Nicolae Sfetcu

Philosophy of Blockchain Technology: Ontologies

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Abstract

In this paper I argue the necessity and usefulness of developing a philosophy specific to the blockchain technology, emphasizing on the ontological aspects. After an *Introduction* that highlights the main philosophical directions for this emerging technology, in *Blockchain Technology* I explain the way the blockchain works, discussing ontological development directions of this technology in *Designing* and *Modeling*. The next section is dedicated to the main application of blockchain technology, *Bitcoin*, with the social implications of this cryptocurrency. There follows a section of *Philosophy* in which I identify the blockchain technology with the concept of heterotopia developed by Michel Foucault and I interpret it in the light of the notational technology developed by Nelson Goodman as a notational system. In the *Ontology* section, I present two developmental paths that I consider important: *Narrative Ontology*, based on the idea of order and structure of history transmitted through Paul Ricoeur's narrative history, and the *Enterprise Ontology* system based on concepts and models of an enterprise, specific to the semantic web, and which I consider to be the most well developed and which will probably become the formal ontological system, at least in terms of the economic and legal aspects of blockchain technology. In *Conclusions* I am talking about the future directions of developing the blockchain technology philosophy in general as an explanatory and robust theory from a phenomenologically consistent point of view, which allows testability and ontologies in particular, arguing for the need of a global adoption of an ontological system for develop cross-cutting solutions and to make this technology profitable.

Keywords: philosophy, blockchain, blockchain technology, ontologies, bitcoin

Introduction

The Internet has completely changed the world, people's culture and customs. After a first phase characterized by the free transfer of information, concerns have arisen about the security of online communications and the confidentiality of users. Blockchain technology (BT) ensures both these goals. BT, relatively new, has the chance to produce a new revolution, fully justifying a philosophical investigation.

The first blockchain was conceptualized by Satoshi Nakamoto in 2008, using a method that excludes an authorized third party. (Narayanan et al. 2016) In 2009, Nakamoto developed Bitcoin, used as a public register for network transactions. (The Economist 2015)

Starting with 2014, new technology applications (Nian and Chuen 2015) known as *blockchain 2.0* have been developed for more sophisticated smart contracts that share documents or automatically send owners' dividends if profits reach a certain level. In *Philosophical Engineering: Toward a Philosophy of the Web*, Halpin and Monnin discussed some philosophical aspects of this emerging technology, (Halpin and Monnin 2014) such as the relationship between the physical world and the virtual world, the individual and society, the concepts of materiality, temporality, space and possibility. (Institute for Blockchain Studies 2016) We can ask ourselves, ontologically, what this technology is, how it can be characterized, how it is created, implemented and adopted, and how it works; definitions, classifications, possibilities and limitations. From an epistemological point of view, we are concerned about what knowledge can be gained through BT, how it is in relation to reality, what knowledge involves the use of technology, etc. We are also interested in how BT can be exploited, which aspects allow an assessment, what behavioral norms involve, aesthetic and moral aspects involved in the use of this technology. The philosophy of BT can be seen as a conceptual resource for understanding these developments in our modern world.

(Swan and Filippi 2017) Conceptual metaphors can help us approach and understand new ideas. (Lakoff and Johnson 2003)

Blockchain Technology

Blockchain, (The Economist 2015) (D. Z. Morris 2016) (Popper 2017) initially called chain of blocks (Brito and Castillo 2016) (Trottier [2013] 2018) is a growing list of records called blocks, communicating with each other by cryptographic messages. (The Economist 2015) Each block contains a cryptographic hash of the previous block, (Narayanan et al. 2016) a time stamp and transaction data.

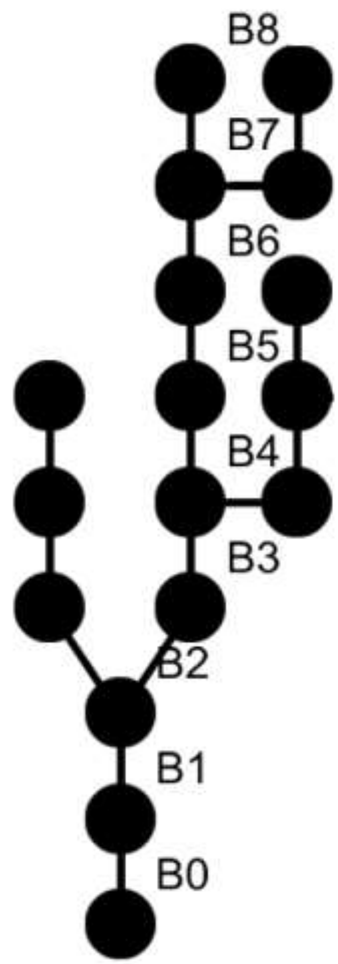

Figure 1 Forming the block chain in the form of the Merkle tree. The main chain (B0 ... B8) consists of the longest series of blocks starting from the initial block (B0) to the current block (B8). All other blocks are orphan blocks that are outside the main chain

By design, a blockchain is "an open, distributed ledger that can record transactions between two parties efficiently and in a verifiable and permanent way", (Iansiti and Lakhani 2017) usually managed by a peer-to-peer network adhering to a protocol for node communication and validation of new blocks. After recording, the data in each block it cannot be modified retrospectively without changing all subsequent blocks, which requires network consensus. Blockchain can be considered a secure design system, distributed, with high error tolerance. (Raval 2016) Block cryptography uses public keys. (Brito and Castillo 2016) Private keys allow owners to access their digital assets or the ability to interact within the blockchain. (The Economist 2015)

Each node in a system has a copy of the blockchain. (Raval 2016) There is no central "official" copy, and no "trustworthy" user more than any other. (Brito and Castillo 2016) Mining nodes validate transactions, (Tapscott and Tapscott 2016) adds them to the block they are building and then spreads the block to other nodes. (Bhaskar and Chuen 2015) Blockchain uses various timestamp schemes, such as proof-of-work, to serialize the changes. (Gervais, Karame, and Capkun 2015)

Other emerging blockchain applications include e-government, such as Bitnation, (Allison 2015) initiatives for citizens involvement and new forms of democratic participation such as D-Cent (D-Cent 2015) and digital platforms for creating diverse decentralized applications, such as Ethereum platform. (Wood 2014) Blockchain technology is considered to have a particularly important contribution to the future transformation of organizations, democratic governance and human culture as a whole. (Tapscott, Tapscott, and Cummings 2017)

According to statistics synthesized by the World Economic Forum, interest in the blockchain has expanded globally, (WEF Financial Services 2016) nearly 30 countries are currently investing in blockchain projects.

There are three types of blockchains - public (no access restriction), private (access based on invitation by network administrators, participants and validators are restricted), and consortium (semi-decentralized, with limited chain access)

Design

Ontology engineering, (Smith 2004) along with semantic Web technologies, allow the semantic development and modeling of the operational flow required for blockchain design. The semantic Web, in accordance with W3C, "provides a common framework that allows data to be shared and reused across application, enterprise, and community boundaries" (W3C 2013) and can be seen as an integrator for various content, applications and information systems. Tim Berners-Lee had the first vision of data network power (Berners-Lee 2007) processed by machines: (Berners-Lee 2004)

> “I have a dream for the Web [in which computers] become capable of analyzing all the data on the Web – the content, links, and transactions between people and computers. A Semantic Web , which should make this possible, has yet to emerge, but when it does, the day-to-day mechanisms of trade, bureaucracy and our daily lives will be handled by machines talking to machines. The intelligent agents people have touted for ages will finally materialize.” (Berners-Lee 2000)

Metadata and semantic Web technologies have allowed the application of ontologies for the provenance of knowledge. Computational ontology research can be useful at the economic level (including for companies), socially, and for other researchers, contributing to the development of specific applications. (Kim and Laskowski 2016)

Many researchers regard computational ontology as a kind of applied philosophy. (Tom Gruber 2008) In the paper "*Toward Principles for the Design of Ontologies Used for Knowledge Sharing*," Tom Gruber delivers a deliberate definition of ontology as a technical term in the field of informatics. (Thomas Gruber 1994) Gruber introduced the term as a specification of conceptualization:

> "An ontology is a description (like a formal specification of a program) of the concepts and relationships that can exist for an agent or a community of agents. This definition is consistent with the usage of ontology as set-of-concept-definitions, but more general. And it is certainly a different sense of the word than its use in philosophy." (Tom Gruber 1992)

To distance ontologies from taxonomies, Gruber said: (Tom Gruber 1993)

> "Ontologies are often equated with taxonomic hierarchies of classes, but class definitions, and the subsumption relation, but ontologies need not be limited to these forms. Ontologies are also not limited to conservative definitions, that is, definitions in the traditional logic sense that only introduce terminology and do not add any knowledge about the world (Enderton, 1972) . To specify a conceptualization one needs to state axioms that do constrain the possible interpretations for the defined terms." (Tom Gruber 1993)

Feilmayr and Wöß have refined this definition: "An ontology is a formal, explicit specification of a shared conceptualization that is characterized by high semantic expressiveness required for increased complexity." (Feilmayr and Wöß 2016)

One of the most elaborated ontologies in this regard is the ontology of traceability (Kim, Fox, and Gruninger 1995) which helped to develop the TOVE ontologies for enterprise modeling (Mark Stephen Fox and Grüninger 1998) considered as the main source for blockchain design.

Blockchain design is based on the fundamental principles of the Internet architecture: survival (Internet communications must continue despite network or gateway loss), variety of service types (multiple types of communications services), variety of networks (multiple types of networks), distributed resource management, profitability, ease of hosting, and responsibility in resource use. (Hardjono, Lipton, and Pentland 2018)

Models

The most widely used blockchain modelling system, by abstract representation, description and definition of structure, processes, information and resources, is the enterprises modelling. (Leondes and Jackson 1992) Enterprise modelling uses domain ontologies by model representation languages. (Vernadat 1997)

Based on component-based design, blockchain ontology decomposes blocks into functional or logical individual components, and identifies the possibilities, assisting in designing, implementing, and measuring the performance of different block architectures. (Tasca and Tessone 2017) According to Paolo Tasca, the methodological approach is basically composed of the following steps:

1. Comparative study of different blocks: vocabulary and term analysis to solve ambiguities and disagreements

2. Definition of the framework: identification and classification of components, defining a hierarchical ontology
3. Categorization of levels: Different aspects are introduced and compared for components from the lowest level of the hierarchical structure.

Like any ICT technology, a blockchain is driven by the fundamental principles of data decentralization, transparency, security and confidentiality. (Aste, Tasca, and Matteo 2017) Other fundamental features of blockchain include data automation and data storage capability.

According to Fox and Gruninger, from a design perspective, a business model should provide the language used to explicitly define an enterprise. (Mark Stephen Fox and Grüninger 1998) From the perspective of operations, the enterprise modelling must be able to represent what is planned and what has happened, and provide the information and knowledge needed to support operations. (Mark Stephen Fox and Grüninger 1998) Functions are modeled through a structured representation (FIPS PUBS 1993) a graphical representation in a field defined to identify information needs, identify opportunities and determine costs. (Department Of Defense (DOD) Records Management (RM) 1995) Other perspectives may be behavioral, organizational, or informational. (Koskinen 2000)

An appropriate blockchain functional modelling focuses on the process, using four symbols for this purpose:

- Process: Illustrates the transformation from input to output.
- Storage: Collecting data or other material.
- Flow: Moves data or materials into the process.
- External entity: External to the modelling system but interacting with it.

A process can be represented as a network of these symbols. In Dynamic Enterprise Modeling (DEMO), for example, a decomposition is done in the control model, function model, process model, and organizational model.

Data modelling uses the application of formal descriptions in a database. (Whitten, Bentley, and Dittman 2004) The data model will consist of entities, attributes, relationships, integrity rules and object definitions, being used to design the interface or the database.

Bitcoin

Bitcoin is the main peer-to-peer and digital currency payment system that uses blockchain technology. Bitcoin network features: (Calvery 2013)

- There is no central server, the Bitcoin network is peer-to-peer.
- There is no central repository, the Bitcoin registry is distributed.
- The register is public, anyone can store it on your computer.
- There is no administrator, the registry is maintained by a network of equally privileged miners.
- Anyone can become a miner.
- Additions to the registry are maintained through competition. Until a new block is added to the registry, it is not known which miner will create the block.
- The bitcoin emission is decentralized. These cryptocurrencies are issued as a reward for creating a new block.
- Anyone can create a new Bitcoin address (a bitcoin correspondence of a bank account) without the need for approval.
- Anyone can send a transaction on the network without the need for approval, the network only confirms that the transaction is legitimate.

Researchers have highlighted a "centralization trend": on the one hand, Bitcoin miners join large mining bases to minimize their revenue variation. (Böhme et al. 2015, 215–22) On the other hand, a Bitcoin "aristocracy" was formed as a result of the architecture of the code; the members of this aristocracy are those who entered Bitcoin early on.

Nigel Dodd argues in *The Social Life of Bitcoin* that the essence of Bitcoin's ideology is to take the money out of social control, including the government, there is even a Bitcoin Statement of Independence. The statement includes a message of crypto-anarchism with the words: "Bitcoin is inherently anti-establishment, anti-system, and anti-state. Bitcoin undermines governments and disrupts institutions because bitcoin is fundamentally humanitarian." (von Hayek 1976)

David Golumbia states that the ideas that influence Bitcoin supporters appear from the right-wing extremist movements and their anti-central bank rhetoric, or, more recently, the libertarianism of Ron Paul and the Tea Party. (The Economist 2018)

Kroll et al. argue that Bitcoin's ecology will need governance structures to survive, (Kroll, Davey, and Felten 2013) already showing signs of emerging governance structures. These modes of government can be based on consensus and, if leadership opposes, the community can choose another course. Beyond that, recent developments have shown that a single mining pool could contribute so much to Bitcoin's computational processes that it could effectively control the whole system, putting an end to its decentralized structure. (Kostakis and Giotitsas 2014)

Bauwens and Kostakis argue that Bitcoin is not a community-based project, but a currency that reflects a new type of capitalism - "distributed" capitalism (Kostakis, Bauwens, and Niaros 2015) based on the liberal political ideology advocating the elimination of the state in favor of individual sovereignty. In practice, what is being achieved is concentrated capital and centralized governance.

Vasilis Kostakis and Chris Giotitsas also consider that Bitcoin exemplifies a type derived from "distributed capitalism" (Kostakis and Giotitsas 2014) although it should rather be seen as a technological innovation.

Philosophy

Donncha Kavanagh and Gianluca Miscione introduced the concept of digital heterotopia[1] as a way to describe and analyze the special and evolutionary relationship between contemporary state and digital money, including block-based cryptocurrencies. (Miscione and Kavanagh 2015)

State features are affected by the connection with digital coins. Social systems create their own limits and remain alive according to their internal logic, which does not derive from the system environment. So, social systems are operationally and autonomously closed - interacting with their environment and there is a general increase in entropy, but individual systems work to maintain and preserve their internal order. Autopoietic systems (like the state, with the tendency to maintain the inner order with a remarkable degree of independence from the outside world) may contrast with allopoietic ones. It results in a state with a finite influence area, but recently troubled by the new forms of digital money and the corresponding infrastructure.

In general, the current world is polarized politically, with very few exceptions. New monetary systems, such as cryptocurrencies, fall within these exceptions, with the tendency to decouple from the state.

Satoshi Nakamoto, in designing the most powerful cryptocurrency, has in fact considered an imaginary world populated by individuals who do not trust each other. According to the

[1] Heterotopia is a concept developed by philosopher Michel Foucault to describe some cultural, institutional and discursive spaces that are in a different way: disturbing, intense, incompatible, contradictory, or transforming. Heterotopias are worlds in worlds, which at the same time mirror and still disturb those outside.

ideology of freedom, one of the key objectives was to avoid any authority. The solution was Bitcoin, a variant that disturbs all current formal infrastructures.

Foucault used the idea of heterotopia to identify where hegemonic rules and constraints are not applied. He first used the term to describe spaces with multiple meanings (Foucault and Miskowiec 1986) which reflect other spaces, identifying different types of heterotopias. Blockchain manifests these attributes of heterotopia at the digital level. Blockchain is a growing element of "cyber space" that has already been identified as a form of heterotopia, (Young 1998) but it also has particular traits.

In the blockchain system we find the separate and opposable categories of heterotopias: the center and periphery, the interior and exterior, foreign and local, etc. In this space, "libraries" and "museums" as a heterotopic type function with "unlimited accumulation time". (Foucault and Miskowiec 1986, 26) So, the blockchain functions according to a similar logic.

Heterotopic spaces avoid the rules and structures established in favor of alternative social order processes that do not limit imagination, alterity and difference.

Digital technologies can also be interpreted as notational technologies, respectively a syntactic notation in a reference field, a technology version of what Nelson Goodman called a "notational system". (Dupont 2017) Notational technologies produce abstract entities through positive and reliable tests, or constitutive tests of socially acceptable sense. Consequently, blockchain technologies are effective in managing digital assets, because they produce abstract identities through scoring performance. Digital technologies create representations by abstracting complex object properties and then using these newly formed identities to control and manage entities. This process is then used to control and manage "real" entities. More recently, these technologies can control and manage real people and goods, relying on their ability to abstain and manage their identities.

Goodman believes that: "A system is notational, then, if and only if all objects complying with inscriptions belong to the same compliance class, and we can, theoretically, determine that each mark belongs to, and each object complies with inscriptions of, at most one particular character." (Goodman 1968, 156) Codes, such as binary code, machine code, and software code, are considered to be a kind of writing. There is an ontological gap between alphabetical scripting (human code) and Javascript (code for computers). But there is a simple and smooth translation between Javascript and the binary code (apparently the "language" used by computers).

Blockchain technology is an artifact of the asynchronous interaction of a network of thousands of independent nodes with simple and algorithmic rules to accomplish a multitude of financial processes. (Antonopoulos 2014, 177)

Ontologies

Social ontology is concerned with the nature of the social world, constituents, or building blocks of social entities in general. Some theories claim that social entities are built from people's psychological states, others are built up of actions, others from practice, and other theories deny that even a distinction can be made between social and non-social. One of the ways to clarify assertions about building social entities is to use different forms of the supervenience[2] relationship. An advantage of the supervenience relationship is that it allows relatively easy articulation of important distinctions in precise ways. But there may also be well-known shortcomings regarding the relationship of supervenience. (Fine 2001) Various other relationships besides supervenience,

[2] Supervenience is a relationship between sets of properties or sets of facts. It is said that X supervene on Y if and only if a distinction is required in Y so that any distinction in X is possible.

including identity, parties, merger, aggregation, membership, constitution, and substantiation, can be discussed for the social blocks of the social world. (List and Pettit 2011)

Narrative ontologies

For Paul Ricoeur[3], there is an order and a structure of history transmitted through the narration of history, otherwise the history would be unintelligible. But the events and facts of this narrated history disrupt the dominant order and reorder it.

Ricoeur has examined a number of different forms of extended speech, starting with metaphorical discourse. Narrative discourse is one of the forms investigated by Ricoeur, (Pellauer and Dauenhauer 2002) setting up heterogeneous concepts that identify actions at a time when something happens not only after something else, but also because of another thing from a story or history that can be followed. It reforms physical events as narrative events, which make sense because they say what happens in a story or history. The narratives are always a synthesis of the heterogeneous concepts that configures storytelling episodes.

In *Time and Narrative*, Ricoeur emphasized the importance of the idea of a narrative identity. (Ricoeur 1988) Ricoeur's argument on individualization continues through a succession of stages. It starts from the philosophy of language and from the problem of identifying the reference to persons as individuals themselves, not just things. This leads to the consideration of the speaker as an agent, passing through the semantics of the action that Ricoeur had learned from

[3] Paul Ricoeur was a French philosopher preoccupied with philosophical anthropology in the tradition of French reflective philosophy. Ricoeur concluded that, in order to properly study human reality, the phenomenological description should be combined with the hermeneutical interpretation, thus developing a theory of interpretation that could be grafted on phenomenology. While philosophical language always pursues univocal concepts, the language actually used is always polysemic, so all language uses necessarily require interpretation. In his later work he put an increasing emphasis on the fact that we live in time and history. (Pellauer and Dauenhauer 2002)

analytical philosophy. Then comes the idea that the self has a narrative identity. (Pellauer and Dauenhauer 2002)

The narrative paradigm is a theory of communication conceptualized by Walter Fisher, (Fisher 1984) which states that all significant communication takes place by telling or reporting events. Stories are more convincing than arguments. Stories have the power to include the beginning, middle, and end of an argument. (Rowland 1988)

Narrative rationality requires consistency and fidelity. (Dainton and Zelley 2011) Narrative coherence is the extent to which a story makes sense. Narrative fidelity is the extent to which a story fits into the prior understanding of the observer. The narrative paradigm is generally considered an interpretive theory of communication. (Spector-Mersel 2010)

Wessel Reijers and Mark Coeckelbergh describe ontologically the technology with reference to the ever-growing digital chain, which contains transaction records. (Reijers and Coeckelbergh 2018) The blockchain is made up of the programming code as a sequence of symbols that can be read by the computing devices. This code has a significant human and socio-institutional dimension. John Searle offers an ontological theory of social reality that explains the similarity between the law and the programming code, indicating their linguistic origin. The origin of certain artificial phenomena, called institutional deeds, is traced back to the linguistic entities called statements of status functions. (Searle 2010, 13) The linguistic act of the agreement (speech act) results in a new reality: (Searle 2006, 69) it gives the agreed party a new set of digital rights and duties, the constitutive rules defining the ontology of the ICT environment. (Reijers and Coeckelbergh 2018)

Declarations on status functions include both internal aspects (linguistic aspects, sentences) as well as illustrating aspects (extra-linguistic aspects: intentional states such as beliefs and desires). Thus, if we declare something, we can create an ontological reality while we want it to happen. (Searle 2006, 112)

In the case of blockchain technology, the individual act of trading a quantity of cryptocurrency depends on the collective intentionality of this act, and a collective consensus is needed to make the system work. (Nakamoto 2008, 8)

Wessel Reijers and Mark Coeckelbergh consider post-phenomenological theories in the philosophy of technology about the role of technological mediation and social studies of science and technology (mapping social networking groups or human and non-human actors) to analyze blockchain technology by conceptualizing the type of relationship which he represents between the subject and his world. Thus, the development of technologies such as Bitcoin indicates a policy understood as an interaction between social discourses and social imaginations.

There are different philosophical views on how the ontological significance of narrative can contribute to our understanding of the social world and the way in which social reality is modeled. Some researchers consider that narrative is an instrumental cognitive skill or linguistic tool, while others regard it as an ontological category related to how people exist in the world (Meretoja 2014, 89) or understand human life as a narrative. (MacIntyre 2007, 114) Another theoretical division of the role of the narrative exists between an empirical tradition denouncing the narrative as a fundamental philosophical concept (Strawson 2004) and a hermeneutical tradition rejecting the idea of a narrative-free experience and claims that all representations of the human social world are mediated by the human linguistic interpretation (Taylor 1971, 4) that subjectivity is always mediated by language, signs, symbols and texts. (Meretoja 2014, 96) Thus narrative should be understood as a fundamental ontological aspect of human social reality.

Narrative ontology can be used to study the different aspects of our social world. Ricoeur characterizes narratives as cultural phenomena and explains why narratives can outline our social reality: because it configures narrative portions that recreate social events (Borisenkova 2010, 93) and thus renews our social reality. Organizing the narrative structure helps us to understand the social world, but at the same time understanding the social world is the basis of any new narrative structure.

David Kaplan established a connection between Ricoeur's work and the philosophy of technology. He suggests that Ricoeur's hermeneutical method as well as the hermeneutic circle analysis between human experience and narrative can be fruitful in technology discussions, (Kaplan 2006, 43–44) as these elements can enrich the analysis of technological mediation by including the notion of linguistic and social mediation.

Blockchain technology and narrative-constructed monetary technologies do not organize people and interactions directly with each other, but rather quasi-characters (e.g., addresses, exchange houses) and quasi-events (e.g., transactions) in quasi-plotting (e.g., mining a block). (Ricoeur 1990, 181)

Enterprise ontologies

Enterprise ontology for blockchain transactions includes datalogical, infological and essential levels. OntoClean (Guarino 1998) developed by Nicola Guarino and Chris Welty (Guarino and Welty 2000) analyzes ontologies based on formal, domain-independent properties (metaproperties), being the first attempt to formalize the notion of ontological analysis for computer systems. The notions are extracted from the philosophical ontology. In the semantic web, a property is a binary relationship, with a subtle distinction between ownership and class. Thus, a metaproperty is a property of a property or a class.

Identity for the ontologies of computer systems includes conceptual modeling of the database, especially those that expose the existence or at least the need to represent other entities. In OntoClean, identity criteria are associated with, or carried by a class whose instances are identified in the same way, called *sortal*. Identification criteria and sortals are intuitively designed to respond to the linguistic way of associating identity with certain classes.

The design of ontology can be done when there is a basic understanding of the blockchain analysis. Blockchain comes in three forms: public, private or hybrid. (Buterin 2015) Blockchain ontology should also refer to the operations and business processes of potential adopters. Enterprise ontology provides a collection of relevant terms and definitions of natural language. Examples of frameworks for enterprise ontology are TOVE, EO and DEMO. (Kruijff and Weigand 2017)

TOVE, the acronym of the *TOronto Virtual Enterprise* project, is a project for an ontological framework for enterprise integration based and tailored for enterprise modeling. (Totland 1997) The initial objectives of the project were: (M.S. Fox 1992)

Creating a distributed representation or an ontology of the enterprise that every agent in the distributed enterprise can understand and use

- Defining the meaning of all descriptions or semantics
- Implementing semantics into a set of axioms that will allow TOVE to automatically answer to many "common sense" questions about the enterprise, and
- Defining a symbol system to represent a concept in a graphical context.

The project develops a set of integrated ontologies for modeling enterprises. Ted Williams states that it is "multi-level, spanning conceptual, generic and applications layers. The generic and applications layers all also stratified and composed of micro theories spanning, for example, activities, time, resources, constraints, etc.” (Williams 2000)

Fox et al. presented TOVE enterprise models as a second-generation knowledge engineering approach. An approach to first generation knowledge engineering "is extracting rules from experts, while second generation is ontology engineering: They develop comprehensive ontologies for all the aspects of an organization they find necessary (necessity is decided based on competency requirements to the model, i.e., what are the questions the model will have to answer, either by ordinary look-up or by deduction). The background of TOVE is clearly knowledge engineering and to some degree Computer Integrated Manufacturing." (M.S. Fox 1992)

A business modeling methodology for transactions and the analysis and representation of business processes that provide a coherent understanding of communication, information, action and organization was developed in the 1980s by Jan Dietz and is inspired by the perspective language/action introduced in the field of computer science and computer systems design by Fernando Flores and Terry Winograd in the 1980s: (Flores et al. 1988) Design and Engineering Methodology for Organizations (DEMO). (J. L. G. Dietz 2001)

DEMO is based on explicitly specified principles characterized by a rigid modeling methodology (Van Nuffel, Mulder, and Van Kervel 2009) and focuses on building and operating a system rather than on functional behavior. It underlines the importance of choosing the most effective level of abstraction to establish a separation of problems. (Nian and Chuen 2015) DEMO has proven to be a useful methodology to formalize systems that are ambiguous, inconsistent or incomplete, especially when it comes to reducing the complexity of modeling (Wang, Albani, and Barjis 2011) enterprise ontology. (Kruijff and Weigand 2017)

The methodology provides a coherent understanding of communication, information, action and organization, and is based on the following principles: (J. Dietz 1996)

- An organization consists of people with authority and responsibility to act and negotiate.
- Information systems and business processes design leads to uniformity.
- The models should be understandable for everyone interested.
- Information needs to match their users.

This concept has proven to be a new paradigm for the design of information systems, highlighting what people do while communicating, reality through language, and how communication brings a coordination of their activities. (Dignum and Dietz 1997)

DEMO is related to the Natural Language Information Analysis Method (NIAM) developed by Shir Nijssen (Aaldijk and Vermeulen 2001) and Object Role Modeling (ORM) (J. L. G. Dietz and Halpin 2004).

The ontological model of an enterprise in DEMO consists of an integrated set of four layout models, each with a specific vision of the enterprise:

- Construction Model (CM): composition, environment, interaction structure and interstriction structure
- Process Model (PM): the state space and the transition space of its coordinating world
- Action Model (AM): a set of action rules; and
- Factual Model (FM): the state space and the transition space of its production world

An important development in the history of databases was the separation of implementation options from the conceptual model of the database (principle of data independence). A similar separation is very necessary for the blockchain domain. An axiom of distinction of enterprise ontology can be adopted as an ontological basis for this separation. (Kruijff and Weigand 2017)

Enterprise ontology distinguishes three basic human abilities: performa (bringing new things through communication), informa (content aspects of communication and information) and forma (aspects of the form of communication and information). (J. L. G. Dietz 2006)

Following the three abilities, we distinguish three ontological layers: (Kruijff and Weigand 2017) datalogical (describes blockchain transactions at the technical level in terms of blocks and code), an infological abstraction (to describe blockchain transactions as the effect of an open (immutable) register system), and essential (to describe the economic significance of infological transactions). The datalogical level is the level of data structures and data manipulation, using taxonomies identified in the cryptocurrency, (Glaser and Bezzenberger 2015) blockchain research (Christidis and Devetsikiotis 2016) and blockchain technologies and cloud providers. (Gray 2016)

Unified Modeling Language (UML) of Object Management Group, along with Object Constraint Language (OCL), (Purvis and Cranefield 1999) are considered by Joost de Kruijff and Hans Weigand as the best fit for blockchain ontology. (de Kruijff and Weigand 2017) OCL is a declarative language that describes the rules applicable to UML models and is part of the UML standard. Initially, OCL was just an extension of the formal specification language for UML. (Object Management Group 2000) Now, OCL can be used with any meta-model. (Object Management Group 2006) OCL is a precise text language that provides constraint expressions and query objects on any specific model or meta-model that cannot be expressed otherwise by schematic notation. OCL is a major component within the new standard recommendation for model transformation.

OCL is an analysis and design method resulted from a previous second-generation object-oriented method. OCL includes:

1. a context defining the condition when the statement is valid

2. a property of context features (for example an attribute if the context is a class)
3. an operation handling or qualifying a property; and
4. keywords for conditional expressions.

Joost de Kruijff uses OCL for datalogical blockchain ontology (de Kruijff and Weigand 2017) where wallet (that initiates transactions on the blockchain and receives the result), transaction (a request to nodes containing an entry, an amount and an exit, or custom data), and node (an entity to prove or validates and adds transactions to a block using a unique hash, being rewarded for each successful transaction) are most important components of this ontology. In the taxonomy for the ontological structure of a chain, Joost de Kruijff and Hans Weigand distinguish several objects.

Langefors distinguished between information (as well as knowledge) and data (as representation), (Goldkuhl 1995) creating a new field in knowledge engineering called infology, for the administration of complicated structures. (J. L. G. Dietz 2006) Blockchain as a "distributed register" is an infological characterization. A registry consists of accounts. Transactions must comply with trading rules. For each transaction the entry is equal to the output. (de Kruijff and Weigand 2017)

Essential or business level refers to what is created directly or indirectly through communication. In the Language/Action Perspective, (Narayanan et al. 2016) the key notion in communication is commitment as a social relationship based on the common understanding of what is right and true, a change of social reality. (de Kruijff and Weigand 2017)

Enterprise ontology is combined with the business ontology of Resources, Events, Agents (REA) to be used for the content of the change (Huňka and Zacek 2015) REA was originally proposed in 1982 by William E. McCarthy as generalized accounting model. (McCarthy 1982)

REA can add value when shaping current ERP business processes, providing an useful tool for understanding. (Fallon and Polovina 1982)

REA sees the accounting system as a virtual representation of the real business. REA is an ontology, with the following real objects included in the model:

- Resources: goods, services, or money
- Events: business transactions or agreements affecting resources
- Agents: people or other human agents (companies, etc.)

REA philosophy is based on the idea of reusable design patterns, although REA models are used to describe databases.

In ontology-based modeling, conceptualization is the set of ontologies needed to ensure common interpretation of data from one or more databases. If blockchain modeling is a specialized form of inter-enterprise modeling based on ontology results in a blockchain with improved interpretability. (Kim and Laskowski 2016)

- For informal or semi-formal ontologies, can lead to improvement of database standards as well as business practices and processes.
- For formal ontologies, can help with the formal specification of automatic inference and verification.

In the formal ontology approach, the description is very similar to the definition of smart contracts as "pieces of software that represent a business arrangement and execute themselves automatically under pre-determined circumstances." (The Economist 2016)

The REA model developed of Bill McCarthy (McCarthy 1982) can be used in accounting. The accounting perspective is appropriate in the context of the blockchain. (de Kruijff and Weigand 2017)

Since the blockchain transaction refers to events that trigger changes in economic reality, REA is perceived as more suitable for the baseline analysis than DEMO, which is more appropriate for coordinating these events, which is less important for the blockchain.

REA includes the concept of a *contract* as a package of mutual commitments, through transactions and commitments, where some of the engagements are executed automatically. (Szabo 1997)

Referring to REA processes, it can be said that planning (creating a smart contract) and allocation of input resources (output events) materialize on the blockchain, while executing the contract by exchange and conversion (in a smaller extension) triggers output resources (input events) that could go beyond the blockchain, even for physical entities, such as, for example, IoT devices. (de Kruijff and Weigand 2017)

The accounting approach is appropriate for blockchain. The transactions trigger changes in economic reality, so REA is more suitable for the baseline analysis than DEMO, which is more appropriate for coordinating these events (less important). (Kruijff and Weigand 2017)

For REA the contract is seen as a mutual commitment. The smart contract supposes that some of the engagements are executed automatically. (Szabo 1997) Transactions and commitments are made with sets of infological transactions, and fulfillment is accomplished through a transfer from the engagement account. (Kruijff and Weigand 2017)

Planning in REA processes for a smart contract, and allocation of resources and events materialize on the blockchain, while executing the contract triggers resources and events that could go beyond the blockchain.

Conclusions

Blockchain technologies have ontological status specific to emerging web technologies, offering new insights compared to what we know as reality. Blockchain technologies do not work autonomously and discreetly, but intertwined with many other aspects of our conceptions of reality, both physically and virtually. Blockchain technologies extend the aspects of our existence and our ability to shape and create reality. It follows that blockchain is not just a new technology, but even a new type of technology, it can be an innovative and fundamental way of configuring reality. (Swan and Filippi 2017)

The first step in adopting technology was the financial industry by trading bitcoin cryptocurrency. But global payments are only a fraction of the global financial industry use cases. Blockchain technologies can open a new era in IT development and financial transactions, affecting other areas such as IoT, consumer electronics, insurance, energy, logistics, transport, media, communications, entertainment, healthcare, automation and robotics. (Tasca and Tessone 2017) Blockchain technology will allow for an evolution on a higher level of the IoT concept. Tapscott and Tapscott (Tapscott, Tapscott, and Cummings 2017) claim that this new Tutorial Internet will need a Register of All Things and a digital processing system that can be provided by blockchain cryptography. By combining BitTorrent peer-to-peer file sharing with public key cryptography, blockchain technology can also be used to record almost everything that can be expressed in code: birth and death certificates, marriage permissions, property titles, financial accounts, medical records, votes, records of origin, etc. (Kim and Laskowski 2016)

Currently, a blockchain 2.0 governance initiative uses technology to enable refugees across Europe to create digital identities that can be used to identify theirs and their families cryptographically and to receive and spend money without bank accounts. (K. Morris 2015) Swan provides a "Blockchain 3.0" stage where blockchain technology will also apply in other areas such as health, literacy, culture and art. (Swan 2015, 55–78)

The blockchain philosophy is still at the beginning of the road. It will need to be supported in the future by an explanatory and robust phenomenological, consistent and test-proof theory. Efforts can focus on both ontological and epistemological issues, through an understanding of the conceptual, theoretical and fundamental dimensions of technology, based on which new fields of investigation - technological, economic, financial, and political - can be developed.

Using the conceptual framework of narrative technologies, Wessel Reijers and Mark Coeckelbergh have come to the conclusion that blockchain technology actively configures our understanding of social reality, configures narrative structures that abstracted from the sphere of action, and configures the distances between the second order narratives of technology and the first order narratives deriving from the active configuration of technology, (Reijers and Coeckelbergh 2018) with potential implications and normative, ethical and political contributions, both positive and negative.

For enterprise ontologies, a blockchain transaction, regardless of its ecosystemic and cryptographic complexity at a datalogical level, presents conceptual similarities critical and essential to traditional economic transactions. In addition to verification using top ontologies such as DOLCE, subsequent validation can be done with applications, and by mapping to the various implementations of the existing blockchain. (de Kruijff and Weigand 2017) A major step forward is to understand and formalize interactions between networks, side chains and off-line chains in public, private and hybrid domains (zoning of blocks).

At present, there is no formal blockchain ontology required for global adoption and compatibility to develop cross-cutting solutions and provide cost-effective solutions. Blockchain ontology breaks blocks into functional or logical individual components, and identifies possibilities to help design, implement, and measure the performance of different block architectures.

All these possibilities suggest a new world that we have to understand, a task where philosophy could help by providing a conceptual framework on how to do that.

Bibliography

Aaldijk, Rob, and Erik Vermeulen. 2001. “Modelleren van Organisaties -- Nieuwe Methoden En Technieken Leiden Tot Beter Inzicht.” http://api.ning.com/files/rgM-chfmWQA57MkWjSFxZ7XWLp0A7Ywf0KgaZUNxl0O1OMj*TRFOkPpXb7-Kj7nNa7YRcC-jXrY6w4gl0JkcWvxytMNf9aB2/Aaldijk.pdf.

Allison, Ian. 2015. “Decentralised Government Project Bitnation Offers Refugees Blockchain IDs and Bitcoin Debit Cards.” International Business Times UK. 2015. https://www.ibtimes.co.uk/decentralised-government-project-bitnation-offers-refugees-blockchain-ids-bitcoin-debit-cards-1526547.

Antonopoulos, Andreas M. 2014. *Mastering Bitcoin: Unlocking Digital Cryptocurrencies*. 1 edition. Sebastopol CA: O’Reilly Media.

Aste, Tomaso, Paolo Tasca, and Tiziana di Matteo. 2017. “Blockchain Technologies: The Foreseeable Impact on Society and Industry.” *Computer* 50: 18–28. https://doi.org/10.1109/MC.2017.3571064.

Berners-Lee, Tim. 2000. *Weaving the Web: The Original Design and Ultimate Destiny of the World Wide Web*. HarperCollins.

———. 2004. “Semantic Web.” ResearchGate. 2004. https://www.researchgate.net/publication/307845029_Tim_Berners-Lee's_Semantic_Web.

———. 2007. “Q&A with Tim Berners-Lee - Bloomberg.” 2007. https://www.bloomberg.com/news/articles/2007-04-09/q-and-a-with-tim-berners-leebusinessweek-business-news-stock-market-and-financial-advice.

Bhaskar, Nirupama Devi, and David LEE Kuo Chuen. 2015. “Bitcoin Mining Technology.” In *Handbook of Digital Currency*, edited by David Lee Kuo Chuen, 45–65. San Diego: Academic Press. https://doi.org/10.1016/B978-0-12-802117-0.00003-5.

Böhme, Rainer, Christin Nicolas, Edelman Benjamin, and Tyler Moore. 2015. “Bitcoin: Economics, Technology, and Governance.” https://pubs.aeaweb.org/doi/pdfplus/10.1257/jep.29.2.213.

Borisenkova, Anna. 2010. “Narrative Refiguration of Social Events: Paul Ricoeur’s Contribution to Rethinking the Social.” *Études Ricoeuriennes / Ricoeur Studies* 1 (1): 87–98. https://doi.org/10.5195/errs.2010.37.

Brito, Jerry, and Andrea Castillo. 2016. *Bitcoin: A Primer for Policymakers*. 2 edition. Arlington, Virginia: Mercatus Center at George Mason University.

Buterin, Vitalik. 2015. “On Public and Private Blockchains.” 2015. https://blog.ethereum.org/2015/08/07/on-public-and-private-blockchains/.

Calvery, Jennifer Shasky. 2013. “Statement of Jennifer Shasky Calvery, Director Financial Crimes Enforcement Network United States Department of the Treasury Before the United States Senate Committee on Homeland Security and Government Affairs.” https://www.fincen.gov/sites/default/files/2016-08/20131118.pdf.

Christidis, K., and M. Devetsikiotis. 2016. “Blockchains and Smart Contracts for the Internet of Things.” *IEEE Access* 4: 2292–2303. https://doi.org/10.1109/ACCESS.2016.2566339.

Dainton, Marianne, and Elaine D Zelley. 2011. *Applying Communication Theory for Professional Life: A Practical Introduction*. Thousand Oaks, Calif.: SAGE Publications.

D-Cent. 2015. “Tools for Democratic Participation and Citizen Empowerment.” https://dcentproject.eu/wp-content/uploads/2015/10/publishable-summary-10-2015-for-web.pdf.

Department Of Defense (DOD) Records Management (RM). 1995. “Reader’s Guide to IDEF0 Function Models.” https://www.archives.gov/files/era/pdf/rmsc-19951006-dod-rm-function-and-information-models.pdf.

Dietz, Jan. 1996. “Introductie Tot DEMO.” http://www.fredvroom.nl/Downloads/Introductie%20tot%20DEMO%20-%20Prof.%20Dr.%20Ir.%20J.L.G.%20Dietz.pdf.

Dietz, Jan L. G. 2001. “DEMO: Towards a Discipline of Organisation Engineering.” *European Journal of Operational Research* 128: 351–63. https://doi.org/10.1016/S0377-2217(00)00077-1.

———. 2006. *Enterprise Ontology: Theory and Methodology*. Berlin Heidelberg: Springer-Verlag. //www.springer.com/la/book/9783540291695.

Dietz, Jan L. G., and Terry A. Halpin. 2004. “Using DEMO and ORM in Concert: A Case Study.” In *Advanced Topics in Database Research, Vol. 3*. https://doi.org/10.4018/978-1-59140-255-8.ch011.

Dignum, Frank, and Jan Dietz. 1997. “Communication Modeling, The Language/Action Perspective. Second International Workshop on Communication Modeling.” https://pdfs.semanticscholar.org/7dd5/7b8af197433f295ef553f88e3b361b1a383e.pdf.

Dupont, Quinn. 2017. “Blockchain Identities: Notational Technologies for Control and Management of Abstracted Entities.” 2017. https://philarchive.org.

Fallon, Richard, and Simon Polovina. 1982. “REA Analysis of SAP HCM; Some Initial Findings.” http://ceur-ws.org/Vol-1040/paper4.pdf.

Feilmayr, Christina, and Wolfram Wöß. 2016. “An Analysis of Ontologies and Their Success Factors for Application to Business.” *Data & Knowledge Engineering* 101: 1–23. https://doi.org/10.1016/j.datak.2015.11.003.

FIPS PUBS. 1993. “FIPS Publication 183 Released of IDEFØ December 1993 by the Computer Systems Laboratory of the National Institute of Standards and Technology (NIST).” http://www.idef.com/wp-content/uploads/2016/02/idef0.pdf.

Fisher, Walter R. 1984. “Narration as a Human Communication Paradigm: The Case of Public Moral Argument.” *Communication Monographs* 51 (1): 1–22. https://doi.org/10.1080/03637758409390180.

Flores, Fernando, Michael Graves, Brad Hartfield, and Terry Winograd. 1988. “Computer Systems and the Design of Organizational Interaction.” *ACM Trans. Inf. Syst.* 6 (2): 153–172. https://doi.org/10.1145/45941.45943.

Foucault, Michel, and Jay Miskowiec. 1986. “Of Other Spaces.” *Diacritics* 16 (1): 22–27. https://doi.org/10.2307/464648.

Fox, Mark Stephen, and Michael Grüninger. 1998. “Enterprise Modeling.” ResearchGate. 1998. https://www.researchgate.net/publication/220604924_Enterprise_Modeling.

Fox, M.S. 1992. “The TOVE Project: Towards A Common-Sense Model of the Enterprise.” http://www.eil.utoronto.ca/wp-content/uploads/enterprise-modelling/papers/fox-tove-uofttr92.pdf.

Gervais, Arthur, Ghassan Karame, and Vedran Capkun. 2015. “Is Bitcoin a Decentralized Currency?” ResearchGate. 2015. https://www.researchgate.net/publication/270802537_Is_Bitcoin_a_Decentralized_Currency.

Glaser, Florian, and Luis Bezzenberger. 2015. “Beyond Cryptocurrencies - A Taxonomy of Decentralized Consensus Systems.” *Proceedings of the 23rd European Conference on*

Information Systems, ECIS 2015, Münster, Germany, May 26-29. https://publikationen.bibliothek.kit.edu/1000073771.

Goldkuhl, Goran. 1995. "Information as Action and Communication, The Infological Equation." http://www.vits.org/publikationer/dokument/145.pdf.

Goodman, Nelson. 1968. *Languages of Art*. Bobbs-Merrill.

Gray, Marley. 2016. "Introducing Project Bletchley and Elements of Blockchain Born in the Microsoft Cloud." 2016. https://azure.microsoft.com/en-us/blog/bletchley-blockchain/.

Gruber, Thomas. 1994. "Toward Principles for the Design of Ontologies Used for Knowledge Sharing." ResearchGate. 1994. https://www.researchgate.net/publication/2626138_Toward_Principles_for_the_Design_of_Ontologies_Used_for_Knowledge_Sharing.

Gruber, Tom. 1992. "What Is an Ontology?" 1992. http://www-ksl.stanford.edu/kst/what-is-an-ontology.html.

———. 1993. "A Translation Approach to Portable Ontology Specifications." 1993. http://tomgruber.org/writing/ontolingua-kaj-1993.htm.

———. 2008. "Ontology." 2008. http://tomgruber.org/writing/ontology-definition-2007.htm.

Guarino, Nicola. 1998. "Formal Ontology and Information Systems." https://klevas.mif.vu.lt/~donatas/Vadovavimas/Temos/OntologiskaiTeisingasKoncepcinisModeliavimas/papildoma/Guarino98-Formal%20Ontology%20and%20Information%20Systems.pdf.

Guarino, Nicola, and Chris Welty. 2000. "Ontological Analysis of Taxonomic Relationships." ResearchGate. 2000. https://www.researchgate.net/publication/2637003_Ontological_Analysis_of_Taxonomic_Relationships.

Halpin, Harry, and Alexandre Monnin. 2014. "Philosophical Engineering: Toward a Philosophy of the Web." Wiley.Com. 2014. https://www.wiley.com/en-ro/Philosophical+Engineering%3A+Toward+a+Philosophy+of+the+Web-p-9781118700181.

Hardjono, Thomas, Alexander Lipton, and Alex Pentland. 2018. "Towards a Design Philosophy for Interoperable Blockchain Systems." ResearchGate. 2018. https://www.researchgate.net/publication/325168344_Towards_a_Design_Philosophy_for_Interoperable_Blockchain_Systems.

Hayek, Friedrich von. 1976. "Denationalisation of Money: The Argument Refined." https://nakamotoinstitute.org/static/docs/denationalisation.pdf.

Huňka, František, and Jaroslav Zacek. 2015. "A New View of REA State Machine." ResearchGate. 2015. https://www.researchgate.net/publication/277942361_A_new_view_of_REA_state_machine.

Iansiti, Marco, and Karim R. Lakhani. 2017. "The Truth About Blockchain." *Harvard Business Review*, 2017. https://hbr.org/2017/01/the-truth-about-blockchain.

Institute for Blockchain Studies. 2016. "Blockchain Philosophy - Institute for Blockchain Studies Website." 2016. http://blockchainstudies.org/BlockchainPhilosophy.html.

Kaplan, David M. 2006. "Paul Ricoeur and the Philosophy of Technology." *Journal of French and Francophone Philosophy* 16 (1/2): 42–56. https://doi.org/10.5195/jffp.2006.182.

Kim, Henry M., Mark S. Fox, and Michael Gruninger. 1995. “An Ontology of Quality for Enterprise Modelling.” In , 105. IEEE Computer Society. http://dl.acm.org/citation.cfm?id=832309.837247.

Kim, Henry M., and Marek Laskowski. 2016. “Towards an Ontology-Driven Blockchain Design for Supply Chain Provenance.” *ArXiv:1610.02922 [Cs]*. http://arxiv.org/abs/1610.02922.

Kostakis, Vasilis, Michel Bauwens, and Vasilis Niaros. 2015. “Urban Reconfiguration after the Emergence of Peer-to-Peer Infrastructure: Four Future Scenarios with an Impact on Smart Cities.” In *Smart Cities as Democratic Ecologies*, edited by Daniel Araya, 116–24. London: Palgrave Macmillan UK. https://doi.org/10.1057/9781137377203_8.

Kostakis, Vasilis, and Chris Giotitsas. 2014. “The (A)Political Economy of Bitcoin.” ResearchGate. 2014. https://www.researchgate.net/publication/287241993_The_APolitical_Economy_of_Bitcoin.

Kroll, Joshua A., Ian C. Davey, and Edward W. Felten. 2013. “The Economics of Bitcoin Mining , or Bitcoin in the Presence of Adversaries.” In .

Kruijff, Joost de, and Hans Weigand. 2017. “Towards a Blockchain Ontology.” In .

Kruijff, Joost de, and Hans Weigand. 2017. “Understanding the Blockchain Using Enterprise Ontology.” Springerprofessional.De. 2017. https://www.springerprofessional.de/en/understanding-the-blockchain-using-enterprise-ontology/12328482.

Lakoff, Johnson, and Mark Johnson. 2003. “Metaphors We Live.” 2003. https://www.press.uchicago.edu/ucp/books/book/chicago/M/bo3637992.html.

Leondes, Cornelius T., and Richard Henry Frymuth Jackson. 1992. *Manufacturing and Automation Systems: Techniques and Technologies*. Academic Press.

List, Christian, and Philip Pettit. 2011. *Group Agency: The Possibility, Design, and Status of Corporate Agents*. Oxford University Press. http://www.oxfordscholarship.com/view/10.1093/acprof:oso/9780199591565.001.0001/acprof-9780199591565.

MacIntyre, Alasdair. 2007. *After Virtue: A Study in Moral Theory, Third Edition*. University of Notre Dame Press. https://muse.jhu.edu/book/52441.

McCarthy, William E. 1982. “The REA Accounting Model: A Generalized Framework for Accounting Systems in a Shared Data Environment.” *The Accounting Review* 57 (3): 554–78. https://www.jstor.org/stable/246878.

Meretoja, Hanna. 2014. “Narrative and Human Existence: Ontology, Epistemology, and Ethics.” *New Literary History* 45 (1): 89–109. https://doi.org/10.1353/nlh.2014.0001.

Miscione, Gianluca, and Donncha Kavanagh. 2015. “Bitcoin and the Blockchain: A Coup D’État through Digital Heterotopia?” SSRN Scholarly Paper ID 2624922. Rochester, NY: Social Science Research Network. https://papers.ssrn.com/abstract=2624922.

Morris, David Z. 2016. “Leaderless, Blockchain-Based Venture Capital Fund Raises $100 Million, And Counting.” Fortune. 2016. http://fortune.com/2016/05/15/leaderless-blockchain-vc-fund/.

Morris, Kelly. 2015. “Aiding Refugees? Yes, The Blockchain Can Do That And More.” *Huffington Post* (blog). 2015. https://www.huffingtonpost.com/melissa-jun-rowley/aiding-refugees-yes-the-b_b_8149762.html.

Nakamoto, Satoshi. 2008. “Bitcoin: A Peer-to-Peer Electronic Cash System.” https://bitcoin.org/bitcoin.pdf.

Narayanan, Arvind, Joseph Bonneau, Edward Felten, Andrew Miller, and Steven Goldfeder. 2016. *Bitcoin and Cryptocurrency Technologies: A Comprehensive Introduction*. Princeton University Press.

Nian, Lam Pak, and David Lee Kuo Chuen. 2015. "A Light Touch of Regulation for Virtual Currencies | Request PDF." ResearchGate. 2015. https://www.researchgate.net/publication/286055684_A_Light_Touch_of_Regulation_for_Virtual_Currencies.

Object Management Group. 2000. "ObjectConstraintLanguage Specification." http://homepage.divms.uiowa.edu/~tinelli/classes/5810/Spring08/Papers/OCL_1.5.pdf.

———. 2006. "Object Constraint Language - OMG Available Specification - Version 2.0." http://www2.imm.dtu.dk/courses/02291/files/OCL2.0_06_05_01.pdf.

Pellauer, David, and Bernard Dauenhauer. 2002. "Paul Ricoeur." https://plato.stanford.edu/archives/win2016/entries/ricoeur/.

Popper, Nathaniel. 2017. "A Venture Fund With Plenty of Virtual Capital, but No Capitalist." *The New York Times*, 2017, sec. Business. https://www.nytimes.com/2016/05/22/business/dealbook/crypto-ether-bitcoin-currency.html.

Raval, Siraj. 2016. *Decentralized Applications: Harnessing Bitcoin's Blockchain Technology*. O'Reilly Media, Inc.

Reijers, Wessel, and Mark Coeckelbergh. 2018. "The Blockchain as a Narrative Technology: Investigating the Social Ontology and Normative Configurations of Cryptocurrencies." *Philosophy & Technology* 31 (1): 103–30. https://doi.org/10.1007/s13347-016-0239-x.

Ricoeur, Paul. 1988. "Time and Narrative, Volume 3, Ricoeur, Blamey, Pellauer." 1988. https://www.press.uchicago.edu/ucp/books/book/chicago/T/bo3711629.html.

———. 1990. *Time and Narrative, Volume 1*. Translated by Kathleen McLaughlin and David Pellauer. 1 edition. Chicago, Ill.: University of Chicago Press.

Rowland, Robert C. 1988. "The Value of the Rational World and Narrative Papradigms." *Central States Speech Journal* 39 (3–4): 204–17. https://doi.org/10.1080/10510978809363250.

Searle, John. 2006. "Social Ontology: Some Basic Principles."

———. 2010. *Making the Social World: The Structure of Human Civilization*. Oxford University Press. http://www.oxfordscholarship.com/view/10.1093/acprof:osobl/9780195396171.001.0001/acprof-9780195396171.

Smith, Barry. 2004. "Beyond Concepts: Ontology as Reality Representation." In *Formal Ontology in Information Systems (FOIS)*, edited by Achille C. Varzi and Laure Vieu, 1–12.

Spector-Mersel, Gabriela. 2010. "Narrative Research: Time for a Paradigm." *Narrative Inquiry* 20 (1): 204–24. https://doi.org/10.1075/ni.20.1.10spe.

Strawson, Galen. 2004. "Against Narrativity." *Ratio* 17 (4): 428–452.

Swan, Melanie. 2015. *Blockchain: Blueprint for a New Economy*. O'Reilly Media, Inc.

Swan, Melanie, and Primavera de Filippi. 2017. "Toward a Philosophy of Blockchain: A Symposium: Introduction." *Metaphilosophy* 48 (5): 603–619.

Szabo, Nick. 1997. "Formalizing and Securing Relationships on Public Networks." *First Monday* 2 (9). https://doi.org/10.5210/fm.v2i9.548.

Tapscott, Don, and Alex Tapscott. 2016. “Here’s Why Blockchains Will Change the World.” Fortune. 2016. http://fortune.com/2016/05/08/why-blockchains-will-change-the-world/.

Tapscott, Don, Alex Tapscott, and Jeff Cummings. 2017. *Blockchain Revolution: How the Technology Behind Bitcoin and Other Cryptocurrencies Is Changing the World*. Unabridged edition. Brilliance Audio.

Tasca, Paolo, and Claudio J. Tessone. 2017. “Taxonomy of Blockchain Technologies. Principles of Identification and Classification.” *ArXiv:1708.04872 [Cs]*. http://arxiv.org/abs/1708.04872.

Taylor, Charles. 1971. “Interpretation and the Sciences of Man.” *The Review of Metaphysics* 25 (1): 3–51. https://www.jstor.org/stable/20125928.

The Economist. 2015. “The Great Chain of Being Sure about Things.” *The Economist*, 2015. https://www.economist.com/briefing/2015/10/31/the-great-chain-of-being-sure-about-things.

———. 2016. “Not-so-Clever Contracts.” Internet Archive. 2016. https://archive.org/details/perma_cc_QNH7-5BJZ.

———. 2018. “Bitcoin and Other Cryptocurrencies Are Useless.” *The Economist*, 2018. https://www.economist.com/leaders/2018/08/30/bitcoin-and-other-cryptocurrencies-are-useless.

Totland, Terje. 1997. “Toronto Virtual Enterprise (TOVE).” http://www.idi.ntnu.no/grupper/su/publ/html/totland/ch0523.htm.

Trottier, Leo. (2013) 2018. *Historical Repository of Satoshi Nakamoto’s Original Bitcoin*. C++. https://github.com/trottier/original-bitcoin.

Van Nuffel, Dieter, Hans Mulder, and Steven Van Kervel. 2009. “Enhancing the Formal Foundations of BPMN by Enterprise Ontology.” In *Advances in Enterprise Engineering III*, edited by Antonia Albani, Joseph Barjis, and Jan L. G. Dietz, 115–29. Lecture Notes in Business Information Processing. Springer Berlin Heidelberg.

Vernadat, F. B. 1997. “Enterprise Modelling Languages.” In *Enterprise Engineering and Integration: Building International Consensus Proceedings of ICEIMT ’97, International Conference on Enterprise Integration and Modeling Technology, Torino, Italy, October 28–30, 1997*, edited by Kurt Kosanke and James G. Nell, 212–24. Research Reports Esprit. Berlin, Heidelberg: Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-60889-6_24.

W3C, W3C. 2013. “W3C Semantic Web Activity Homepage.” 2013. https://www.w3.org/2001/sw/.

Wang, Yan, Antonia Albani, and Joseph Barjis. 2011. “Transformation of DEMO Metamodel into XML Schema.” In *Advances in Enterprise Engineering V*, edited by Antonia Albani, Jan L. G. Dietz, and Jan Verelst, 46–60. Lecture Notes in Business Information Processing. Springer Berlin Heidelberg.

WEF Financial Services. 2016. “The Future of Financial Infrastructure. An Ambitious Look at How Blockchain Can Reshape Financial Services. Technical Report, WEF, 2016.” http://www3.weforum.org/docs/WEF_The_future_of_financial_infrastructure.pdf.

Whitten, Jeffrey L., Lonnie D. Bentley, and Kevin C. Dittman. 2004. *Systems Analysis and Design Methods*. McGraw-Hill Irwin.

Williams, Ted. 2000. “TOVE Toronto Virtual Enterprise.” http://www.pera.net/Methodologies/TOVE.html.

Wood, D. 2014. “Ethereum: A Secure Decentralised Generalised Transaction Ledger.” In .

Young, Sherman. 1998. "'Of Cyber Spaces: The Internet & Heterotopias." 1998. http://journal.media-culture.org.au/9811/hetero.php.