice is accessible to a wider range of people than just experts in the field or a niche of new media artists.

Critically-made artifacts are a kind of politicised art that aim to disrupt the "relationship between the visible, the sayable, and the thinkable without having to use the terms of a message as a vehicle" (Rancière 2006, 63). These artifacts introduce new perceptions and affections that "transmit meanings in the form of a rupture with the very logic of meaningful situations" (ibid.). As a result of a new materialist perspective, critically-made artifacts create an impure aesthetics based on openness, influx and hybridisation. As hybrids, critically-made

artifacts result from an interplay with matter, digital and non-digital materials that blur human and non-human agencies to include the incalculable, or what is outside the realm of computation.

To conclude, critically-made artifacts reject the rhetoric of immateriality affiliated with digital technologies and is better understood based on hybridisation, a critical tactic that unfolds the digital spatially. These artifacts have the potential to influence and transform our affections and perceptions of everyday life pervaded with digital technologies as well as to unmask the sociocultural consequences, political, economic and environmental impacts brought about by digital technologies in computational capitalism.

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