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A preliminary study on artificial intelligence oracles and smart contracts: A legal approach to the interaction of two novel technological breakthroughs

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ABSTRACT

Artificial Intelligence and Smart Contracts are two cutting-edge technological achievements of the so-called 4th Industrial Revolution era. Both have already had a significant impact on various aspects of modern life, including transactions, and each one has already been under scientific investigation. Instead, their interaction has not become the subject of a debate, although it can further (positively) affect the transactions. This interconnection takes place through specific mechanisms, called Oracles, which can be, among others, highly sophisticated Artificial Intelligence systems (autonomous systems). The present article aims to present the role of the Artificial Intelligence Oracles throughout the 'smart contractual procedure', as well as to shed light on the potential (new) legal issues this interconnection may raise. The main result of this article is to indicate the appropriate legal directions in case of Artificial Intelligence Oracles' failures, based on the most prevalent current approaches to AI's (the user's) contractual and/or non-contractual liability. The major research's conclusion is that the Artificial Intelligence Oracle's failures may result in one of the following situations: (a) breach of a (smart) contract, (b) unjust enrichment, (c) conclusion of a (voidable) smart contract that should not have been concluded, or (d) non-conclusion of a smart contract that should have been concluded. The responsibility of each person participating in the 'smart contractual procedure', i.e. the contractual parties, the blockchain platform and the Artificial Intelligence user/owner (or even the Artificial Intelligence system itself), as well as the AI provider or designer, is examined in each of the afore-mentioned situations separately. Given that legislative initiatives have already begun, the present article aspires to contribute to the consistent address of the newly raised legal issues.

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1. Introduction

Artificial Intelligence (henceforth *AI*)[1] and Smart Contracts (henceforth SmC)[2] are two cutting-edge technological achievements of the 4th Industrial Revolution era.[3] They both have a significant impact on various aspects of modern life, from daily activities (e.g., transportation and entertainment) to the job market, banking, finance, the medical sector, and transactions.

A lot has been written in recent decades regarding each of these breakthroughs and their impact from a legal perspective. However, the 'cooperation' of these novel technologies has not become the subject of debate yet, although their interaction has already become apparent.[4] Indeed, the use of AI applications on blockchain technology, and particularly on SmC, has proven to be a useful tool for bringing into touch the on-chain world, i.e., a SmC running on a blockchain platform, with the off-chain one, i.e. the 'real' world where the contractual outcomes occur. Such an interaction can further benefit transactions, enhancing their velocity, decreasing costs as well as the possibility of contractual non-performance, either by default or without default.

Nonetheless, this interconnection poses some legal issues that have never been raised before. For instance, in the event of a malfunction attributed to an AI system that affects the operation of a SmC it is questionable as to whether the user-contractual party on-chain should be held liable and as to what rights they have, in comparison with a party in a 'traditional' contract concluded and executed entirely off-chain, if they can be released from their liability, etc. However, there is no specific legal framework regulating the interaction between AI and SmC, which poses a challenge for legal doctrine. The main points of interest are the fitness of classical legal doctrine and, especially, contract law, to successfully regulate the new transaction reality created by these technologies and the systemization of any new legislative enactment thereon.[5]

This paper aims to present the interconnection between AI and SmC, shed light on the potential legal issues this interconnection may raise, and suggest certain legal directions to be addressed.

The paper consists of four parts: the first two parts seek to introduce the reader to the concept of AI and SmC accordingly, as well as to describe their role at modern transactions (2, 3). Of course, all technical aspects cannot be presented in this article. Apart from being extensively discussed in literature already, they are not necessary for understanding the legal concerns this interaction induces. For this reason, the article puts emphasis only on those technicalities which are significant from a legal point of view. In this framework, the paper also examines the legal treatment of AI, as well as of SmC. As far as AI is concerned, the analysis is restricted to the *autonomous AI systems* (or *autonomous machines*) for two reasons: first, because they constitute the most representative type of AI systems nowadays, with an extended usage in almost all sectors of modern life, including transactions; second, because they show great levels of autonomy that cast doubts on the appropriateness of the 'traditional' rules of law about human liability in the event of damage caused by autonomous AI systems. In the paper, the prevalent opinion about AI users' contractual (and non-contractual) liability is adopted, enhanced with further arguments. Respectively, the paper examines the various types of SmC and their legal nature, which is particularly important to understand in order to formulate the liability issues raised in case of damage caused by the interconnection between SmC and AI.

The next part presents the *oracles*: the mechanisms which facilitate the interconnection between the SmC and the off-chain world (4). Although there are several types of oracles, the paper focuses on the autonomous AI oracles since they are the oracles that can enable an autonomous interaction with the SmC, revolutionizing the way people carry out transactions.

In the fourth part, the various types of AI oracle failures, as well as their impact on SmC, are analyzed (5). This impact may vary depending on the underlying kind of SmC and can raise, inter allia, one of the following situations: (a) breach of a (smart) contract, (b) unjust enrichment, (c) conclusion of a (voidable) SmC that should not have been concluded, or (d) non-conclusion of a SmC that should have been concluded. Further, the analysis shows that all the persons taking part in the 'smart contractual procedure', i.e., the contractual parties, the blockchain platform, the AI user/owner, as well as the AI provider or designer, may be held liable based on different liability regimes (i.e. contractual, non-contractual liability regimes) in each of the afore-mentioned situations.

In the last part the main conclusions regarding the interconnection of the two novel technologies from a legal point of view are presented (6).

[1] Henceforth "AI".

[2] Henceforth "SmC", used for both singular and plural Smart Contracts.

[3] See more about the 4th Industrial Revolution Braütigam & Klindt, "Industrie 4.0, das Internet der Dinge und das Recht" (2015) NHW 1137; European Law Institute (ELI) Principles on Blockchain Technology, Smart Contracts and Consumer Protection (2022) <www.europeanlawinstitute.eu/fileadmin/user_upload/p_eli/Publications/ELI_Principles_on_Blockchain_Technology__Smart_Contracts_and_Consumer_Protection.pdf> accessed 15 Jan 2022 (p. 11).

[4] See one of the first approaches to both technologies in Taherdoost, "Blockchain Technology and Artificial Intelligence Together: A Critical Review on Applications" (2022) 12 Applied Science 1; Zou, "When AI Meets Smart Contracts: The Regulation of Hyper-Autonomous Contracting Systems?" in *Contracting and Contract Law in the Age of Artificial Intelligence* (Ebers, Poncibo & Zou (edt.)), (Hurt Publishing, 2022).

[5] See, inter alia, in the European Union the European Commission's recent Proposal for a Regulation of the European Parliament and of the Council on Laying Down Harmonized Rules on Artificial Intelligence (Artificial Intelligence Act), COM (2021) 206 final; European Commission's Proposal of Directive of the European Parliament and of the Council on Liability of Defective Products, COM (2022) 495 final; European Commission's Proposal of Directive of the European Parliament and of the Council on Adapting Non-Contractual Civil Liability Rules to Artificial Intelligence (AI Liability Directive), COM (2022) 496 final.

2. The role of artificial intelligence in modern transactions: applications, limitations and legal treatment

2.1. *Applications of AI and inherent limitations*

Over the past decades, AI has become a scientific field of primary importance on a global scale.[6] Since its official[7] establishment in 1956 at the Dartmouth College Conference,[8] until today,[9] its technological breakthroughs have significantly affected various areas of modern life,[10] even though sometimes this has remained unnoticed.[11]

The most typical representatives of AI systems today are deemed to be the so-called *autonomous AI systems* or *autonomous machines*, whose performance is exceptional in diverse fields,[12] thanks to their *ability to learn*. This ability, called *machine learning*,[13] enables the AI system to improve itself at the execution of any assigned task by gaining its own experience and knowledge[14] through the processing of vast amounts of data ('Big Data').[15] Thanks to this ability autonomous AI systems can have a significant impact on transactions,[16] where they are proven to be able to fully replace humans in a contractual procedure.[17]

The application of the autonomous AI systems brings significant advantages for transactions, since they significantly reduce the time needed for negotiations.[18,19] Nonetheless,

[6] Although the term *'Artificial Intelligence'* is widely accepted, the scientific community does not fully agree about its specific content, see Rissland, "Artificial Intelligence and Law: Stepping Stones to a Model of Legal Reasoning" (1990) Yale L Rev 1957; Ertel, *Introduction to Artificial Intelligence* (2[nd] edn., Springer 2017); UNESCO, Preliminary Study on the Ethics of AI (2019) <https://unesdoc.unesco.org/ark:/48223/pf0000367823> accessed 20 Dec 2022 (pp. 7-9); Müller, "Ethics of Artificial Intelligence and Robotics", *The Stanford Encyclopedia of Philosophy* (2021) Zalta (ed.), <https://plato.stanford.edu/archives/sum2021/entries/ethics-ai/> accessed 20 Dec 2022.

[7] Nonetheless, the first thoughts about AI had already been expressed in 1950 by *Alan Turing* in his article "Computing Machinery and Intelligence" (1950) 59 Minds and Machines 433, where the famous 'imitation game' was first introduced.

[8] Summer Research Project on Artificial Intelligence organized by *John McCarthy* for studying the possibilities of using computers to simulate human intelligence, see "Darmouth workshop" <https://en.wikipedia.org/wiki/Dartmouth_workshop> accessed 20 Dec 2022.

[9] See more about AI history Smith, Huang, McGuire & Yang, *The History of Artificial Intelligence* (2016) <https://courses.cs.washington.edu/courses/csep590/06au/projects/history-ai.pdf> accessed 20 Dec 2022 (p. 12); UNESCO (2019), pp. 10-11; Ebers, Poncibo & Zou (eds.), *Contracting and Contact Law in the Age of Artificial Intelligence*, (Hart Publishing, 2022).

[10] See European Commission, White Paper on AI – A European Approach to Excellence and Trust, COM (2020) 65 final, 1; European Commission, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions empty - Building Trust in Human-Centric Artificial Intelligence, COM (2019) 168 final, 1; Kemper & Kolkman, "Transparent to Whom? No Algorithmic Accountability Without a Critical Audience" (2019) 22 Information, Communication and Society 2081 (p. 2082).

[11] See an overview at Zekos, *Economics and Law of Artificial Intelligence* (Springer, 2021) (p. 233 ff.).

[12] Their uses include facial recognition, the issuing of invoices and legal or medical documentation, inventory forecasting, robots in deep sea and space exploration, weapon systems, software agents, self-driving vehicles for delivering products or guiding ships remotely, as well as many more functions, see European Commission, Statement on Artificial Intelligence, Robotics and 'Autonomous Systems' (2018) <http://earthnet.ntua.gr/wp-content/uploads/2018/07/Artificial-inteligence-robotics-and-autonomous-systems.pdf> accessed 27 Dec 2022).

[13] Russell & Norvig, *Artificial Intelligence: A Modern Approach* (4[th] Edition, Pearson Series in Artificial Intelligence, 2020), p. 651 ff.; Wettig & Zehhendner, "A Legal Analysis of Human and Electronic Agents" (2004) 12 Artificial Intelligence and Law 111 (2004), pp. 111-135. See also Sartor (2018), p. 266 ff.

[14] Wettig and Zehendner (2004), pp. 111-135; Borges, „Rechtliche Rahmenbedingungen für autonome Systeme" (2018) NJW 977 (p. 978).

[15] Buchner, "Artificial Intelligence as a Challenge for the Law: The Example of "Doctor Algorithm"" (2022) 3 International Cybersecurity L Rev 181 (p. 182).

[16] Kerr, "Spirits in the Material World: Intelligent Agents as Intermediaries in Electronic Commerce" (1999) 22 Dalhousie L J 185; Lerouge, "The Use of Electronic Agents Questioned under Contractual Law: Suggested Solutions on a European American Level" (2000) 18 J. Marchall J Computer & Info Law 403 (p. 406).

[17] Balke, ""Entity" and "Autonomy" - The Conclusion of Contracts by Software Agents in the Eyes of the Law" (2020) 24 Revue d' Intelligence Artificielle 391; Grundmann & Hacker, "Digital Technology as a Challenge to European Contract Law-From the Existing to the Future Architecture" (2017) 13 Eur Rev Contract L 13 255; Sartor, "Contracts in the Infosphere" in Grundmann (ed.) *European Contract Law in the Digital Age* (Cambridge U Press, 2018), 263 (pp. 263-264). See also Karnow, "Liability for Distributed Artificial Intelligences" (1996) 11 Berkley Tech L Rev 147 (pp. 152-153); Allen & Widdison, "Can Computers Make Contracts (1996) 9 Harvard L Rev 26 (p. 29); Pagallo, "What Robots Want: Autonomous Machines, Codes and New Frontiers of Legal Responsibility" in Hildebrandt & Gaakeer (eds.), *Human Law and Computer Law: Comparative Perspectives* (Springer, 2013) (pp. 47-65).

[18] Köhler, „Die Problematik automatisierter Rechtsvorgänge, insbesondere von Willenserklärungen" (1982) 182 AcP 126 (p. 129); Allen & Widdison (1996), p. 29; Lerouge (2000), pp. 404-434; Kerr (1999), p. 184; Wettig and Zehendner (2004), p. 112. See also Cornelius, "Vertragsabschluss durch autonome elektronische Agenten" 2002 MMR 353.

[19] It is also claimed that AI significanly reduces the actual cost of transactions, see Deranty & Corbin, „Artificial Intelligence and Work: A Critical Review of Recent Research from the Social Sciences" 2022 AI & Society; Perifanis & Kitsios, „Investigating the Influence of Artificial Intelligence on Business Values in the Digital Era of Strategy" A Literature Review: (2023) 14 Information. Nonetheless, it is also supported that AI increases the (transactional) costs because the costs associated with AI are huge (e.g. cost of hardware, cost of data, cost for trianing models, cost deployment auomation, security costs, continuous optimization costs), see Mhlanga, „Industry 4.0 in Financne: The Impact of Artificial Intelligence (AI) on Digital Financial Inclusion" (2020 8 Inter J Financial Studies; Birdzell, „How to Decrease the Cost of AI", availabe at <https://ask.kristasoft.com/webinar-cost-of-ai> accessed 9 Jul 2023. See, contra, about the reduction of transactional costs OECD, „Artificial Intelligence, Machine Learning and Big Data in Finance: Opportunities, Challenges and Implications for Policy Makers" (2021)

machine learning renders their function *opaque*, which although exceptional, is inexplicable for humans, even for their designers. This constitutes the so-called *black box effect* or *black box problem,* from which all autonomous systems suffer.[20] This is an inherent limitation of the AI systems that can negatively affect their rendered outcomes,[21] jeopardizing AI sustainability[22] and its further public acceptance. Further, it sparks a hot debate in the literature about the appropriate legal treatment of autonomous AI systems, as analyzed immediately below.

2.2. *Legal treatment*

Despite the extensive use of autonomous machines in transactions, there is no consensus in literature with regard to their legal treatment in the case of contractual[23] (as well as in the case of non-contractual) liability.

According to the most prevalent opinion,[24] the law as it now stands should consider autonomous machines as *mere communication tools,* like any other software system (e.g., email) or electronic devices (e.g., telephones and fax machines), or like a messenger (*nuntius*),[25] whose role is merely to convey the declaration of intention (offer or acceptance) of its user-principal to the other contractual party, and/or like an agent, who performs the contractual obligations on behalf of the principal. Although AI systems show greater levels of autonomy, this approach adopts a *legal fiction* that anything issued by an autonomous AI system is actually issued by its user,[26] given that the system lacks the necessary legal and contractual capacity for being itself legally bound by the contract and civil liability.[27]

Highlighting the trait of autonomy, other opinions suggest that autonomous machines should be legally treated as representatives under the *mutatis mutandis* application of the law of disclosed agency;[28] or that they should be attributed a *legal personhood,* in order to acquire legal and, thus, contractual capacity, like legal persons;[29] or that they should be considered as contemporary *electronic "slaves"*[30] that will not bear full legal capacity but will have a restricted capacity of contracting, like the Ancient Roman slaves,[31] and a civil insurance in case they cause any damage; or that they should be *electronic persons* or *hybrid-electronic persons,*[32] which is a business registry for up-to-date certificated autonomous machines[33] that will be civil insured and possess a bare minimum of property deposited by their owners,[34] whose liability in the case of damage is limited accordingly.

<https://www.oecd.org/finance/artificial-intelligence-machine-learning-big-data-in-finance.htm> accessed 9 Jul 2023 (p. 7, 9, 21, 22, 26, 30, 34, 39).

[20] Wulf & Seizov, "Artificial Intelligence and Transparency: A Blueprint for Improving the Regulation of AI Applications in the EU" (2020) 31 Eur Bus L Rev 611 (p. 619); Papadouli, "Transparency in Artificial Intelligence: A Legal Perspective" (2022) 4 J of Ethics and Legal Tech 25.

[21] For instance, the famous *IBM*'s AI system 'Watson' was accused of giving incorrect medical treatment, see Ross & Swetlitz, "IBM's Watson supercomputer recommended 'unsafe and incorrect' cancer treatments, internal documents show" (see Statnews, 25 Jul 2018) <https://www.statnews.com/2018/07/25/ibm-watson-recommended-unsafe-incorrect-treatments> accessed 27 Dec 2022; *Apple*'s credit card system for assessing the creditworthiness of loan applicants was accused of issuing biased decisions against African Americans, due to algorithm malfunction, see Vigdor "Apple Card Investigated After Gender Discrimination Complaints" (see The New York Times, 2019) <https://www.nytimes.com/2019/11/10/business/Apple-credit-card-investigation.html> accessed 27 Dec 2022; *Amazon*'s AI system for assessing candidates' qualifications in hiring processes was found to conduct sexual discrimination against women (see Dastin, "Amazon scraps secret AI recruiting tool that showed bias against women" (Reuters 11 Oct 2018) <ww.reuters.com/article/us-amazon-com-jobs-automation-insight-idUSKCN1MK08G> accessed 15 Feb 2023).

[22] Cf. Licht & Licht, "Artificial Intelligence, Transparency and Public Decision Making" (2020) 35 AI & Society 915 (p. 918).

[23] See an overview of various supported opinions at Solum, "Legal Personhood for AI" (1992) 70 North Carolina L Rev 1231; Karnow (1996); Allen & Widdison (1996); Fisher, "Computer as Agents: A proposed Approach to Revised U.C.C. Article 2" (1997) 72 Indiana L J 545; Mehrings, "Vertragsabschluss im Internet. Eine neue Herausforderung für das "alte" BGB" (1998) MMR 30; Kerr (1999); Cornelius (2002); Wettig and Zehendner (2004); Chopra & White, "Artificial Intelligence and the Contracting Problem" (2009) U of Illinois J L, Tech & Policy 363; Katz, "Intelligent Agents and Internet Commerce in Ancient Rome" (2009) <https://www.scl.org/articles/1095-intelligent-agents-and-internet-commerce-in-ancient-rome> accessed 27 Dec 2022; Pagallo, "Killers, Fridges, and Slaves: A Legal Journey in Robotics" (2011) 26 AI & Society 347; Eidenmüller, "Robots Legal Personality" (2017) <https://blogs.law.ox.ac.uk/research-and-subject-groups/research-collection-law-and-technology/blog/2017/02/robots%E2%80%99-legal> accessed 17 Jun 2023; Boden, Bryson, Caldwell, Dautenhahn, Edwards, Kember et al., "Principle of Robotics: Regulating Robots in the Real World" (2017) 29 Connection Science 124; Keßler, "Intelligente Roboter-neue Technologie im Einsatz" (2017) MMR 589; Papadouli, "The Role of Autonomous Machines at the Conclusion of a Contract: Contractual Responsibility according to Current Rules of Private Law and Prospects" in Artificial Intelligence and Normative Challanges (Kornilaks, Nouskalis, Pergantis, Tzimas (eds.)), (Springer, forthcoming 2023).

[24] Allen & Widdison (1996), p. 43 ff.; Mehrings (1998), p. 31; Brozek & Jakubiec, "On the Legal Responsibility of Autonomous Machines" (2017) 25 Artificial Intelligence L 293 (pp. 293 and 303).

[25] Wettig and Zehendner (2004), p. 125; Keßler (2017), p. 592.

[26] Allen & Widdison (1996), p. 46. See also Weitzenboeck, "Electronic Agents and the Formation of Contracts" Inter J of Law and Info Tech (2001) 9 204 (p. 207); Kerr (2011), pp. 219 and 232; Chopra and White (2009), p. 372; Balke (2010), p. 5.

[27] Allen & Widdison (1996), p. 44; Mehrings (1998), p. 31; Kerr (2001), p. 232; Cornelius (2002), p. 355.

[28] Fisher (1997), p. 545; Chopra and White (2009), pp. 369-370 and 384. See also Linarelli, "A Philosophy of Contract Law for Artificial Intelligence: Shared Intentionality" in *Contracting and Contract Law in the Age of Artificial Intelligence* (Ebers, Poncibo & Zou (eds.)), (Hurt Publishing, 2022) (p. 62 ff).

[29] Solum (1992), passim.; Eidenmüller (2017); Cheong: "Granting Legal Personhood to Artificial Intelligence Systems and Traditional Veil-Piercing Concepts to Impose Liability" (2021) SN Social Sciences 1 231.

[30] Kerr (2001), pp. 236-238.

[31] Katz (2009), p. 5; Pagallo (2011), pp. 5-6; Pagallo (2013), pp. 59-60.

[32] Wettig and Zehendner (2004), p. 128 ff.; (2013), p. 9.

[33] Karnow (1996), p. 193 ff. (*"Turing Register"*). See also Weitzenboeck (2001), pp. 36-37; Balke (2010), pp. 18-19.

[34] Bellia, "Contracting with electronic agents" Emory L J (2001) 50, 1047 (p. 1067). Contra Lerouge (2000), p. 411.

The basic advantage of these approaches is that they take into account that AI systems act *autonomously*.[35] Nevertheless, they fail, in fact, to provide practical solutions, while they "exceed" the current legal framework: the current rules of private law have not (yet) attributed legal personhood to the autonomous AI systems,[36] while it cannot be held that they could have contractual capacity, even a restricted one, without legal capacity. Besides, in practice, no registry about AI systems has been established yet,[37] while the existence of a "legal representative" who bears no property does not facilitate in any way the third party-claimants.

Therefore, the prevalent opinion, according to which the autonomous machines should be treated as communication tools and any contractual liability arising from their use should be attributable directly to their users, seems to be the most consistent one within the current legal framework. Further, this approach boosts the *transaction security*, since it clarifies the person who should be responsible in the case of non-performance: the *AI user*. It also provides the latter with a *strong incentive* to ensure that their "employed" autonomous machine operates properly. Indeed, had the AI user not been considered legally bound regarding the contract concluded by their "employed" autonomous machine, they would not have been cautious enough about their AI system's proper function.[38] Moreover, any AI user could rely on the system's alleged malfunction or opaque function (the aforementioned *AI black box problem* or *black box effect*) to avoid their engagement in the contract; as a result, the other contractual party would bear the risk of the AI system's (mal)function, without having any power over it and, most of the time, without even knowing that they transact with an autonomous machine and not with a human.

This is a typical situation of *information asymmetry* between the contractual parties of a contract, where one of them has an incentive to increase their exposure to risk because their contractual partner will bear the cost in the case of loss (*moral hazard*).[39] In the case of autonomous machines, the problem of information asymmetry is exacerbated due to the black box effect. The prevalent opinion "protects" the counter contractual party from this risk, providing at the same time a certain element of justice: since the AI user is the one who opts to employ an autonomous machine and to involve it in trading, the assumption that they should bear the cost of any (mal)function of it sounds logical.[40]

Given that in common law systems the contractual liability is non-fault based, while in the civil law ones the relevant fault is being presumed, this approach is also quite aligned with the prevalent opinion about the AI user's *non-contractual* liability, which endorses that the negligence-based liability regime, like the tort liability, should be put aside, and a strict liability regime be adopted.[41] It is claimed that until then,[42] the rules of law about *vicarious liability*,[43] or about the *parents'* or *animal keeper's* ones,[44] should be implemented *mutatis mutandis* since they are more suitable for handling any damages caused by autonomous AI systems.

The above analysis is crucial for handling damages raised in the case of SmC, when they cannot be self-concluded, self-performed and/or self-executed due to an AI oracle's failure, as it is analyzed thoroughly below.

3. The role of smart contracts in modern transactions: applications, limitations and legal treatment

3.1. *SmC applications and inherent limitations*

Smart Contracts were first introduced in legal doctrine in the mid-1990s by Nick Szabo, a legal scholar and technologist, in

35 Pagallo (2013), p. 58.

36 See also the recent proposal of the *European Financial and Social Commission* Com (2020) 65 final, which strongly recommends no legal personhood should be attributed to AI.

37 It is noteworthy that according to Art. 60 of Proposal of European Commission for a Regulation of the European Parliament and of the Council regarding harmonized rules on AI ('AI Act' COM (2021) 206 final), a database for *stand-alone high-risk AI systems* is yet to be established.

38 See also regarding liability of autonomous vehicles Di, Cehn & Talley, "Liability for Autonomous Vehicles and Human-Driven Vehicles: A Hierarchical Game-Theoretic Approach" Transportation Research Part C" (2020) 118 Emerging Technologies 1.

39 Firstly, the concept of moral hazard appeared in assurances (see also Abraham & Rabin, "Automated Vehicles and Manufacturer Responsibility for Accidents: A New Legal Regime for a New Era" 105 (2019) Virginia L Rev 127 (p. 134), but today one can encounter it in many other fields as well (see Dembe and Boden, "Moral Hazzard: A Question of Morality?" (2000) 10 New Solutions 257; Bannier, *Vertragstheorie. Eine Einführung mit finanzökonomischen Beispielen und Anwendungen* (Physica-Verlag, Heidelberg, 2005) (pp. 69-71)).

40 Allen & Widdison (1996), p. 46. See also Cornelius (2002), p. 355; Shavell, "On the Redesign of Accident Liability for the World of Autonomous Vehicles" 49 J of L Studies 214.

41 Especially as far as car accidents and defected products are concerned, see Bertolini, "Robots as Products: The Case for a Realistic Analysis of Robotic Applications and Liability Rules" 5 (2013) L of Innovations and Economics 214; Abraham & Rabin (2019); De Chiara, Elizanlde, Manna & Segura-Moreiras, "Car accidents in the age of robots" 68 (2021) Inter Rev of L and Economics 1; see also the concerns of Shavell (2019), arguing about a new type of "*strict liability with damages paid to the state*", as well as the new liability regime "*which blends negligence-based rules and strict manufacturer liability rules*", by Guerra, Parisi & Pi, "Liability for robots II: legal challenges" (2022) 18 J of Institutional Economics 553 (passim.).

42 See a recent survey on legislative initiatives worldwide Guerra et al. (2022), p. 336 ff.

43 Čerka, Grigienė & Sirbikytė, "Liability for Damages Caused by Artificial Intelligence" Computer L & Security Rev 31 (2015) 376; Wendehorst, "Liability for Artificial Intelligence. The Need to Address Both Safety Risks and Fundamental Right Risks" in the *Cambridge Handbook of Responsible Artificial Intelligence* (Cambridge U Press, 2022) <https://www.cambridge.org/core/books/cambridge-handbook-of-responsible-artificial-intelligence/liability-for-artificial-intelligence/12A89C1852919C7DBE9CE982B4DE54B7> accessed 17 Jun 2023. See also Schrimer, "Rectsfähige Roboter?" (2016) 71 JZ, 660; Teubner, "Digitale Rechtsubjecte" (2018) 218 AcP, 155.

44 Buiten, de Streel & Peitz, "The Law and Economics of AI Liability" Computer L & Security Rev 48 (2023) 1.

a series of papers,[45] in which he presented a concept of contracts that can be self-performed and self-executed without, or with little, human intervention. According to Szabo, SmC are the technological evolution of classic vending machines[46] that facilitate automated contract performance and contract execution, significantly decreasing transactional costs and enhancing transactions' velocity.

Szasbo's revolutionary concept did not become a reality until over 10 years later. Although some progress had been made in this direction,[47] for many years the concept of SmC remained unknown in the trade industry. It was the development of *blockchain technology* in 2000 that enabled SmC to thrive.[48] Although this technology[49] was first introduced as a technological backbone for cryptocurrencies, especially *Bitcoin*,[50] it was soon found to also be able to facilitate other applications as a communication path for trusted transactions that can securely convey and store data.[51] Among those, the most significant one is *smart contracts*.[52] The most widespread blockchain platform for SmC is the public blockchain platform *Ethereum*.[53] Established in 2013 by Vitalik Buterin, Ethereum blockchain infrastructure allows anyone who has access to the decentralized network to exchange any virtual asset (digital or digitally represented) with the use of a cryptocurrency called *Ether*.[54]

The advent of SmC brings about several significant changes for transactions, most of which are due to the distributed ledger technology on which they are based (automatic performance of contractual obligations;[55] no - or at least restricted possibilities for - breach of contract;[56] trust between con-

[45] According to *Szabo*'s 'definition', smart contracts are "*a set of promises, specified in digital form, including protocols within which the parties perform on these promises. The protocols are usually implemented with programs on a computer network, or in other forms of digital electronics*". Thus, they can "*formalize and secure digital relationships"* more efficiently *"than their inanimate paper-based ancestors*", "Formalizing and Securing Relationships on Public Networks" (1997) First Monday; "Smart Contracts: Building Blocks for Digital Markets" (1996) <http://www.fon.hum.uva.nl/rob/Courses/InformationInSpeech/CDROM/Literature/LOTwinterschool2006/szabo.best.vwh.net/smart_contracts_2.html> accessed 30 Dec 2022; "Smart Contracts" (1994) <http://www.fon.hum.uva.nl/rob/Courses/InformationInSpeech/CDROM/Literature/LOTwinterschool2006/szabo.best.vwh.net/smart.contracts.html> accessed 30 Dec 2022.

[46] Their first appearance is placed in antiquity, described by the ancient Greek engineer and mathematician *Hero* Ctesibius (also referred to as *Heron*) and his work *Pneumatika* in 62 AD, where he refers to the function of a machine that dispensed holy water in Egyptian temples, when the practitioner inserted a coin, see *Hero of Alexandria*, The Pneumatics, section 21 translated from Greek and edited by Woodcroft <https://web.archive.org/web/20101208040820/http://www.history.rochester.edu/steam/hero/index.html> accessed 30 Dec 2022. See also Savelyev, "Contract Law 2.0: "Smart" Contracts As the Beginning of the End of Classic Contract Law" (2016) Higher School of Economics Research Paper No. WP BRP 71/LAW 120; Raskin, "The Law and Legality of Smart Contracts" (2017) 305 Georgetown L Tech Rev 305 (p. 325); Agnikhortam & Kouroutakis, "Doctrinal Challenges for the Legality of Smart Contracts: Lex Cryptographia or a New, 'Smart' Way to Contract?" (2019) 19 J of High Tech L 301 (p. 312). – See also de Filippi & Wright, *Blockchain and The Law* (Harvard U Press, 2018) (p. 72-73), where the paradigm of *Gulbert's* invention "*Berlin Airlift*" in 1948 is described.

[47] Indeed, insurance companies offer passengers the possibility to purchase flight insurance from a 'vending machine' stationed in airports, usually at flight gates. To do this, the customer inputs their personal data and flight information on the machine's screen and makes payment, by inserting coins in the slot or using another form of payment. When the predefined conditions are met (provision of personal data, flight data, and payment), the machine issues an insurance policy and retains a duplicate for the company's records; see Cannarsa, "Interpretation of Contracts and Smart Contracts: Smart Interpretation or Interpretation of Smart Contracts?" (2018) 26 Eur Rev of Private L 773 (p. 784); Rohr, "Smart Contracts and Traditional Contract Law, Or: The Law of the Vending Machine" (2019) 67 Cleveland State L Rev 71 (p. 82). Furthermore, there are also computer programs being used by financial institutions for bookkeeping transactions or for controlling a car's speed, see Temte, "Blockchain Challenges Traditional Contract Law: Just How Smart Are Contracts" (2019) 87 Wyoming L Rev (p. 95).

[48] Meyer, "Stopping the Unstoppable: Termination and Unwinding of Smart Contracts" (2020) 9 EuCML 17.

[49] Even though blockchain technology does not constitute a sine qua non semantic trait of SmC, it has become a vital prerequisite for their function, see Lehmann & Krysa, "Blockchain, Smart Contracts und Token aus der Sicht des (Internationalen) Privatsrechts" (2019) BRJ 90R.; Pardolesi & Davola, "What Is Wrong in the Debate about Smart Contracts" (2019) Working Paper 2019 <https://ssrn.com/abstract=3339421> accessed 30 Dec 2022; Durovic & Janssen (2019), p. 757; Meyer (2020), p. 18; Junghöfer, "Verbraucher Verträge als Smart Contracts" (2021) Leipzig L J 3.

[50] First proposed by *Sathoshi Nakamoto* (presumably a pseudonym of a person or a group of persons) in 2009, see Satoshi Nakamoto, "Bitcoin: A Peer-to-Peer Electronic Cash System" (2022) <www.bitcoin.org> accessed 27 Dec 2022. His/Their idea was based on the work of Haber & Stornetta, "How to Time-stamp a Digital Document, (1991) 3 J of Cryptography 99; see also Bosch, Tangi & Burian, "European Landscape on the Use of Blockchain Technology by the Public Sector" (2022) < https://publications.jrc.ec.europa.eu/repository/handle/JRC131202> accessed 27 Dec 2022.

[51] Agnikhortam & Kouroutakis (2019), pp. 309-310; Hasting, "Smart Contracts: Implications on Liability and Competence" (2020) 28 Miami Bus L Rev 358 (p. 360).

[52] See other uses of blockchain Panda, Jena, Swain & Satapathy, *Blockchain Technology: Applications and Challenges* (Springer, 2021).

[53] Diedrich, *Ethereum* (Wildfire Publishing, 2015); see also Temte (2019), p. 95; Tjong Tjin Tai, "Force Majeure and Excuses in Smart Contracts" (2018) 6 Eur Rev of Private L 787 (p. 790); Durovic & Jansen (2020), p. 63. See thoroughly about Ethereum's operation Idelberger, "Connected Contracts Reloaded – Smart Contracts as Contractual Networks" in Grundmann (ed.) *European Contract Law in the Digital Age* (Cambridge U Press, 2018) (p. 212 ff.). Other similar platforms are *Ripple* (https://ripple.com/ accessed 15 Jan 2023), *Colu* (https://www.colu.co/ accessed 15 Jan 2023), and *Omni* (http://www.omnilayer.org/> accessed 15 Jan 2023).

[54] Blocher, "The next big thing: Blockchain-Bitcoin-Smart Contracts" (2016) Deutscher Juristentag AnwBl 612. In contrast to Bitcoin which facilitates only bitcoin units, see Savelyev (2016), p. 128*;* Lingwall & Mogallapu, "Should Code be Law? Smart Contracts, Blockchain and Boilerplate" (2019) 88 UMKC L Rev 285 (pp. 301-302), where the Ethereum is described as a "*Turing complete*" system in contrast to Bitcoin, which is deemed a "*Turing incomplete*" system.

[55] Savelyev (2016), p. 130.

[56] Caused either by default or not (efficient breach), see Savelyev (2016), p. 127, 130. Cf. Meyer (2020), p. 19.

tractual parties (*trustless trust*);[57] reduction of transactional costs[58] as well as of the time for negotiation and conclusion of the contract[59]).

SmC can be used in any sector where data flow and information storage are required,[60] e.g. in state[61] or corporate[62] governance; in the real estate market[63] (especially for the creation of a digital public record of ownership);[64] in the health sector;[65] in bank transactions, especially for automated payments (e.g. of dividends, stock splits and liability engagement,[66] clearing process[67] or issuing of letters of credit);[68] in logistics and supply chains;[69] even in the law profession for contract drafting.[70] However, the sectors where they have had the most valuable use up to now are the *private insurance industry* and *crowdfunding projects*.[71] In these cases, a SmC usually facilitates the verification of certain events and the allocation of funds to claimers/beneficiaries in a direct and quick way: an insurance company creates a policy in the form of a SmC, which applies when specific conditions are met, e.g. when a natural disaster occurs (like a hurricane, earthquake or drought); once the relative data (e.g. wind speed, location, magnitude of earthquake) are inserted into the system, the compensation can automatically be released to the claimers.[72][73] Accordingly, as an example, in a crowdfunding project,[74] once the amount exceeds the necessary total, it is automatically transferred to the beneficiary.[75]

Apart from these two last cases, SmC can have an extended use in other transactions, facilitating contract performance and execution.[76] For instance, in the stock market they can be used for stock purchase and stock sales, when prices reach a certain level.[77] Moreover, with the advent of the Internet of Things (IoT), SmC are expected to gain even more importance, allocating obligations, duties and rights to connected devices.[78] Their role should not necessarily be limited only to quite rudimentary transactions, such as cryptocurrency transfer from A's wallet to B's when specific conditions occur,[79] or

57 Eenmaa-Dimitrieva & Schmidt-Kessen, "Creating Markets in no-trust environments: The Law and Economics of smart contracts (2019) 35 Computer L & Security Rev 69 (p. 81); Cannarsa (2019), p. 778.

58 Nonetheless, this does not mean that they are more economical in comparison to traditional contracts since the necessary technological equipment is quite expensive, while the electricity consumption, especially for solving the problem and verifying the transaction, is high (see Savelyev (2016), p. 127; Temte (2019), p. 92), while the drafting of a smart contract is not easy for a person, who must resort to a special engineer (see Lingwall & Mogallapu (2019), p. 314 ff.; Temte (2019), p. 97; Pardolesi & Davola (2019), pp. 8-9; Müller & Seiler (2019), pp. 320-321; Junghöfer (2021), p. 8). See also Vatiero, "Smart Contacts vs Incomplete Contracts: A transaction cost economic viewpoint: (2022) 46 Computer L & Security R, 1.

59 Jiang (2018), p. 142; Temte (2019), p. 97.

60 Stazi, *Smart Contracts and Comparative Law* (Springer, 2021) (p. 81 ff.); Kipker, Birreck, Niewöhner & Schnorr, „Rechtliche und technische Rahmenbedingungen der „Smart Contracts"", 2020 MMR 509 (p. 510). According to World Economic Forum by 2027, 10% of the global gross domestic product (GDP) will be stored in blockchain-supported technologies, see Deep Shift Technology Tipping Points and Societal Impact (2015) <http://www3.weforum.org/docs/WEF_GAC15_Technological_Tipping_Points_report_2015.pdf> accessed 30 Dec 2022); see also Hasting (2020), p. 363 ff.; see an overview about potential SmC uses Treiblmaier & Clohessy (ed.), *Blockchain and Distributed Ledger Technology* (Springer, 2020).

61 For more information about gaining easier access to public records and documents or the issue of certifications, see Temte (2019), p. 96; Bosch et al. (2022).

62 For more about inspecting the electronic voting process, see Savelyev (2016), p. 119; Temte (2019), p. 96; Lingwall & Mogallapu (2019), (p. 308); Poblet, Allen, Konashevych, Lane & Valdivia, "From Athens to the Blockchain: Oracles for Digital Democracy" (2020) Frontiers at Blockchain <https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3630713> accessed 30 Dec 2022.

63 Savelyev (2016), p. 119; Lingwall & Mogallapu (2019), p. 308; Hasting (2020), p. 368.

64 See, in full, Spielman, "Blockchain: Digitally Rebuilding The Real Estate Industry" (2016) MIT Libraries <https://dspace.mit.edu/handle/1721.1/106753> accessed 30 Dec 2022; Lehavi & Levine-Schnur (ed.), *Disruptive Technology, Legal Innovation, and the Future of Real Estate* (Springer, 2020); accordingly, in German legal order Heckmann & Schmidt, "Blockchain und Smart Contracts Recht und Technik im Überblick" (2017) Studie U Passau <https://www.vbw-bayern.de/Redaktion/Frei-zugaengliche-Medien/Abteilungen-GS/Wirtschaftspolitik/2019/Downloads/190509-Blockchain-und-Smart-Contracts_neu.pdf> accessed 27 Dec 2022.

65 For more about the capture and storage of clinical data, see Heckmann & Schmidt (2017), p. 9; Temte (2019), p. 9; Hasting (2020), pp. 367-368.

66 Szabo (1997); Heckmann & Schmidt (2017), pp. 7-8.

67 There is an ongoing project where a consortium of major banks, such as HSBC, Barclays, and Credit Suisse, elaborate on the development of a blockchain and smart contract based "settlement coin", designed to allow banks to clear and settle transactions between each other instantaneously, see Rohr (2019), p. 71.

68 Szabo (1997).

69 Hasting (2020), p. 364.

70 See also Timmer, "Contract Automation: Experiences from Dutch Legal Practice" in Corrales, Fenwick & Haapio (eds.), *Legal Tech, Smart Contracts and Blockchain* (Springer, 2019) (p. 147).

71 See more detailed information about crowdfunding de Quesada, "Crowdfunding in Europe" in Grundmann (ed.) *European Contract Law in the Digital Age* (Springer, 2018) (p. 101 ff.).

72 Savelyev (2016), p. 122; Levi & Lipton, "An Introduction to Smart Contracts and their Potential and Inherent Limitations" (2018) Harvard L School Forum for Corporate Governance <https://corpgov.law.harvard.edu/2018/05/26/an-introduction-to-smart-contracts-and-their-potential-and-inherent-limitations/> accessed 27 Dec 2022; Temte (2019), p. 101.

73 Similarly, SmC can be used to determine more efficiently insurance premiums: the higher the possibility of a person having an accident when driving a vehicle, the higher the insurance fee would cost, see Durovic & Jansen, "Formation of Smart Contracts under Contract Law" in DiMatteo, Cannarsa & Poncibo (ed.) *Cambridge Handbook of Smart Contracts, Blockchain Technology and Digital Platforms* (Cambridge U Press, 2020) (pp. 64-65).

74 Savelyev (2016), p. 122.

75 Accordingly, smart contracts can be used in the entertainment industry to fund the creation of new movies or TV series directly by the public, see Lingwall & Mogallapu (2019), p. 310. See also for further uses in the entertainment sector Temte (2019), p. 90.

76 Müller & Seiler, „Smart Contracts auf der Sicht des Vertragsrechts" (2019) 3 AJP/PJA 317 (p. 320).

77 Temte (2019), p. 100.

78 Heckmann & Schmidt (2017), p. 8; Stazi (2021), p. 82.

79 Levi & Lipton (2018).

imposing penalties when the set conditions are not met. Since an economic asset (movable, immovable or data/information) can be digitally represented and controlled by digital means,[80] it can be the subject of a SmC.[81] Instead when contract performance requires effort or expertise, as in service contracts (e.g., in teaching and caring),[82] the contractual object cannot be digitally represented and, thus, it cannot be supported by a SmC. Similarly, transactions which entail non-operational clauses, such as legal concepts of 'good faith', 'undertake best endeavors in', or 'reasonable standard', which demand qualitative judgment, cannot be part of a SmC.[83]

Further, SmC are *inflexible*,[84] i.e., unmodifiable in case the circumstances or the legal landscape change: once put in motion, they are executed according to their predefined smart code, and no one can inhibit or influence the expected and fully foreseeable transactional outcome. This *rigid*[85] character may sometimes contradict good faith and business practices or even legislation that demands more flexibility in transactions. For instance, in the event of an unexpected strike or bad weather conditions that affect transportation, any delay in product delivery or money deposit may be justifiable; or in case the legislation changes (e.g., high interest rates), the amount of money that must be deposited may vary. However, the SmC will be executed anyway, according to its predefined instructions, although contractual parties may act differently off-chain, e.g., accepting delayed performance,[86] or a partial one. This constitutes another inherent limitation of SmC which can be overcome only if they have direct interaction with the off-chain world. Such an interaction can be realized through specific mechanisms, called *oracles*. Should they be AI systems, particularly autonomous ones, the potential of SmC will be unleashed, given the endless capabilities these AI systems have,[87] as analyzed thoroughly below (see under 4).

3.2. *Legal treatment*

The legal nature of SmC has been the subject of an extended debate.[88] On the one hand, a great part of legal scholars claims that SmC do not constitute any legal contract, but rather they are mere computer protocols that execute an already concluded contract. On the other hand, others accept their legally binding character, claiming that they are able even to fully replace traditional legal contracts. In fact, both approaches seem to be incomplete, insofar as they highlight only some of SmC's features (the technical or the legal ones, respectively) belittling others (the legal or the technical ones, respectively). Thus, they only partially capture their dynamic concept, which in fact can have different forms in transactions.

Indeed, a SmC can appear in transactions in one of the following forms:[89] (a) as a tool for self-performance and self-execution of an already concluded contract; (b) as a specific part of a contract (hybrid contract),[90] with a typical example the *Ricardian contracts*;[91] and (c) as a stand-alone SmC. More specifically for each of these types:

(a) The first type of SmC is the most common one in practice so far. With this type, the contractual parties have already communicated in the real (off-chain) world,[92] negotiated the contractual terms, and concluded the contract entirely off-chain, orally or in prose, if required. After having concluded and formed the contract, they choose to encode (part of) the contractual content in the blockchain platform[93] to take advantage of the benefits this technology entails, i.e. the automatic contract's self-performance and self-execution.[94] To that end, the contract must be expressed in a programming language, namely be 'translated' from a natural language to a computer programming one[95] (e.g. to Solidity or to another computer language based on Boolean logic), and, subsequently, be embedded in the blockchain platform (*smart code*). The contractual content translated and embedded into the blockchain platform constitutes the so-called *contractware*.[96] The contractware is not a contract from a legal point of view;[97] it is rather a computer program that serves as a technical tool for facilitating the

[80] Szabo (1997); Durovic & Janssen, "The formation of Blockchain-based Contracts in the Light of Contract Law" (2019) Eur Rev of Private L 753 (p. 757).

[81] Savelyev (2016), p. 119; Woebbeking, "The Impact of Smart Contracts on Traditional Concepts of Contract Law" (2019) 10 J of Intellectual Property, Info Tech and Electronic Comm L 105 (p. 107); Lingwall & Mogalappu (2019), pp. 287-288. See also Levi & Lipton (2018), highlighting that the scientific community is distanced from this because of the difficulty in "translating" legal criteria to computer code.

[82] Savelyev (2016), p. 123; Jiang (2018), p. 143.

[83] Syllaba, "Internet Smart Contracts: Are They Really Smart?" (2020) 19 Common L Rev 19 (p. 20). Contra Raskin (2017), p. 314. See also Blemus, "Law and Blockchain: A Legal Perspective on current regulatory trends worldwide" (2017) 4 Revue Trimestrielle de Droit Financier (Corporate Finance and Capital Markets L Rev) RTDF 14.

[84] Hsiao (2017), pp. 691-692; Cannarsa (2019), pp. 780-781; Temte (2019), p. 98-99.

[85] Temte (2019), p. 98.

[86] Levi & Lipton (2018). Cf. Low & Mik, "Pause the Blockchain Legal Revolution" (2020) 69 Inter and Comparative L Quarterly 135.

[87] Rohr (2019), p. 7.

[88] See an overview at Dimitrieva & Scmidt-Kessen (2019), 69.

[89] See also de Filippi & Wright (2018), p. 74 ff. Cf. Werbach, "Trust but Verify: Why The Blockchain Needs the Law" (2018) 33 Berkeley Tech L 439 (p. 535); de Graaf, "From Old to New: From Internet to Smart Contracts and from People to Smart Contracts" (2019) 35 Computer L & Security Rev 1.

[90] *Idem*. (2018), p. 76 ff.

[91] Grigg, "Ricardian Contracts" (1995) <https://iang.org/papers/ricardian_contract.html> accessed 29 Jan 2023.

[92] i.e., located and run outside the blockchain platform.

[93] De Graaf (2019), p. 10.

[94] Raskin (2017), p. 309; van Adrichem, "Enforceability of Smart Contracts under the Statute of Frauds" 2018 Science & Tech L Rev 1; Bilski, Blockchain-Technologie, "Smart Contracts und selbstvollziehende Vertrage", Gutachten Universität Leipzig (2019) < https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3425805> accessed 4 Jul 2023 (p. 53); Lingwall and Mogallapu (2019), p. 298; Woebbeking (2021), p. 108.

[95] Dimitrieva & Schmidt-Kessen (2019), p. 71, 75.

[96] *Contractware* is called the procedure of 'translation' and implementation of the contractual terms in the blockchain platform, see Raskin (2017), p. 307, 312.

[97] See also Meyer (2020), p. 19 arguing that smart contracts are 'apps' that both reflect the parties' agreement, like the contract document, and initiate its performance. For these reasons, smart contracts cannot be held void or be terminated, unlike legal con-

automatic self-*performance* and self-*execution* of an already off-chain concluded and formed contract.[98] For this reason, the contractware does not have any legal binding character, i.e. it does not pose itself any legal obligations to the contractual parties. Instead, it is the off-chain contract that poses them and deals with all the pertinent legal issues.[99]

(b) In the second type of SmC, the *hybrid contract*, the contractual parties have also communicated in the real off-chain world and negotiated the contractual terms. But they have decided to form the contract partially off-chain and partially on-chain, i.e., a part of the contract is formed in the real world in a natural language, orally or in prose, while the rest part of the contract is directly embedded in the smart code.[100] These two parts complement one another[101] and altogether constitute the one and only contractual content. A typical representative of a hybrid contract would be the *Rircardian Contracts*.[102] Their main feature is that they are readable by a human and a computer program at the same time, as they are written in both a natural and a computer language.[103] From a practical point of view, a Ricardian contract is a digital document that, after applying special software, automatically converts the natural language, in which it is written by the parties, into a computer language; any change made to the contractual text in natural language is automatically "reflected" in the computer code.

The hybrid SmC serves not only as a means for the contract's self-performance and self-execution, like the previous type, but also as a means for the *contract's formation*, while its conclusion is conducted entirely off-chain.

(c) The third type of SmC, *the stand-alone* one, exists entirely on-chain.[104,105] This type is the most uncommon so far, but in fact it constitutes the most revolutionary type of SmC since it can alter for good the way people are used to transacting. The parties usually select this type either because they cannot, or it is difficult to, have any communication in the real off-chain world (e.g. because they live in different countries), or because they do not want to have any. This way they are able to capture their entire contractual agreement in the blockchain platform, from its beginning until its execution. Indeed, contrary to the previous types of SmC, the stand-alone SmC is concluded entirely on-chain through the blockchain platform with the use of the smart contract code as the contractual language.[106] Usually there are no prior negotiations between the contractual parties in the real off-chain world,[107] neither any legal document entailing the parties' declarations of intention. Therefore, in the stand-alone SmC the contractual parties use the smart code not only to automatically perform their legal obligations, but also to *form* their declarations of intention and *communicate* them with each other via the blockchain platform;[108] i.e. the blockchain serves not only as a tool for the contract's self-performance, self-execution, and formation, but also as a means for the contract's *conclusion*,[109] facilitating the exchange of the parties' declarations of intention and the meeting of their minds.

As a result, given that the contractual elements of a contract exist, i.e. the parties' *declarations of intentions (offer and acceptance)*, the *meeting of their minds* (on certain definite contractual terms), their intentions to create legal relations as well as the *consideration* in the common law jurisdictions, or, respectively, a valid *causa* in the civil law ones, the stand-alone SmC constitutes a legal contract under the 'traditional' rules of contract law.[110] Therefore, it is the one which poses the legal obligations to the parties and is subject to (all) rules of law about contracts (e.g. invalidity).[111] Its legally binding character is also supported by the *principle of the freedom of contract*[112] and the *principle of informality of contracts* as well.[113] According to the first one, everyone is free to decide whether to enter a contract, to select the face of their contractual party, and to form the contractual content, under the condition that the law and the morality (*bonos mores*) are not violated, while according to the second one, no formality is required for the conclusion of a contract, unless otherwise it is provided by law. Specific manifestation thereof is the freedom of the contractual parties to choose the contractual language in which they want to form the contractual content; this language can be a spoken one (e.g., English,

tracts; Cuccuru, "Beyond Bitcoin: an early overview on smart contracts" (2017) 25 Inter J of L and Info Tech 179.

98 See also Principle 2 par. A (2) of the ELI Principles on Blockchain Technology and Smart Contracts.

99 Jiang (2018), p. 140-141.

100 See also Principle 2 par. A (4) of the ELI Principles on Blockchain Technology and Smart Contracts.

101 Lingawall & Mogallapu (2019), p. 299.

102 Grigg, "Ricardian Contracts" (1996), according to whom a *Ricardian contract* constitutes "*a single document that is a) a contract offered by an issuer to holders, b) for a valuable right held by holders, and managed by the issuer, c) easily readable by people (like a contract on paper), d) readable by programs (parsable like a database), e) digitally signed, f) carries the keys and server information, and g) allied with a unique and secure identifier*".

103 Chohan, "What is a Ricardian Contract?, Discussion Paper Series: Notes on the 21st Century", (2017) <https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3085682> accessed 17 May 2023; de Graaf (2019), p. 10. See also Werbach (2018), p. 544.

104 i.e. located and run exclusively inside the blockchain platform.

105 Savelyev (2017), p. 124; Jaccard, "Smart Contracts and the Law" (2017) 23 Jusletter IT 1 (p. 22); van Adrichem (2018); Lingwall & Mogallapu (2019), p. 298-299 ("*code-only contract*"), Dimitrieva & Schmidt-Kessen (2019), p. 71.

106 Lingawall & Mogallapu (2019), p.299.

107 Tjong Tjin Tai (2018), p. 804.

108 See also Principle 2 par. A (3) of the ELI Principles on Blockchain Technology and Smart Contracts.

109 See also Lingwall & Mogallapu (2019), p. 299.

110 See also Giancaspro, "Is a 'Smart Contract' Really a Smart Idea? Insights from a Legal Perspective" (2017) 33 Computer L & Security Rev 825; Papantoniou, "Smart Contracts in the New Era of Contract Law" (2020) 4 Digital L J 8.

111 Dimitrieva & Schmidt-Kessen (2019), p. 76, 83 ff.

112 Durovic and Janssen (2019), p. 764; Bilski (2019), p. 53.

113 Jaccard (2017), p. 22.

German, French, etc.) or a written one (e.g., Latin or Ancient Greek). Accordingly, manifestation of the private autonomy should be: first, the selection of a (high-level) programming language like *Solidity* (used by the public blockchain platform Ethereum)[114] as the contractual language, as far as there are no special provisions-restrictions regarding the comprehensibility of the language by the contractual parties;[115] second, the use of the blockchain platform by the contractual parties, as an electronic channel to communicate their declarations of intention to each other (like a fax or an email).

Each of these types of SmC may interconnect with AI systems through specific mechanisms called *oracles,* as they are analyzed immediately below.

4. Oracles

4.1. *Introduction*

An[116] *Oracle* is any mechanism that extracts data, information or expert knowledge from external sources and provides them to a 'closed' system, i.e. a system that has no access to these sources on its own; or vice versa, any mechanism that conveys data from a closed system to the external 'world'.[117] In the case of SmC, oracles serve as a communication channel linking the physical (off-chain) world to blockchain infrastructure (on-chain), thus, mitigating the rigid character of SmC and allowing them to become more flexible and dynamic.

Oracles can provide a blockchain platform with any information about outcomes of events (such as elections or sports), financial data (such as exchange rates or stock prices), or supply chain information (such as temperature, location, and delivery), and vice versa. For instance, in the case of private insurance provided through SmC, according to which compensation must be given to beneficiaries (e.g. farmers) when bad weather conditions occur (such as a hurricane or extended drought), an oracle can provide the blockchain platform with information about the speed of the wind or the total amount of water.[118] Furthermore, in the case of a 'smart lock', when the predefined fee is received, the oracle can transmit the information off-chain, so that the door can automatically open.

There are a lot of types of oracles. One of the most prevalent ones is *software oracles*.[119] These oracles can interact with any sources of information available online, such as databases, servers, and websites, and convey data to the blockchain platform in real time. For instance, a software oracle can transmit information regarding stock prices to the blockchain platform, so that the SmC can buy or sell them.

On the other hand, there are also *hardware oracles*.[120] These ones interact with the physical world and convey the necessary information to the blockchain platform, or vice versa. A hardware oracle is usually installed in physical objects with electronic sensors, like robots, or relates to objects with QR codes/barcodes. Upon receiving the necessary information, a hardware oracle 'transforms' it to digital value that can be 'understood' by SmC and releases it to the blockchain platform. For instance, upon receiving the information that a transporting product has arrived at a loading day, a hardware oracle relays the information to the blockchain platform which then executes decisions based on this information. These oracles have great usage in the supply chain sector.

Both software and hardware oracles can convey information from external sources to the SmC, and vice versa. The ones that transmit data/information/knowledge from external sources to the blockchain platform are called *inbound oracles*, while the ones which send them from the blockchain platform to the physical world are called *outbound oracles*. An example of an inbound oracle is one that informs the blockchain platform about the external temperature; this oracle can be either software (receiving the relevant information from the web), or hardware (receiving it by use of sensors). On the other hand, an example of an outbound oracle is a smart lock: when the necessary funds are deposited to a specified account, the oracle then transmits the information to the physical world and allows a mechanism to unlock the smart lock; or, vice versa, should the agreed funds not be deposited on time, the outbound oracle conveys the information to the physical world and activates the mechanism for inhibiting or interrupting, for example, a vehicle's function.

Further, there are also oracles which can be used not only for transmitting information from the off-chain world to the on-chain one or vice versa (also known as *data carried* or *automated oracles)*,[121] but ones that can perform computation off-chain and subsequently transmit the outcome on-chain (*computation oracles*).[122] For example, a computation oracle can perform a computationally intensive regression calculation off-chain and release this information to the blockchain technology; or assess the creditworthiness of a loan-applicant and release the information to the blockchain platform. These or-

[114] Bilski (2019), p. 54. See also Principle 8 of the ELI Principles on Blockchain Technology and Smart Contract. Cf. Savelyev 123.

[115] Such a restriction is provided, for instance, in the case of business to consumer relationships where the contractual language should be deemed natural, plain and intelligible by the consumers, otherwise the contract is considered not concluded (Directive 93/13 Art. 5), see Bilski (2019), p. 54, 72.

[116] Cohn, West & Parker, "Smart After All: Blockchain, Smart Contracts, Parametric Insurances, and Smart Energy Grids" (2017) Georgetown L Tech Rev 273 (p. 283); de Filippi & Wright (2018), p. 75; Temte (2019), p. 96; Tjong Tjin Tai (2018), p. 791; Müller & Seiler (2019), p. 322; McDonald, "Smart Contracts" (2021) Columbia Bus L Rev; Beniiche, "A Study of Blockchain Oracles" (2020) <https://arxiv.org/pdf/2004.07140.pdf> accessed 5 Jan 2023; Durovic & Jansen, (2020), p. 66; Meyer (2020), p. 18; de Caria (2020), p. 29; Kipker et al. (2020), p. 509.

[117] Temte (2019), p. 96; Poblet et al. (2020), p. 2; Greenspan (2016). Cf. Stazi (2021), p. 81.

[118] Cohn et al. (2017), p. 293 ff. See also the paradigm of AXA and *Etherisc*, insurance companies which offer compensation to travelers experiencing delays or airline cancellations. Once the information about a flight delay or cancelation is acquired, it is automatically provided to the blockchain and compensation is automatically paid to the claimers, see Kipker et al. (2020), p. 510; Stazi (2021), p. 81, footn. 62.

[119] Also known as *deterministic oracles*, see Beniiche (2020) p. 5.

[120] Beniiche (2020), p. 2; Poblet et al. (2020), p. 5.

[121] Beniiche (2020), p. 2.

[122] Id..

acles are quite useful because SmC demand high computational power to be executed and their costs are high.

Since oracles can directly affect SmC operation, only a trusted third party (known as TTP or TP) should be an oracle.[123] Such third trusted parties can be humans or legal entities or other systems.[124] For instance, an oracle can be a courier or an agent[125] who certifies to their tablet that a product has been delivered;[126] or a bank which certifies the conformity of products prior to releasing any amount of money to the beneficiary in the case of a letter of credit; or a system installed in a car, which can send signals to the police, when the car is involved in a car accident.[127] Such a system can use AI, i.e. it can be an autonomous AI system. In this case the oracle does not only serve as a 'bridge' between the on-chain and the off-chain world,[128] but also as a medium for bringing into contact two novel technologies, AI and blockchain, thus, maximizing their potentials.

4.2. AI oracles' applications on SmC and inherent limitations

AI oracles can have a lot of uses throughout the SmC procedure, from its formation and conclusion to its modification. First, as already implied, AI oracles can be used for triggering (smart) contractual conditions in the form of "*if* X occurs, *then* Y is executed".[129] All the above-described paradigms, e.g., information about temperature and weather conditions, money deposits, prices' height, inflation, and exchange rates, are of this type.

But apart from this (expected) use, AI oracles can have more sophisticated applications,[130] such as at the formation of (smart) contractual content.[131] Production of speech constitutes a common subject matter of AI,[132] particularly of autonomous AI systems. When contractual parties have already entered negotiations off-chain, AI oracles can facilitate the formation of SmC by 'translating' natural language to a computer language (e.g. *Solidity*,), and vice versa.[133] Of course, this can take place so far only for simple orders, not for sophisticated ones, like those including abstract legal notions (e.g. good faith) or demanding cognitive judgment (e.g. reasonable efforts). Nonetheless, AI systems are showing significant progress in the fields of legal ontology and legal interpretation,[134] thus, more legally sophisticated AI applications are expected to develop soon.

Further, AI oracles can be used for controlling proper contract performance, identifying the cause of non-performance and whether it is attributable to the debtor.[135] For instance, should a product not be delivered on time, an AI oracle can examine the reason for the delay and identify if it is attributable to the debtor's default or to force majeure (e.g. bad weather conditions or a pandemic that results in disruption and delays), releasing the information to the blockchain platform; in the first case, the information will trigger the predefined penalties (already implemented in smart code) against the debtor, while in the second case the system will refrain from it. Determining the cause of non-performance demands sometimes sophisticated legal analysis, but since scientific research shows significant progress in this field,[136] AI oracles are expected to soon be able to perform well at legal reasoning and argumentation.[137]

Accordingly, an AI oracle can mitigate the rigid character of SmC, allowing them to be modified[138] when needed. For instance, in the event of an unpredictable change of circumstances or force majeure that demands SmC be modified, the AI oracle can release the information to the blockchain platform, thus, enabling SmC modification prior to being executed.[139] Moreover, AI oracles can facilitate the procedure of the undoing of SmC. For instance, in the case of an already executed transaction through SmC that needs to be voided, AI oracles can provide the blockchain platform with information about the judicial process's outcome, in order the transaction to be reserved on-chain. Similarly, AI dispute resolution mechanisms, which are able to apply their existing encoded legal

123 Id.; Durovic & Jansen (2020), p. 66; Stazi (2021), p. 81.
124 Such systems include *Oraclize* or *Provable Things*, see Beniiche (2020), p. 2.
125 Cieplak & Leefatt (2017), p. 424; Tjong Tjin Tai (2018), p. 791.
126 Meyer (2020), p. 18.
127 Cf. Tjong Tjin Tai (2018), p. 791.
128 Its ancestor is deemed the Turing *o-machine*, see Turing, *Systems of Logics Based on Ordinals* (Phd thesis, Princeton U 1938). See more about Turing's o-machines Soare, "Oracle Turing Machines, Online Computing, and three Displacements in Computability Theory" (2009) 160 Annals of Pure and Applied Logic 370; Poblet et al. (2020), p. 3.
129 Poblet et al. (2020), p. 4.
130 See also Sartor (2018), p. 269.
131 Herian, "Smart Contracts: A Remedial Analysis" (2021) 30 Info and Communications Tech L 17 (p. 28).
132 Searle, *The Construction of Social Reality* (Free Press, 1995) (p. 208); Sartor (2018), p. 265.
133 See O'Shields, "Smart Contracts: Legal Agreements for the Blockchain" (2017) 21 North Carolina Banking Institute 177 (p. 189); Clack, "Smart Contract Templates: Legal Semantics and Code Validation" (2018) 2 J of Digital Banking 338.
134 Idelberger (2018), pp. 221-222. Contra Mik, "Smart Contracts: Terminology, Technical Limitations and Real World Complexity" (2017) 9 L, Innovation and Tech 269; Hasting (2020), p. 375; Syllaba (2020), p. 21.
135 Tjong Tjin Tai (2018), p. 798.
136 See Surden, "Computable Contracts" (2012) 46 U of California-Davis L Rev 629; Spyropoulos, Kornilakis, Makris, Bratsas, Tsiantos & Antoniou, "Semantic Representation of the Intersection of Crime Law and Civil Tort (2022) 7 Data 176; also Tjong Tjin Tai, Formalizing Contract Law for Smart Contracts, Tilburg Private L Working Paper 2017 < http://www.ssrn.com/link/Tilburg-Private-Law.html> accessed 30 Jan 2023.
137 See Idelberger (2018), p. 222. Contra Tjong Tjin Tai (2019), pp. 799-800.
138 See also potentials of undoing/modifying SmC from a technical perspective at Marino & Juels, "Setting Standards for Altering and Undoing Smart Contracts" (2016) Lecture Notes in Computer Science <https://www.researchgate.net/publication/304480352_Setting_Standards_for_Altering_and_Undoing_Smart_Contracts> accessed 30 Dec 202; Temte (2019), 99; Chen, Xia, Lo & Grundy, "Why Do Smart Contracts Self-Destruct? Investigating the Self-destruct Function on Ethereum" (2021) 31 ACM Transactions on Software Engineering and Methodology 1; Herian, (2021), pp. 30-31.
139 Stazi (2021), pp. 134, 137-138. See also about 'adaptive systems' Sartor (2018), p. 269.

rules,[140] can be installed in SmC, providing judgment when a dispute arises.[141]

However, the role of AI oracles is going to become even more constructive, should they be used at the stage of the conclusion of the SmC. For instance, AI oracles could be used for identifying the age of contractual parties using biometric data[142] prior to the conclusion of the SmC; or, similarly, for checking the contractual content for any illegality or immorality, especially the standard unfair contract terms which are typical in transactions (e.g., typical terms in consumer contracts, according to EU Directive 93/13/EEC).[143] This way, the possibility of a void SmC being incorrectly concluded will be significantly reduced.

Further, as already mentioned above, autonomous AI systems can dynamically interfere with a contractual procedure, fully replacing human agents, i.e., they can select whether or not to enter a contract, choose the face of the other contractual party and define the contractual content.[144] In a blockchain environment, AI systems can replace human agents both in posting the SmC onto the platform and accepting it. More specifically, when a user wants a SmC to be concluded and executed, they must render it available on the blockchain platform; namely they must implement it in the smart code using a programming language and 'post' the identification number of the SmC on the blockchain platform. Subsequently, another user of the platform 'accepts' the contract by communicating their acceptance to the other contractual party by paying a certain amount of money and combining the payment with SmC identification number.[145] These actions (post and acceptance) could be done autonomously (not just automatically) by oracles using AI.[146] For instance, AI systems can conclude a sale contract on-chain after assessing and comparing counterparties' offers and reliability; or sell/purchase stocks on-chain after comparing the profitability of various choices; or, similarly, conclude loan contracts on-chain after estimating the creditworthiness of loan applicants.[147]

This use of AI oracles is expected to be the most revolutionary one since it introduces a new reality for transactions: the 'real' smart contract procedure. This is the contractual procedure carried out by blockchain platforms interacting with AI systems, where a contract's formation/conclusion is going to be autonomous and its performance/execution (at least) automatic, on behalf of its user(s).

Nonetheless, despite the positive influence AI oracles can have on SmC, they may also decelerate their operation,[148] while the unknown and maybe inaccurate source of their data/information/knowledge may negatively affect the produced outcome, and the whole procedure as well. Indeed, there is always the possibility an oracle, particularly a software type, could convey false or inaccurate data/information. Although this is a common problem of all oracles (also referred to, in literature, as the *oracle problem*),[149] the situation becomes even more difficult for AI oracles due to the inherent opacity they suffer from, i.e., their black box.[150]

A typically proposed solution to the oracle problem are the so-called *consensus oracles*.[151] This is a decentralized network of oracles, which work collectively for the same purpose: before any data is uploaded to the blockchain platform, each oracle renders its outcomes. After considering the outcomes of most of them, or an average amount, the system releases it to the blockchain.[152] Such a type of oracle could be useful, e.g., as a rating system within a prediction market.[153]

Nonetheless, the potential of oracle malfunction remains, leading to systematic risks for SmC. For this reason, legal doctrine is called upon to decide what the appropriate legal treatment is, in case the AI oracle negatively affects the SmC operation, namely who should bear any raised civil liability.

5. Legal assessment of AI oracles' impact upon SmC

As already stated, oracles serve as service providers conveying data/information/knowledge from the off-chain world to a blockchain platform, or vice versa (obligation of result).[154] Any system's malfunction, or transmission of inaccurate data/information/knowledge (henceforth *failure*) affects SmC and may result, inter allia, in the following situations: (a) in SmC non-performance, although it should have been self-performed (e.g. when an AI oracle conveys inaccurate data about weather conditions, so that the SmC is not self-performed, and the money is not transferred from the insurance company's portfolio to the claimer's one on time); (b) in SmC self-performance, although it should not have been self-performed (e.g. when an AI oracle transmits inaccurate data about weather conditions and the SmC is self-performed, when in fact money should not be released to the claimer; (c) a SmC was concluded, although it should not have been concluded (e.g. a loan-SmC is concluded because the AI oracle transmitted inaccurate information about the creditworthiness of a loan applicant; had it conveyed accurate information thereof, the SmC would have never been concluded; or (d) a SmC was not concluded, although it should have been

140 Temte (2019), p. 105.
141 Cf. Tjong Tjin Tai (2019), p. 791.
142 See about restrictions of the recent European Commission Proposal for a Regulation of the European Parliament and of the Council on Laying Down Harmonized Rules on Artificial Intelligence (Artificial Intelligence Act), COM (2021) 206 final, Art. 5.
143 Council Directive 93/13/EEC of 5 April 2013 on unfair terms in consumer contracts OJ L095 21.04.1993, 0029. See also ELI Principles on Blockchain Technology, Smart Contracts and Consumer Protection, (2022), p. 47 ff.
144 Rizos, "A Contract Law Approach for The Treatment of Smart Contracts 'Bugs'" (2022) 5 Eur Rev of Private L 775 (p. 792).
145 Tjong Tjin Tai (2019), pp. 790-791; Durovic & Jansen (2020), p. 65. See also Cieplak & Leefatt (2017), p. 422.
146 Kipker et al. (2020), p. 511; Durovic & Jansen (2020), p. 66. Contra Hasting (2020), p. 375 and Syllaba (2020), p. 19, who characterize SmC's operation *autonomous* (not *automatic*).
147 See also Sartor (2018), p. 270.
148 Meyer (2020), p. 18.
149 "*There is no infallible oracle*," Turing (1939).
150 Stazi (2021), p. 81.
151 Poblet et al. (2020), p. 5.
152 Cf. Cieplak & Leefatt (2017), p. 424.
153 Beniiche (2020), p. 2.
154 Cieplak & Leefatt (2017), p. 423.

concluded (e.g. a sales SmC was not concluded because the AI oracle conveyed incorrect data about the stock's price; had it transmitted accurate information thereof, the SmC would have been concluded). The first two types of failures (a, b) apply to any kind of SmC, i.e. to the SmC as a tool for a contract's self-performance and self-execution, to a hybrid contract, as well as to a stand-alone SmC, while the last ones (c, d) apply only to the stand-alone SmC since it is the only kind that is concluded entirely on-chain through the blockchain platform. These situations raise the following issues: first, which person should be held liable in the case of damage; the parties (if so, which of them) or the blockchain platform? Second, if one of the contractual parties, or the platform accordingly, is held liable, can they claim compensation from the AI oracle user and/or producer (provider/designer), or against the AI oracle itself, accordingly? Further, as far as the third situation is concerned, is the contact valid and legally binding upon the contractual parties, or can they be released by their contractual obligations? Accordingly, in the last case, who should be held liable for the SmC non-conclusion and bear the cost of damage? These questions are going to be answered immediately below.

5.1. *SmC non-performance due to AI oracles' failure*

From a legal perspective, when a SmC is not performed due to the AI oracle's failure, there is a breach of (smart) contract.[155] The person bearing the raised liability depends, primarily, on who requested the involvement of the AI oracle in the blockchain platform: the contractual parties or the blockchain platform?

5.1.1. Should the AI oracle become involved upon a party's command, this party should bear any contractual liability.[156] For example, like in case of an off-chain tool that does not function appropriately and negatively affects the transactional outcome, contractual parties should bear the liability in case the AI oracles they use are defective or convey inaccurate data. For instance, in the case of a defective computational oracle, which releases a wrong outcome onto the platform, the party which uses the AI oracle bears the liability. One would reach the same conclusion, even if they do not accept the role of AI autonomous systems as mere tools, but rather as 'independent parties' endowed with 'legal personhood',[157] or as 'electronic slaves' or 'hybrid persons': like in the case of experts that the contractual parties consult in the off-chain world before executing their contractual obligations, the risk of inaccurate knowledge is upon the contractual party who asked for it.

Of course, a differentiated liability allocation can result from an agreement between the contractual parties,[158] under general legal conditions, while the platform itself can also predict and manage the issue. Indeed, it will be beneficial for both contractual parties, should they agree in advance which AI oracle is going to be used, namely which AI oracle they both trust, and what will happen in the case of an AI oracle's failure. For instance, they can agree that none of them will be held liable and that the SmC should be performed anyway, retrospectively. As far as the liability of the AI oracle is concerned, the prevalent opinion[159] holds the AI user accountable,[160] as has already discussed (see above, Section 2.2.). Between the AI user/owner and the on-chain contractual party who asks for the AI oracle's assistance, a service agreement[161] (or particularly, in the EU, a *digital content service* based on the recent Directive 2019/770)[162] is concluded but breached due to the AI system's failure, so the latter can claim compensation against the former for non-performance of the (service) contract.[163]

Further, the AI provider or designer can be held liable for the AI oracle's failure as producer or manufacturer of a defective product. In civil law jurisdictions, which are member-states of the European Union, this is a strict liability regime based on the European Directive 84/374 for product liability,[164] which is due to be amended soon.[165] Accordingly, in common law jurisdictions, it is based, *de lege ferenda*, inter allia, on the Consumer Protection Act 1987 in the UK, and on section 402A of the Restatement (Second) of Torts in the USA, which are strict liability regimes, too.[166] Otherwise, compensation claims against the AI provider or designer can be based on 'traditional' rules of law, like the fault-based tort liability, or, *de lege ferenda,* vicarious liability, as well as liability for parents and animal keepers.[167]

155 Cf. Rizos (2022), p. 799 ff.

156 Cf. Casey & Niblet, "Self-Driving Contracts" (2017) 43 J of Corporation L (p. 26 ff.).

157 See Solum (1992); Karnow (1996).

158 Temte (2019), p. 110; Tjong Tjin Tai (2019), p. 796-797.

159 See Allen & Widdison (1996), p. 44; Mehrings (1998), p. 31; Cornelius (2002), p. 355; Boden, Bryson, Caldwell, Dautenhahn, Edwards, Kember et al., (2011), passim.

160 Although the term 'user' is more appropriate to describe the person who exploits an AI system, in the present paper the term 'owner' is adopted because the term 'user' is used to refer to the contractual parties of a SmC.

161 See also Ebers, "Artificial Intelligence, Contacting and Contract Law: An Introduction" in *Contracting and Contract Law in the age of Artificial Intelligence* (Ebers, Poncibo & Zou (eds.)), (Hart Publishing, 2022), p. 20.

162 Idem. (p. 37). See also the Sein, "Legal Tech Solutions as Digital Services under the Digital Content Directive and E-Commerce Directive" in *Contracting and Contract Law in the Age of Artificial Intelligence* (Ebers, Poncibo & Zou (eds.)), (Hart Publishing, 2022), p. 135 ff.

163 The same conclusion applies also for the supporters of the *mutatis mutandis* application of the rules of law about representative (see above, Section 2.2.) as well as for the proponents of the theories of the "*AI legal personhood*", "*electronic slaves*" and "*e-person*" (see also above, Section 2.2) with the difference that in the last three cases the service contract will have been concluded between the contractual party and the AI system itself.

164 See also Bertolini (2013), 214; Chatzipanagiotis, "Product Liability Directive and Software Updates of Automated Vehicles" Proceedings of SETN 2020 <https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3759910> accessed 27.6.2023.

165 See European Commission Proposal for a Directive of the European Parliament and of the Council on Liability of Defected Products COM (2022) 495 final.

166 See an extended analysis at Abraham & Rabin (2019), p. 129 ff.; Talley, "Automatorts: How Should Accident Law Adapt to Autonomous Vehicles?" 2019 Lessons from Law and Economics 10 <https://www.hoover.org/sites/default/files/ip2-19002-paper.pdf> accessed 17.6.2023.

167 The European Commission has already proposed special rules of law regarding the alleviation of the burden of proof in favor of

5.1.2. On the other hand, when the involvement of AI oracles takes place upon the platform's command, it is questionable whether the contractual parties should bear any contractual liability, since they seem to have no default for the produced outcome: even when they know that the uploaded information is inaccurate, they cannot intervene in smart code and inhibit its automatic execution, or trigger it, respectively. For instance, in the afore-mentioned example, the private insurance company holds no responsibility for the fact that the money was not transferred to the claimer's portfolio and could not alter the predefined outcome. This is crucial for civil law systems, where contractual liability is based on the debtor's default, contrary to common law ones where contractual liability is strict, i.e., irrespective of the debtor's default, but for frustration; in this case, it is essential that force majeure clauses be agreed between contractual parties.

Further, given that the AI oracle has intervened upon the platform's command, the liability of the blockchain platform should also be investigated.[168] Platforms' liability depends on the following: first, on its role as a provider of information society services, according to the relevant definition of the European Directive 2000/31 on Electronic Commerce,[169] or of autonomous ones, i.e. whether they act as mere intermediaries, just facilitating the transaction on-chain, or have a more crucial role in the transaction;[170] second, on its legal nature as a public or private (permissioned) network.[171] In the latter case, it is reasonably expected that the platform will be responsible for (smart) contract non-performance, so it could be held liable (at least jointly with any liable contractual party) for the breach of (smart) contract.

Should the blockchain platform be held liable for (smart) contract non-performance, it can claim compensation against the AI owner for breach of the service contract (or the digital service contract), which has been concluded between them, according to the prevalent opinion (see above, Section 2.2). Moreover, in the case of defective AI design, the AI providers or designers could also be held liable, according to the afore-mentioned rules of law (i.e., the European Directive 85/374, the Consumer Protection Act 1987, and the section 402A of the Restatement (Second) of Torts). In case these legal enactments do not apply, their liability can be based on tort law, or, *de lege ferenda*, on vicarious liability, or, accordingly, on the rules of law about parents' or animal keepers' liability.

5.2. *SmC performance due to AI oracles' failure*

On the other hand, it is also possible that a SmC is self-performed due to an AI oracle's failure, although it should not have been performed. In this case, there is no breach of contract, but rather a situation of unjust enrichment:[172] one party (e.g., the insurance claimer) receives a certain benefit at the expense of another (e.g., of the insurance company) via the blockchain platform without justification. Indeed, in the above-mentioned paradigm, there is no valid legal basis for the insurance claimer's enrichment, because the insured risk (e.g., a hurricane or an earthquake) has not occurred and it was the AI system's failure that enabled the unduly payment to be made. Accordingly, because the AI oracle released inaccurate data about stock prices in the blockchain platform, the SmC was self-performed, and the stocks were sold at the wrong price.

The remedy for unjust enrichment is restitution, i.e., the restoration of what was conferred to the claimant. Regarding SmC, restitution means that the SmC must be deleted from the ledger retrospectively, or that another SmC with the adverse outcome must be concluded and performed.

Further, also in this case, the AI oracle's failure constitutes a breach of the service contract, which has been concluded between the contractual party, or the blockchain platform accordingly, and the AI owner.[173] What has already been written above in relation to the liability of the AI owner as well as the AI provider or designer applies also in this case (see above, Section 5.1).

5.3. *SmC conclusion due to AI oracles' failure*

Further, when an AI oracle is used at the conclusion stage of a (stand-alone) SmC, its failure can result in the conclusion of a (stand-alone) SmC that should not have been concluded. For instance, because an AI oracle wrongfully assesses the creditworthiness of a loan applicant and releases this inaccurate information to the blockchain platform, a loan-SmC is concluded between the platform users, i.e. the applicant and the credit institution, that otherwise would never have been concluded.

In this case, it is questionable whether the contractual party (e.g. the credit institution) can be released from their contractual obligations. Taking into account the above analysis, one should accept that, when the AI oracle becomes involved in the blockchain platform, upon a contractual party's command, then this party should be held legally bound by the concluded (stand-alone) SmC; that is to say, the (stand-alone) SmC is held valid, and the contractual party who commanded the AI oracle's involvement should perform - in fact, accept the self-performance of - their contractual obligations. The only way to be released from their contractual obligations is by in-

the claimants in cases of fault-based non-contractual civil liability, see European Commission Proposal for a Directive of the European Parliament and of the Council on AI liability COM (2022) 496 final.

[168] See also Savelyev (2017), p. 131.

[169] See Directive 2000/31/EC of the European Parliament and of the Council of 8 June 2000 on certain legal aspects of information society services, in particular electronic commerce, in the Internal Market ("*Directive on electronic commerce*") OJ L178 17.7.2000, 001, as being recently amended by the Regulation 2022/2065 of the European Parliament and of the Council of 19 October 2022 on a Single Market For Digital Services and amending Directive 2000/31/EC ("Digital Service Act (DSA)"). See also thereof de Graaf (2019), passim.

[170] Cf. Case C-320/16 *Uber France SAS v. Nabil Bensalem* (2018); Case C-390/18 ⟨13:italic ⟩Airbnb Ireland⟨/13:italic⟩ (2019).

[171] See an overview Dimitrieva & Schmidt-Kessen (2019), 72, where they discribe the operation of *public, consortium* and *permissioned* blockchain platforms.

[172] Cf. Rizos (2022), p. 784, 795.

[173] Or with the AI oracle itself, should it be treated as a legal person or an electronic slave or as a hybrid person.

voking the rules of law about *mistake*,[174] if it is so important, i.e. to contend that they would never have entered the (stand-alone smart) contract, had they known the true situation, according to the relevant provisions of each jurisdiction.[175]

In the above paradigm, where the AI oracle conveyed inaccurate information about the creditworthiness of the loan-applicant, the importance of the mistake is obvious. However, in other paradigms the contractual parties may face great difficulty in proving their mistake. Where they do not rescind the (stand-alone) SmC, they could claim compensation against the AI owner for a breach of contract that they have concluded, as well as against the AI provider or designer for defective design, based on the above analysis (see above, Section 5.1.1).

Further, should the AI oracles take part in a contractual procedure upon the blockchain platform's command, the SmC is valid, but the parties are entitled to the right to rescind it on the grounds of it being a mistake. In such a case, it will be easier for the contractual parties to prove their mistake. In addition, they can claim compensation against the blockchain platform, especially if the latter is a private network, and provides the services, i.e. the infrastructure of the platform and the rest of the operations, with a fee (see also above, Section 5.1.2).

5.4. *SmC non-conclusion due to AI oracles' failure*

An AI oracle's failure can also result in the non-conclusion of a (stand-alone) SmC, even when it was supposed to have been concluded. For instance, if an AI oracle transmitted incorrect information about a stock price (e.g. if it states it is higher or lower than its actual value), then the SmC would not be concluded, because, according to its predefined conditions, the contract can only be concluded when the stock price's value reaches a certain level.

On the one hand, should the AI oracle intervene in the contractual procedure upon the parties' command, the latter bears the risk, i.e. they lose the opportunity to conclude a profitable contract. Nonetheless, they can submit compensation claims (especially loss of profit) against the AI owner for breaching the contract that has been agreed between them. Accordingly, the AI provider or designer can be held liable, either as the producer of a defective product, or according to any of the other legal bases already discussed above (i.e. law of torts, vicarious liability, and parents' or animal keepers' liability) (see above, Section 5.1.1).

On the other hand, if the AI oracle took part in the contractual procedure upon the blockchain platform's command, the contractual parties could submit compensation claims against the blockchain platform for breach of contract because of the improper function of the platform. However, as already mentioned above (see above Section 5.1.b), the liability of the blockchain platforms depends on various factors: first, on their role as intermediaries (provider of information society services) or as crucial-structural parties of the transaction; second, on their legal nature as public or private (permissioned) networks; third, on the agreement between them and the platforms' users. Usually when the service (i.e. the infrastructure of the platform and the operations it performs) is offered by a private blockchain network for a fee, it would be agreed, or would be reasonably expected, that the platform bears the liability for the proper operation of its services; so, any improper operation of the platform constitutes a breach of contract that establishes their contractual liability for non-performance.

Subsequently, if the blockchain platform is held liable, then it can claim compensation against the AI owner for breach of the contract that has been agreed between them, as well as against the AI provider or designer, in accordance with the above legal analysis (see above Section 5.1.2).

6. Conclusions

The interconnection of AI and blockchain technology is expected to bring significant advantages to transactions, altering for good the way people carry out them. Since the invention of the Internet, the interaction of this cutting-edge technology is going to be the next real 'big thing' in the trade industry. However, it also poses significant legal concerns that will only increase in future, as both fields make rapid progress.

The present paper constitutes a preliminary study of the interconnection of these novel technologies, putting emphasis on the mechanisms this interconnection is achieved through, the oracles. Should these mechanisms be AI systems, particularly an autonomous one, they can have extended use in transactions carried out through blockchain technology, from the formation and conclusion of a SmC to its performance, execution, and undoing, thus, maximizing SmC potential.

However, the use of AI oracles may also raise several legal issues in the event of failure. The present paper focused especially on the contractual liability issues in the case of potential AI oracles' failures, although non-contractual liability may also exist. The above analysis has shown that any oracle's failure can result, inter allia, in these legal situations: in a SmC non-performance, i.e., a breach of a (smart) contract (see 5.1); in a SmC performance which in fact constitutes an unjust enrichment (see 5.2); in the conclusion of an undesirable SmC (see 5.3); or in the non-conclusion of a desirable one (see 5.4).

Moreover, all persons participating in the 'smart contractual procedure', i.e. the contractual parties, as well as the blockchain platform and the AI owner (or the AI system itself), can be held liable, depending on who requested the AI oracle's intervention in the transaction and who is responsible for its proper operation; should the AI oracle intervene in the "smart contract procedure" upon the contractual parties' command, then the latter bear the most risk, based on the aforementioned situations, i.e. they bear the contractual liability (see 5.1.1), or they are obliged to restitute the unjust enrichment (see 5.2), or they are legally bound by a smart (voidable) contract (see 5.3), or, lastly, they lose the opportunity to conclude a profitable (smart) contract. In all these cases, the contractual parties are entitled to the right to claim compensation against: (a) the AI user/owner for non-performance, and/or (b)

[174] See also Ebers (2022), p. 31 ff.; Poncibo, "Remedies for Artificial Intelligence" in *Contracting and Contract Law in the age of Artificial Intelligence* (Ebers, Poncibo & Zou (eds.)), (Hart Publishing, 2022), p. 205 ff.

[175] Giancaspro (2017), (passim.).

the AI provider or designer. The latter (i.e. the AI provider or designer) can be held liable, either as the producer of a defected product, or based on the tort liability regime or, *de lege ferenda*, on vicarious liability, or parents' or animal keepers' liability.

Accordingly, should the AI oracle intervene in the 'smart contractual procedure' upon the blockchain platform's command, especially when the latter is a private (permissioned) one that plays a crucial role in the transaction and offers its infrastructure for a fee, then it is the platform itself that will bear any increased risk, i.e. they compensate the contractual parties for the non-performance of the SmC (see 5.1.2), or for a performance that should not have happened (see 5.2), or for the conclusion of the stand-alone SmC that should not have been concluded (see 5.3), or for the non-conclusion of the stand-alone SmC that should not have been concluded (see 5.4). Third parties, like the AI providers or designers, may also bear liability in the case of defective AI as the producers of a defective product,[176] or according to the tort law liability regime, or the vicarious liability, or parents' or animal keepers' liability, *de lege ferenda*.

Given that a legislative initiative has already begun, at least regarding AI, and a new legal framework is going to be enacted soon, the legal doctrine should focus on the transactions carried out through blockchain platforms, with the aid of AI systems, and address the newly raised legal issues consistently. The present paper aspires to provide some appropriate legal directions for handling the legal issues raised by the interconnection of SmC and AI.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

Data availability

No data was used for the research described in the article.

[176] See also Raskin (2017), 9. 328; Rizos (2022), p. 800. Heading in this direction is the recent proposal of the European Commission for a Directive of the European Parliament and of the Council on Liability of Defective Products COM (2022) 495 final.

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