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# THE CONTINUOUS MATERIALITY OF BLOCKCHAIN

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Both cryptocurrency researchers and early adopters of cryptocurrencies agree that they possess a special kind of materiality, based on the laborious productive process of digital ‘mining’ [1]. This idea first appears in the Bitcoin White Paper [2] that encourages Bitcoin adopters to construct and justify its value in metaphoric comparison to gold mining. In this paper, I explore three material aspects of blockchain: physical infrastructure, human language and computer code. I apply the concept of 'continuous materiality' [3] to show how these three aspects interact in practical implementations of blockchain such as Bitcoin and Ethereum. I start from the concept of ‘digital metallism’ that stands for ‘fundamental value’ of cryptocurrencies, and end with the move of Ethereum to ‘proof-of-stake’, partially as a countermeasure against ‘evil miners’. I conclude that ignoring material aspects of blockchain technology can only further problematize complicated relations between their technical, semiotic and social materiality.

## 1. Introduction

Blockchain technology further complicates the already problematic divide between software and hardware. In a way, it is an answer to ‘digital immateriality’ of online services and transactions. Digitization of records, including accounting journals and ledgers, has led to new challenges to prove their authenticity. A cryptographic record on blockchain has been proposed as one of such solutions, because it is validated by an unintermediated, even if often costly, consensus between many participants of a network.

Architecture of a blockchain platform does not require a central server to keep the records. Results of each transaction are validated by a majority of nodes in a network or by a reasonable share of selected representatives on a digital platform, and then recorded as the next block on each node. In the common process of validation, computing takes place at many machines at once, which makes blockchain platforms particularly robust and, ideally, affords their democratic self-regulation. For example, Filipe Calvão believes that "the work of digital mining... enables the formation of democratic communities" [1], and compares mining pools to trade unions, even though empirical results of his own research show heavy ‘capitalization’ of industrial ‘mining’.

Material conditions of blockchain platforms have been the subject of many researchers since the early years of Bitcoin studies [4]–[6]. Many turn to the ‘material’ value of cryptocurrencies: for instance, in their studies of early Bitcoin hype, Garcia et al. suggest that the “fundamental value” of one Bitcoin equals at least the cost of its production [4]. From this perspective, the exchange price of mined cryptocurrencies is tied to the material conditions of ‘mining’, although this existing relation has only been further complicated with time. At an early stage of blockchain adoption, Henrik Karlstrøm calls for more attention to the 'material embeddedness' of Bitcoin, or its connection to specific material and institutional arrangements [5]. This paper relies on development and specification of this approach within technology studies.

Taking the previous research in blockchain studies into account, I counterpose it with factual implementations of roadmaps for Bitcoin and Ethereum. To integrate the history and the genealogy of blockchain into a wider perspective of information and communication technologies, I turn to the “material history of bits” [7], and to the critical study of ‘continuous materiality’ of computer code [3]. Blockchain-related discourse has many features of ‘rupture talk’ [8], and I propose to look at the specific material conditions of decentralization that may have been overshadowed by it.

## 2. The Rigs, the Fees and the Lags of Blockchain Technology

There are many ways to build a blockchain solution today, and most of them do not require dedicated hardware. Still, the initial ‘proof-of-work’ protocol popularized by Bitcoin and the first version Ethereum, involves so-called collective ‘mining’ of a cryptographic hash. The material technology behind blockchain solutions is represented by physical 'rigs' - stacks of equipment for industrial ‘mining’ - and the non-trivial amount of electricity spent on it.

Initially, bitcoins were ‘mined’ on CPUs of personal computers. Since around 2011, mining was mostly performed on dedicated GPUs due to growing complexity of calculations [6]. Some miners’ continued to use GPUs late into 2017, mostly to mine various (and often highly speculative) ‘altcoins’ [1], but production of bitcoins has mostly moved to industrial facilities as early as in 2013 [5].

A basic unit for professional or industrial mining is a dedicated ASIC (Application Specific Integrated Circuit), also simply called a 'miner'. A large farm can have thousands if not hundreds of thousands, of ASICs. As an illustration, a documentary from a cryptocurrency-related YouTube channel VoskCoin invites its viewers to visit one of the biggest farming facilities in the USA, located in North Carolina. Its power is around 100 megawatt, which is comparable to a large data center. Around 90% of the mining equipment is owned by clients who rent the facility. As of 2020, some of them still use GPUs, due to their relatively low cost. [9]. The software company that owns the farm states that it uses 80% renewable energy; however, the magnitude of industrial mining defies the notion of energetic efficiency.

At a certain point in history, industrial ‘mining’ expanded to an almost planetary scale. Same as major data centers and server farms, economic efficiency of big ‘mining’ farms depends on the climate at their location. In addition to that, they gravitate towards cheap sources of energy such as hydroelectric power plants in geologically diverse regions. In the golden days of Bitcoin, a lightweight version of its software could run on any personal computer; now, the principal hardware is to be found among picturesque mountains of China, not far from the controversial Three Gorges Dam. On certain days, the speed of a cryptocurrency transaction literally depends on the weather in China. Mining capacities are regularly damaged by seasonal floods [10], [11]. Although not directly related to material conditions, we should also consider the sociopolitical environment of China, where cryptocurrencies have been effectively banned since 2017 [12], but the state simultaneously heavily invested in blockchain technologies and even designed a state digital currency [13].

The unprecedented energetic cost of Bitcoin validation has led to very material ecological concerns. “You are a miner, you are destroying the world!” - the host of VoskCoin playfully teases the farm keeper in the documentary [9]. The inefficiency of this process is so jarring that Alexander Galloway even compares cryptocurrency farms to the XIX century steam machines “that run on heat and energy” [14]. In his critical essay Anti-Computer, he applies the Marxist perspective to Bitcoin farms, which makes them “essentially large batteries for value” in the same way as the machines used to produce steel or textile: both “burn fuel to release value” (ibid.). Symbolically, the farm visited by VoskCoin occupies several buildings of a former textile factory [9]. This makes Bitcoin rather steampunk than cyberpunk.

## 3. ‘Digital Metallism’: the Semiotic Materiality of Bitcoin

‘Bitcoin mining’ is a primary metaphor used to explain how a cryptocurrency works. This rhetorical tool first appears in the Bitcoin White Paper: “The steady addition of a constant of amount of new coins is analogous to gold miners expending resources to add gold to circulation” [2]. The metaphor defined the language of blockchain adopters for the years to come, spawned countless memes and even influenced narratives of many ‘crypto games’ such as Ether Kingdoms and My CryptoHeroes, which could be considered educational in this regard.

Rhetorically, the metaphor of ‘mining’ has everything to do with material existence and circulation of gold as a metal. Building from Nakamoto’s statements, blockchain aficionados justify the fundamental value of Bitcoin and several other cryptocurrencies by referring to their limited supply and presumable scarcity, and comparing them to the ‘gold standard’. Comparison of Bitcoin to gold is sometimes dramatically reversed, so gold is compared to Bitcoin [15], especially after the recent surge in price of the former.

Such comparisons highlight a specific form of an ‘authentic’ value that also relies on natural scarcity. However, it is problematic to speak about the scarcity of digital tokens that are mined in large quantities on an industrial level, can be divided into almost infinitely small parts and, most importantly, have very little use value outside of professional trading. The problem of ‘fundamental value’ of cryptocurrencies circulates not only in research circles [4], but also in online communities of traders and early adopters. According to their views, Bitcoin, as well as many following cryptocurrencies, derives its value from the computational work put into ‘mining’. Semiotically, mining is “an algorithmic imitation of the limited supply of metallic currencies” such as golden dollar coins [15, p. 72]. Elizabeth Ferry even noticed that the rhetorics of Bitcoin adherents is similar to those who invest in physical gold, especially in their political stance. This principle of value creation in cryptocurrencies has been described as ‘digital metallism’ [6].

Does ‘digital metallism’ make Bitcoin more material? Even though it is a discursive construction, it has real implications in the real world. It creates an additional level of conceptualizing and comprehending blockchains. The current level of public understanding would be impossible without this interpretive discourse.

Blockchain technologies are often seen as too complex and difficult to comprehend. This is often mentioned as the reason for relatively slow adoption, although the absence of actual use cases might be the real reason. However, metaphoric interpretation affects not just the human users and developers of blockchain applications, but also the machines they build, the money they invest, and the code they write. Looking at countless visual and verbal representations of ‘miners’ in online discussions, we cannot simply discard their image as ‘immaterial’, even knowing that the real owners and workers of cryptocurrency farms are nothing like that.

## 4. How ‘Miners’ Became Evil: Blockchain as a Sociotechnical Object

Contrary to its initial ambition as a global currency, the current design of Bitcoin does not allow for scalability, which is an inherent problem of blockchains in general. This failure of the seemingly immaterial code involves not only limitations of hardware, but also existing socioeconomic arrangements. One simple example is storage, even though it is not as obvious as processing power. Hosting full nodes, which would participate in the global verification process, would require more and more storage: as of August 2020, recommended disk space for hosting a full node is 350 Gb [16]. Some voices in the community would point out that the size of a full node would eventually surpass the technical capacities of an ordinary Bitcoin user and leave verification to a dedicated and wealthy few. Exactly this is likely to happen to the second major cryptocurrency, Ether.

The block size problem is the most discussed scalability problem of Bitcoin. The size of a single block that contains records of new transactions is limited to 1 Mb. This limits the number of transactions that can be performed and verified throughout the whole network. A number of solutions have been presented since 2015, but the problem generally remains unsolved due to the lack of consensus between developers, miners, investors and other representatives of the community [17]. Unfortunately, all efforts to establish a democratic procedure for reasonable decision-making in the Bitcoin community were futile.

The impressive scale of the scalability debate does not allow to follow it in this paper, but I would like to draw attention to ‘miners’ who unexpectedly appeared as independent social agents in the dramatic process of Bitcoin infrastructuring [18]. ‘Miners’, or, more specifically, owners of facilities for industrial mining, became important actors behind decentralization after the rapid industrialisation and the following centralization of Bitcoin mining. Also, this is when ‘miners’ became ‘evil’ in ordinary discourse of blockchain adopters.

The initial vision of ‘miners’ among Bitcoin portrays them as agents of digital democracy. Miners not only contribute to the algorithmic consensus on the validity of every next transaction, they also represent the interests of the Bitcoin community, accept or reject the changes to the code. This idea originates in Nakamoto’s writing: as of 2008, he suggested that “proof-of-work also solves the problem of determining representation in majority decision making. If the majority were based on one-IP-address-one-vote, it could be subverted by anyone able to allocate many IPs. Proof-of-work is essentially one-CPU-one-vote” [2]. This idea quickly became outdated as mining moved to GPU rigs and then to industrial-level ASICs, and the computational power was organized in pools. The promise of decentralization has been broken many times since then [19]. Democracy or not, ‘miners’ as social agents can influence decisions about the future of blockchain.

Another event that involves the code, the hardware and the community is the ‘halving’ of Bitcoin. ‘Halving’ is decreasing a reward for mining in half. This is a pre-programmed event that happens after mining every 210,000 blocks. It also raises the ‘fundamental value’ of Bitcoin, as twice more resources are required to mine the same quantity of bitcoins [4]. It usually leads to a noticeable surge in Bitcoin price, although the consequences of mining are unique for each time. The difficulty of mining has been constantly growing since the introduction of Bitcoin, although it can be algorithmically adjusted to match the total mining power. After the reward to miners of Bitcoin had been halved on May 11, 2020, its volatility decreased and difficulty of mining increased [20], which led to concerns about economic unsustainability of ‘mining’. These concerns return every time the price of Bitcoin approaches its ‘fundamental value’, as it was during its crash in December 2018, when mining difficulty temporarily dropped -15% and many miners left the business [21]. Bitcoin still would be impossible to use without the work of miners. This work is becoming less and less rewarding, and relations between the market, the code and the hardware are still far from reaching a long-lasting equilibrium.

## 5. The Challenges of Ethereum

The Ethereum platform, fueled by the most used ‘altcoin’ Ether, arrived in 2015 as a revitalizing solution to realize a variety of use cases on blockchain. It reached the limits of its scalability after 5 years, effectively freezing all activities made possible by a massive and dedicated community of developers. As a response to this situation, in summer 2020, it is moving from proof-of-work, which required miners, to proof-of-stake where transactions are validated by cryptocurrency holders who own stakes worth at least 32 ETH per validator.

The new platform, Ethereum 2.0, postulates energy efficiency as one of its major advantages - finally, ecological concerns were addressed - but it comes at the cost of partial centralization. Now validation of transactions and other matters that require consensus are under control of a limited group of wealthy individuals (32 ETH roughly amounted to USD12,000 since April 2020). The community-written resource EthHub suggests that the proof of stake is fairer than the proof of work: “$10 million of coins will get you exactly 10 times higher returns than $1 million of coins, without any additional disproportionate gains because at the higher level you can afford better mass-production equipment” [22]. This statement represents the platform economy of Ethereum as a ‘fair game’ where everyone is rewarded proportionally to their input. It still remains blind to the fact that the initial distribution of wealth may not have granted most Ether to the most honest, or even the most reasonable individuals.

As such, the proof-of-stake protocol goes against the initial crypto-anarchist beliefs of Bitcoin adopters, because it replaces democracy with plutocracy. This also affects miners on both industrial and ‘artisan’ scale: even before the staking of Ethereum, Calvão suggested that “private-led blockchain-based initiatives based on the stake in the network may push small-scale (crypto) miners and, by extension, artisanal miners out of the system of rewards and incentives in place” [1]. However, it is still presented as a measure against centralization in the discourse of Ethereum supporters, mostly because the proof-of-stake protocol reduces involvement of big ‘mining’ companies in decision-making and safeguards against 51% attacks.

The algorithmic basis of value is also affected. Ethereum 2.0 allows ‘sharding’, or breaking down blocks. It decreases demand for Ether to fuel transactions on Ethereum, which leads to concerns about its artificial scarcity. However, the exchange rate of Ethereum to Bitcoin is on the rise in 2020:

more importantly, Ethereum 2.0 affords passive income by hosting the nodes with the locked value of 32ETH or more, which means more predictable return of investments in the long run.

Finally, let us look at the physical materiality of Ethereum 2.0. Hosting a node requires a server that remains online 24/7. Of course, it can be a rented server, but the usual rhetorics of ‘the cloud’ should not prevent us from remembering that even so-called ‘cloud services’ are not hosted in the thin air. To the contrary, they usually require large scale server farms, as in the case of the leading service from Amazon. Even though such facilities are much more energy saving, they are still basically the same kind of ‘power plants’ as ‘mining farms’.

## 6. ‘Continuous Materiality’ of Blockchain

Exploration of technicalities behind the distributed architecture of Bitcoin, Ethereum and other blockchain solutions may make us wonder whether electronic communications have ever been ‘immaterial’. Computer code does not exist without the hardware to run on, and it also needs people to make use of it. Actions of these people have material consequences in the real world, and this is also the side of blockchain technologies that is somehow underdeveloped due to limited adoption.

Materiality of technology is seen as threefold in studies of technology and society. Firstly, it is material technology behind blockchain solutions: physical 'rigs' and the electricity spent on ‘mining’. Secondly, it is the semiotic level that reveals itself in metaphors like 'mining' ground the code in material reality. Thirdly, practical implementations of blockchain become embedded into active human networks of early adopters, miners, developers, investors and other actors such as researchers (who sometimes go no further than the semiotic level). This corresponds to three definitions of materiality: matter, significance and practical instantiation [23]. The latter, which is the social dimension of materiality, describes how software exists as a part of a social practice that “compels people to follow the abstract plan” [23], for instance, to trade cryptocurrencies as a part of the real-world economy.

‘Continuous materiality’ of electronic communications can be understood as multi-level amalgamation of computer code, human language and physical entities: “a wide spectrum of materiality activated by a hierarchy of codes” [3]. Such assemblages also include social codes of behavior, which becomes visible, for example, when Bitcoin developers blame miners for violating such code in their refusal to update the Bitcoin software. In the end, such arrangements become solidified in the legal code: acknowledgement of cryptocurrencies as a specific type of assets, and, in different areas of application, property rights and personal identification based on blockchain. This is how records on blockchain become hard institutional facts that directly define the rules for the material world.

Eventually, before solidifying the code in legal and institutional relations, it is important to consider the basic level of its (im)materiality. The very real physical matter of decentralized calculations often remains hidden beyond the promise of decentralization. As Blanchette writes, "a focus on materiality highlights that computation is a mechanical process based on the limited resources of processing power, storage, and connectivity" [7, pp. 1042–1043]. These exact resources were exhausted by blockchain technologies in just over 10 years. This is another sad confirmation of Blanchette’s thesis that “Yet we today have neither technical language nor intuition for something akin to the tensility, durability, or density of computing resources” [7, p. 1055]. While decentralized blockchain records can account for great durability, the underlying infrastructure can never ensure the required plasticity and flexibility. Of course, there have always been rightful warnings about exactly this problem: as early as in 2013, Karlstrøm noticed that "the materially embedded features of the currency, such as its reliance on very specific physical technologies, can point towards an underlying tension within the rhetoric behind Bitcoin" [5]. This tension between the material and the discursive reality of blockchain has only intensified during the following five years of public adoption.

Practical implementations of blockchain may rely on problematic assumptions that have more to do with the discourse than with the technology itself. For example, in a much publicized partnership with IBM, the national clearing house of Poland, Krajowa Izba Rozliczeniowa (KIR), developed a blockchain solution for ‘durable medium’ on blockchain [24], even though such records are still much more of a message that may or may not be delivered depending on the state of the network. To prevent unwanted disruptions, developers should consider that “the boundary of software is always affected by the limitation of hardware” [3].

Blockchain technologies are usually presented as ‘disruptive’, which makes the blockchain discourse yet another example of ‘rupture talk’. It is not uncommon in the history of technology when “the sharp breaks proclaimed by elites masked profound continuities”[8, p. 692], and the rupture in fact ‘conjugated’ the same sociotechnical relations it was supposed to abruptly end. The usual promise of cryptocurrencies to ‘bank the underbanked’ has evolved into an abundance of investment schemes for those who already had, or were lucky enough to quickly acquire, enough ‘digital wealth’ to invest.

Metaphors are an excellent tool to understand new technologies and to form meaningful connections with them. However they should not replace the material reality that makes them work. For example, the metaphor of ‘cyberspace’ influences the way we envision the internet, sometimes in a confusing way. “‘Cyberspace’, in this sense, is conceived of as both an ethereal alternate dimension which is simultaneously infinite and everywhere (...), and as fixed in a distinct location, albeit a non-physical one

(...)" [25, p. 179]. Such a view remains blind to the physical infrastructure of electronic networks, which is costly and often vulnerable. Another example is the discourse of ‘regulating cyberspace’, against which so many early blockchain adopters have argued, - and yet, the blockchain-related discourse never acknowledges the fact that blockchain platforms function within the existing (or non-existent, or temporarily unavailable) material infrastructures of the internet.

## 7. Conclusion

Does decentralization mean dematerialization? Could it be that, by taking the blockchain agenda at face value, we are following the same path as with still unfulfilled promises of ‘cyberspace’? Constraints and affordances of software can shape the material world “in much the same way as physical artifacts do” [23]. Software is nothing without hardware, and decentralization does not free the participants of an electronic network from material constraints. It merely obfuscates the role of hardware and material expenditures such as the cost of electric energy.

The material aspect of digital currencies is well represented in ‘digital metallism’. Images of mining rigs resting under buzzling coolers represent the materiality of Bitcoin and allow to treat it as authentic ‘digital gold’. However, time has shown that ‘digital metallism’ does not guarantee the future of digital currencies. Integrity of the network and authenticity of records on blockchain can be safeguarded by a sheer amount of computational power, but this is still not enough to impose integrity on the community or create value beyond expenditures.

After all, blockchain networks are only a superficial layer over the existing internet infrastructure, Due to their unprecedented speed, electronic communications were expected to overcome the limitations of time and space, but laborious verification of data and the need to update it at each node have brought these limitations back into the equation. Almost unsolvable scalability issues are the final reminder about the fundamental fact that blockchain technologies are never ‘synchronous’, but inherently ‘historical’. While the data kept and transferred on blockchain is discrete, the time to calculate and verify the results is continuous, and usually very long. As a result, operations on blockchain tend to slow down to an almost full halt, as in the case of Ethereum, especially when ‘mining’ is a part of the process. Furthermore, blockchain platforms are simultaneously electronic and social networks, which brings interactions between embodied, and often very passionate, human agents into the equation. To avoid inefficiency and stagnation, developers and investors should not forget about material limitations of immaterial blockchains. The revolutionary and disruptive potential of electronic communications should be evaluated by taking technological, semiotic and social aspects into account.

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