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RESEARCH ARTICLE

Digital Materialisms: Frameworks for Digital Media Studies

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Since the 1980s, digital materialism has received increasing interest in the field of media studies. Materialism as a theoretical paradigm assumes that all things in the world are tied to physical processes and matter. Yet within digital media studies, the understanding of what should be the core object of a materialist analysis is debated. This paper proposes to untangle some of the principal theoretical propositions that compose the field of digital materialism. It outlines six frameworks that share the assumption that digital stuff is composed of material entities: the Berlin School of media, the field of software studies, the literary critique of electronic texts, the forensic approach, the 'new materialist' media ecology, and the field of Marxian critical studies. These different options are positioned along three main lines of tensions: between a semantic and an engineer's perspective on media, between technological and social determinism, and between critical or post-humanist political propositions.

Keywords: Digital; Materialism; Immateriality; Politics; Ecology

In a perfect blue sky stands a man in a white suit. Raising his arm towards a transparent screen floating in front of him, he delicately brushes his finger upon the surface. A desktop icon lights up, a flow of numbers materialize in the air. Streams of 0s and 1s travel at the speed of light from the screen to an immaculate cloud drifting in the background. Somewhere in Asia, a woman shovels cloud trash: bit and parts of electronic circuits, smashed screens and toxic waste.

How did the trope of immateriality colonize our imagination to the point where we came to believe computing exists beyond the material world? Dazzled by virtual space opening up on our screens, we figured a new world, independent from matter, unconstrained by finitude. Pure information would travel along electricity flows though machine systems. The trope of immateriality assumes that digital stuff is weightless, supplied by unlimited resources and immune to decay.

Since the 1980s, 'digital materialism' has become a new field of interest in communication and media studies, increasingly gaining momentum in the 2000s. Materialism as a theoretical

paradigm assumes that all things in the world, including things of the mind and digital stuff, are tied to (and in some cases, determined by) physical processes and matter. Yet, within digital media studies, the understanding of what should be the core object of a materialist analysis is debated. Are we talking about a contemporary reconfiguration of Marxian perspectives on the political economy of the web (Dyer-Witheford, 1999; Fuchs, 2011)? Is this *digital material turn* inspired by the *material turn* that regenerated sociocultural anthropology in the 1970s (Miller, 1987)? Or should we understand it as a spreading interest for philosophies of *new materialism* (DeLanda, 2000; Bennett, 2009) that since the end of the 1990s advocate for a postcartesian and posthumanist perspective?

In this paper, I propose to untangle some of the principal theoretical propositions that compose the field of digital materialism. I will outline six frameworks that share the assumption that digital materiality is composed of 'material bits', as Jean-François Blanchette puts it (2011): the Berlin School of media, the field of software studies, the literary critique of electronic texts, the forensic approach, the 'new materialist' media ecology, and the field of Marxian critical studies. These different materialist options rest upon contrasted theoretical backgrounds, which we can position along three main lines of tensions: between a semantic and an engineer's perspective on media, between technological and social determinism, and between critical or post-humanist political propositions.

From Immateriality to Material Bits

Since the telegraph, electrical media has raised the fantasy of immateriality. Its promise is metaphysical: 'by annihilating space and time, it allows humankind to escape physical limitations. The power and ubiquity of electricity are metaphorically attached to a newly disembodied consciousness' (Rosenheim, 1997, 93). A technique so powerful it dissolves matter and becomes pure power, pure consciousness. In the 'Electric Age' of Marshall McLuhan, electricity is the 'ultimate medium', an extension of the Mind, source of one single collective conscience (McLuhan, 1964). Paradoxically, McLuhan's media theory shifted the attention to the materiality of the medium. He highlighted how the physical constraints of media shape the way information is produced, the way social relationships are organised, and the way we see the world.

Cybernetic theory, although operating on the abstract level of information organisation, was clearly aware of the physical constraints of electronic systems. Noise, errors, signal distortion and entropy result from material phenomena such as failures in circuit components or signal interference on transmission lines. The ability of feedback loops to detect and correct these errors, restoring signal 'to near perfection at every stage' (Hillis, 1999, 18), allows computers to auto-erase the defects that 'typically signals the materiality of media' (Blanchette, 2011, 1047). By detecting error and correcting it, these feedback routines maintain an illusion of immateriality, protecting the integrity of the signal against degradation (Kirschenbaum, 2008).

Cyberculture partially lost sight of the physicality of digital media in the 1980s and 1990s. 'There is no matter' in cyberspace, declared John Perry Barlow in his 'Declaration of the Independence of Cyberspace' (1996). Representations of cyberspace as an immaterial simulated data environment grew from science fiction literature. In his popular novel *Neuromancer* (1984), a hallmark of the cyberpunk movement, William Gibson depicted a global computer network called the 'Matrix', wiring together brains and machines into a 'consensual illusion' located in 'the nonspace of the mind'. Left behind, the body remains inert while 'a disembodied subjectivity inhabits a virtual realm' (Hayles, 1999, 379).

But cyberculture did not only separate the material world of the body from the disembodied existence of information. It also explored the blurred frontier between the mind and the

computer, introducing the vision of a hybrid human, half-organic and half-machine, a mythical monster. Donna Haraway's 'Cyborg Manifesto' (1991) was intended as a feminist, socialist and materialist effort to break the rigid boundaries between animal, human and machine. Unlike Barlow whose libertarian politics relied on the immaterial nature of digital networks, Haraway introduced politics from a critical materialist perspective.

The 'Material Turn' in Digital Media Studies

Since the 1980s, swelling criticism against the trope of immateriality led various authors to propose new theoretical models that could take into account the materiality of digital computation. The great variety of traditions, intellectual trajectories and emerging trends that could qualify as 'materialist' prevents from picturing what is now labelled a 'material turn' in digital media studies as a homogeneous movement. As a matter of fact, this 'material turn' is profoundly indebted to cross-disciplinary influences and its contours extend well beyond the disciplinary boundaries of media studies. References to the materiality of digital worlds is now widespread across social sciences and humanities, including in science and technology studies, human–computer interaction, design, sociology, literature, library and information sciences, and organizational communication.

Social anthropology is an interesting exception regarding the recent trend toward materiality, because it has never stopped focusing on material practices since its own material turn in the 1970s. The 'material turn' in social anthropology refers to a tradition that emerged among British anthropologists. It proposed to pay greater attention to the materiality of objects in social exchange and consumption processes. This turn was a reaction to what was perceived as a dominant focus of anthropology on relationships following from Marcel Mauss who favoured a sociological orientation in the analysis of exchange systems (Basu, 2013). Daniel Miller was particularly vocal in criticising the 'fetishism of sociability', calling instead for 'a return to a more object-centered approach' (Basu, 1987, 146). In a landmark book published in 1987 under the title *Material Culture and Mass Consumption*, Miller makes it clear that he is not interested in the physical object in itself, nor in the social relations themselves, but in studying the interaction between these two dimensions. With his colleague Christopher Tilley, he created the emblematic *Journal of Material Culture* (1996), which sheltered the development of an inclusive interdisciplinary field around a common interest in the material constitution of social relations.

Yet the 'material turn' in media studies is not so much indebted to anthropology, but rather to theoretical insights and empirical studies imported from the fields of media history and computer science. By situating digital media within the long-term evolution of technical media, historical perspectives push aside the presentist temptation of separating old media from supposedly new immaterial ones. Providing a better understanding of the physical constraints of data storage, processing devices and network infrastructure, computer sciences also contributed to bringing back attention to the material dimension of computing.

Computing as Material Practice

The objects of study considered by materialist approaches are quite diverse. They embrace both the material substrates and abstract programming languages required for data storage, processing and exchange: code, hardware devices, operating systems, software, applications, platforms, interfaces, documents, file formats as well as networking protocols and infrastructure. The key argument of digital materialism is that there is no 'pure information': code is inscribed; bits are written. Furthermore, the resources of computation are limited in terms of processing power, storage capacity and connectivity; its signals are prone to degradation, its devices to decay and toxicity.

If we were to open the blackbox of our computers, find the hard drive and examine the surface of its platters, all we would see is a sleek empty surface. And yet just like microbes, imperceptible to human vision, bits are material creatures. They do not float in clouds, they proliferate on the tens of thousands of concentric tracks of hard disks, in palimpsest-like imprints (Drucker, 2013). All digital data consists of physical inscriptions (Kirschenbaum et al., 2010, 40). Coded in bits (basic units that can have two values: 0 or 1) information is stored in the form of magnetic polarities on hard drives, electric charges on flash memory cards, or microscopic pits on the surface of optical disks. In early digital computers, bits were materialized by the presence or absence of a hole at a predefined point of a punch card. A collection of punchcards was called a 'file', a term still in use today to designate digital documents (Haigh, 2009). Processed and exchanged on digital networks, bits take the form of electric voltages or radio waves, signals that 'travel over physical media—whether air, copper wire or fibre optic—each bringing different characteristics to the job, with regard to susceptibility to interference, dissipation, capacity, and cost' (Blanchette, 2011, 1051).

The different approaches composing the field of materialist media studies may share a common interest in the material substrate of digital culture, their objects of study, methodologies, and theoretical takes are quite contrasted. Starting with Friedrich Kittler's work, let's explore in detail some of the main propositions mapping the field of digital materialism today.

The Berlin School of Media: Hardware and Logical Structures

The German school of media, also called the Berlin school of media studies, formed at the end of the 1980s around the influential work of philosopher, historian and media theorist Friedrich Kittler. For Nicholas Gane (2005), Kittler is one of the pioneers of *media materialism* or *information materialism.* Interested in the way information is 'transformed into matter and matter into information' (Kittler, 1997: 126), he developed an approach that privileges the material structures of technology, especially 'their logical structure (informatics) on the one hand and their hardware (physics) on the other' (Ernst in Lovink and Ernst, 2003).

Influenced by Shannon's mathematical theory of communication (1948), Kittler and his followers treat communication as a question of engineering rather than of semantics (Gane, 2005, 26). Media are conceptualized as inscription machines, but instead of focusing on alphabetical texts, they give special attention to the level of mathematics and the storage capacity of technical media: the way computers, but also older media such as typewriters, gramophones, or cameras, produce technologized memory, and therefore, produce history itself (Kittler, 1999).

Kittler distances himself from subject-centred approaches, and especially from the meaning-centred focus of cultural studies. Seeking to open a 'semantics-free space' (Kittler, 1992, 67), he refuses to place human subjects at the starting point of his analysis. Rather than focusing on the meanings audiences or users attach to objects or machines, he is interested in 'the ways in which meanings are generated by an underlying technological framework' (Gane, 2005, 39). For Kittler, the digital code is an abstract language independent from the signifying realm, a logical sequence of signs without meaning. In this post-hermeneutical framework, it is 'the very technologies that make both the social and meaning possible' (Gane, Ibid., 38).

Kittler's provocative formulas such as 'media determine our situation' (1999, xxxix) earned him the label of technodeterminist – although, according to Geoffrey Winthrop-Young, he also takes into account social factors. For Kittler, 'the ultimately determinant element is the production and reproduction of data, but to twist that into saying that the

media-technological element is the only determining one is to transform the proposition into meaningless – or at best trivial – insight' (Winthrop-Young, 2013, 123–124).

The Programmable Objects of Software and Platform Studies

A second research stream on digital materialism investigates the programmable nature of digital objects, platforms and interfaces. Whereas the German school of media stems from the history of hardware and early computing forms, this series of works focuses on computability in contemporary digital culture, including video games, design and media based. Following late 1990s theoretical explorations of 'new media' (Manovich, 2001), the related fields of software studies (Fuller, 2003; Manovich, 2008; Wardrip-Fruin, 2009) and platform studies (Bogost and Montfort, 2009) quickly developed in the 2000s.

Lev Manovich was one of the early promoters of this approach. With the goal of building a theory of 'new media', he imported insights from computer sciences and media art practices into cultural studies. 'Digital materialism' is an expression he uses to describe his method: a scrutiny of 'the principles of computer hardware and software and the operations involved in creating cultural objects on a computer to uncover a new cultural logic at work' (2001, 10). From this perspective, he analyses the production and online dissemination of cultural media objects, with a special focus on visual culture: films, videos, photographs, graphic designs, illustrations or web graphics.

In Manovich's terms, the materiality of 'new media objects' is primarily defined as mathematical and programmable, as well as 'mutable' and 'liquid'. Understanding digital materiality as a phenomenon rooted in the logical abstraction of code, he proposed five principles to characterize it: numerical representation, modularity, automation, variability, and transcoding (2001). Special attention is given to the interface and usability of programs, an analysis carried on by observing the formal organisation of information on the screen, its interactive potential and the phenomenological aesthetic experience proposed to the user. Contrary to Kittler, this framework includes socio-cultural factors on par with data-processing structures. The social dimension of use and the cultural dimension of meaning are put forward to explain how media objects are 'experienced, created, edited, remixed, organized and shared', and how they make sense to people who create and use them (Manovich, 2008).

Electronic Texts as Material Artefacts

A third trend of digital media materialism is rooted in the literary tradition. Taking as a point of departure the study of literary texts, this approach taps into computer sciences to combine a functional and semiotic approach to electronic creation (Hayles, 2002). A second generation of literary scholarship stemmed from the field of bibliography, incorporating insights from forensic experts, textual criticism and archival sciences (Kirschenbaum, 2008; Blanchette, 2011).

Since the beginning of the 1990s, N. Katherine Hayles contributed to the emergence of the field of electronic textuality, bringing back attention to the material basis of literary production. Trained in chemistry, with a knowledge of programming languages, Hayles proposed a framework for 'media specific analysis' which she describes as 'a mode of critical interrogation alert to the ways in which the medium constructs the work and the work constructs the medium' (2002, 6).

Considering the electronic text itself as a material object, she investigates its hypertextual and multimedia properties, including sound, image, and other software functionalities. Her interest in materiality is tied to questions of social use and interpretation. From an hermeneutic point of view, she analyses how changes in modes of textual inscription affect the reader's interaction with the text, which in turn changes its possible meanings: 'the physical

form of the literary artifact always affects what the words (and other semiotic components) mean' (2002, 25).

As a matter of fact, she does not conceive materiality as a pre-existing physical property, but as the result of an interaction between objective attributes and subjective processes:

> 'An emergent property, materiality depends on how the work mobilizes its resources as a physical artifact as well as on the user's interactions with the work and the interpretive strategies she develops—strategies that include physical manipulations as well as conceptual frameworks. In the broadest sense, materiality emerges from the dynamic interplay between the richness of a physically robust world and human intelligence as it crafts this physicality to create meaning' (Ibid., 32).

This semiopragmatic framework gives a central role to the user and her engagement with media objects, an assemblage of embodied signs activated and performed by the subject. Human action is involved not only in the creation of meaning and social uses, but in the production of materiality itself.

Such a position is close to Joanna Drucker's definition of materiality as inhering in 'a process of interpretation rather than a positing of the characteristics of the object' (1994, 43). In this perspective materiality is shaped by signifying activity, and affected by localized, historical and cultural system of values. However, Drucker distances herself from radical constructionism: 'the inherent physical properties of stuff function in the process of signification in intertwined but not determined or subordinate relation to their place within the cultural codes of difference where they also function' (Ibid., 45–46).

Forensic Traces

With a background in literary studies, Matt Kirschenbaum analyses electronic writing from another perspective: that of computer forensics techniques. Observing that the critical literature on new media has focused primarily on 'the phenomenological manifestation of the application or digital event on the screen' (2008, 6), he intends to move beyond 'screen studies' and their formalist and poststructuralist frameworks. His book *Mechanisms: New Media and the Forensic Imagination* (2008) focuses on storage and the inscription of digital information on hard drives.

Unsatisfied with Kittler's narrative of 'the universal ones and zeros of digital computation' he sets himself to discovering 'the heterogeneity of digital data and its embodied inscriptions' (Ibid., 6). He turns to forensic expertise to find a vocabulary that accounts for the residual documentary status of digital inscription. The physical and chemical analyses used in criminology for reconstructing digital evidence shifts attention to the physical properties of digital inscription, a dimension also relevant for archival preservation. For Kirschenbaum, 'a forensic perspective furnishes us with two key concepts for an alternative approach to electronic textual studies: trace evidence and individualization' (Ibid., 19).

The model he proposes distinguishes between *forensic* materiality and *formal* materiality. Forensic materiality rests upon the idea that bits are inscribed in the form of individualized physical traces, and that no two things in the world – even the micron-sized residue of digital inscription – are ever exactly alike. Formal materiality describes the state of bits as symbols, series of 0 and 1, manipulated by the computer. These two categories do not exactly reproduce the distinction between hardware and software, 'because the lines between hardware and software are themselves increasingly blurred, as is manifest in so-called firmware, or programmable hardware' (Ibid., 12).

The Politics of Digital Materiality

Taking as a starting point the physical substrate of digital reality, the four approaches described above focus on technologized memory (Kittler), user-experience of programmable objects (Manovich), electronic texts (Hayles) and forensic traces (Kirschenbaum). These frameworks provide tools to critique the trope of immateriality, but they do not address frontally the political dimension of digital materialism.

Two pressing political concerns were brought to the forefront of digital media studies in recent years. The first one derives from Edward Snowden's revelations, which brought to light the reliance upon internet submarine cables for state surveillance apparatuses and the material site of data traffic interception. These revelations fostered research on the spatial distribution of network infrastructures and the local as well as global political contexts they are tied to. Tackling issues of ownership, policy, regulation, privacy and surveillance, this subfield comprises empirical studies on the political economy of cable infrastructure (Starosielski, 2013), the geographic localisation of data storage centres (Jaeger et al., 2009) and the national laws that govern data management (Jaeger et al., 2008).

The second political issue gaining growing attention in digital media studies concerns the degradation of natural environments in the era of the Anthropocene. A new generation of scholars has highlighted the connection between environmental issues and the political economy of digital media (Parikka, 2011; Maxwell and Miller, 2012). Issues range from pollution of rivers and farmlands due to ICT-related industries, energy consumption and CO^2 production in server farms, green computing, built-in obsolescence in digital material culture, e-waste and the management of electronic media remains. In the next sections, I will examine two frameworks that address the question of digital politics and environmental degradation: a renewed version of media ecology inspired by 'new materialism' and a body of work stemming from neomarxist studies.

'New Materialist' Media Studies: Waste and the Vibrancy of Digital Matter

The 'new materialist' framework in media studies has been developed at the interface between philosophy and media ecology approaches. The term 'ecology' in the sense of 'media ecology' does not necessarily refer to issues of environmentalism. In its classical sense, as defined in the 1970s by authors close to the Toronto school of media and American cultural studies, 'media ecology' is the study of media environments as complex systems of interrelations between media techniques and people (Postman, 1970).

Since the 2000s, the label media ecology has been reappropriated by a new generation of scholars (Fuller, 2005; Cubitt, 2005; Goddard and Parikka, 2011; Parikka, 2012). Interested in the aesthetic and political dimensions of media, they propose to look at media ecologies in terms of 'materialist energies in art and technoculture' (Fuller), 'ecomedia' (Cubitt) or 'media archaeology' (Parikka). Reframed to address the entanglement of humans and non-humans, media ecology has become a site to investigate the link between nature and technologies, questioning the role of digital media in natural environments degradation.

Jussi Parrika embraces media ecology by weaving philosophies of new materialism into media history and media archaeology. In a paper entitled 'New Materialism as Media Theory' (2012), he describes the 'weird materialities' of technical media as processual, relational, ephemeral and 'vibrant': 'the basis for signal-processing, use of electromagnetic fields for communication, and the various non-human temporalities of vibrations and rhythmics – of for instance, computing and networks - are based in non-solids' (96). His reference to the 'vibrancy' of digital materiality is borrowed from Jane Bennett (2009), whose work is emblematic of a specific trend in new materialism called 'vital materialism'.

At the heart of Bennett's ecologies of matter is the 'vitality' of things. She describes the world as a continuum of 'living matter', with no radical split between life and material things. Rejecting the dualism between active subject and passive object, her model operates on the level of immanency and flat ontologies. This model is positioned against radical versions of social constructivism (where all things in the world are considered a social construction), and against mechanist approaches that treat objects as inert and determined, where humans are the only privileged entities to be granted agency. The neo-vitalist option defended by Bennett is inspired by ancient materialist philosophers, such as Democritus and other pre-Socratic atomist theories, for whom all things are composed of primary chunks of matter (atoms) in movement. Her philosophy is also directly influenced by Gilles Deleuze's ontologies of 'becoming' (1987), and Henri Bergson's notions of 'life-matter' and 'matter-flow'(1889).

'Thing-power' is a concept Bennett developed to characterize the agential powers of non-human entities. It refers to the phenomenological capacity of things, or 'actants' (Latour, 1999) to self-organize, create new assemblages (De Landa, 1997) and exercise a force upon humans. 'Thing-power materialism figures materiality as a protean flow of matter-energy and figures the thing as a relatively composed form of that flow' (Bennett, 349). She describes for example the (impersonal) life of metal in an attempt to escape anthropocentrist and biocentrist conceptions of life.

According to Parikka, new materialism allows for a political analysis of electronic media that is lacking in Kittler's work, especially in regards to issues of electronic waste and 'dirty matter'. Bennett herself describes her proposition as a radical framework aiming to ground a political ethics in a project of ecological sustainability. However, it is debated among philosophical circles whether Bennett's version of new materialism can provide suitable political concepts to orientate social action. Bennett's approach is sometimes labelled 'naive materialism', a denomination she uses herself to describe her approach (2004). Explicitly positioning her framework as an alternative to Marxist critical materialism, she aims to challenge the dominant position of Marxism among materialist perspectives (Ibid.). However, the expression 'naive materialism' was appropriated by her opponents as a pejorative name to criticize the lack of political consistency in her proposition.

Christian Thorne (2013), for example, wonders how to derive a political program from new materialist ontologies such as Bennett's. He judges that the proposition that 'the cosmos is full of living matter in a constant state of becoming' is 'warmed over Ovid', unable to solve any political problem:

> 'one wonders which problems a vitalist considers still unsolved? If Bennett and Connolly are right, is there anything left for politics to *do*? Has Becoming bequeathed us any tasks? Won't living matter get by just fine without us?' (2013, 107).

Thorne argues that focusing on the properties of things is depoliticizing and leads *in fine* to an 'anti-political program'. Bennett herself describes her political strategy as 'indirect': targeting 'not the macro-level politics of laws, policy, institutional change but the micro-politics of sensibility-formation', hoping that 'new attentiveness will translate into more thoughtful and sustainable public policies' of 'greener' modes of consumption and production, including in the way we produce and consume digital media (Bennett in Gratton, 2010). Yet if the value of Bennett's contribution is to draw attention to largely ignored non-human organizing forces and mechanisms in social configurations (Bryant, 2012), new vocabulary for direct political intervention is to be found elsewhere, notably in Bruno Latour's *Politics of Nature* (2009) or in critical approaches of materialism.

Neomarxism and the Materiality of Digital Labour

In recent years, several authors pointed out the necessity to tackle the ecological crisis and the materiality of digital media within the field of critical studies (Dyer-Witheford, 2008; Maxwell & Miller, 2012; Fuchs, 2014). Marxist frameworks articulate the issues of materiality, politics and ecology around the traditional concepts of ownership, labour and class struggle. This version of digital materialism brings to the forefront the material nature of economy with the aim of criticizing capitalism and its excesses. It postulates that the material infrastructure of media industry acts as a determining force in the production of media content and discourse. A whole body of works in critical internet studies shows how digital media contributes to reproducing exploitative economic structures and alienating ideologies (Garnham, 1990; Mosco, 2009; Fuchs and Dyer-Witheford, 2013). In recent years, a new body of work on 'digital materiality' emerged from the critique of the notions of 'immaterial labour' and 'dematerialised' economy.

The term 'immaterial labour' stems from the analysis of computerized work in Italian autonomist Marxism. First introduced by Maurizio Lazzarato (1996), it was popularized by Michael Hardt and Toni Negri (2000) to account for the contemporary transformations in capitalist modes of production. By 'immaterial labour', Lazzarato refers to 'labour that produces the informational and cultural content of the commodity' (1996, 133). Hardt and Negri describe a form of labour 'that creates immaterial products, such as knowledge, information, communication, a relationship, or an emotional response' (2005, 108). However, this term is problematic because it reproduces the trope of digital immateriality and extends it to the realm of labour. For Christian Fuchs, 'the term 'immaterial' creates the impression that information work is detached from nature and matter and that there are two substances in the world - matter and spirit – that result in two different types of work' (2014, 252). Against this representation, he asserts that information work is material itself: information is produced by human brains, which are material, not pure spirits, and digital infrastructure involves the exploitation of raw materials and equipment.

In a book called *Digital Labour and Karl Marx* (2014), Fuchs investigated the material conditions of labourers in the ICT industry from the perspective of Marxist political economy. He argues that issues of labour were neglected by communication and cultural studies after the linguistic turn, and that it needs to be placed back on the agenda. With his critique of how 'digital media capital' exploits human labour-power, Fuchs clearly moves away from over-optimistic perspectives on digital technology. His book includes case studies on low wage information work performed by Amazon's Mechanical Turk, unpaid overtime in the Indian software industry and worker's exposure to toxic chemicals in Chinese assembling factories where iPads are produced.

His own account of the 'life of minerals' exposes the conditions of production of raw minerals used in the production of digital devices such as laptops and cell phones. Indeed, the range of materials involved in the construction of digital machines is quite vast: plastics, copper, aluminium, silver, gold, palladium, lead, mercury, arsenic, cadmium, selenium and hexavalent chromium are only but a few substances populating our digital environments (Pinto, 2008). Fuchs investigated the conditions of mineral extraction in Africa, particularly in Democratic Republic of Congo, where 53% of the world's cobalt was produced in 2011 (Fuchs, 2014, 180). Considering the demand of Western ICT industries for cheap mineral, he calls 'digital slavery' the violent exploitation of labour in ICT-related mineral extraction. Slavery is widespread in RDC's mining industry. Miners often work without basic equipment, using arms and fingers to physically remove the mineral, facing cave-ins, malnutrition, exhaustion, poor sanitation and exposure to extremely polluted air and water. After four to

five years working in the mines, the body of villagers enslaved by armed soldiers is 'completely deteriorated' (Ibid., 179).

Fuchs also emphasizes the link between digital industry and environmental degradation (2008). He challenges the idea that ICTs necessarily advance ecological sustainability by reducing the need to travel and lowering energy and resource consumption. For him, ICTs should rather be considered in their capacity to pose 'both new opportunities and risks for the ecosphere' (Ibid., 292). The myth of a 'dematerialised' and 'weightless' knowledge economy tends to obscure the fact that computers are consuming vast amounts of energy and that many physical commodities need to be transported and sold for this economy to function. 'Burning digital music on compact discs and DVDs, printing digital articles and books, etc. results in rebound effects that cause new material and energy impacts' (Ibid., 291). As a matter of fact, downloading a CD over the internet consumes 2.5 times more energy as buying it in a music store (Ibid., 297). Fuchs concludes that the idea of a sustainable information society will remain a popular myth unless we consider environmental problems as 'social problems, not technological problems'. The direction he points to requires alternative models of economic production as well as 'a conscious reduction of profits by not investing in the future of capital, but the future of humans, society, and nature' (Ibid., 308).

Conclusion

Rather than retracing the genealogies of traditions and ruptures that influenced the 'material turn' in digital media studies, an endeavour that runs the risk of producing a unifying narrative, this paper mapped out some of the key perspectives, theoretical positions and political concerns that contribute to our understanding of digital materiality today. In all of the frameworks presented above, we find the shared assumption that digital information has a material substrate, and that the trope of immateriality obscures the labour, materials and natural resources of digital culture. Yet beyond this common premise, differences in theoretical approaches lead to contrasted - sometimes oppositional - propositions.

Tensions are visible in the way each framework positions itself in debates on hermeneutics and social determinism *vs* technical determinism. Kittler's approach is anti-hermeneutical, realist and centred on technical causality. His emphasis on the techno-mathematical aspect of digital information leads him to relegate semantics, textuality and social factors to the margins of his framework. Manovich's framework is closer to Anglo-American cultural studies in a user-centered perspective. While focused on the programmable feature of digital materiality, he pays much attention to questions of design, usability, aesthetic experience and cultural meaning. Hayle's textual approach rests even more strongly on hermeneutics. Rooted in subjectivism and social constructionism, it considers materiality as a dialectic process between physicality and interpretation. Kirchenbaum retains some of the textual framework while shifting the attention towards the material inscription of bits. Drawing from forensic studies, he investigates objective phenomena such as data permanence and degradation.

The politics of digital materialism are tackled by new materialist frameworks in media ecology and by a new generation of authors in Marxist critical studies. Both propose to analyse the political dimension of digital media through the lens of materialism. They share an interest in the various ecological ties that bridges digital materiality and its political economy. Far from the clean and pure imagery of a 'dematerialized society' made of free flows and clouds, these studies point out the contribution of digital industry to the unsustainable growth model of industrial capitalism. Yet their theoretical backgrounds are oppositional. Bennett's philosophy of new materialism is explicitly positioned as an alternative to hermeneutic subject-centred approaches and to the Marxist focus on people's (political) subjectivities. She would

claim instead, following Latour, that "[h]istory is no longer simply the history of people, it becomes the history of natural things as well" (Latour, [1991] 1993, 82). Marxist authors criticize the lack of strong operational concepts for political intervention in new materialist philosophies and emphasize the centrality of human labour exploitation, while also taking into account the exploitation of non-humans and natural resources.

Another way to look at the dialectics between subject and objects is to be found in Miller's anthropology of material culture. Miller turns back to Hegel to propose a dialectical theory of material culture that does not postulate the centrality of society, humanity or the subject, without however giving up the analysis of social and cultural meanings (2010, 77). Indeed, the trope of technical immateriality is in itself a cultural object of study for digital materialist studies. Investigating technical immateriality in the myth of 'the digital sublime' (Mosco, 2004) would enrich our understanding of both Western technical imaginations and material processes of objectification.

Competing Interests

The author declares that they have no competing interests.

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