TOWARDS A TAXONOMY FOR SMART CONTRACTS

Research paper

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Abstract

With the increasing number of applications based on smart contracts, the debate over ethical, legal and social issues is of great importance. These applications promise, for example, lower costs, increasing efficiency, security and trust. However, to the best of our knowledge there is no structured and systematic taxonomy to classify applications involving smart contracts. A two-pronged approach is employed to identify prior literature dealing with taxonomies and classifications for smart contracts. By analysing 84 papers on smart contracts, we found 17 dimensions and 58 characteristics. An initial extensive typology was then reduced down to a manageable extent. The result is a taxonomy for smart contracts with 17 dimensions and 48 characteristics, which we have empirically tested and successfully evaluated against 15 real use cases. Our taxonomy provides a better understanding of use cases today and future challenges in the field of smart contracts.

Keywords: Smart Contracts, Taxonomy, Blockchain, Legal aspects.

1 Introduction and Motivation

The term "smart contract" was first used in 1994 by the computer scientist Nick Szabo. He notes that the most important traditional way of formalizing a business relationship between two business partners is the contract. He also remarks that, despite the developments in the world's computer networks, the self-assurance of formulating written contracts on paper still exists (Szabo 1994). In recent years, many attempts have been made to make the contracting process more efficient (Kölvart/Poola/Rull 2016). Only the spread of the blockchain technology has enabled the movement from automatic contracts to truly autonomous smart contracts, capable of self-execution and self-enforcement (Lauslahti/Mattila/Seppälä 2017). Large organizations such as Unicef or the European Parliament are concerned with the opportunities and risks of this innovation. Unicef ventures assess and prototype smart contracts based on Ethereum to improve efficiency, transparency and accountability (unicef 2017). The European Parliament conducted an in-depth analysis in 2017 on how blockchain technology in general and smart contracts in particular could change our lives. They raise the question whether the technical code of a smart contract is the most important legal form (Boucher 2017).

There are several definitions of smart contracts and numerous applications that use smart contracts in a specific area. Some definitions are based on computer science such as "smart contracts are self-executing codes on a blockchain that automatically implements the terms of an agreement between parties" from Ream/Chu/Schatsky (2016) or "smart contracts are programs executed by all miners" from Kosba et al. (2016) or "smart contracts are agreements existing in the form of software codes implemented on the blockchain platform" from Savelyev (2016). Clack/Bakshi/Braine (2016a) propose a broader definition of smart contracts. They differentiate between smart contracts which are enforced through institutions like courts of arbitration or law and smart contracts which are enforced through "tamper-proof" technology (Clack/Bakshi/Braine 2016a).

Today, neither the current nor the future role of smart contracts can be clearly defined. The Blockchain technology allows for the connection of unknown people across national borders and the digitized representation and execution of declarations of intent by means of smart contracts. However, despite the recognized freedoms of contract and form, the legal effects of digitally executed declarations of intent still remain unclear and there are a lot of open questions. One question, for example, relates to the risk of the code being misunderstood between the programmer and the contracting parties or differences between implementation and intent (Savelyev 2016). Another aspect concerns the performance of an acceptance-and-offer model, because in practice parties often negotiate the terms until they reach an agreement. Also the question of how concluded smart contracts can be modified in case of mutually agreed contract changes yet remains open (Idelberger et al. 2016).

We have not found a clear terminology in the field of smart contracts. Thus, to the best of our knowledge and in order to gain a better understanding of current use cases and future challenges, we propose the first taxonomy of smart contracts by targeting research in information systems science in general and contract law in particular. The aim is to fill the research gap by answering the question: What are the archetypes of smart contracts and how can these be classified to understand questions from the legal perspective?

In this paper, we develop a taxonomy for smart contracts with a three phase approach. Phase 1 is based on the literature review and the development of the first taxonomy. In the following, we identify a set of use cases that serve as a basis for the empirical-to-conceptual approach in phase 2, in which the final taxonomy is developed. In phase 3, we evaluate the final taxonomy by interviewing lawyers and through a discussion of results.

2 Backround

In his work, Nick Szabo is not concerned with the digital image of a contract per se, but, given the high computing power and global networking, he is rather concerned with the question how the necessary steps prior to the contract conclusion (e.g., negotiations, mapping, checking and enforcement of contractual regulations) can technically be supported in full or at least partially (Szabo 1994).

With the introduction of the digital currency Bitcoin in 2009, the underlying technology of blockchain found its way into new business areas. As the blockchain technology is one of the most known distributed ledger technologies, we use the terms interchangeably. Within a blockchain, data and programs are distributed and stored decentrally on participating computers on a peer-to-peer network, in which individual computers can offer services, functions and resources, as well as use those from others (Rückeshäuser 2017). Given the fact that within the blockchain technology all data records are chronologically chained together, whereby more recent data records verify preceding records, retrospective modifications or deletion of data are impossible.

Based on the blockchain technology, smart contracts "intelligently" perform one or more event-driven actions. Thereby, the contracts consist of an agreement between two parties as well as the software code (Clack/Bakshi/Braine 2016b). These agreements must be both enforceable and automated in the blockchain (Clack/Bakshi/Braine 2016a).

The smart contracts are mapped in a script language on the blockchain and executed in a virtual machine on all involved computers of the peer-to-peer network. The programming of a smart contract can be done in an Ethereum blockchain with a JavaScript-like language called Solidity (Bhargavan et al. 2016). Solidity is an object-oriented, higher-level programming language compiled by the virtual machine of the Ethereum blockchain in bytecode.

3 Research Process

"Taxonomies structure or organize the body of knowledge that constitutes a field, with all the potential advantages that that brings for the advancement of the field" (Glass and Vessey 1995). Further, the classification of objects helps researchers and practitioners understand and analyse complex domains (Nickerson/Vashney/Muntermann 2013). We employed the taxonomy development method described by Nickerson/Vashney/Muntermann (2013) in the way that we first designed an extensive typology and then eliminated certain dimensions (Baily 1994). To this end, we carried out a comprehensive literature search for papers on smart contracts and contractual law to identify classifications, typologies, groups or taxonomies. On this basis and with the involvement of an expert in the field of contracting in networks, we designed an extensive typology and subsequently eliminated certain dimensions to create the first taxonomy (cf. Table 1). Following the empirical-to-conceptual approach by Nickerson/Vashney/Muntermann (2013), we searched for use cases mainly based on smart contracts. Then, we followed the iterative process approach by the same authors to determine meta-characteristics and ending conditions in order to classify the identified use cases within the taxonomy. After we met the ending conditions and the final taxonomy was in place, we surveyed lawyers about the taxonomy, which led to further relevant information for the dimensions and characteristics of smart contracts.

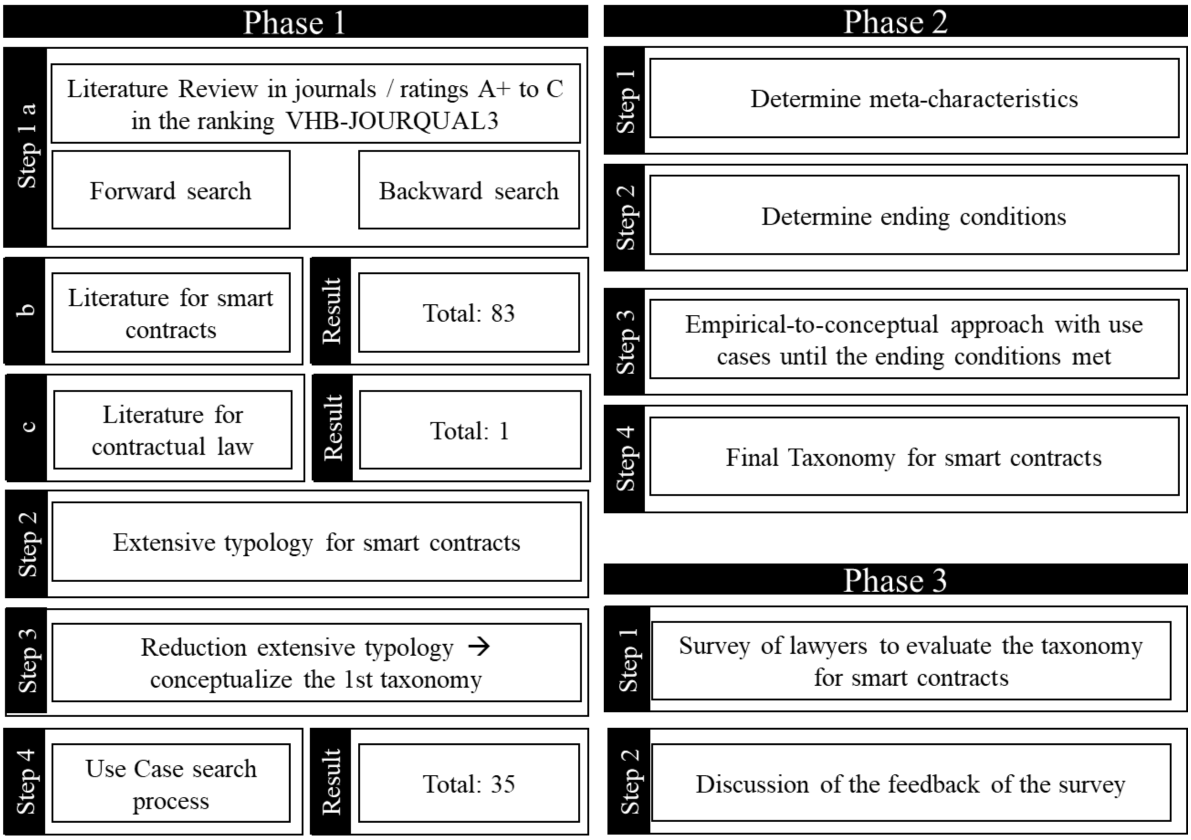

Figure 1. The taxonomy development process based on Nickerson/Vashney/Muntermann (2013).

3.1 Literature Search

A two-pronged approach was employed to identify prior literature dealing with taxonomies or classification systems for contract law. First, a search for existing literature on smart contracts was conducted. For this purpose, we searched the databases EBSCO, ScienceDirect, Web of Science, ACM Digital Library, IEEE Explore and AISEL. Further, we examined the relevant conferences (Multikonferenz Wirtschaftsinformatik (MKWI), Wirtschaftsinformatik (WI), European Conference on Information Systems (ECIS), International Conference on Information Systems (ICIS), Hawaii International Conference on Systems Sciences (HICSS), Americas Conference on Information Systems (AMCIS) and Pacific

Asia Conference on Information Systems (PACIS). Then, we selected relevant journals on the basis of the VHB-JOURQUAL3 rating “Wirtschaftsinformatik” (Information Systems). To ensure high professional standards, the research was carried out exclusively in journals with peer-to-peer reviews. By means of a forward (author-based) and backward search (sources-based), we identified a total of 83 papers focusing on smart contracts. In a next step, we examined these for classification systems. For example, Bartoletti and Pompianu classify smart contracts based on the intended application domain (Bartoletti and Pompianu 2017), whereas Bourque and Ling Tsui (2014), Norta et al. (2017) as well as Raskin (2017) and Szabo (1998) thematise the lifecycle of smart contracts.

In our second approach, we searched for contributions on classifications and taxonomies for contractual law. Here, we followed an analogue approach in applying existing classifications or taxonomies of contract law to smart contracts. In their paper “A Proposed Taxonomy of Contracts”, Mouzas and Furmston (2013) introduce a classification that is based on their real-life usage of contracts and involves several cycles of inquiry. Our paper differentiates from the identified papers as we started from the perspective of the identified use cases and carried out the classification for smart contracts only subsequently.

3.2 Use Case Search

In this phase, we searched for use cases and applications of smart contracts. Therefore, we carried out a literature review in journals, databases and conferences and also searched on relevant homepages (e.g. www.blockchain.info, www.blockchain.com, www.blockchain.capital, www.github.com, www.the-blockchain.com) Additionally, we used search engines like Google, Bing etc. to identify relevant use cases and applications of smart contracts as well as practice reports and white papers on this topic. We selected the use cases according to the fact that the applications were familiar to us and that relevant information was available. The order of use cases in the iteration process is random (Nickerson/Vashney/Muntermann 2013). In the end, we found some nonspecific use cases in journals and white papers, but also concrete applications.

4 Results

We conducted the literature survey within the scientific domain and examined real smart contract based use cases in order to identify various kinds of classifications, groups and characteristics for smart contracts and contractual law.

In phase 1 step 2 we employed the conceptual-to-empirical approach because we identified the proposed taxonomy of contracts by Mouzas and Furmston (2013) in our previous literature review. The dimensions and characteristics proposed within their classification are shown in Table 1.

Mouzas and Furmston’s first dimension “By subject matter (D1)” describes the traditional classification in contract law and focuses on the subject matter of contracts, for which the authors mention three possible manifestations. The dimension “By the way the contract is made (D2)” refers to the characteristic that contracts can be verbal, written, real or consensual. The authors further mention that the function of the contract is a relevant taxonomic criterion. In this context, the dimension “By the function of the contract (D3)” refers to the contracts’ nature and purpose. In the dimension "By the Time-horizon (D4)", the authors distinguish between long-term, medium-term and short-term contracts. For instance, long-term contracts can be insurance, leasing or building contracts, while short-term contracts rather regulate transactions of the daily life. The dimension “By the ability to renegotiate terms (D5)” constitutes another important classification criterion for contracts and involves the possibility to partially or wholly renegotiate contracts. Besides, Mouzas and Furmston designate the dimension “By the involvement of Consumers (D6)”, which refers to the fact that contracts involving consumers are regulated by statutes. Therefore, they distinguish between commercial and consumer contracts. By means of the dimension "By existence of mutual trust (D7)", the two authors cover the aspect of trust. Despite the fact that in many contracts the contracting parties do not know each other, trust arises through interpersonal relations or through repeated exchange.

Dimension	Characteristics
By subject matter (D1)	Sale (C11), Employment (C12), Insurance (C13)
By the way the contract is made (D2)	Verbal (C21), Literal (C22), Real (C23), Consensual (C24)
By the function of contracts (D3)	Executory (C31), Framework (C32)
By the time-horizon (D4)	Long-term (C41), Medium-term (C42), Short-term (C43)
By the ability to renegotiate terms (D5)	Complete (C51), Certain terms (C52)
By the involvement of consumers (D6)	Consumer involved (C61), Consumer not involved (C62)
By the existence of mutual trust (D7)	Interpersonal (C71), Repeated (C72)
Subcategories of contracts (D8)	informal cash transactions (C81), standard form printed contracts (C82), individually negotiated contracts (C83)
Framework contracts (D9)	Regular (C91), Stable (C92), Established commercial relationships (C93)
Consensual contracts (D10)	Sale (C101), Hire (C102), Partnership (C103), Mandate (C104)

Table 1. First taxonomy for smart contracts based on Mouzas and Furmston (2013).

The paper by Bartoletti and Pompianu contains a classification for smart contracts based on the intended application domain (Bartoletti and Pompianu 2017). The financial application domain describes contracts that predominantly manage, gather or distribute money, while contracts in the notary application domain particularly benefit from the immutability of the blockchain to store some data persistently. Different variants of games are characterized by the game application domain. The wallet dimension handles keys, sends transactions and manages money, while the library describes contracts implemented for general-purpose operations (Bartoletti and Pompianu 2017). The paper by Bourque and Ling Tsui proposes four dimensions for the composition of a contract. The offer describes the first step of agreements between parties. The next step is an acceptance of the offer. The consideration is, from the point of view of a court, legally enforceable (Bourque and Ling Tsui 2014). The intention is the legal consequences attached to their agreement between the parties (MacMillan and Stone 2012). Norta et al. consider the lifecycle of a rental contract and divide the process into preparatory, negotiation, contract execution, rollback and a contract expiry stage (Norta et al. 2017). Moreover, they consider the different stages of processing within the lifecycle of a smart contract. The contract is inactive if the precondition of an obligation has not been met. It is active when an agent takes an obligation into consideration. Furthermore, a smart contract can be performed, delayed, defective or terminated (Norta et al. 2007). In “The law and legality of smart contracts” Raskin differentiates a smart contract from legal purposes (Raskin 2017). Whereas smart contracts where no or low costs of revocation and modification occur are considered as weak, smart contracts with high costs of revocation and modification are considered strong (Raskin 2017). Further, the entire lifecycle of a smart contract consists of several different stages and phases. From our meta-characteristic view, we have to use stages in a more specific way. Therefore, we use the stages search, negotiation, commitment, performance and adjudication of contracting from Nick Szabo (Szabo 1998), instead of the shorter version by Raskin which includes the phases formation, performance and breach (Raskin 2017).

Having completed our literature review in Step 1, we identified the dimensions and characteristics in the extensive typology for smart contracts in Step 2 as shown in Table 2. The initial typology contained 17 dimensions and 58 characteristics, which we reduced to a manageable level (Baily 1994). In 1937 Lazarsfeld described three methods of reduction: functional reduction, arbitrary numerical reduction and pragmatic reduction (Lazarsfeld 1937). We followed the pragmatic reduction method in which certain combinations are aggregated based on the research process (Lazarsfeld 1937). For example, Dimensions D14 and D17 can be condensed, since they contain similar characteristics about the process or stages of smart contracts. While the lifecycle by Norta et al. is tailored to rental contracts, Nick Szabo’s lifecycle refers to smart contracts in general. Given its more general approach, we kept the lifecycle dimension from Nick Szabo in our taxonomy and eliminated dimension D14. The next reduction involved dimensions D1 and D11, as both categorize the application. Because we believe that the application of a smart contract use case is less important than the object of the contract in dimension D1, we eliminated dimension D11. The second typology was the basis for the evaluation of the dimensions and properties against real applications and use cases (see 3.2 use case search).

The first step in phase 2 was the determination of meta-characteristics. Our work aims at both academics and practitioners in the field of smart contracts and the digitalisation of contractual law. Given the fact that this research field is yet new and unexplored, there are numerous questions concerning the legal aspects of smart contracts. Our taxonomy can provide valuable research approaches for scientists and practitioners alike, which, in consequence, may promote the progress of research in this field. For example, lawyers could identify relevant topics for investigation. Taking the above into account, we identified *legal aspects of smart contracts* as our meta-characteristic.

The second step in phase 2 was to determine the ending conditions for the process of developing our taxonomy. We decided to follow the approach in Nickerson/Vashney/Muntermann (2013) which describes objective and subjective ending conditions to terminate the iteration. The objective ending conditions are: all objects or representative samples of objects have been examined, no new dimensions or characteristics were added in the last iteration and no dimensions or characteristics were merged or split in the last iteration (Nickerson/Vashney/Muntermann 2013). Subjective ending conditions, according to the authors, should be concise, robust, comprehensive, extendible and explanatory (Nickerson/Vashney/Muntermann 2013).

In step 3 phase 2, we followed the empirical-to-conceptual approach in Nickerson/Vashney/Muntermann (2013) because we identified smart contract based applications in our use case search. We went through step 3 to check whether or not the ending conditions are met.

- Rental agreement (Norta et al. 2017). A lessor and a lessee make a rental agreement on behalf on an owner of an immovable property, for example, a plot of land or a house.
- SCM Pharma (Schöner et al. 2017). In this use case the focus is on the supply-chain process to increase security for the pharmaceutical industry.
- Betting Weather (Koulu 2016). Two parties are betting about the weather.

We identified the new characteristics rental and betting for dimension D1. From the meta-characteristics point of view, transactions like rental and betting differ enormously from the existing characteristics. Another important aspect is that characteristics are missing for dimension D5 as there is no ability to renegotiate terms of the contract. Therefore, we need a new characteristic. Dimension D9 assumes a framework contract, however, there is no framework contract in these use cases. First we used the characteristic No. As we did not find a characteristic in the dimension D11 for the use case rental agreement, we added the rental characteristic.

Since we created five further characteristics in this iteration, the objective ending condition “No new dimensions or characteristics were added in the last iteration” did not apply, which required a second iteration with the following applications:

- StromDAO Energy (StromDAO 2017). A photovoltaic system is built in a three-family house, the cost of which is to be transferred to the owner-run community on a consumption-based basis.
- Home flooding insurance (Roughton and Bidewell 2017). The use case is the contact between customers and insurers for home flood.
- ADEPT (IBM Institute for Business Value 2017). This application demonstrates the Autonomous Decentralized Peer-to-Peer-Telemetry.

Dimension	Characteristics	References	1st taxonomy	2nd taxonomy
By subject matter (D1)	Sale (C11), Employment (C12), Insurance (C13)	D1 (Mouzas and Furmston 2013)	X	X
By the way the contract is made (D2)	Verbal (C21), Literal (C22), Real (C23), Consensual (C24)	D2 (Mouzas and Furmston 2013)	X	X
By the function of contracts (D3)	Executory (C31), Framework (C32)	D3 (Mouzas and Furmston 2013)	X	X
By the time-horizon (D4)	Long-term (C41), Medium-term (C42), Short-term (C43)	D4 (Mouzas and Furmston 2013)	X	X
By the ability to re-negotiate terms (D5)	Complete (C51), Certain terms (C52)	D5 (Mouzas and Furmston 2013)	X	X
By the involvement of consumers (D6)	Consumer involved (C61), Consumer not involved (C62)	D6 (Mouzas and Furmston 2013)	X	X
By the existence of mutual trust (D7)	Interpersonal (C71), Repeated (C72)	D7 (Mouzas and Furmston 2013)	X	X
Subcategories of contracts (D8)	informal cash transactions (C81), standard form printed contracts (C82), individually negotiated contracts (C83)	D8 (Mouzas and Furmston 2013)	X	X
Framework contracts (D9)	Regular (C91), Stable (C92), Established commercial relationships (C93)	D9 (Mouzas and Furmston 2013)	X	X
Consensual contracts (D10)	Sale (C101), Hire (C102), Partnership (C103), Mandate (C104)	D10 (Mouzas and Furmston 2013)	X	X
Application domain (D11)	Financial (C111), Notary (C112), Game (C113), Wallet (C114), Library (C115)	D11 (Bartoletti and Pompianu 2017)	X	-
Composition (D12)	offer (C121), acceptance (C122), consideration (C123), intention (C124)	D12 (Bourque and Ling Tsui 2014)	X	X
Trigger (D13)	By an external prompt (C131), Based on a timer or schedule (C132)	D13 (Bourque and Ling Tsui 2014)	X	X
Stages (D14)	preparatory (C141), negotiations (C142), contract execution (C143), rollback (C144), a contract expiry stage (C145)	D14 (Norta et al. 2017)	X	-
Lifecycle (D15)	inactive (C151), active (C152), performed (C153), performed (C154), delayed (C155), defective (C156), terminated (C157)	D15 (Norta et al. 2017)	X	X
Cost of altering (D16)	strong smart contracts (C161), weak smart contracts (C162)	D16 (Raskin 2017)	X	X
Stages (D17)	search (C171), negotiation (C172), commitment (C173), performance (C174), adjudication (C175)	D17 (Szabo 1998)	X	X

Table 2. The 1st and 2nd taxonomy for smart contracts.

In dimension D2, which classifies contracts by the way they are made, the two most important categories are verbal and consensual (Mouzas and Furmston 2013). As smart contracts can only be consensual, it is obvious that only C24 is relevant, which led us to the deletion of dimension D2 and its characteristics. Although the situation with dimension D6 is similar, because all previous use cases are consumer involved (C61), we maintained D6 to check its validity for other use cases covering business-to-business smart contracts.

More use cases existed that needed to be examined. In this iteration, the objective ending condition "All objects or representative sample of objects have been examined" was not met. Therefore, we investigated the following applications in the third iteration in Step 3:

- Prediction market (GNOSIS 2017). GNOSIS is a forecasting tool for the prediction markets.
- SURETLY (SURETLY 2017). This application is a crowd vouching platform.
- DOVU (DOVU 2017). This use case uses the blockchain for mobility.

The use case SURETLY introduces the new characteristic lending in D1. The use cases Prediction market and DOVU could be easily classified. At the end of the third iteration we eliminated dimension D9, because a framework from the legal aspects is not relevant for use cases and not applicable to smart contracts. Furthermore, we eliminated dimension D10, because the characteristics were very similar to the characteristics in dimension D1.

Given the fact that the objective ending conditions "No new dimensions or characteristics were added in the last iteration" and "No dimensions or characteristics were merged or split in the last iteration" were not met, we investigated further applications in a fourth loop:

- Bluzelle (bluzelle 2017). A blockchain-powered system for a global insurer where the consumer bought a policy and had their entire claim processed in real-time.
- ETHLend (ETHLend 2017). An application for decentralized lending based on Ethereum.
- KyberNetwork (Luu and Velner 2017). This application allows instant exchange and conversion of digital assets and cryptocurrencies.
- QChain (QChain 2017). A decentralized marketing and advertising platform built on Ethereum.

These applications were easily classified in our taxonomy. The first classification of the characteristic "Commercial contracts" for the use case Qchain was worth mentioning. Notwithstanding, we eliminated the characteristics "Employment" in the dimension "By subject matter", "Informal cash transactions" in dimension "Subcategories of contracts", "Defective" and "Terminated" in the dimension "Lifecycle" due to a non-existing assignment. And as Raskin (2017) claims, personal service contracts are not subject to computer control. Further, we eliminated the dimension Composition, because we merged this dimension with Stages D17.

As neither in this iteration the ending conditions were met, the condition "No dimensions or characteristics were merged or split in the last iteration" did not apply, another iteration with new use cases was required. The fifth iteration in Step 3 was carried out on the following applications:

- PayPie (Chandi 2017). PayPie is a blockchain accounting platform to bring trust and transparency to the financial markets.
- Trippki (Trippki 2017). This application is a decentralized ecosystem for customer rewards.

We had no problems classifying these use cases in our taxonomy. While examining all representative samples of objects during the last iteration, we neither had to add new dimensions or characteristics, nor was there the need to merge or split dimensions or characteristics. Therefore, the objective ending conditions were met. The subject ending conditions were that the taxonomy should be concise, robust, comprehensive, extendible and explanatory (Nickerson/Vashney/Muntermann 2013). As our proposed taxonomy only has a limited number of dimensions and a limited number of characteristics in each dimension, it can be considered concise as our empirical-to-conceptual approach showed, the taxonomy contains enough dimensions and characteristics to classify all use cases and a clear differentiation is possible, so our taxonomy is robust. It is comprehensive, because all known use cases were classified. As the process of iteration showed, our taxonomy allowed the enlargement of new dimensions and/or new characteristics. Thus, our taxonomy is extendible. Our dimensions and characteristics are sufficiently detailed to allow for a correct classification.

To evaluate our proposed taxonomy, we asked 50 lawyers between September and November 2017 to provide feedback about our dimensions and characteristics. For this purpose, we designed an online survey with closed- and open-ended questions to ensure in-depth results. The lawyers were asked to assess each dimension and their characteristics. They could equally specify additional dimensions and characteristics. The identification of relevant lawyers was on the one hand a secondary result of our literature review on smart contract based papers and on the other hand the result of a search within the internet for "blockchain and lawyer" or "smart contract and lawyer". In total, we got back nine surveys. With respect to our initial question whether smart contracts are legally binding, 40% affirmed the legal validity, while 20% expressly denied it. The remaining 40% were unsure. In terms of our dimensions, the evaluation shows that three out of nine dimensions are uncertain. Although Mouzas and Furmston outline the importance of the dimension “By the time-horizon” by claiming that long-term contracts are recognised as a legal category, only 40% of the lawyers approved of it.

Dimension	Characteristics	Number	Total	Share individual
By subject matter (D1)	Sale (C11)	7	15	46.7%
	Insurance (C12)	2		13.3%
	Rental (C13)	2		13.3%
	Betting (C14)	1		6.7%
	Lending (C15)	3		20.0%
By the function of contracts (D2)	Executory (C21)	13	15	86.7%
	Framework (C22)	2		13.3%
By the time-horizon (D3)	Long-term (C31)	2	15	13.3%
	Medium-term (C32)	2		13.3%
	Short-term (C33)	11		73.3%
By the ability to renegotiate terms (D4)	Complete (C41)	4	15	26.7%
	Certain terms (C42)	1		6.7%
	Nothing (C43)	10		66.7%
By the involvement of consumers (D5)	Consumer contracts (C51)	14	15	93.3%
	Commercial contracts (C52)	1		6.7%
By the existence of mutual trust (D6)	Interpersonal (C61)	2	15	13.3%
	Repeated (C62)	2		13.3%
	No trust (C63)	11		73.3%
Subcategories of contracts (D7)	standard form printed contracts (C71)	12	15	80.0%
	individually negotiated contracts (C72)	3		20.0%
Trigger (D8)	By an external prompt (C81)	14	15	93.3%
	Based on a timer or schedule (C82)	1		6.7%
Cost of altering (D16)	strong smart contracts (C161)	6	15	40.0%
	weak smart contracts (C162)	9		60.0%

Table 3. The results of the development of the taxonomy.

The dimensions “By the existence of mutual trust” and “Subcategories of contracts”, on the contrary, obtained an approval rate of 60%. All other dimensions were approved with ratings between 80 – 100%. Only three characteristics had a low rating, whereby the characteristics “strong smart contracts” within the dimension “cost of altering” and “Betting” within the dimension “By subject matter” achieved the lowest ratings. The characteristic “Medium-term” within the dimension “By the time horizon” had an approval rate of 40%.

From Table 3, it can be seen that most of the smart contracts use cases involve consumers (93.3%), instead of business partners (6.7%). As mentioned by Mouzas and Furmston (2013), many contractual arrangements between business partners and consumers are not individually negotiated, which corresponds to the figures: In 66.7% of the cases there is no option to renegotiate contractual terms, further, 80% of the contracts are standard form printed contracts. Due to the fact that smart contracts guarantee consideration, no trust in an anonymous contract partner is necessary (Savelyev 2016). Therefore, 73.3% of the smart contract applications do not require the existence of mutual trust. Besides, most contracts are weak smart contracts (60%), which means that a smart contract is easy to alter after execution (Raskin 2017). Almost all smart contracts are triggered by external prompts (93.3%), because the application requires information from the external world. The only smart contract based on a schedule is in the “Rental agreement” use case. Table 4 shows the main focus areas of the use cases in the final classification.

Applications	D1					D2		D3			D4			D5		D6			D7		D8		D16	
	C11	C12	C13	C14	C15	C21	C22	C31	C32	C33	C41	C42	C43	C51	C52	C61	C62	C63	C71	C72	C81	C82	C161	C162
Rental agreement			X			X		X					X	X				X	X			X	X	
Pharma SCM	X					X			X				X	X			X		X		X		X	
Betting Weather				X		X				X			X	X		X				X	X			X
STROMDAO Energy	X					X		X					X	X		X				X	X			X
Home floot insurance		X				X			X			X		X				X	X		X		X	
ADEPT	X					X				X	X			X			X			X	X			X
prediction market	X						X			X			X	X				X	X		X			X
SURETLY					X	X				X			X	X				X	X		X			X
DOVU	X					X				X	X			X				X	X		X			X
bluzelle		X					X			X			X	X				X	X		X		X	
ETHLend					X	X				X			X	X				X	X		X		X	
KyberNetwork	X					X				X			X	X				X	X		X			X
Qchain	X					X				X	X				X			X	X		X			X
PayPie					X	X				X	X			X				X	X		X			X
Trippki			X			X				X			X	X				X	X		X		X	

Table 4. The final taxonomy for smart contracts applied by the examined use cases.

5 Discussion

In this paper, we developed a taxonomy for smart contracts which follows a three-step approach. The classification of 15 use cases in the taxonomy clearly shows a focus on sales (C11) with consumers (C51) on the basis of standard form printed contracts (C71) with non-negotiable terms (C43) and triggered by external events (C81). Our taxonomy delivers a classification of smart contracts on the basis of their real-life usage, which helps researchers to understand the context in which smart contracts are used and provides starting points for future research concerning the legal consequences. A practitioner like a blockchain programmer has to bear the legal consequences of smart contracts in mind. Thus, our taxonomy is an important contribution to the design of applications based on smart contracts and their legal consequences. We would like to emphasize ten main implications.

Implication 1) Initiators of smart contracts (e.g. Pharma SCM, StromDAO Energy or ADEPT) normally are companies running a business based on a blockchain application. This automatically puts consumers who do not possess detailed understanding of the necessary programming language in a weaker position. However, contracting parties do not have a duty to investigate or make enquiries about the contract (Lauslahti/Mattila/Seppälä 2017). Questions such as who is liable if the smart contract is incorrectly programmed or implemented (Werbach and Cornell 2017) and whether it is possible for a consumer to determine if a valid contract exists, need to be addressed by practitioners. Despite the above, the consumer needs to be able to understand the role of the smart contract used in the application.

Implication 2) Sometimes it remains unclear to the contract parties whether a legal contract came into effect or not. But which party is to decide (Lauslahti/Mattila /Seppälä 2017)? The taxonomy helps developers and practitioners to classify their application as having either an executory (C21) or framework (C22) function. In case of an application classified as executory, the consumer should be informed that the smart contract is a legal contract. As soon as an application is classified as framework, the consumer should be informed about the length of the framework contract.

Implication 3) 14 out of 15 smart contracts in the use cases need to react to external data outside the blockchain and do not have a mechanism to verify whether the external data is correct. As an example, the Betting Weather use case needs weather data from outside the blockchain to determine the winner of the bet. The question rises whether the loser of this bet can check the underlying data in the smart contract? Each party to a smart contract must be able to check the validity of the data in the blockchain in order to understand the outcome of a smart contract (Lauslahti/Mattila/Seppälä 2017). The relevant question thus is, who is responsible for including the relevant information in the smart contract? What legal consequences arise when false data is provided?

Implication 4) 80% of the subcategories of contracts are standard form printed contracts which are designed and used by use cases to increase operational efficiency by replicating similar commercial transactions (Mouzas and Furmston 2013). The parties to these contracts need the ability to understand the standard forms that are stored on the blockchain. Furthermore, consumer protection has to be considered. If the software code contains pre-formulated contract conditions for a large number of contracts, a general terms and conditions check should be carried out (Rikken et al. 2016).

Implication 5) since 93.3% of all smart contracts are consumer contracts where the contract is made before the performance. They are significantly more important than framework contracts which are usually more relevant in business-to-business relationships. Here, the question raises whether the terms in smart contracts are negotiable between business and private individuals and the legal consequences. The Examination of the use cases shows that 68.4% of smart contracts are more or less short-term. One of the main legal questions is, how can a short-term smart contract be altered? What legal consequences are to be expected when there is not enough time between the ending condition of a smart contract and the jurisdiction of a court stating that the contract is terminated? The implementation of basic contractual safeguards and consumer protection provisions in smart contracts is another issue for research in this area (Wright and Filippi 2015).

Implication 6) In 10 out of 15 smart contracts the parties do not have the possibility to renegotiate contractual terms. Who has the power to determine the conditions of a contract, and what are the corresponding legal consequences? Can the weaker partner be certain that all execution parameters have been identified by the operations staff (Clack/Bakshi/Braine 2016a)?

Implication 7) From the legal perspective, there is a substantial difference between a contract between business and private individuals and between commercial partners. Therefore, the dimension “By the involvement of consumers” plays a significant role in the development of smart contracts, because the aim of these statutory regulations is to ensure consumer protection and fairness in transactions with consumers (Mouzas and Furmston 2013).

Implication 8) The dimension “By the existence of mutual trust” showed that in 73.3% of the smart contracts, there is no mutual trust, which is particularly noteworthy since most contracts are concluded between strangers (Mouzas and Furmston 2013). In a global world, however, cross-border smart contracts between strangers are legally uncertain. Which legal system is relevant - the system of the initiating or the accepting party? Our taxonomy provides assistance for understanding the legal requirements necessary to run an application between strangers where trust is required. Interpersonal trust (C61) requires identity management for the contract parties. Trust based on repeated contracts needs a record of the history of the contracts stored on the blockchain.

Implication 9) What happens if the consumer is not able to fully comprehend the smart contract and its procedure, and the declaration of intent differs from the result of the smart contract? How can dispute resolution in a blockchain infrastructure be organized? As each data block on the blockchain is immutable, what does this irreversibility mean from the legal perspective (Koulu 2016)?

Implication 10) This leads us to the issue of wrongly executed contracts. In this context, the dimension "Cost of altering" differentiates between weak and strong smart contracts or rather the correspondingly arising alteration costs. We showed that 40% are strong smart contracts that have significant consequences. It is questionable how, should the need arise, an efficient redress in cross-border, online transactions between unknown parties can be ensured (Koulu 2016)?

6 Conclusion, Limitations and Future Research

For methodical reasons, we evaluated and applied our taxonomy only by means of a limited sample of 15 use cases. Thus, the taxonomy's validity will undeniably benefit from classifying more real-world use cases and applications based on smart contracts from different contexts and application domains.

We believe that our taxonomy represents the current state-of-the-art for smart contracts. However, our research comes with some limitations: Any bias in the selected literature leads to a bias in our results and thus limits the completeness of our taxonomy. Further, the analysed use cases will soon be outdated and new applications based on smart contracts might extend or change the current taxonomy with regard to both dimensions and characteristics. Another aspect is that the results from our survey of lawyers require further discussion although the foundation for a good classification system had been laid out.

The anonymity of blockchain, the absence of regulatory intermediaries and cross-border business relationships increase the necessity for legally binding and valid contracts. The assurance of the contractual capacity and the adaption of varying country-specific legislations are essential prerequisites for valid contracts. Furthermore, the fact that 73.3% of the smart contracts are built without trust between strangers increases the risk that one of the smart contract parties is a minor (Giancaspro 2017).

But then again, limitations stimulate further research. Apart from our taxonomy with the focus on legal aspects, it could be useful to create taxonomies that concentrate on applications from technical, economic and corporate point of views. We hope that our taxonomy will provide fellow researchers with valuable insights into the different legal aspects of smart contracts.

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